Southdown Magnetite Project

Response to Submissions under *the Environment Protection and Biodiversity Conservation Act 1999*

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SRT GRANGE RESOURCES

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1. INTRODUCTION

This report presents a summary of the public comment and consultation process undertaken by Grange Resources Limited (Grange) for the proposed Southdown Magnetite Project (the Project) under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The report includes a compilation of submissions received throughout the process, and how they have been responded to by Grange. Public notification and assessment of comments has been undertaken by Grange in accordance with a Direction to Publish (8 October 2017) from the Department of Environment and Energy (DoEE) (refer to Appendix 1).

This document provides an overview of the following:

- Section 2 outlines the public comment process undertaken by Grange;
- Section 3 outlines the public submissions received and Grange's response to these; and
- Section 4 outlines how the documentation made publicly available by Grange has been amended in response to the public submissions received.

1.1. Background

The Project involves the construction and operation of an open pit magnetite mine located approximately 90 kilometres (km) east north-east of Albany, and 10 km south-west of Wellstead in the Great Southern region of Western Australia, and pipelines for ore slurry transport and return water, connecting the mine site and new port loading facilities in the Port of Albany. The new port loading facilities will include a concentrate thickener, filter plant, storage shed and ship loader. The Project also includes the construction and operation of a desalination plant near Cape Riche and infrastructure corridor to provide a reliable and independent water supply for the mine and its associated activities.

Grange is the proponent for the Project on behalf of the Southdown Joint Venture (SDJV). The Project has been subject to the EPBC Act referral and assessment process since 2011, as summarised below:

- The Project was referred to the Department of Sustainability Environment Water Populations and Communities (DSEWPaC, now Department of the Environment and Energy (DoEE)) under the EPBC Act in 2011;
- On 25 August 2011, the delegate of the Minister for the Environment determined the Project is a Controlled Action requiring assessment and approval under the EPBC Act before it can proceed;
- It was also determined the Project would be assessed by Preliminary Documentation (EPBC Ref: 2011/6053, DSEWPaC, 25 August 2011); and
- Variations to the Project to take an action were approved under Section 156B(1) of the EPBC Act (EPBC Ref: 2011/6053, DoEE, 22 July 2016).

2. PUBLIC COMMENT PROCESS

2.1. Direction to Publish

On the 8th of October 2017 the Minister for the Environment, by delegate, directed Grange to publish the preliminary documentation, this being the information made available during the public comment period. Please refer to Appendix 1. The letter from the Minister advised:

> *"You are now required to publish the information you have provided on the proposed action **within 20 business days of the date of this letter**. This allows for public consultation on the potential impacts of your project. The information must be available for comment for 20 business days and during this time any third parties can comment on the proposed action."*

The Minister's direction was issued under section 95A(3) of the EPBC Act, which requires the Minister to issue a direction to a proponent to undertake public notification for a minimum period of 10 business days.

The letter from the Minister further advised Grange:

> *"Public comments will come directly to you so that you have an opportunity to address any issues raised. You are then required to provide us with:*
>
> - *a copy of all public comments received (if any);*
> - *a summary of each of the comments (if any) and how you have addressed each of them; and*
> - *a revised version of your documentation with any changes or additions needed to take account of the public comments (if any); or*
> - *if no public comments are received, a written statement to that effect."*

2.2. Public Comment Period

As directed, the time frame for receiving public comments was 20 business days, which is twice the minimum period required under the EPBC Act for public comment. Public comment period advertisements noted that the period for consultation was Friday 3 November to Thursday 30 November 2017. During that period, a total of four submissions were received, with another received after the closing date on 2 December 2017. Copies of email and written submissions received are included in Appendix 7.

2.3. Public Comment Period Advertisements

Public comment period advertisements were placed as follows:

- The West Australian on Friday 3 November 2017;
- The Albany Advertiser on Thursday 2 November 2017; and
- Wellstead Whisper, November 2017 Edition, issued 1st November 2017. This notification was not mandatory under the EPBC Act.

A copy of the public comment period advertisement is included in Appendix 2.

2.4. Availability of Documentation

The information package made publicly available included the following:

- The original 2011 referral to DSEWPaC (now DoEE); and
- The *Summary Report for the assessment of the Southdown Magnetite Project under the EPBC Act*, dated September 2017 (SDJV 2018). The Summary Report provided an overview of the Project, its potential environmental impacts and proposed avoidance, management and mitigation measures. It consolidated the following information:
    - The original 2011 referral;
    - Additional information submitted by Grange to the DoEE since the original referral; and
    - Relevant studies undertaken and information prepared since the original referral. Of particular relevance to this response to submissions are the following reports:
        - Bamford Consulting Ecologists (BCE) (2016a). *Southdown Joint Venture (SDJV) Southdown Magnetite Project. Matters of National Environmental Significance (MNES) - Terrestrial Fauna* (included as Appendix 4 of the Summary Report);
        - BCE (2016b). *Southdown Joint Venture (SDJV) Southdown Magnetite Project. Summary of studies and impact assessment Carnaby's Black-Cockatoo. Report to Southdown Joint Venture* (included as Appendix 5 of the Summary Report); and
        - Strategen (2015). *Southdown Magnetite Project Groundwater drawdown and Matters of National Environmental Significance. Report to Grange Resources Limited,* April 2015 (included as Appendix 6 of the Summary Report).

Printed versions of this documentation were made available at the following locations:

- Albany Public Library – 221 York Street, Albany 6330;
- J.S. Battye Library, State Library of Western Australia – 25 Francis St, Perth Cultural Centre, Perth, WA 6000;
- Wellstead Community Resource Centre- 49 Windsor Rd, Wellstead 6328; and
- Department of the Environment and Energy- 51 Allara Street, Canberra.

A PDF version was made available on the Grange Resources website:
http://www.grangeresources.com.au/southdown-magnetite-project-epbc-public-comment-period

There were no requests for assistance with documentation related to special needs such as English being a second language or vision impairment.

2.5. Proactive Stakeholder Consultation

Grange took additional proactive steps to ensure stakeholders were aware of the opportunity to provide public comment. These steps were not mandatory requirements under the EPBC Act. This included additional written notification of the public comment period to a range of stakeholders, including all landowners along the proposed pipeline routes, relevant government departments, interested environmental groups, and elected politicians for the local electorates, totalling 99 recipients. A template of the letters sent is included in Appendix 3.

Further, in addition to publishing a notice of the public comment period in the West Australian and the Albany Advertiser, an invitation to provide comment was published in the Wellstead Whisper on 1 November 2017, prior to the public comment period commencing. This notification was not mandatory under the EPBC Act.

Extensive stakeholder engagement was undertaken to provide updates on the Project, the EPBC Act process, the findings of impact assessments and mitigation measures. This included meetings with interested environmental groups and government departments and a presentation to the Wellstead Progress Association.

3. SUBMISSIONS AND RESPONSES

Four (4) submissions were received during the public notification period with another arriving after the closing date. Copies of all submissions received have been provided in Appendix 7. Table 1 identifies who made a submission and a summary of the general issues raised. Table 2 summarises the submissions and responses.

Table 1: Public Submissions Received

Submissions received before the closing date		
Ref	**Who**	**Issues Raised**
1	Peter McKenzie	• Timing of public comment period.
2	Sylvia Leighton	• Aquifer and groundwater extraction; • Fauna Matters of National Environmental Significance (MNES); • Flora MNES; • Threatened Ecological Communities (TECs); and • Timing of public comment period.
3	Hon. Diane Evers MLC	• Timing of public comment period.
4	Deborah Fitzgerald	• Fauna MNES; • TECs; and • Timing of public comment period.
Submission received after the closing date		
5	Jonas Mitchell (Received on 2 December 2017)	• TECs; and • Connectivity.

Table 2: Response to Submissions

Submission No	Key issue raised	Response
1	1-1 The timing of the public comment period in relation to the busiest farming periods for the local community was questioned and criticised.	On the 8th of October 2017 the Minister for the Environment, by delegate, directed Grange to publish the preliminary documentation, this being the information made available during the public comment period. The letter from the Minister advised *“You are now required to publish the information you have provided on the proposed action* ***within 20 business days of the date of this letter****. This allows for public consultation on the potential impacts of your project. The information must be available for comment for 20 business days and during this time any third parties can comment on the proposed action.”* The Minister's direction was issued under section 95A(3) of the EPBC Act, which requires the Minister to issue a direction to a proponent to undertake public notification for a minimum period of 10 business days. In accordance with the Minister's direction, Grange published the preliminary documentation between Friday 3rd of November 2017 and Thursday 30th of November 2017. Grange has consistently been advised by Wellstead locals that December is their busiest month, for harvest. Cooperative Bulk Handling (CBH) confirmed that the busiest time at Wellstead CBH Receival Point (the wheat bins) is December. Once harvest is completed, people try to take a holiday in January and then return for the commencement of school. Grange has also been advised seeding is also a very busy time which generally occurs from April to June depending when it rains. Therefore Grange was satisfied the public comment period, which occurred in November, avoided all these times.

Submission No	Key issue raised	Response
		Grange took additional proactive steps to ensure stakeholders were aware of the opportunity to provide public comment. These steps were not mandatory requirements under the EPBC Act. This included additional written notification of the public comment period to a range of stakeholders, including all landowners along the proposed pipeline routes, relevant government departments, interested environmental groups, and elected politicians for the local electorates. Further, in addition to publishing a notice of the public comment period in the West Australian and the Albany Advertiser, an invitation to provide comment was published in the Wellstead Whisper on 1 November 2017, prior to the public comment period commencing. There was no feedback until the 28 November 2017 (the last few days of the public comment period) of concern regarding the timing of the public comment period. It should also be noted that there has been no further comment or complaint since the cessation of the public comment period that the timing was inappropriate. Grange considers that the period of 20 business days, which was twice the minimum period prescribed in the EPBC Act for public comment, and avoided what Grange was advised were the busiest times of the year for the local community, did provide a reasonable opportunity for the public to provide comment in relation to the Project.

Submission No	Key issue raised	Response
2	2-1 Grange has stated that they intend to extract up to 5 Gigalitres per year of groundwater in the identified Wellstead aquifers (Figure 6-1) for water supply to the mine site. I argue we do not understand the vegetation community/hydrology relationship well enough in the southcoast region to allow 5 billion litres of our shallow groundwater supply in Wellstead aquifers to be made accessible annually to the Southdown Mine project.	The issues raised in Submission 2 are largely focussed on the potential environmental effects of abstraction of up to 5 GL/yr of groundwater for the Project water supply. This groundwater abstraction will be taken from deep aquifers and not from the shallow water table aquifers. Any groundwater dependent vegetation that occurs within the vicinity of the Project area does not rely on the deeper groundwater as a water source and will consequently not be affected by groundwater abstraction for the Project. This understanding of the hydrogeology is based on the results of an extensive groundwater exploration drilling and testing program and groundwater modelling conducted in progressive stages since 2006. This knowledge has been combined with an understanding of the potential for dependency of vegetation on available groundwater, as developed through extensive research by Edith Cowan University and presented in Strategen 2018 (Appendix 4 of this document). The hydrogeological investigations undertaken in the area have been summarised in Rockwater 2018 (included as Appendix 2 to Strategen 2018 (Appendix 4 of this document)). In summary, this work has identified three hydrogeological occurrences of groundwater in the area proximate to the Project footprint: 1. Surface and near-surface occurrences of perched water tables, which support wetlands and shallow rooted phreatophytic vegetation. By their nature perched water tables are separate from, and are not affected by, abstraction from other aquifers.

Submission No	Key issue raised	Response
		2. The regional water table, which occurs in the Pallinup Siltstone, within which water table depths are generally in excess of 9 m below ground surface and depths to the water table in the locality of the Project are approximately 15 m. This aquifer is brackish and is generally unlikely to support groundwater dependent ecosystems because of its depth to groundwater and salinity. Areas with shallower depths to groundwater such as the seasonal Springwell Lake and Mettler Lake will be monitored to ensure there are no unexpected changes in the water table at these locations. The deepest part of the Mettler Lake basin floor is estimated to be approximately 5 m and the depth to watertable below Springwell Lake is approximately 8 m. Any surface water in these lakes is derived from rainfall and perched watertables (Ecological 2018). Shallow water tables also occur in the deeply incised Wilyun Creek and Eyre River close to the coast. 3. Groundwater occurring within the Werillup Formation, which extends from depths of 30 m or more below the ground surface down to bedrock. Water levels in the Werillup Formation are several metres below those in the overlying Pallinup Siltstone, which indicates that the Pallinup Siltstone aquifers are not being recharged from the lower formations. Groundwater within the Werillup Formation occurs within two aquifers, which are confined by carbonaceous clay layers with negligible transfer of water across these layers. As a consequence, abstraction of water from these aquifers is not expected to significantly affect water levels in the shallower groundwater systems. This hydrogeological configuration is presented diagrammatically in Figure 2 in Rockwater 2018 (included as Appendix 2 to Strategen 2018 (Appendix 4 of this document)). The availability of water to the local vegetation through both perched water tables and field capacity within the soil profile above the regional water table is expected to satisfy all the vegetation water requirements. The vegetation is unlikely to be groundwater dependent due to the depth to groundwater and the brackish nature of the groundwater.

Submission No	Key issue raised	Response
		Abstraction of the expected 5 GL/yr of groundwater for supply purposes will be from the Werillup Formation. No effect on the local vegetation communities outside of the Southdown Magnetite Project area is expected because of the following: • No significant drawdown in the Pallinup Siltstone as a result of abstraction from the Werillup Formation as described above; • Modelling results showing that the area of drawdown from mine pit dewatering is relatively small and contained; • lack of any hydraulic connection between the regional water table in the Pallinup Siltstone and any overlying perched waterbodies that may support local vegetation; and • local vegetation not being dependent on the regional water table due to depth and salinity. An adaptive management process has been developed and will be implemented to address any issues of uncertainty regarding potential impacts of groundwater abstractions for the Southdown Magnetite Project on local vegetation communities of concern. This process will be based on monitoring both deep groundwater responses to the Project, and changes in shallow groundwater levels, with proponent responses defined in the event of any unexpected or untoward impacts on either groundwater or ecological resources. The adaptive Groundwater Monitoring and Management Plan has been developed and is included in Appendix 5. This Plan has been specifically designed to respond to questions raised in the EPBC assessment and has not been designed to meet the requirements of MS 816.

Submission No	Key issue raised	Response
2	2-2 Grange predicts that the 5 billion litres extraction will have no impact on Matters of National Environmental Significance (MNES) and have specifically referenced the one species – the Carnaby Cockatoo. The specific aquifers that Grange have identified in Figure 6-1 actually extend under areas where there are other species of national significance; the Vulnerable Forest Red-tailed Black-Cockatoo, Karrak (*Calyptorhynchus banksii naso*), Baudin's Cockatoo, (*Calyptorhynchus baudinii*), Malleefowl (*Leipoa ocellata*) and the Endangered Australasian Bittern (*Botaurus poiciloptilus*) (has been recorded in Mettlers Lake Nature Reserve in the past) are other faunal MNES that need to be considered.	As outlined in the response to 2-1, there is no impact predicted on any vegetation outside of the Southdown Magnetite Project area. Mettler Lake is 7.5 km from the mine pit so there is negligible potential for this area to be affected by the mine dewatering. Mettler Lake is within the vicinity of the palaeovalleys where abstraction for water supply will be undertaken. The depth to groundwater at Mettler Lake is likely to be approximately 5 m. Therefore, any surface water in the lake is not related to the regional groundwater table and may be perched or semi-perched. The depth to water means that there is potential for groundwater dependent vegetation to occur, although it is unlikely to be an important source of water as the Pallinup aquifer is brackish. The abstraction of water from the Werrilup Formation is not expected to result in drawdown of the overlying Pallinup Formation, however groundwater levels will be monitored near Mettler Lake to ensure that no unexpected drawdowns occur as a result of the project. This monitoring is outlined in the Groundwater Monitoring and Management Plan attached in Appendix 5. As there is predicted to be no impact to potential habitat of MNES as a result of dewatering or water supply abstraction; the only potential impact to the fauna MNES mentioned in the submission is from clearing required for the borefield. This has already been included in the Project impact assessments (see sections 3.5, 3.6, 6.1, 6.2 and 7.2 of the Summary Report (SDJV 2018). A conservative allowance for clearing of up to 6 ha of native vegetation to locate bores and associated pipelines within the Southern and Central Palaeovalleys has been included for the purposes of impact assessment. Potential areas for the borefield are mostly cleared paddock and the likelihood of impacting fauna MNES outside of what is

Submission No	Key issue raised	Response
		currently being assessed is very low. Grange is committed to undertaking botanical and fauna surveys to ensure the only potential impact to fauna MNES is that which is currently being assessed. That is the clearing of no more than 6 ha of native vegetation that may be foraging habitat to Carnaby's Black-Cockatoos.
2	2-3 There are also floral MNES that need to be considered. The proposed Southdown Mine site itself is actually located within a native vegetation community that was recently listed as a Threatened Ecological Community (TEC), the Proteaceae Dominated Kwongkan Shrublands of the south east coastal floristic province. Much of the proposed extraction aquifers sit in under native vegetation areas which fall in under this TEC classification. The aquifers also extend under a WA Priority Ecological Community (PEC) made up of Flat Topped Swamp Yate (*Eucalyptus occidentalis*). These trees are located in seasonally inundated clay basin and are adapted to be able to survive with their roots under water for over 18 months duration.	The Southdown Magnetite Project Summary Report (SDJV 2018) details the assessment of the impact of the action on listed threatened species and communities. This assessment addresses species and communities listed as at the date of the Minister's 'controlled action' decision on 25 August 2011. Consistent with section 158A of the EPBC Act, Grange has not addressed species and communities listed after this date, including the Subtropical and Temperate Coastal Saltmarsh (Coastal Saltmarsh) TEC listed as a Vulnerable TEC under the EPBC Act on 10 August 2013; and the Proteaceae Dominated Kwongkan Shrublands TEC listed as Endangered under the EPBC Act on 1 February 2014. Most West Australian (WA) Priority Ecological Communities (PECs) are not listed as relevant matters under the EPBC Act and so are not addressed by the DoEE in this assessment. This includes the Flat Topped Swamp Yate (*Eucalyptus occidentalis*). The potential impact to WA PECs was considered by the WA Environmental Protection Agency (EPA) in its assessment of the Project under the *Environmental Protection Act 1986* (WA).

Submission No	Key issue raised	Response
		In any event, the hydraulic disconnect between the perched aquifers which may support the Flat Topped Swamp Yate and the regional water table as summarised in the response to section 2-1 of this table, will ensure no effect on this vegetation as a consequence of groundwater abstraction from the Werrilup Formation for the Southdown Magnetite Project. The monitoring and adaptive management process is outlined in the Groundwater Monitoring and Management Plan attached in Appendix 5.
2	2-4 The Grange Summary Report for the Southdown Magnetite Project identifies that much of the Wellstead District water table is more than 9-10m below the surface, and as such, any vegetation present in these areas is understood to be a facultative groundwater user that would not be affected by changes in the regional water table level. There have been no studies in the southcoast region on the root zone depth and the water extraction characteristics of the vegetation community's specific to southcoast region and more specifically in the Wellstead District. Grange have relied on data extrapolated from just one study by Froend & Loomes (2006) who investigated ecological water requirements on	The Wellstead area is climatically similar to the area studied by Department of Water in the Southern Blackwood and Scott Coastal Plain to the west (Froend & Loomes 2006). The decreasing dependence on groundwater with depth is also outlined in Eamus et al. 2006 and has been found to be relevant to environments throughout Western Australia. The conclusion that there will be no significant impact on vegetation is based not only on the low likelihood of the vegetation being dependent on regional groundwater (rather than perched aquifers which may be important in some wetlands but will not be affected by the Project) but also on the low likelihood of drawdown in the Pallinup aquifer. This prediction will be monitored to ensure that no unexpected impacts occur, as outlined in the adaptive Groundwater Monitoring and Management Plan attached in Appendix 5.

Submission No	Key issue raised	Response
	the Southern Blackwood and Eastern Scott Coastal Plain. Froend & Loomes postulate that vegetation requirements for groundwater decrease with depth to the water table, and that vegetation is more tolerant to water table decline due to the corresponding increase in alternative water sources.	
2	2-5 I live in Wellstead District and have a particular interest in the native vegetation communities, landform, soils, soil moisture profiles and water tables. The annual rainfall can range from 430mm - 915mm. We do not have any idea as to what depth the root zone is for different vegetation species or vegetation communities. It has been observed that the recent 20 year bluegum plantations in the southern part of the District have definitely dried out the soil moisture profile. One excavation of the root zone of blue-gums detected them down to a 20 metre depth. The blue-gums have visually caused a detrimental effect on the native vegetation communities in the District that are dependent on occasional seasonally	No significant drawdown of the water table is predicted as a result of the project outside of the Project area (Rockwater 2018). Therefore, there is little potential for cumulative impacts with other land uses.

Submission No	Key issue raised	Response
	wet soils like the Swamp banksia (*Banksia littoralis*) woodlands, *Melaleuca cuticularis* and *Eucalytpus occidentalis* swamp areas.	
2	2-6 Froend & Loomes (2006) effectively classify vegetation overlying water tables at a depth greater than 10 m as being facultative groundwater users. That is, the individual plants may use groundwater if it is available, but do not experience any adverse impacts in its absence. I am deeply concerned about the recent deaths to certain vegetation communities in our District that appear to be reliant on damp seasonal soils. A change in the natural hydrology whether it was just the soil profile or there was also reduced access to ground water has not been ascertained. I believe we do not understand the vegetation/hydrology relationship well enough in the southcoast region to allow 5 billion litres of our shallow groundwater supply in Wellstead aquifers to be made accessible to the Southdown Mine Project on an annual basis.	The project is not predicted to cause significant drawdown of the regional groundwater levels and there is no potential for perched or semi perched systems to be affected. This is based on drilling investigations, pump tests and hydrological modelling (Rockwater 2018). Therefore, any impact on vegetation outside of the Project area is considered highly unlikely. If any impact was to occur, it would be in areas with shallow groundwater levels in the Springwell or Mettler Lake or associated with the Wilyun Creek or Eyre River. The groundwater table in these areas will be monitored to determine whether there is any unexpected impacts as outlined in the Groundwater Monitoring and Management Plan included in Appendix 5.

Submission No	Key issue raised	Response
2	2-7 The proposed aquifers that Grange has targeted are located under four catchments in Wellstead District; Cordinup Creek, Wilyun Creek, Eyre River (including Windy Windy Creek and the Pallinup River Catchment. All four of these catchments are poorly researched and it is not known how much drainage from the shallow groundwater table flows into these surface creeks and is important to their yearly surface flow. These creeks and rivers are home to freshwater turtles, freshwater crayfish and water rats (*Hydromys chrysogaster*). Once again - it would be a shame to cause a major change to the ecology of these creeks by reducing the water supply BEFORE we have properly researched the special qualities of these four catchments and then can record if there are any impacts occurring by the proposed water extraction by Grange.	The surface water resources in the district are fed from water in the Pallinup Siltstone, while groundwater abstraction for the Project is from the underlying Werillup Formation, which is effectively hydraulically disconnected from the Pallinup Siltstone. As summarised in the response to section 2-1 of this table, there is no significant drawdown of the Pallinup aquifer expected and therefore, there is no change expected to surface water discharges to the coastal creeks. Groundwater monitoring will be undertaken to confirm this prediction as outlined in the Groundwater Monitoring and Management Plan attached in Appendix 5.
2	2-8 The timing of the public comment period in relation to the busiest farming periods for the local community was questioned and criticised.	Please see the response to section 1-1 of this table.

Submission No	Key issue raised	Response
3	3-1 The submission requested an extension for the public comment period based on the timing of local farming busy periods.	Please see the response to section 1-1 of this table. As outlined in section 1-1 the 20 business days required for the public comment period, which was determined by the Minister, was twice the minimum period of 10 business days provided for in the EPBC Act.
4	4-1 It is my opinion that flora surveys conducted over the project area when the project was referred in 2011 require further examination under the referral process, due to the project area now occurring in a Threatened Ecological Community (TEC). The proposed Southdown Mine site is located within a native vegetation community that was listed as the Proteaceae Dominated Kwongkan Shrublands of the south east coastal floristic province TEC, which was nationally listed in 2014. Based on this listing there are now floral MNES that need to be considered. The fact that the MAIA report 2016 states that "No ecological community MNES occurred adjacent to or near to the Wellstead Aquifer	The Southdown Magnetite Project Summary Report (SDJV 2018) details the assessment of the impact of the action on listed threatened species and communities. This assessment addresses species and communities listed as at the date of the Minister's 'controlled action' decision on 25 August 2011. Consistent with section 158A of the EPBC Act, Grange has not addressed species and communities listed after this date, including the Subtropical and Temperate Coastal Saltmarsh (Coastal Saltmarsh) TEC listed as a Vulnerable TEC under the EPBC Act on 10 August 2013; and the Proteaceae Dominated Kwongkan Shrublands TEC listed as Endangered under the EPBC Act on 1 February 2014. Grange has committed to retain 416 ha of native vegetation on site and will avoid impact to all TECs where possible, regardless of when they were listed. To this end, Grange has been working since 2014 to identify areas of the Proteaceae Dominated Kwongkan Shrublands and Subtropical and Temperate Coastal Saltmarsh TECs and has proposed implementation of management measures to address impacts to all retained vegetation, including the TECs and other sensitive areas. These will include: • Finalising infrastructure design to avoid confirmed areas of TEC where possible; • Educating staff;

Submission No	Key issue raised	Response
	Investigation Area when the project was referred in July 2011" should now be reconsidered given the implications of the proposed project area lying within the nationally listed TEC.	• Vehicles staying on formed roads; • Mapping, buffers and flagging of conservation significant areas such as the TEC; • Erosion, sediment and drainage management; • Dust management; • Bushfire management; • Weed management; • Dieback management; • Adaptive groundwater management; • Rehabilitation and reinstatement including re-establishing natural contours and drainage lines and topsoil management; • Operational maintenance; • Maintaining clearing records; and • Updating Grange's Threatened Flora and Conservation Management Plan to include information and management actions relating to TECs.
4	4-2 In addition to the TEC there are several WA Priority Ecological Communities, requiring consideration, particularly the Flat Topped Swamp Yate (*Eucalyptus occidentalis*), which is of State significance.	Most West Australian (WA) Priority Ecological Communities (PECs) are not listed as relevant matters under the EPBC Act and so are not addressed by the DoEE in this assessment. This includes the Flat Topped Swamp Yate (*Eucalyptus occidentalis*). The potential impact to WA PECs was considered by the WA Environmental Protection Agency (EPA) in its assessment of the Project under the *Environmental Protection Act 1986* (WA).

Submission No	Key issue raised	Response
		Some of the PECs are listed as being part of the Proteaceae Dominated Kwongkan Shrublands TEC in the most recent (June 2017) PEC list. However these are not included in this assessment as per the explanation in section 4-1 of this table.
4	4-3 Further, there is little evidence of the implications of mine and infrastructure development on habitat for other nationally listed threatened species including the critically endangered Western ring tailed possum (*Pseudochierus occidentalis*) and the Vulnerable Noisy scrub bird (*Atrichornis clamosus*).	All relevant terrestrial fauna species that are nationally listed have been adequately addressed in the BCE (2016a) *Review of Matters of National Environmental Significance (MNES) – Terrestrial Fauna* included as Appendix 4 in the Summary Report made publicly available (SDJV 2018). This includes both of the species mentioned in the submission. **Western Ring Tailed Possum** The potential impacts to the Western Ring Tail Possum have been addressed extensively within the Summary Report (SDJV 2018) and impact assessments made publicly available. **The predicted impact to this species was found to be negligible**. Please refer to the following sections in the publicly available Summary Report (SDJV 2018): • Executive Summary; • Sections 7.1.2 (Figure 7-1 shows all evidence of Western Ring Tail Possums found during surveys. All are outside the Project footprint); • Section 7.2 which summarises conclusions of the Western Ring Tail Possum impact assessment; • Appendix 2 which includes detailed mapping of the entire slurry pipeline and clearing required; and

Submission No	Key issue raised	Response
		• Appendix 4 BCE (2016a) *Review of Matters of National Environmental Significance (MNES) – Terrestrial Fauna).* This is the impact assessment that addresses the species in great detail including a Western Ring Tail Possum habitat analysis for the proposed slurry pipeline. Surveys for the species were conducted in 2006, 2014 and 2016. The 2006 and 2014 surveys found no evidence of Western Ringtail Possum, or habitat capable of supporting this species at the mine site, desalination plant infrastructure or Wellstead Aquifer Investigation Area of the Project. The 2016 survey looked at the slurry pipeline only. The only Project component that may have a potential impact on the Western Ringtail Possum is the construction of the slurry/return water pipelines where vegetation may need to be cleared or trimmed. Whilst evidence of the species has been located adjacent to the slurry pipeline at one location, no evidence of the species was found directly within the slurry pipeline corridor during surveys and inspections conducted. This species will not be directly impacted by the pipeline infrastructure as the construction footprint of the slurry pipeline is narrow (the construction easement is up to 25 m wide within the indicative infrastructure corridor) and largely avoids native vegetation, and therefore **any impact is expected to be negligible**. To further reduce the potential for impact on the Western Ringtail Possum, Grange will conduct a pre-clearing survey in areas of suitable habitat along the pipeline construction easement. The focus of these surveys will be to determine if any dreys have been constructed in overhanging trees that might be

Submission No	Key issue raised	Response
		disturbed or need to be pruned during construction. If such dreys are found to be occupied immediately prior to construction activities, animals will be relocated in consultation with the Department of Biodiversity, Conservation and Attractions (previously the Department of Parks and Wildlife). **Noisy Scrub-bird** This species was included in the BCE (2016a) *Review of Matters of National Environmental Significance (MNES) – Terrestrial Fauna* (Appendix 4 of the Summary Report) and it was **concluded that no impact from the Project is expected**. It has not been recorded during surveys and is unlikely to occur in the Project areas as they do not support the very dense vegetation in gullies that provide habitat for the species. Known populations are located at Two Peoples' Bay, Bald Island and Mt Manypeaks. All of these are outside of the Project areas. Please see the figure in Appendix 6 of this document for the location of the Noisy Scrub-bird's known locations. The species is addressed in the BCE (2016a) *Review of Matters of National Environmental Significance (MNES) – Terrestrial* (Appendix 4 of the Summary Report) in Table 2, in its own section within section 4.1, and in the EPBC Act Protected Matters Report. Further, the Noisy Scrub-bird Recovery Plan (Danks, Burbidge and Smith, 1996) was consulted.

Submission No	Key issue raised	Response
4	4-4 The timing of the public comment period in relation to the busiest farming periods for the local community was questioned and criticised.	Refer to response for section 1-1 of this table.
Submission received after the closing date		
5	5-1 I wanted to make comment about the proposed road diversion of Gnowellen Road as indicated in Figure 3-2 Southdown Magnetite Project - Mine Area and Indicative Infrastructure Layout. I was talking to a Reserves Officer at the City of Albany and they have identified the roadside bushland on Gnowellen Rd as a very significant floral corridor between the Stirling Range National Park and the Cape Riche coastal reserve. The road reserve bushland is in good health and one of the few bits of bush that has continuous connectivity through to the southern coastal reserve. It is extremely important that this vegetation corridor connectivity is maintained. Some of this bushland is also part of the native vegetation	Proposed clearing of vegetation along Gnowellen Road will not have a significant impact to MNES listed at the time of referral in 2011. **Flora** Flora and vegetation surveys carried out in the footprint of the mine site, slurry/return water pipelines, and the desalination plant and its infrastructure corridor footprints did not locate any flora species listed under the EPBC Act. This includes Gnowellen Road. **TEC** Potential impacts to the TEC are not included in this assessment for the reasons outlined in section 4-1 of this table. However, TEC desktop studies undertaken by Grange and referred to in 4-1 have identified areas 'High Likely' to be the TEC. The design proposed allows for avoidance of these areas within the Gnowellen Road area. **Fauna**

Submission No	Key issue raised	Response
	community that was recently listed as a Threatened Ecological Community (TEC), the Proteaceae Dominated Kwongkan Shrublands of the south east coastal floristic province. I would therefore expect that it has special protection restricting its removal.	Carnaby's Black-Cockatoo is the only fauna MNES relevant to the mine site area and hence Gnowellen Road. The BCE (2016b) *Southdown Joint Venture (SDJV) Southdown Magnetite Project. Summary of studies and impact assessment Carnaby's Black-Cockatoo. Report to Southdown Joint Venture* (Appendix 5 of the Summary Report (SDJV 2018)) addresses connectivity. The impact assessment concluded" The *remnant vegetation within the project footprint does not lie in a critical position for connectivity; that is the patches do not lie between large areas of remnant vegetation and do not particularly contribute to a series of 'stepping stones' of remnants. This is not to suggest that the remnants will not be used by birds travelling across the landscape, but their layout does indicate they are unlikely to have a critical connectivity function."* Grange has proposed revegetation of the site with up to 273 ha of native vegetation based on locally selected species suitable for Carnaby's Black-Cockatoo foraging and offering biodiversity value for other fauna species. Revegetation plans will focus on improving connectivity in the local area where possible. Native vegetation cleared from Gnowellen Road will be mulched and used for revegetation in these other areas. Mulched vegetation will help stabilise the soil surface, provide a source of seed and also a source of shelter for some animals. Further to this Grange has proposed to purchase 953 ha of local native vegetation areas that offer important habitat and connectivity for Carnaby's Black-Cockatoo, and other local fauna and flora. Land purchased for offset will be incorporated into the state conservation

Submission No	Key issue raised	Response
		estate and managed by the Department of Biodiversity, Conservation and Attractions (formerly the Department of Parks and Wildlife).

4. AMENDMENTS TO THE SOUTHDOWN MAGNETITE PROJECT SUMMARY REPORT IN RESPONSE TO PUBLIC COMMENTS

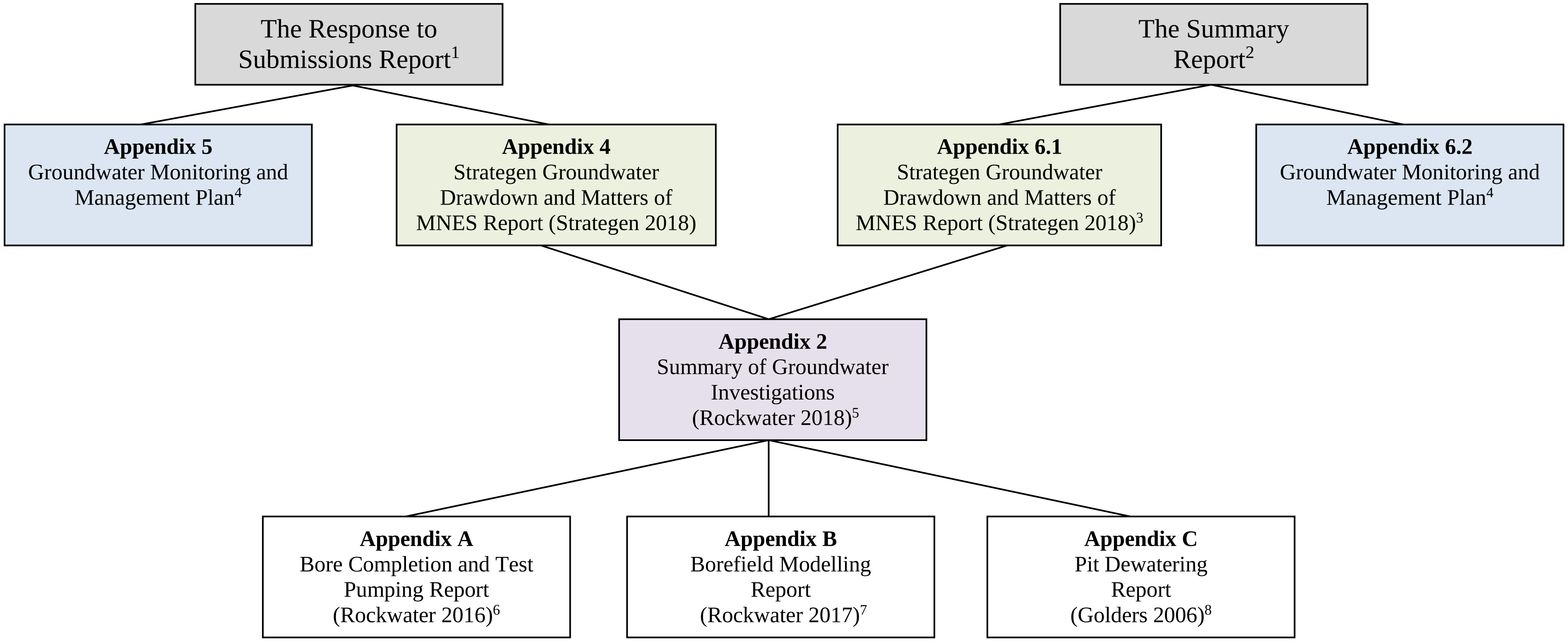
All of the submissions received have been adequately addressed and none require amendment to the Project. The Summary Report (SDJV 2018) has been updated to include more detailed information with regard to groundwater and in response to Submission Two.

The following lists the amendments made to the Summary Report and associated groundwater reports. For ease of reference, the updated reports from the Summary Report have also been appended to this document. Refer to Figure 1 for a list of reports associated with groundwater and their location within this document and the Summary Report.

- The Executive Summary, and Sections 6.2, 7.2.2 and 7.3 of the Summary Report have been updated to incorporate further information with regards to groundwater. A new section (section 6.1.3) has also been added to the Summary Report to provide further context on groundwater.
- Appendix 2 (Rockwater 2018) of Appendix 6.1 (Strategen 2018) of the Summary Report has been updated to include more detailed information on the hydrogeology of the Project area. This information is based on extensive drilling, testing and modelling that was finalised in late 2017 and was not ready to be included in the Summary Report at that time.
- Appendix 2 (Rockwater 2018) of Appendix 6.1 (Strategen 2018) has also been amended to include the following three documents as appendices:
    - Rockwater (2016). Southdown Magnetite Project, Wellstead Area Groundwater Exploration Programme, Bore Completion and Test Pumping Report. May 2016.
    - Rockwater (2017). Southdown Magnetite Project, Numerical Modelling of Groundwater Supply from the Wellstead Sub-basin. October 2017.
    - Golder Associates (2006). Report on Estimates of Groundwater Inflow and Drawdown around the Proposed Open Pit, Southdown Iron Ore Project. July 2006.

  The updated Strategen (2018) report which includes the updated Rockwater (2018) report has been included as Appendix 4 of this document (refer Figure 1).
- The Groundwater Monitoring and Management Plan has been added as Appendix 6.2 of the Summary Report. It has also been included as Appendix 5 of this document (refer Figure 1).
- Commitment to undertake fauna surveys when designing the borefield to ensure the only potential impact to fauna MNES is that which is currently being assessed. That is the clearing of no more than 6 ha of native vegetation that may be foraging habitat to Carnaby's Black-Cockatoos.

Figure 1: Key Reports Associated with Groundwater and their Location within the Response to Submissions Report and Summary Report



[1] Southdown Joint Venture (2018). *Response to Submissions under the Environment Protection and Biodiversity Conservation Act 1999* (the Response to Submissions Report) Rev 3: December 2018

[2] Southdown Joint Venture (2018). *Summary Report for Assessment of the Southdown Magnetite Project under the Environment Protection and Biodiversity Conservation Act 1999* (the Summary Report) Rev 4: December 2018

[3] Strategen (2018). *Southdown Magnetite Project Groundwater Drawdown and Matters of National Environmental Significance under the Environment Protection and Biodiversity Conservation Act 1999* (Strategen Groundwater Drawdown and Matters of MNES Report) Rev 5: September 2018

[4] Ecological Australia (2018). *Southdown Magnetite Project Groundwater Monitoring and Management Plan* (the Groundwater Monitoring and Management Plan) Rev 6: November 2018

[5] Rockwater (2018). *Summary of Groundwater Investigations, Southdown Magnetite Mine* (Summary of Groundwater Investigations) August 2018

[6] Rockwater (2016). *Southdown Magnetite Project, Wellstead area groundwater exploration programme, bore completion and test pumping report* (Borefield Completion and Test Pumping Report) May 2016

[7] Rockwater (2017). *Southdown Magnetite Project, Numerical Modelling of Groundwater Supply from the Wellstead Sub-basin* (Borefield Modelling Report) October 2017

[8] Golder Associates (2006). *Report on Estimates of Groundwater Inflow into and drawdown around the proposed open pit, Southdown Iron Ore Project* (Pit Dewatering Report) July 2006

5. REFERENCES

Bamford Consulting Ecologists (BCE) (2016a). *Southdown Joint Venture (SDJV) Southdown Magnetite Project. Matters of National Environmental Significance (MNES) - Terrestrial Fauna*, August 2016.

BCE (2016b). *Southdown Joint Venture (SDJV) Southdown Magnetite Project. Summary of studies and impact assessment Carnaby's Black-Cockatoo.* Report to Southdown Joint Venture, August 2016.

Eamus, D., Froend, R., Loomes, R., Hose, G. & Murray, B. 2006. A functional methodology for determining the groundwater regime needed to maintain the health of groundwater-dependent vegetation. *Australian Journal of Botany* 54, 97-114

Grange Resources Limited (Grange) (2011). *Referral of proposed action. Project Referral and Report for Southdown Magnetite Project Offset Management Strategy*. July 2011.

Rockwater Proprietary Limited (Rockwater) (2018). *Summary of Groundwater Investigations, Southdown Magnetite Mine*. August 2018.

Strategen (2018). *Southdown Magnetite Project Groundwater drawdown and Matters of National Environmental Significance.* Report to Grange Resources Limited, September 2018, Revision 5.

Southdown Joint Venture (SDJV) (2018). *Summary Report for the assessment of the Southdown Magnetite Project under the Environment Protection and Biodiversity Conservation Act 1999,* December 2018, Revision 4.

Appendix 1 – Direction to Publish

EPBC Ref: 2011/6053

Mr Honglin Zhao
Grange Resources Limited
PO Box 659
BURNIE TAS 7320

Dear Mr Zhao

Direction to publish preliminary documentation.
Southdown Magnetite Project, WA (EPBC 2011/6053)

I am writing to you in relation to your proposal to construct and operate an open pit magnetite mine approximately 90 kilometres east-north-east of Albany, along with associated infrastructure including a desalination plant, pipelines and a port facility.

On 25 August 2011, a delegate of the Minister decided that the proposed action is a controlled action and that it requires assessment and a decision about whether approval should be given under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

The Department of the Environment and Energy (Department) has advised me that it is satisfied that the information in the preliminary documentation, comprising the referral information and additional information provided on 27 September 2017, addresses all requests for information.

You are now required to publish the information you have provided on the proposed action **within 20 business days of the date of this letter**. This allows for public consultation on the potential impacts of your project. The information must be available for comment for 20 business days and during this time any third parties can comment on the proposed action. Detailed directions on what information you need to publish and where to publish are attached to this letter.

Public comments will come directly to you so that you have an opportunity to address any issues raised. You are then required to provide us with:

- a copy of all public comments received (if any);
- a summary of each of the comments (if any) and how you have addressed each of them; and
- a revised version of your documentation with any changes or additions needed to take account of the public comments (if any); or
- if no public comments are received, a written statement to that effect.

Once you have provided us with this information, you will then need to publish the summary of comments and your responses, together with the original documentation including any changes or additions made in response to the published comments (or a notice which meets the requirements of the relevant provisions of Part 16.03 (5 – 7) of the *Environment Protection and Biodiversity Conservation Regulations 2000* (EPBC Regulations)).

The assessment process will commence once we have received any public comments and your responses to them. A decision on whether the proposed action can be approved or not would generally be expected within 40 business days of that time, unless further information is required.

If you have any questions about the assessment process or this decision, please contact the project manager, Matt Whitting, by email to matt.whitting@environment.gov.au or telephone 02 6274 1869 and quote the EPBC reference number at the top of this letter.

Yours sincerely

Gregory Manning
Assistant Secretary
Assessments (WA, SA, NT) and Air Branch

8 October 2017

Publication of Information for Assessment on Preliminary Documentation under section 95A of the *Environment Protection and Biodiversity Conservation Act 1999*

Information to be published:

(a) the referral for the Project, including its appendices A-I, which was validated and published by the Department of the Environment and Energy on 27 July 2011

(b) specified information relating to the action that was received in response to the Minister's request under subsection (2), specifically the Summary report for assessment of the Southdown Magnetite Project under the EPBC Act (September 2017)

(c) an invitation for anyone to give Grange Resources Limited, within the 20-day period specified in the direction, comments in writing relating to the information or the action.

As the material is more than 200 words, a notice may be published instead.

The published notice must **invite public comments** and state:

(a) the provision of the Act that requires the material to be published: **Section 95A(3) of the *Environment Protection and Biodiversity Conservation Act 1999* (Cth)**;

(b) the identification number for the action, allocated by the Department: **EPBC 2011/6053**;

(c) a descriptive title for the action: **Southdown Magnetite Project, WA**;

(d) the location of the action: **90 km north-east of Albany, WA**;

(e) the name of the person intending to take the action: **Grange Resources Limited**;

(f) each matter protected by a provision of Part 3 of the Act: **listed threatened species and communities (s18 & s18A)**;

(g) where a copy of the material may be viewed or obtained:

   (i) in electronic and hard copy form; and

   (ii) at a reasonable cost or without charge;

(h) the final date for providing comment;

(i) that persons with special needs (i.e. for whom English is a second language or who has a vision impairment) may contact a designated person for assistance in accessing the material.

The notice must be approved by the Department before it is published.

Where to be published:

(a) at an appropriate location on the internet;

(b) in a national or state daily newspaper that circulates in the state or territory in which the action occurs; and

(c) if practical, in regional newspapers that circulate in any regions of Australia where the action is likely to have a significant impact on a matter protected by a provision of Part 3 of the Act.

The designated proponent must:

(a) give 2 copies of the material to:

(i) at least 1 local authority, or at least 1 local or regional library, for the area where the action is likely to have a significant impact on a matter protected by a provision of Part 3 of the Act;

(ii) a state government authority responsible for environmental protection, or a state library, in the state where the action is likely to have a significant impact on a matter protected by a provision of Part 3 of the Act;

(iii) the Department; and

(b) ask the authority or library to display the material publicly.

Appendix 2 – Advertisement Advising of Public Comment Period

INVITATION FOR PUBLIC COMMENT

PUBLIC NOTICE: SOUTHDOWN MAGNETITE PROJECT, GREAT SOUTHERN REGION, WESTERN AUSTRALIA (EPBC ACT REF: 2011/6053)

The following notice is published pursuant to Section 95A (3) of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). **Grange Resources Limited (Grange**) (ACN 009 132 405) is the proponent as Feasibility Manager and on behalf of the Southdown Joint Venture, comprising Grange and SRT Australia Pty Ltd. Grange proposes to develop the **Southdown Magnetite Project, in the Great Southern Region of Western Australia** which consists of a magnetite mine, transport via pipeline of magnetite to the Port of Albany for shipping, and a desalination plant for water supply. The Project minesite is located near Wellstead, approximately 90 km east-north-east of Albany. The proposed development will require clearing of native vegetation, some of which is considered to be potential foraging habitat for the Endangered Carnaby's Black Cockatoo *(Calyptorhynchus latirostris)*.

The proposed action is a controlled action under the EPBC Act and will be assessed through preliminary documentation. The controlling provision under Part 3 of the EPBC Act are 'Listed threatened species and communities' (sections 18 and 18 A).

In accordance with Section 95A (3) of the EPBC Act, the public are invited to comment on the referral documentation and additional information related to the proposed action. Documentation related to the proposal is available for viewing and comment between Friday 3rd November 2017 and Thursday 30th November 2017 (inclusive).

The documents above are available to view at:
- **Albany Public Library** - 221 York Street, Albany 6330.
- **J.S. Battye Library, State Library of Western Australia** - 25 Francis St, Perth Cultural Centre, Perth, WA 6000.
- **Wellstead Community Resource Centre** - 49 Windsor Rd, Wellstead 6328

The documents can also be viewed at:

www.grangeresources.com.au by clicking on the button labelled "Southdown Magnetite Project EPBC Documents".

Additional information can be provided by contacting Grange Resources on 08 9841 4255.

Any person/s and organisation/s are invited to submit comments in writing on the published material. **Comments are to be received by close of business on Thursday 30th November 2017.**

Written submissions can be sent to Grange Resources Ltd by:
- mail - PO Box 5454, Albany, WA, 6332
- email - **sdnapprovals@grangeresources.com.au**
- phone or fax - 08 9841 4255 (phone) or 08 9841 3643 (fax)

Persons with special needs (i.e. for whom English is a second language or who have vision impairment) may contact Grange via the above details for assistance accessing the material.

Appendix 3 – Template of Letter Sent to Stakeholders Advising of Public Comment Period

Date

GRANGE RESOURCES

Grange Resources Limited
ABN 80 009 132 405
'Pyrmont House'
116 Serpentine Road
Albany Western Australia 6330
PO Box 5454
Albany Western Australia 6332
T +61 8 9841 4255
F +61 8 9841 3643
info@grangeresources.com.au
www.grangeresources.com.au

To whom it may concern,

SOUTHDOWN MAGNETITE PROJECT – EPBC APPLICATION ADVERTISING

As you may be aware, the Southdown Joint Venture requires a federal environment approval under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the Southdown Magnetite Project near Albany, WA.

As part of the assessment process, the information which will be assessed by the Department of the Environment and Energy is subject to a public comment period.

The public comment period and associated information will be advertised in *The Albany Advertiser* on 2nd November 2017 and *The West Australian* on 3rd November 2017. This letter is to notify you of the upcoming advertising.

Further information will be made available on Grange's website www.grangeresources.com.au

Yours sincerely

Glenda Stirling
Community Liaison Manager

Appendix 4 – Revised Strategen Report to Address Public Comments "Southdown Magnetite Project Groundwater Drawdown and Matters of National Environmental Significance'' September 2018, Revision 5

intelligent outcomes | respected experience

Southdown Magnetite Project

Groundwater drawdown and Matters of National Environmental Significance

Prepared for
Grange Resources Limited
by Strategen

September 2018

strategen ENVIRONMENTAL

Southdown Magnetite Project

Groundwater drawdown and Matters of National Environmental Significance

Strategen is a trading name of
Strategen Environmental Consultants Pty Ltd
Level 1, 50 Subiaco Square Road Subiaco WA 6008
ACN: 056 190 419

September 2018

Limitations

Scope of services

This report ("the report") has been prepared by Strategen Environmental Consulting Pty Ltd (Strategen) in accordance with the scope of services set out in the contract, or as otherwise agreed, between the Client and Strategen. In some circumstances, a range of factors such as time, budget, access and/or site disturbance constraints may have limited the scope of services. This report is strictly limited to the matters stated in it and is not to be read as extending, by implication, to any other matter in connection with the matters addressed in it.

Reliance on data

In preparing the report, Strategen has relied upon data and other information provided by the Client and other individuals and organisations, most of which are referred to in the report ("the data"). Except as otherwise expressly stated in the report, Strategen has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report ("conclusions") are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. Strategen has also not attempted to determine whether any material matter has been omitted from the data. Strategen will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Strategen. The making of any assumption does not imply that Strategen has made any enquiry to verify the correctness of that assumption.

The report is based on conditions encountered and information received at the time of preparation of this report or the time that site investigations were carried out. Strategen disclaims responsibility for any changes that may have occurred after this time. This report and any legal issues arising from it are governed by and construed in accordance with the law of Western Australia as at the date of this report.

Environmental conclusions

Within the limitations imposed by the scope of services, the preparation of this report has been undertaken and performed in a professional manner, in accordance with generally accepted environmental consulting practices. No other warranty, whether express or implied, is made.

Client: Grange Resources Limited

Report Version	Revision No.	Purpose	Strategen author/reviewer	Submitted to Client	
				Form	Date
Draft Report	Rev A	Client review	H Ventriss	Electronic	29 Mar 2018
Final Report	**Rev 3**	**For Issue**	**H Ventriss**	**Electronic**	**10 Apr 2018**
Revised Final Report	**Rev 4**	**For Issue**	**H Ventriss**	**Electronic**	**10 Apr 2018**
Revised Final Report	**Rev E**	**Client submission**	**H Ventriss, M Dunlop/ K Moyle**	**Electronic**	**7 Sept 2018**
Revised Final Report	**Rev 4**	**For issue**	**H Ventriss, M Dunlop/ K Moyle**	**Electronic**	**11 Sept 2018**
Revised Final Report	**Rev 5**	**For issue**	**H Ventriss, M Dunlop/ K Moyle**	**Electronic**	**13 Sept 2018**

Filename: GRL14086_04 R002 Rev 5 - 13 September 2018

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1. Introduction

Grange Resources Limited (Grange), as listed proponent and Feasibility Study Manager on behalf of the Southdown Joint Venture (SDJV) (Grange 70% and SRT Australia Pty Ltd 30%), proposes to develop a magnetite mine (the Southdown Magnetite Project) as part of the Albany Iron Ore Project, in the Wellstead area east of Albany. Development of the mine will involve dewatering to enable safe mining of the identified magnetite deposit, a portion of which is located below the regional watertable. A wellfield is also being contemplated for installation near the mine as a possible source of water supply for the project (construction water supply and supplementation of desalinated supply during operation); however, no decision has yet been made on this proceeding.

The proposal for the mine was referred to the now Department of the Environment and Energy (DEE) under the provisions of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) on 11 July 2011, and was determined to be a 'controlled action', to be subject to assessment on preliminary documentation. The single matter of national environmental significance (MNES) was foraging habitat for Carnaby's Black-Cockatoo.

In assessing the project, DEE requested additional information to support the assessment. This request included hydrological studies of the potential impacts of dewatering on MNES. See Appendix 1 for a copy of the DEE request. This report presents the response to that request for the relevant hydrological studies.

2. Hydrogeological setting

The hydrogeology of the site is described in detail in the Public Environmental Review (PER) document (Grange 2007) prepared for assessment under Part IV of the *Environmental Protection Act 1986* and the EPBC Act.

The proposed mine occurs in the vicinity of two sub-basins of the Bremer Basin, which contain sedimentary strata including some spongolite and sand/ sandstone aquifers to depths of 140 m. One sub-basin is centred on Sunday Swamp, 25 km south-west of the deposit, and the other is near Wellstead, 7 km north-east of the deposit (Rockwater 2005). These strata contain aquifers within the Werillup Formation and Pallinup Siltstone of the Plantagenet Group (see Sections 2.2 and 2.3 for more detail). The proposed mine is located within the Werillup Sub Basin.

2.1 Climatic conditions

The closest meteorological recorded station to the Southdown Magnetite Deposit is at Mettler, approximately 7 km to the south-east of the deposit. Regular climatic conditions recorded at Mettler are considered representative of the Project area, which has a Mediterranean-type climate with generally warm summers and cool, wet winters. The climatic conditions are described more fully in the PER (Grange 2007). The annual average rainfall at Mettler is 606 mm/yr (Bureau of Meteorology 2014).

The Wellstead area is climatically similar to the area studied by Department of Water in the Southern Blackwood and Scott Coastal Plain to the west (Froend & Loomes 2006).

2.2 Groundwater occurrence

Groundwater in this area occurs in small to moderate quantities and has an erratic distribution (WRC 2001). The main aquifers in the area are the Pallinup Siltstone and the Werillup Formation of the Bremer Basin. These sediments infill a buried topography on the basement rocks and are a maximum of around 130 m thick. Groundwater occurs in fractures in the upper parts of the basement granites of the south coast and in weathered layers near the surface.

The detailed hydrogeology of the locality is based on an extensive groundwater exploration drilling and testing program and groundwater modelling conducted by Grange in progressive stages since 2006. This work is described in various internal reports, and has been synthesised in Rockwater 2018 (see Appendix 2). In summary, this work has identified three hydrogeological occurrences of groundwater in the area proximate to the project footprint:

1. Surface and near-surface occurrences of perched watertables, which support wetlands and shallow rooted phreatophytic vegetation. By their nature perched water tables are separate from, and are not affected by, abstraction from other aquifers.
2. The regional water table, which occurs in the Pallinup Siltstone, within which watertable depths are generally in excess of 9 m below ground surface and depth to water table in the locality of the Project average approximately 15 m (Figure 1). The Pallinup Siltstone forms an unconfined aquifer of horizontally bedded siltstone, claystone, spongolite and minor sandstone referred to as the Pallinup Formation (Donson 1997). This aquifer is brackish and is generally unlikely to support groundwater dependent ecosystems because of its depth to groundwater and salinity. Areas with shallower depths to groundwater such as the seasonal Springwell Lake and Mettler Lake (where depths range from 5-8 m) will be monitored to ensure there are no unexpected changes in the water table at these locations (Ecological 2018). Shallow water tables also occur in the deeply incised Wilyun Creek and Eyre River close to the coast (Figure 1).
3. Groundwater occurs within the Werillup Formation, which extends from depths of 30 m or more below the ground surface down to bedrock. The Werillup Formation comprises dark clay, carbonaceous material, siltstone, and sand beds. It underlies the Pallinup Siltstone and extends to depths in the range 30 to 140 m (Rockwater 2018, Appendix 2). Water levels in the Werillup Formation are several metres below those in the overlying Pallinup Siltstone, which indicates a general downward movement of water between these two formations. Groundwater within the Werillup Formation occurs within two aquifers, which are confined by carbonaceous clay layers with negligible transfer of water across these layers. As a consequence, abstraction of water from these aquifers is not expected to significantly affect water pressures or levels in the shallower groundwater systems. The location of the Werillup Aquifers are presented in Figure 2.

The conceptual hydrogeological configuration is presented diagrammatically in Figure 3 and Rockwater 2018 (Appendix 2).

At the Southdown Magnetite Deposit, the bedrock is shallow and the superficial material would be either weathered bedrock or Pallinup Siltstone. In adjacent areas, bedrock deepens to more than 100 m and is overlain by Werillup Formation. Moderately large supplies of groundwater are available where the Werillup Formation contains several metres of coarse sand and where the unit is relatively deep.

Groundwater levels beneath the sandplain are generally 10 to 40 m below ground surface, depending on ground elevation (Rockwater 2005). This is consistent with the regional trend for groundwater levels within the sandplain area of this region. In the area of the ore body where the bedrock is near the ground surface, the main aquifer is located within the upper fractured Southdown Magnetite Proposal bedrock zone, while to the north and south from the deposit the aquifer is located within the sand and spongolite deposits. Locally, there appears to be minor near-surface groundwater perched on clay or hardpan. These perched water bodies give rise to seepages in low-lying areas (Rockwater 2005).

Pallinup Formation watertable levels observed in the vicinity of the Southdown Magnetite Project are presented in Figure 1 (Rockwater 2018, Appendix 2). The data presented represents aggregated data from a range of sources, including the Department of Water WIN database. Although not synoptic, these water levels reflect the general depth to the regional water table, and support the descriptions of this waterbody being at depths greater than 10 m over most of the locality. Areas with shallower depths to groundwater such as the seasonal Springwell Lake and Mettler Lake have depths to water of 5-8 m and will be monitored to ensure there are no unexpected changes in the water table at these locations.

There are several wetlands and damplands present over the region that reflect the presence of near-surface (potentially perched) groundwater bodies, with water levels at depths at or close to the ground surface that are above the regional groundwater table and thus appear to be perched.

Groundwater abstraction by the project for water supply purposes will be strictly limited to the Werillup Formation, with no abstraction from the overlying formations.

2.3 Groundwater quality

The regional landscape reflects a low topography with most of the rocks and their weathered products having low permeability, transmitting water slowly (less than 1 m/yr) regionally towards the south and locally from higher elevations before discharging into the rivers and sea (WRC 1999). Salinity of groundwater at or below the regional watertable varies from fresh at the coast to extremely saline inland with levels as high as 15 000-20 000 mg/L inland of Denmark and Albany (WRC 2001).

Donson (1997) notes that groundwater salinity generally increases with depth and to the north and east as rainfall decreases. Rockwater (2018) notes the salinity of the Pallinup Formation varies widely from 300 to 7,000 mg/L, with no pattern in the salinity distribution clearly evident (refer to Appendix B of Appendix 2).

2.4 Hydrology

2.4.1 Wetlands

The region between the sand plain and the coast is characterised by wetlands (seasonal lakes that form in depressions in the landscape) directly linked to recharge by rainfall (Rockwater 2005). GHD (2012) reports on an unregistered wetland located 4 km east of the proposed pit. Four groundwater monitoring wells, installed at locations near the wetland to define the wetland system hydrogeology, demonstrated that groundwater levels in the area surrounding the wetland were approximately nine metres below ground level, and approximately six metres below the centre of the wetland. This suggested that the regional water table is disconnected from the ephemeral water body and any groundwater level change induced by pit dewatering is unlikely to affect the wetland.

GHD (2012) notes that:

> *"This un-named wetland is likely to be similar to those described by Hopkinson (2001) in a study of Bremer Bay wetlands (the proposed mine is within the Bremer Bay region). His study concluded: 'Discharge is probably vertically and laterally into the surrounding ground after great surface input into the wetlands will make the wetlands have a higher water level than the water table' and 'the wetlands influence the water table, but not the other way round'. It is therefore likely that the regional groundwater table is not hydraulically linked to the wetland, that is, the wetland is not dependant on groundwater. Changes in groundwater level brought about as a result of pit dewatering are therefore unlikely to impact on water levels in the wetland. Whilst it is unlikely that groundwater level changes will impact on the wetland, the presence of monitoring wells installed for the wetland assessment will allow monitoring groundwater level changes in this area."*

Aerial photography shows the project area as being populated with a number of wetlands of various sizes that can be expected to have a similar geomorphology to the wetland investigated by GHD (2012).

2.4.2 Watercourses

Grange (2007) describes the surface hydrology as comprising rivers that generally flow in a southerly or south-easterly direction and discharge into estuaries, most of which are permanently or intermittently closed to the ocean. The Southdown Magnetite mine is located in the Albany Eastern Hinterland Catchment. There are no watercourses evident within 5 km of the minesite.

The surface water resources in the district are fed from water in the Pallinup Siltstone, while groundwater abstraction for the project is from the underlying Werillup Formation, which is effectively hydraulically disconnected from the Pallinup Siltstone. As a consequence, abstraction from the Werillup Formation by the proposed project is not expected to affect the surface water discharges or any environmental features or values dependent upon these discharges.

3. Matters of National Environmental Significance

The MNES of concern in the vicinity of the Southdown Magnetite Project have been identified as being limited to foraging habitat for Carnaby's Black-Cockatoo (*Calyptorhynchus latirostris*), based on site surveys and desktop assessment by Bamford (2015), whose report is presented in Appendix 3. The potential impact on the species of groundwater drawdown from dewatering relates to the potential impacts on the habitat of that species. These potential impacts will be relevant if and where the species habitat is dependent on groundwater in the aquifer subject to drawdown impacts from the dewatering operations. The potentially affected habitat within the extent of the watertable drawdown zone comprises scattered various sized areas of remnant native vegetation and pine plantations. The majority of the vegetation species are upland species, which are understood to have a facultative rather than obligate dependence on groundwater. Three vegetation units were identified within the mine site area as occurring in association with seasonally water logged or inundated areas (Grange 2007):

- Chittick (*Lambertia inermis*) and other scrub-heaths on shallow, seasonally-waterlogged laterite.
- Tallerack (*Eucalyptus pleurocarpa*) mallee-heath on seasonally water-logged heavy soils.
- Swamp Yate (*Eucalyptus occidentalis*) woodland in seasonally inundated clay basins.

These species appear to be associated with the perched aquifer(s) rather than the underlying regional groundwater system, given the depths to the regional water table (see Section 4.1 for a more detailed discussion of this).

4. Impact assessment

The potential impact of dewatering drawdown and groundwater abstraction on MNES directly relates to the groundwater dependency of Carnaby's Black-Cockatoo foraging habitat, and the extent to which that dependency might be affected by groundwater drawdown. These two factors are discussed in the following sections. Bamford (2015) describes the Carnaby's Black-Cockatoo habitat as follows:

> *"Foraging habitat is represented within impact areas but there is no breeding habitat. The possible roost in a Blue Gum plantation … is outside areas of direct impact and lies within a possible offset area."*

4.1 Groundwater dependency of Carnaby's Black-Cockatoo habitat

As discussed in Section 2.2, the regional watertable is at depths greater than 9–10 m over the locality of the Southdown Magnetite Project. Froend & Loomes (2006) note that depth to groundwater is generally the most important attribute for ecosystems that rely predominately on groundwater, while depth and frequency of inundation are most important to ecosystems that rely on both surface expressions of groundwater and overland flow of surface water (i.e. floodplains, wetlands and base-flow rivers). While no studies have been undertaken of groundwater dependency of vegetation in the Albany region, the work of Froend & Loomes (2006), which investigated ecological water requirements on the Southern Blackwood and Eastern Scott Coastal Plain, can be interpreted into the Albany region as climatic conditions are similar, in being a relatively cool climate with regular rainfall usually occurring in all months of the year.

Froend & Loomes (2006) postulate that vegetation requirements for groundwater decrease with depth to the watertable, and that vegetation is more tolerant to water table decline due to the corresponding increase in alternative water sources. The primary alternative water source is the volume of unsaturated zone (that increases with depth to watertable) that is exploitable by plant root systems. Froend & Loomes (2006) notes that:

> *"Quantitative information suggests reduced importance of groundwater to terrestrial vegetation existing at depths to groundwater of >10 m (Eamus et al., in press). It is assumed that at depths of 10–20 m there is a probability of vegetation groundwater use, although it is thought to be negligible in terms of total plant water use, and that at depths of 20+ m this probability is substantially lower (Froend & Zencich, 2001)."*

Froend & Loomes (2006) effectively classify vegetation overlying watertables at a depth greater than 10 m as being facultative groundwater users. That is, the individual plants may use groundwater if it is available, but do not experience any adverse impacts in its absence.

Where depth to groundwater is less than 10 m, a portion of vegetation water use is anticipated to be derived from groundwater where this is of a suitable quality (Froend & Loomes 2006). The proportion of groundwater used by vegetation decreases with depth, as the use of soil moisture increases. Where the depth is 6-10 m, less than 50% of daily summer water use comes from groundwater (Froend & Loomes 2006).

This work indicates that in a locality such as occupied by the Southdown Magnetite Project, where the regional watertable is at depths greater than 9–10 m, the overlying vegetation could be expected to be a facultative groundwater user. This is particularly the case given the regularity of recharge of the unsaturated zone by rainfall, and the presence of perched waterbodies near and at the surface that provide a virtually permanent and available source of water.

Annual variations in regional watertable levels are less than 1 m (based on review of monthly monitoring dataset from March 2006 to October 2014 provided by Rockwater).

The availability of water to the local vegetation through both perched water tables and field capacity within the soil profile above the regional water table is expected to satisfy all the vegetation water requirements.

The water quality of the regional aquifer is brackish to saline and as such, is unlikely to provide a preferred water supply source to any vegetation, as the species present within the mine locality do not represent salt tolerant species (Ecologia 2007) and are unlikely to utilise groundwater, even in areas where depth to groundwater is shallow (Ecological 2018).

Borefield drawdown

Further to this, groundwater abstraction by the Southdown Magnetite Project is expected to result in up to 25 m of drawdown in the potentiometric surface in the lower Werillup aquifer, but negligible drawdown in the regional watertable (in the overlying Pallinup Formation). As a consequence, abstraction of water from the Werillup aquifers will not significantly affect water levels in the shallow groundwater system used by agriculture, stygofauna, native vegetation or the coastal drainage system (Rockwater 2018).

This leads to the obvious conclusion that the Carnaby's Black-Cockatoo habitat present in the project area is not dependent on the regional watertable, and lowering of that watertable as a consequence of mine dewatering will not affect the health or condition of that habitat.

Grange is considering development of a water supply wellfield in an as yet undefined location in the Wellstead palaeovalley aquifers (see Figure 2). Depths to the regional watertable over the majority of this area are greater than 9–10 m, and no adverse effects of drawdown on overlying vegetation would be expected. The effect of these abstractions has not been modelled, as decisions have not yet been made regarding which, if any, of these sources might be developed.

Where depths to groundwater are less than 10 m and potentially groundwater dependent ecosystems occur in the vicinity of dewatering areas, monitoring and adaptive management will be undertaken as a precautionary measure consistent with *Southdown Magnetite Project: Groundwater monitoring and management plan* (Ecological 2018).

Mine pit dewatering

All areas of groundwater drawdown outside of the mine footprint are either within cleared agricultural areas or have depths to groundwater greater than 10 m, so that there are unlikely to be any groundwater dependent ecosystems in these areas (Rockwater 2018).

4.2 Potential effects of drawdown on Matters of National Environmental Significance

Carnaby's Black-Cockatoo foraging habitat is present in the form of scattered areas of low value remnant native vegetation and pine plantations over the area overlying the dewatering drawdown footprint. However, as the regional watertable is more than 9–10 m below the surface, this vegetation is understood to be a facultative groundwater user, and would not be affected by changes in the regional watertable level (see Section 4.1). Further to this, groundwater abstraction by the project is not expected to result in other than negligible drawdown in the regional watertable. As a consequence, such abstraction will not significantly affect water levels in the shallow groundwater system used by native vegetation.

That is, neither dewatering of the mine nor development of a groundwater supply wellfield is expected to result in any effects on MNES. However, as a precautionary measure, an adaptive management process is being developed and will be implemented to address any issues of uncertainty regarding potential impacts of groundwater abstractions for the Southdown Magnetite Project on local vegetation communities of concern. This process is based on monitoring both groundwater responses to the project, and changes in vegetation community health and condition, with proponent responses defined in the event of any unexpected or untoward impacts on either groundwater or ecological resources. The full details of such a process will be outlined in detailed groundwater management plans to be prepared for project implementation as a requirement of the existing state environmental approvals, specifically within the conditions of Ministerial Statement 816.

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Figure 1: Pallinup Formation water level depth

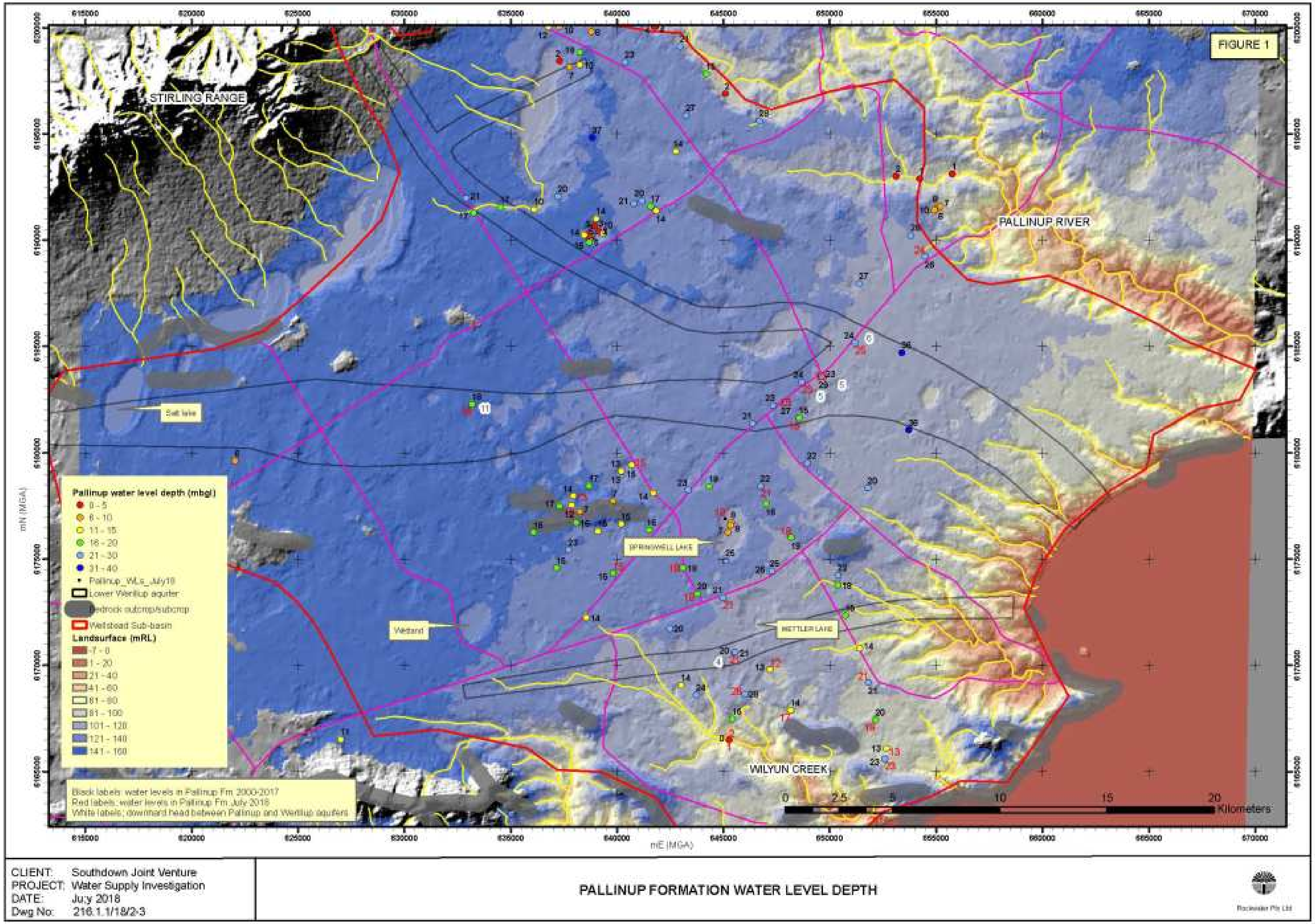


Figure 2: Bores, palaeovalleys and Werillup Aquifers

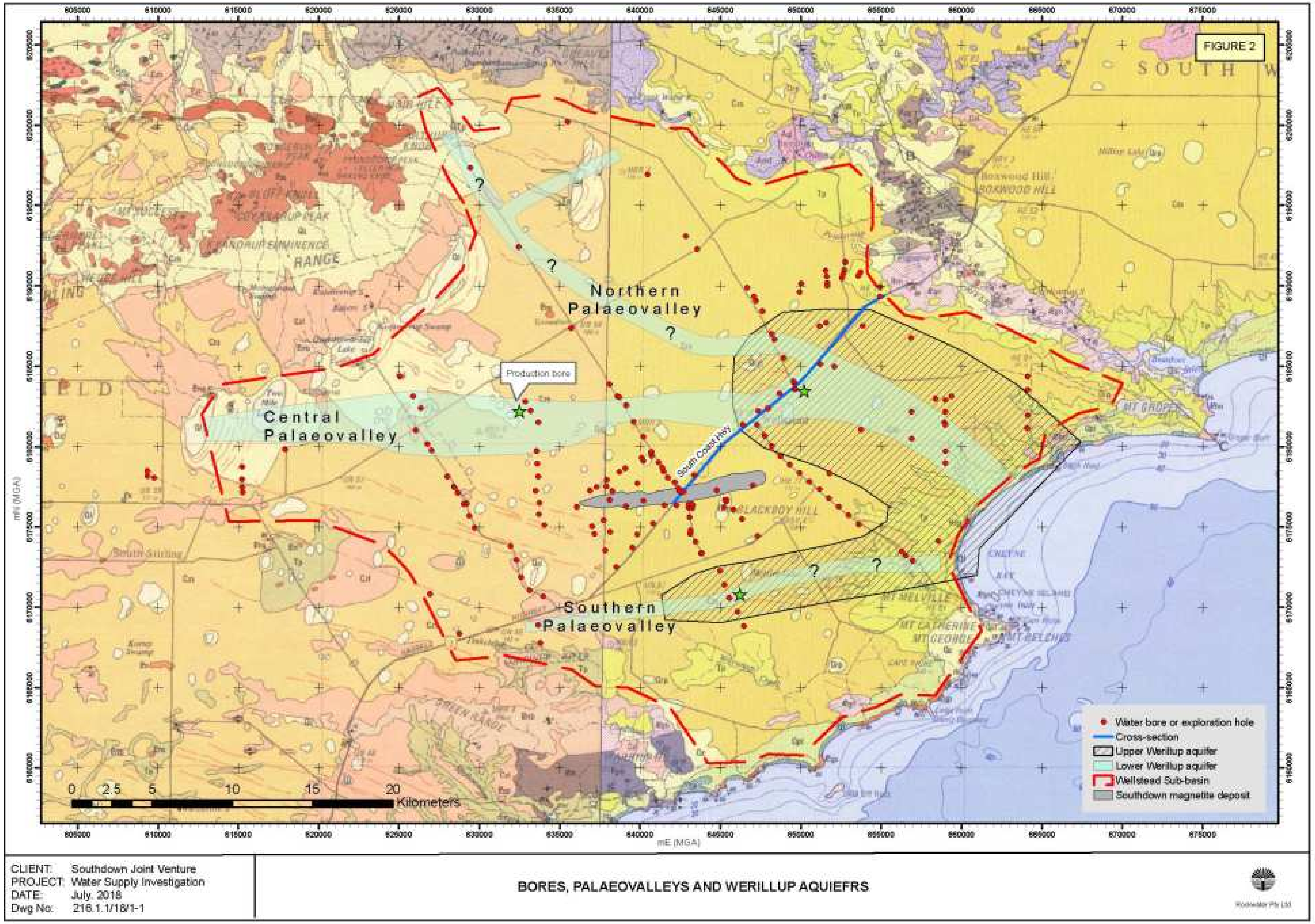
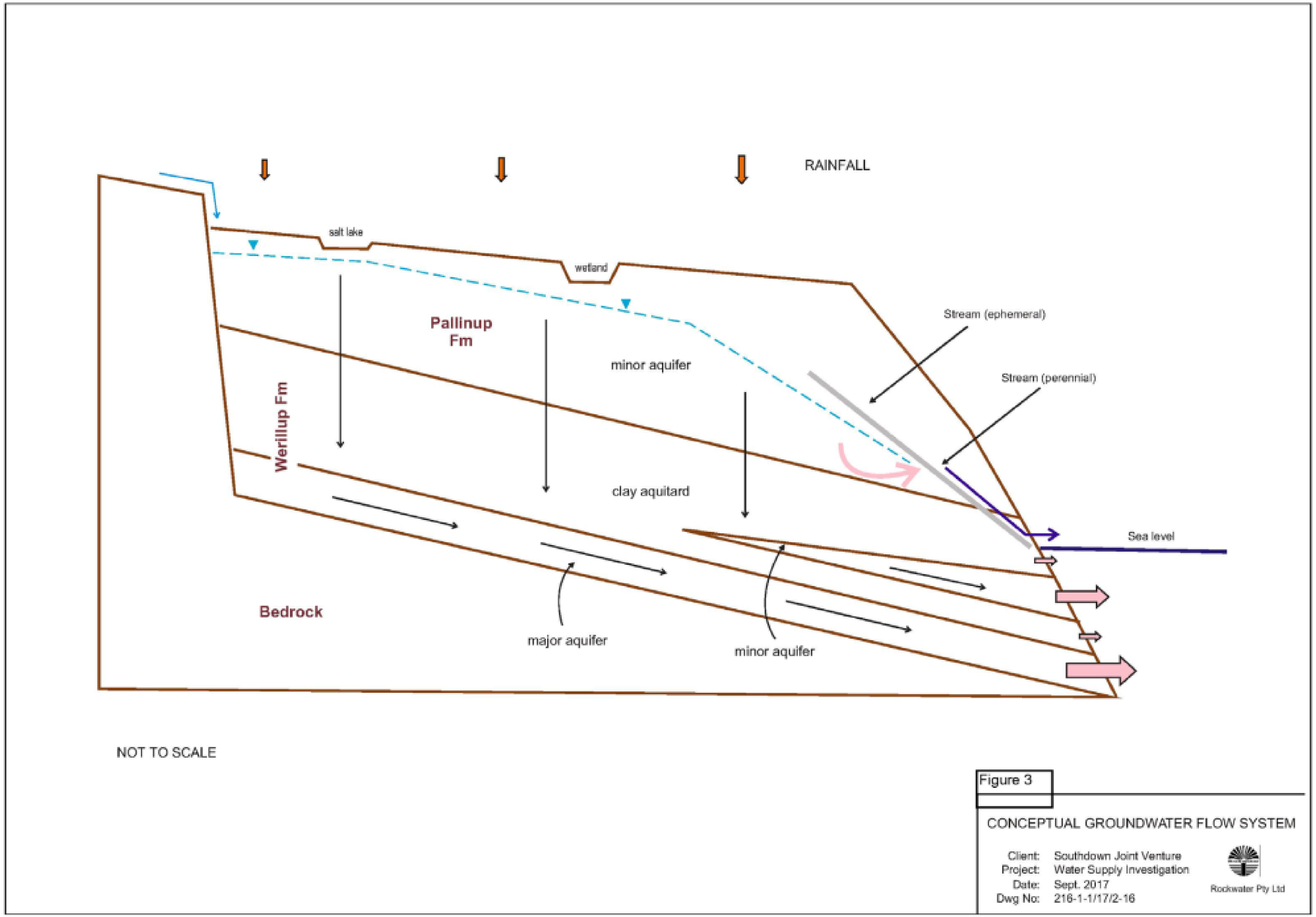


Figure 3: Conceptual groundwater flow system



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Appendix 1
Department of the Environment email request for additional information

McMillan, Elizabeth

From: McMillan, Elizabeth
Sent: Friday, 30 November 2012 8:40 AM
To: 'julia.lawson@grangeresources.com.au'
Subject: EPBC 2011/6053 Southdown Magnetite Project [SEC=UNCLASSIFIED]

Hi Julia

Thanks for the call yesterday, it was good to catch up with what is happening on the project.

As discussed, I have now had an opportunity to review the material provided in the referral and additional information and have the following comments:

1. Dewatering – I understand that the hydrological studies to support an assessment of the impacts of dewatering on matters of national environmental significance are still being completed. This material is required before the department would be comfortable that there is sufficient material for us to undertake a thorough and robust assessment of the project.

2. Offsets – from our discussion, the offset package is still being finalised. The department has recently released a new offset policy and guide. Any offset package put forward for this project will need to be assessed against the requirements of the policy. Link to the policy: http://www.environment.gov.au/epbc/publications/environmental-offsets-policy.html

Once the above information is received to the department's satisfaction, the preliminary documentation can then go out for public comment.

Happy to discuss the above and projected time frames.

I am on leave from the 15th of December and back at work on the 7th of January 2013.

Regards

Liz McMillan
Assistant Director
outh West Section
Environment Assessment and Compliance Division
Dep't of Sustainability, Environment, Water, Population and Communities

Ph: 02 6274 1026
elizabeth.mcmillan@environment.gov.au
GPO Box 787 CANBERRA ACT 2601

Appendix 2
Summary of Groundwater Investigations, Southdown Magnetite Mine (Rockwater 2018)

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SUMMARY OF GROUNDWATER INVESTIGATIONS, SOUTHDOWN MAGNETITE MINE

SOUTHDOWN JOINT VENTURE

August 2018

1. INTRODUCTION

The Southdown Joint Venture (SDJV) is planning to mine the Southdown magnetite iron-ore deposit, located nearby to Wellstead, about 90 km north-east of Albany. The operation of the mine will require pit dewatering. Further, a borefield will need to be established to supply water during the construction and operational phases of the mine. The purpose of this report is to summarise the results of both the water supply and pit dewatering hydrogeological investigations.

1.1. WATER SUPPLY BOREFIELD

A desalination plant will be constructed over a period of about 18 to 24 months at Cape Riche to supply the water for the mine, but until then an alternative source of groundwater, preferably with a low salinity, is required to allow the commencement of mine construction.

Initial estimates for the non-potable supply are that about 20 L/s (1,700 kL/d) will be required for the first 12 months, which will then increase to 55 L/s (4,700 kL/d) for another 8 months, before peaking at about 150 L/s (13,000 kL/d), at which point the desalination plant will be in operation. The potable water supply demand is expected to peak at about 8.5 L/s (750 kL/d) during this period.

An extensive exploration drilling program undertaken by Rockwater (2006, 2010, 2014), followed by the drilling and test-pumping of four production bores by Rockwater (2016), has revealed the presence of two deep, confined, sand aquifers within the Werillup Formation (Fm) nearby to Wellstead that have the potential to supply water required during the construction phase of the mine. Subject to satisfactory performance of the borefield, the Werillup aquifers could also be used during the operational phase of the mine, thereby reducing production from the desalination plant.

Using data from the drilling and test-pumping programs, a numerical groundwater model was constructed by Rockwater (2017) to assess the maximum supply capacity of the Werillup aquifers over a mine life of 15 years, which is the planned duration of mining at a rate of 10 Mpta.

Copies of the bore completion and test-pumping report (Rockwater 2016) and the ensuing borefield modelling report (Rockwater 2017) are presented as Appendix A and B to this summary report. These

documents should be consulted for details of the hydrogeological investigations conducted by SDJV for water supply at Southdown Magnetite Project.

1.2. PIT DEWATERNG

A groundwater model for dewatering of the proposed Southdown Pit was prepared by Golder (2006) as part of a Public Environmental Review (PER) for the Southdown Project. The model was based on a 6,000 m long, 600 m wide and 300 m deep pit that will be progressively mined and backfilled in an easterly direction over a 20-year period. Packer tests, performed in four geotechnical diamond holes, were used to estimate the permeability of the saturated overburden, fresh bedrock and several faults which transect the ore-body. Five model layers were used, with the model domain extending from the foot of the Stirling Range to the coast. A copy of the modelling report prepared by Golder (2006) is provided in Appendix C.

2. MAIN AQUIFERS

The exploration drilling has shown that three broad palaeovalleys, infilled with alluvial to shallow marine sediments of Eocene age, known as the Werillup Fm, occur in the Wellstead area (Fig. 1). As shown in a cross-section of the central palaeovalley along the South Coast Highway (Fig. 2), the aquifers occur at two vertically-distinct levels within the palaeovalleys. The lowermost sand, referred to as the lower Werillup aquifer, is optimally developed at the base of the Werillup Fm in the deepest (axial) parts of the palaeovalleys. It lies at depths greater than 90 m and typically comprises up to 30 m of poorly consolidated, fine- to very coarse-grained, poorly sorted sand, confined below by bedrock and above by carbonaceous clay.

The other sand unit, referred to as the upper Werillup aquifer, occurs at about 70 to 85 m depth in the middle of the Werillup Fm within the lower (coastal) reaches of the palaeovalleys (Fig. 1). It is dominantly composed of 5 to 10 m of green, poorly consolidated, variably clayey, fine- to medium-grained sand, and is confined above and below by carbonaceous clay. Because of its fine grain size and small thickness, the upper Werillup aquifer has a much lower transmissivity and yield than the lower Werillup aquifer, but is considerably less saline and therefore of potential use to the project.

Overlying the Werillup Fm and exposed over much of the land-surface is a thick, tabular unit of shallow-marine, silty very fine sand, which yields low volumes of brackish groundwater for stock supply and provides base-flow to the lower reaches of coastal streams that are strongly incised, such as the Pallinup River and Wilyun Creek (Fig. 1). Extraction from the deeper, confined Werillup aquifers needs to ensure that there is no significant drawdown in the Pallinup aquifer so that these economic and environmental benefits are preserved.

3. WATER LEVELS

Water level depths for about 150 shallow bores, nearly all slotted in the Pallinup Fm, are shown in Figure 3. The water levels range in date of measurement from 2000 to 2017, but repeat monitoring of a subset of the bores during July 2018 shows that water levels in the Pallinup Fm have not changed substantially since this period.

The average depth to water in the Pallinup bores is about 15 m. Shallow water levels (<5 m) are restricted to the middle to lower reaches of deeply-incised drainages, such as Pallinup River and Wilyun Creek. The depth to water in the Pallinup Fm at Mettler Lake, within the Mettler Lake Reserve, is unknown, but at Springwell Lake, located 4 km NNE of Mettler, it is about 8 m (Fig. 3).

Water level data from nests of monitoring bores drilled by Rockwater (2006, 2016) show that the confined water level (potentiometric surface) in the Werillup aquifers is 4-11 m deeper than the water level (phreatic surface) in the Pallinup Fm, which is indicative of recharge to the deeper aquifers. However, no drawdowns in the Pallinup Fm were produced during test-pumping of nearby production bores screened in the lower Werillup aquifer (Rockwater 2016, pp 11-15). This indicates that the vertical permeability of the intervening Werillup clay layers is very low and that very limited hydraulic connection occurs between the Pallinup Fm and Werillup aquifers.

4. MODELLING OF BOREFIELD DRAWDOWN

The results of groundwater modelling, performed by Rockwater (2017), indicate that a supply of up to 150 L/s can be extracted from the lower Werillup aquifer in the central palaeovalley for at least 15 years. As shown in Figure 4, the extraction will result in up to 25 m of drawdown in the potentiometric surface in the lower Werillup aquifer. As this represents a change in pressure only and the lower Werillup aquifer is strongly confined above by clay, no significant drawdown is predicted to occur in the overlying Pallinup Fm, although water levels in the Pallinup Fm will be monitored to confirm that this is not the case.

5. MODELLING OF PIT DEWATERING DRAWDOWN

The results of the groundwater modelling, performed by Golder (2006), indicate that a dewatering rate of 8-59 L/s will be required to keep the pit dry over the assumed 20 years of mining. Modelled drawdowns for the end of mining, shown in Figure 5, are highest for the western margin of the pit, where they extend up to 1km from the pit margin. Most of the cone of depression is predicted to lie under the waste dump and other components of the mine infrastructure. All areas of groundwater drawdown outside of the mine footprint are either within cleared agricultural areas or have depths to groundwater greater than 10 m, so that there are unlikely to be any groundwater dependent ecosystems in these areas.

Dated: 10 August 2018 **Rockwater Pty Ltd**

P de Broekert

Principal Hydrogeologist

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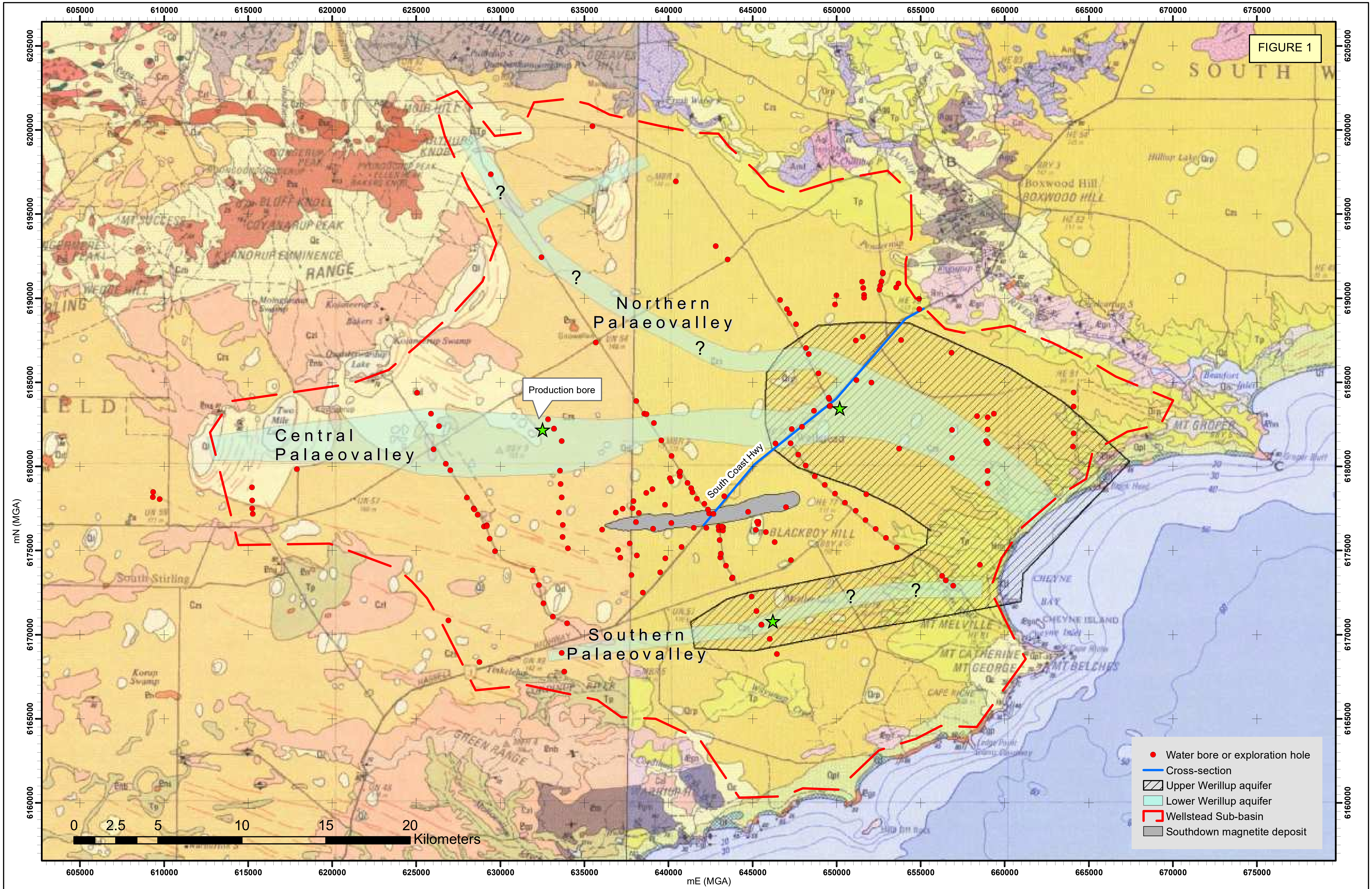
FIGURES

APPENDICES

FIGURES



CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: July. 2018
Dwg No: 216.1.1/18/1-1

BORES, PALAEOVALLEYS AND WERILLUP AQUIEFRS

Rockwater Pty Ltd

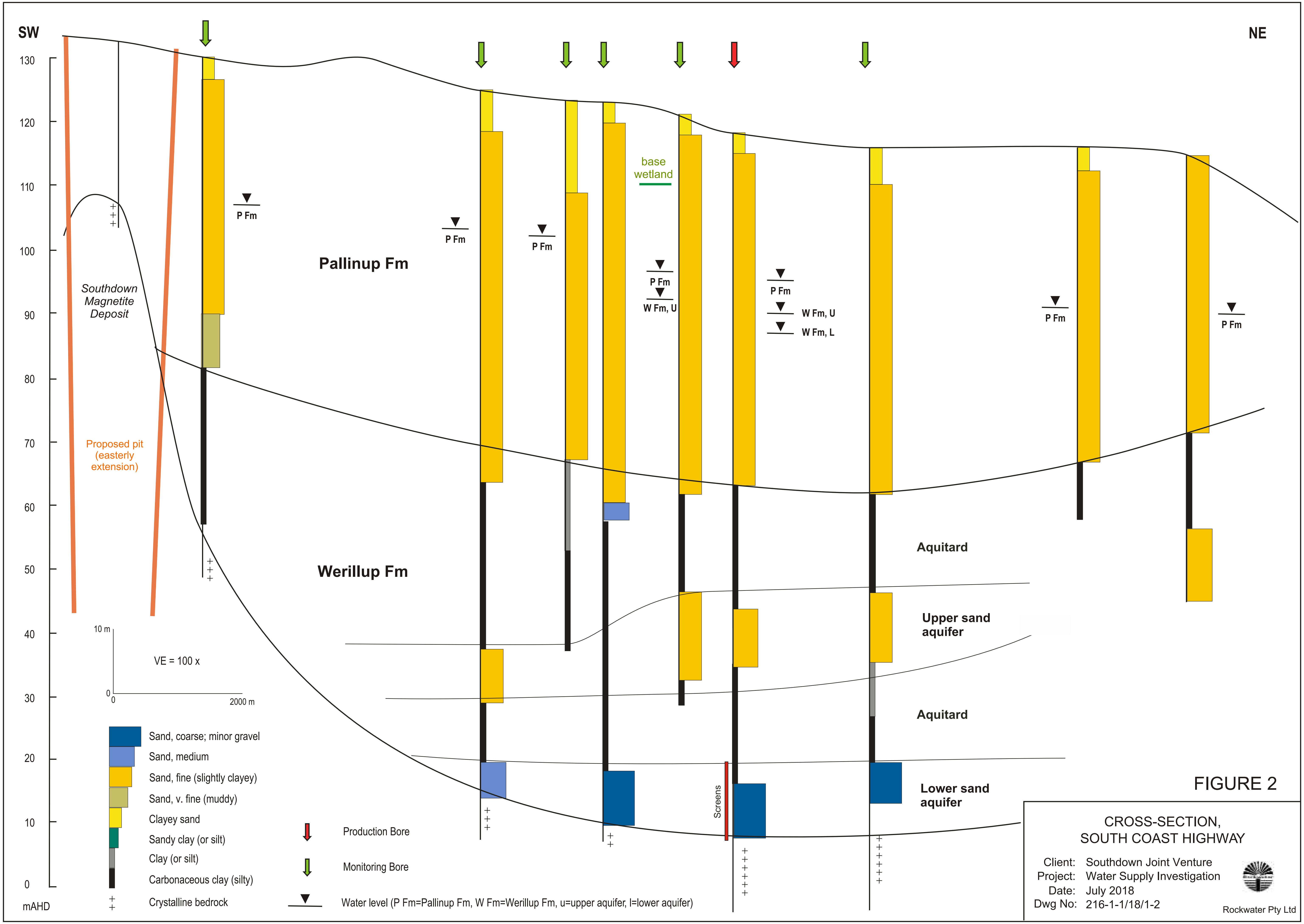
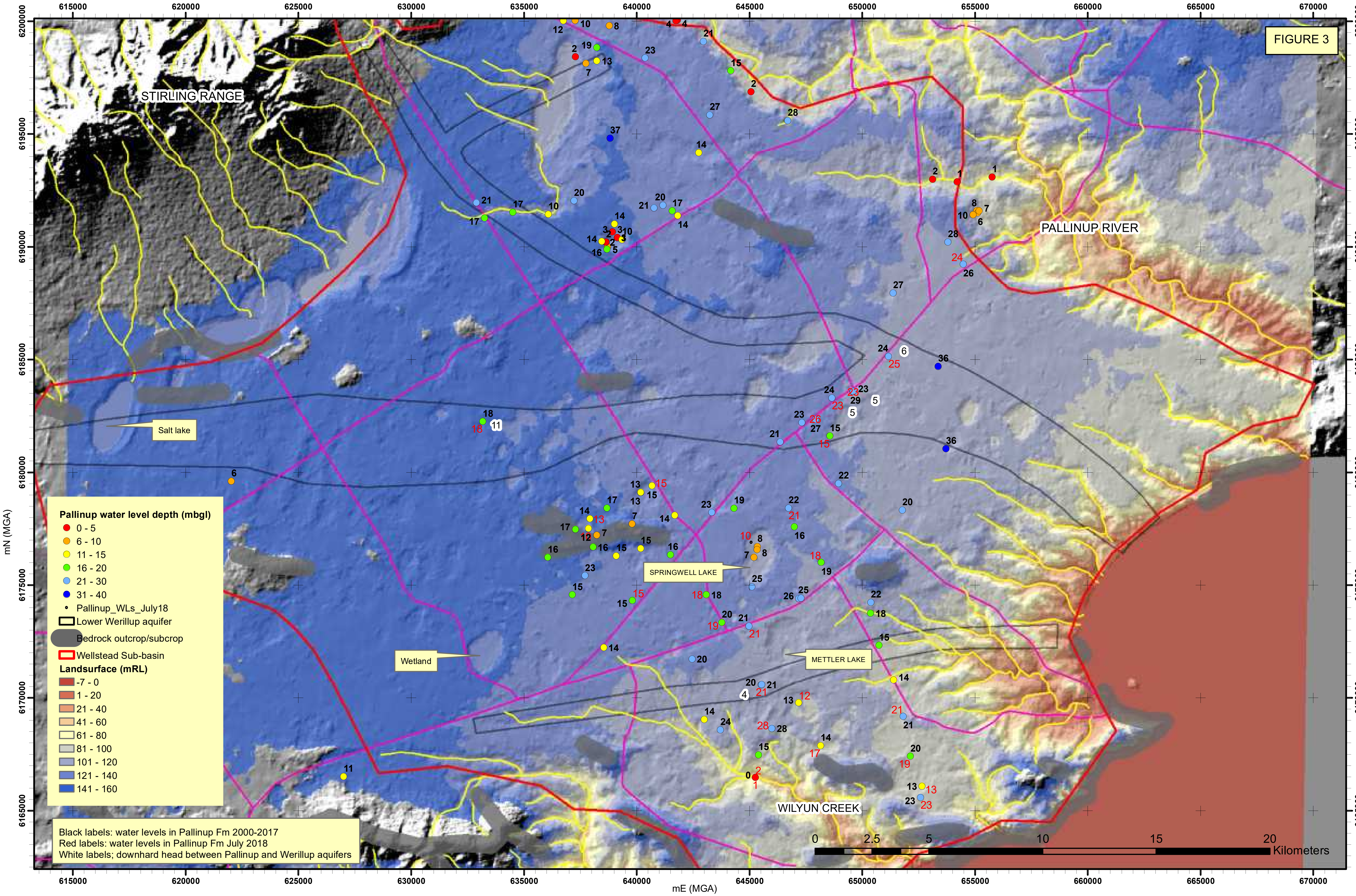


FIGURE 2

CROSS-SECTION,
SOUTH COAST HIGHWAY

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: July 2018
Dwg No: 216-1-1/18/1-2

Rockwater Pty Ltd

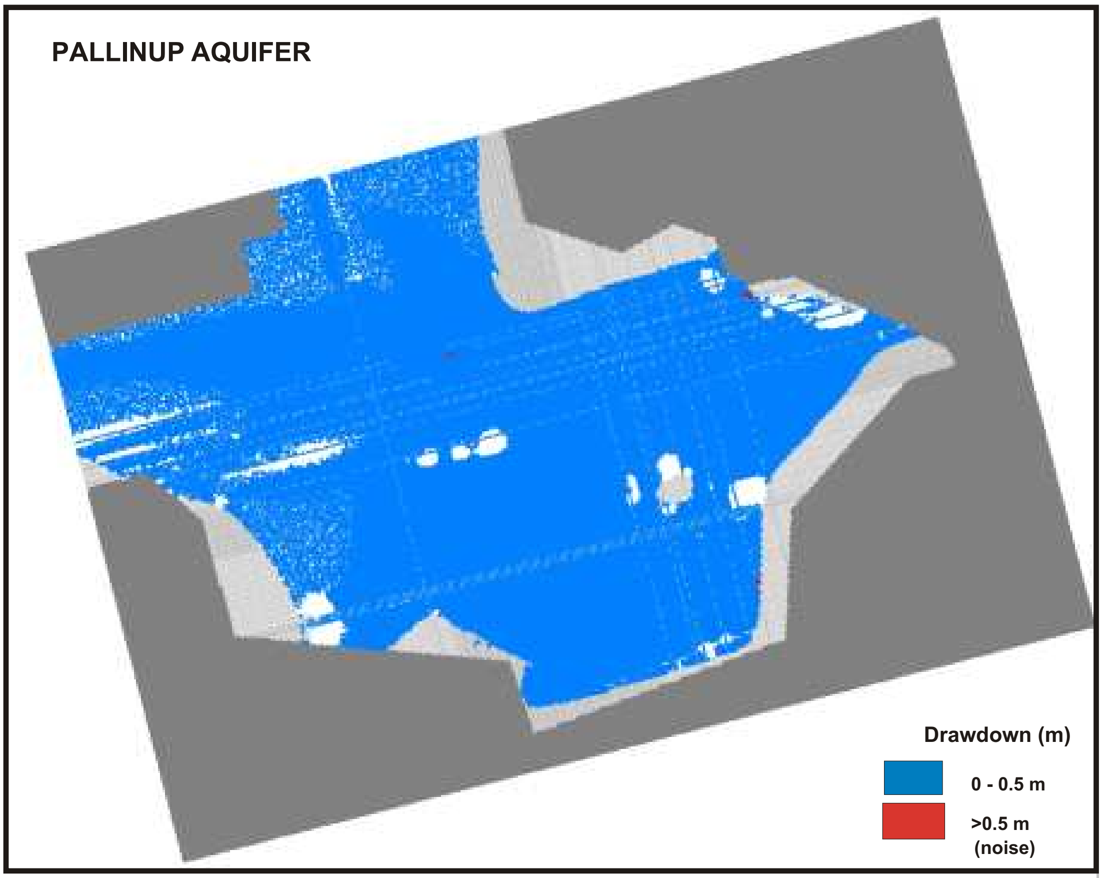


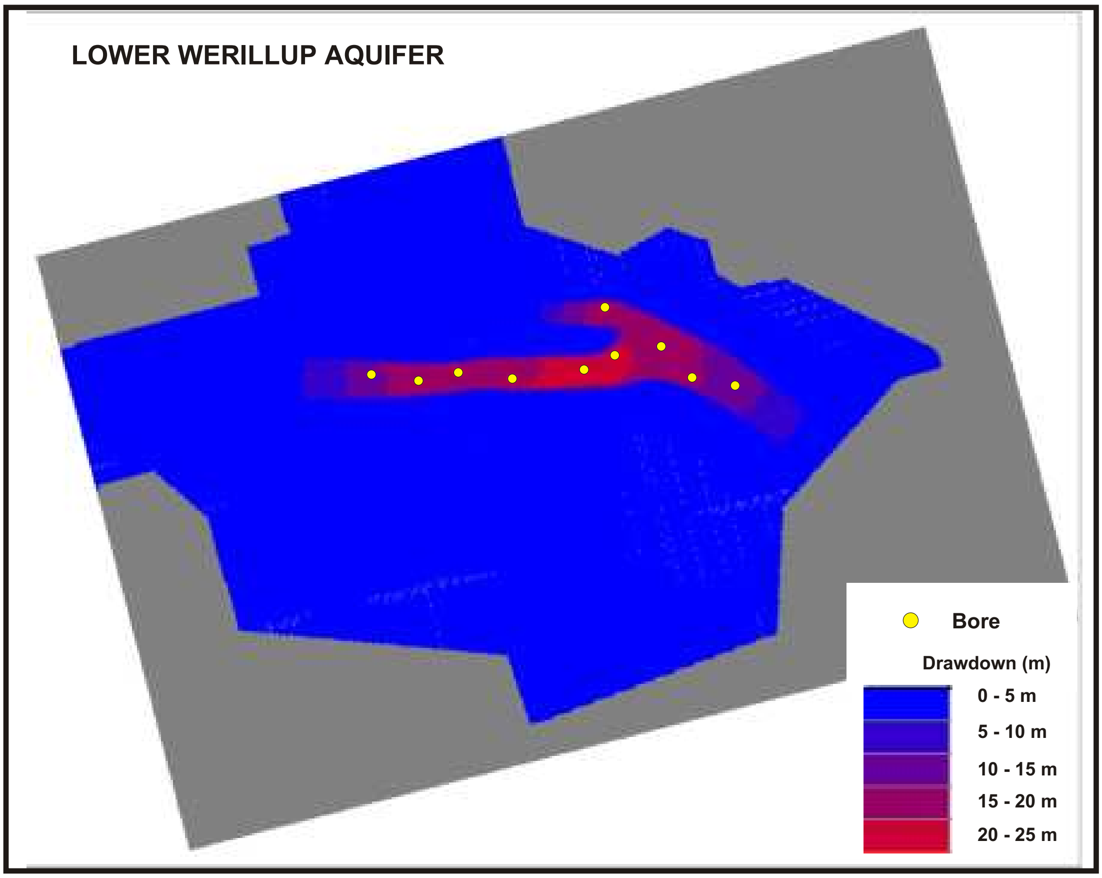
CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: Ju;y 2018
Dwg No: 216.1.1/18/2-3

PALLINUP FORMATION WATER LEVEL DEPTH

Rockwater Pty Ltd

FIGURE 4



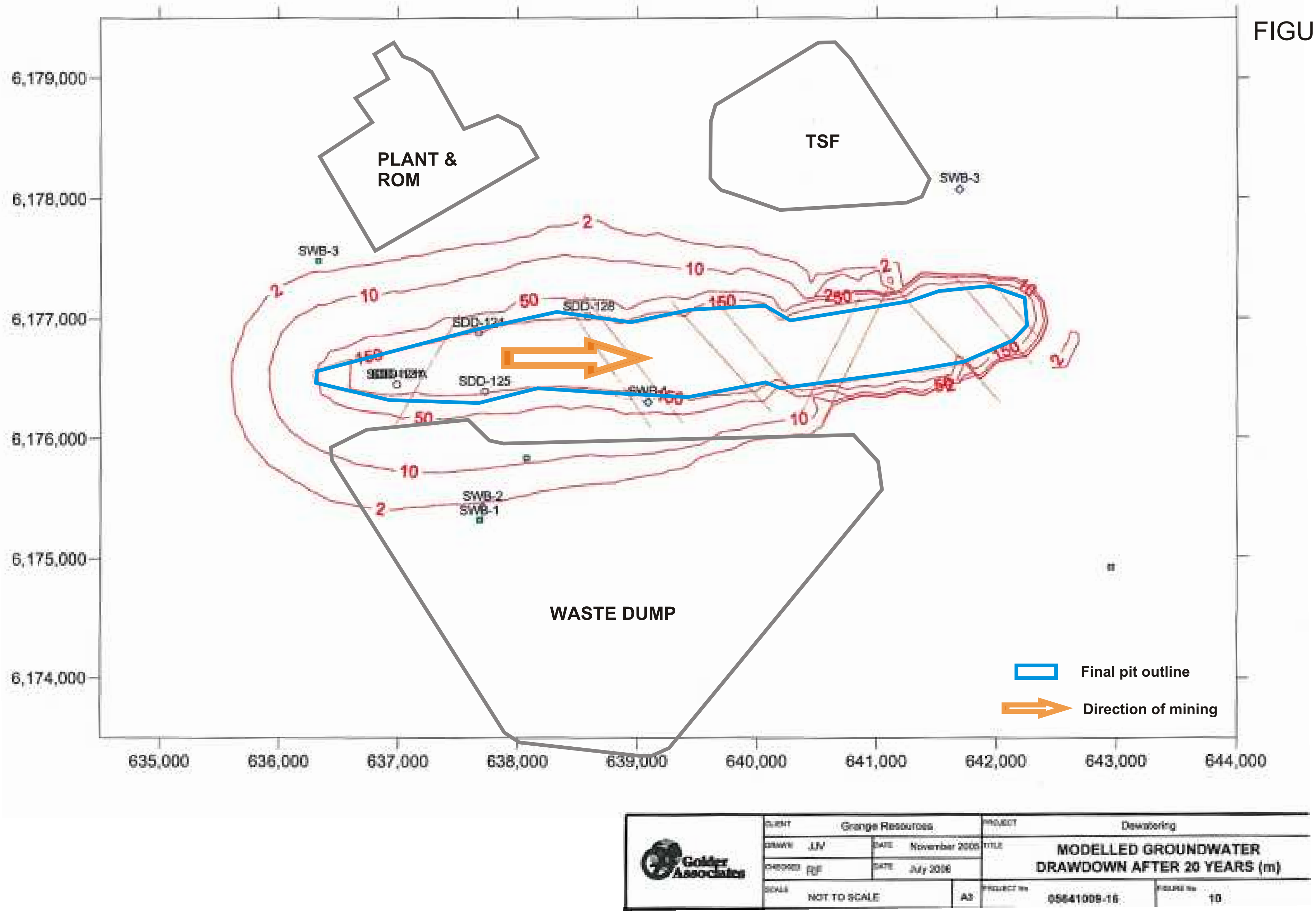


Client:	Southdown Joint Venture
Project:	Water Supply Incestigation
Date:	July 2018
Dwg No:	216.1.1/18/1-4

PREDICTED DRAWDOWN AFTER PUMPING FROM LOWER WERILLUP AQUIFER AT 150 L/s FOR 15 YEARS

Rockwater Pty Ltd

FIGURE 5



Client:	Southdown Joint Venture	
Project:	Water Supply Investigation	PREDICTED DRAWDOWN AROUND PIT AFTER 20 YEARS OF MINING
Date:	July 2018	
Dwg No:	216.1.1/18/1-5	Rockwater Pty Ltd

APPENDIX A
Bore Completion and Test-Pumping Report (Rockwater 2016)

SOUTHDOWN MAGNETITE PROJECT

WELLSTEAD AREA GROUNDWATER EXPLORATION PROGRAMME

BORE COMPLETION AND TEST-PUMPING REPORT

MAY 2016

REPORT FOR
SOUTHDOWN JOINT VENTURE

Report No. 216.1.1/6/01

Rockwater
HYDROGEOLOGICAL AND ENVIRONMENTAL CONSULTANTS

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REVISION	AUTHOR	REVIEW	ISSUED
Rev 0	PdeB	GLB	24/05/16
Rev 1	PdeB	Mike Everitt Grange Resources	30/06/16

1 INTRODUCTION

The Southdown Joint Venture (SDJV) is planning to mine the Southdown magnetite iron-ore deposit, located nearby to Wellstead, about 90 km north-east of Albany. The total mineral resource is 1.25Bt at 33.7% DTR (Davis Tube Recovery), and it is expected that up to 10Mtpa of magnetite concentrate will be produced over an initial mine life of 14 years.

It is estimated that about 2,000 to 8,000 kL/d (23 to 92 L/s) of water will be required for the mine construction phase. Thereafter, a much larger supply of about 12 GL/a (380 L/s) will be required for dust suppression, beneficiation of the ore and transport of the concentrate via a slurry pipeline to the port of Albany. A desalination plant will eventually be constructed at Cape Riche to supply the water for operation of the mine and slurry pipeline, but until then an alternative source of groundwater, preferably with a low salinity, is required to allow the commencement of mine construction.

Exploration drilling performed by Rockwater (2006, 2010) revealed the presence of two sand aquifers within the Werillup Formation nearby to Wellstead that have the potential to supply the mine. Follow-up air-core exploration drilling performed by Rockwater (2014) along several widely-spaced transects further revealed that the Werillup sand aquifers are confined to a network of palaeovalleys developed within the Proterozoic basement rocks of the Bremer Basin, as was also found to occur in the King River area, nearby to Albany (Rockwater, 2011).

To test the yield and water quality of the Werillup sand aquifers delineated by Rockwater (2006, 2010, 2014), four production bores and three associated monitoring bores were drilled, test-pumped and sampled by Rockwater during December 2015 to February 2016. Two of the production bores (WSD15P and WSD16P) were installed in the lower of the two Werillup aquifers, one bore (WSD17P) was installed in the upper of the two Werillup aquifers, and a fourth bore (WSD13P) was slotted across both aquifers. The bores were drilled in groups at three sites to the north, south and east of Southdown to assess the variation in yield and water quality in different parts of the palaeovalley network. The results of the 2015–16 testing programme are presented in this report.

2 LOCATION

The Southdown magnetite deposit is situated immediately north of the South West Highway, about 90 km north-east of Albany and 8 km south-west of Wellstead (Fig. 1). The deposit has a length of about 12 km and strikes in an east-west direction, straddling the intersection between the South West Hwy and Gnowellen Rd, although only that part of the orebody which lies within M70/1309, to the west of this intersection, is currently proposed for mining.

Mineral tenements E70/3073, E75/2512 and E70/3896 (all held by SDJV) surround the Southdown magnetite deposit for a distance of up to 20 km and occupy most of the area between the South Coast in the east, Green Range in the south, Chillinup Rd in the north, and Kojaneerup Spring Rd in the west (Fig. 2).

3 LICENCES

Permission to drill the production and monitoring bores during December 2015 was obtained from the landholders by way of access agreements, and from the Department of Minerals and Petroleum by way of Programmes of Works (PoWs). No authority from the Department of Water was required, as the mineral tenements do not lie within a Proclaimed Groundwater Area and the aquifers being investigated are not artesian (free-flowing at the land-surface).

4 CLIMATE

The climate at Southdown is mild Mediterranean, with monthly average maximum temperatures ranging from 16 to 25 ^{o}C (Table 1). Average annual rainfall is about 600 mm, 72 % falling between May and October. Potential evaporation, obtained from gridded (interpolated) data, is about 1,600 mm/yr and exceeds rainfall during every month except June and July.

Table 1 : Long-Term Monthly Climate Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Rainfall (mm)^	28	25.9	40.7	50.5	65.2	67	71.3	66.6	60.2	54.9	43.9	31.6	604.9
Pot. Evaporation (mm)*	233.8	193.7	168.9	110.1	74.2	56.4	58.9	73.1	93.6	132.0	170.2	218.3	1,583.4
Max. Daily Temp. (^{o}C)#	25.1	25.1	23.9	22	19.2	17	16.2	16.4	17.8	19.7	21.8	23.8	-

^ BOM data for Mettler [Stn 009754] (1966-2014)
* Data Drill Dataset, QLD Dept of Environment and Resource Management (1950-2014)
# BOM data for Mettler [Stn 009754] (1966-1997)

Within the study area, it is likely that rainfall decreases significantly with increasing distance from the coast. To a lesser extent, it may also decrease in an easterly direction, as the annual rainfall at Manypeaks (located 49 km south-west of Southdown) is 727 mm, and the annual rainfall at Boxwood Hill (located 27 km north-east of Southdown) is 503 mm.

5 LANDFORMS AND DRAINAGE

The land-surface at Southdown largely comprises a fairly flat and featureless plain that slopes gently downwards in a south-easterly direction from about 200 mAHD at the foot of the Stirling Range, to about 100 mAHD approximately 5 km inland from the coast (Fig. 2). This surface is widespread along the South Coast and is known as the Ravensthorpe Ramp. Seawards of the 100 mAHD topographic contour, the land-surface slopes downward, more steeply at a gradient of about 1.6% to the coast.

Local highpoints with an elevation of about 160 mAHD and a relief of 25–30 m occur at Blackboy Hill, the Southdown magnetite deposit, and an un-named hill located about 7 km north of the deposit (Fig. 2). These are underlain by shallow bedrock and therefore relate to palaeo-topographic highs within the sedimentary basin.

External drainage within the area is largely limited to the narrow, steeply-sloping coastal zone; although two drainages (Wilyunup Creek and Tinkelelup Creek/Cordinup River) extend almost as far inland as the South Coast Hwy (Fig. 2). The north-eastern part of the study area is bounded by the Pallinup River, which drains a large area north of the Stirling Range, and has been sufficiently active to erode through the sedimentary cover and expose the bedrock along most of its length.

It is likely that the more deeply incised drainages, such as the Pallinup and Cordinup Rivers, are at least partly sustained by groundwater discharge from the sedimentary strata. In the case of the Cordinup River, this is clearly demonstrated by perennial flows in its headwater tributaries, such as Tinkelelup Creek. It is also likely that some of the other, shorter, drainages developed along the coastal zone are fed by groundwater baseflow.

Numerous closed depressions, with a relief of up to about 15 m, lie scattered across the inland plain (Figs 2, 3). These form ephemeral wetlands (Yate swamps) that are filled to a shallow depth by surface water run-off and possibly also the inflow of perched groundwater during particularly wet winters. The wetlands are situated above the water table, as demonstrated by drilling conducted at a wetland nearby to the proposed Southdown pit (see bore SMD0011 in Fig. 3), where the base of the wetland lies at about 112 mAHD, whereas the water table lies at about 104 mAHD (GHD, 2012).

6 GEOLOGY AND HYDROGEOLOGY

Bedrock in the region is composed of high-grade metamorphic rocks of the Proterozoic-age Albany-Fraser Orogen. Felsic gneisses are dominant in the Southdown study area, but to the north the bedrock comprises quartzite and schist of the Mount Barren Group, which crop out to

form the Stirling Range (Fig. 2). The Proterozoic bedrock has been intensely deformed, resulting in the widespread development of faults and shears that typically trend in an easterly and north-westerly direction.

Unconformably overlying the Proterozoic bedrock are Middle to Upper Eocene-aged strata of the Plantagenet Group. The sediments are widely distributed along the south coast of Western Australia between Walpole and Esperance, where they occupy shallow basins developed within the Proterozoic basement. The basins are interconnected, and in combination with a much thicker accumulation of Tertiary sediments offshore, are termed the Bremer Basin. At Southdown–Wellstead, the basin is bounded by outcrops of Proterozoic bedrock along the Green Range in the south, the Stirling Range in the north and the Pallinup River in the north-east (Fig. 2). In view of its isolation from the remainder of the Bremer Basin, this area is referred to as the Wellstead sub-basin (Rockwater, 2005).

Two major lithostratigraphic units occur within the Plantagenet Group, both of which are well represented in the Wellstead sub-basin. The basal unit, termed the Werillup Formation (Fm), is dominantly composed of grey to black, poorly consolidated, variably silty and carbonaceous clay, and fine- to coarse-grained sand, deposited in a continental to marginal marine environment.

Drilling by Rockwater (2006, 2010, 2014) has shown that the Werillup Fm sands occur at two vertically-distinct levels within three main palaeovalleys (referred to as the northern, central and southern palaeovalleys) that drained the Wellstead sub-basin (Figs 4, 5). The lowermost sand, referred to as the Lower Werillup Aquifer, is optimally developed at the base of the Werillup Fm in the deepest (axial) parts of the palaeovalleys (Fig. 4). It lies at >90 m depth and typically comprises up to 30 m of grey, poorly consolidated, fining-upwards, fine- to very coarse--grained, poorly sorted sand, and is confined below by bedrock and above by thick carbonaceous clay.

The other sand unit, referred to as the Upper Werillup Aquifer, occurs at about 70 to 80 m depth in the middle of the Werillup Fm within the lower (coastal) reaches of the palaeovalleys (Fig. 5). It is dominantly composed of 5 to 10 m of green (glauconitic or possibly chloritic), poorly consolidated, variably clayey, fine- to medium-grained sand, and is confined above and below by carbonaceous clay. Because of its fine grain size and small thickness, the Upper Werillup Aquifer is likely to have a much lower transmissivity and yield than the Lower Werillup Aquifer, but may be less saline and is therefore worthy of investigation.

The other main lithostratigraphic unit of the Plantagenet Group is the Pallinup Fm, which was deposited in a shallow marine environment. The formation conformably overlies the Werillup Fm with a gradational contact of up to 10 m. At Wellstead, the Pallinup Fm is mainly composed of a coarsening-upwards (shallowing) sequence of muddy, very fine-grained sand, grading upwards into slightly clayey, fine-grained sand. The Pallinup Fm has a low permeability, but on

account of its widespread distribution and relatively low salinity is widely exploited for farm water supplies.

6.1 BORES YIELDS AND WATER QUALITY

Air-lift, water quality and completion data for the bores drilled by Rockwater during 2006, 2010 and 2015 (i.e., including the current programme) are shown in Table 2. Locations of these bores, and those drilled by others around the Southdown project, are shown in Figure 3.

The most productive bores (WSD4, WSD14, WSD15P, WSD16P), with individual air-lift yields of up to 22 L/s, are screened in the Lower Werillup Aquifer situated in the deepest parts of the palaeovalleys (Fig. 4). Yields are highest in bores WSD14 and WSD15P, where the central palaeovalley narrows and the Lower Werillup sand becomes thicker and coarser. However, the salinity of these bores is about 60,000 mg/L Total Dissolved Solids (TDS), which is probably too high for use at the proposed mine, other than perhaps for dust suppression.

The very high salinity of bores WSD14 and WSD15P probably results from a wedge of hypersaline water extending down the central palaeovalley from a chain of salt lakes located at foot of the Stirling Range (Fig. 2). To the east of bores WSD14 and WSD15P, the salinity of the Lower Werillup Aquifer within the central palaeovalley decreases to about 20,000 mg/L at bore WSD16P, and may decrease further with proximity to the coast.

In the case of the central palaeovalley, much lower salinity water occurs within the Upper Werillup Aquifer than the Lower Werillup Aquifer. For example, the salinity of bores WSD5, WSD7, WSD17P and WSD18 is 6,500 to 7,500 mg/L, whereas the salinity of the Lower Werillup Aquifer bores at these locations (WSD4, WSD16P) is 20,000 to 30,000 mg/L (Table 2). Yields of the Upper Werillup Aquifer bores are, however, very low (2–4 L/s), so that a comparatively large number of bores would be needed to obtain a significant quantity of (brackish) water from this aquifer alone.

The salinity of the Lower Werillup Aquifer appears to be much lower in the southern palaeovalley than in the central palaeovalley. For example, bores WSD12 and WSD13P, which are slotted across both aquifers, have salinities of about 5,000 mg/L. Although the Lower Werillup Aquifer in the southern palaeovalley is less well-developed than in the central palaeovalley, it is still sufficiently thick and permeable to produce yields of up to 10 L/s when pumped. Bores screened over both Werillup aquifers in the southern palaeovalley are therefore probably the best option for supplying a moderate quantity of low salinity (brackish) groundwater for the Southdown project.

Table 2: Summary of Drilling and Completion Data, Rockwater Bores 2006–2015

Hole	Type	mE (MGA)	mN (MGA)	Collar RL	TOC	Drill Depth	Bedrock Depth	Casing Diam. (NB)	Screen interval	Screened Aquifer	Airlift Yield	Pallinup SWL		Werillup SWL		TDS Airlift	TDS End CRT
				(mAHD)	(magl)	(m)	(mbgl)	(mm)	(mbgl)		(L/s)	(mbgl)	(mAHD)	(mbgl)	(mAHD)	(mg/L)	
Bores Drilled by Rockwater in Jan. 2006																	
WSD1	MB	643770	6173348	122.89	0.4	50	>50	100	19.3-45.3	Pallinup	0.6	19.50	103.39	NA	NA	2,700	
WSD3	MB	643081	6174580	127.26	0.38	44	>44	100	20-38	Pallinup	0.2	18.19	109.07	NA	NA	2,600	
WSD4	MB(x2)	649587	6183582	117.99	0.46	127	109	100	100.2-112.2	Werillup; U, L	9.4	blocked	blocked	30.84	87.15	28,000	
WSD5	MB(x2)	651165	6185140	115.93	0.46	130	102	100	70.9-88.9	Werillup; U	3.4	24.49	91.44	31.28	84.65	7,200	
WSD6b	MB	647322	6182214	123.85	0.29	60	>86	100	23.4-59.4	Pallinup	0.8	22.82	101.03	NA	NA	4,800	
WSD7	MB(x2)	648653	6183300	121.19	0.52	92	>92	100	71.2-89.2	Werillup; U	2.5	23.94	97.25	28.22	92.97	7,600	
Bores Drilled by Rockwater in April 2010																	
WSD8	MB	643321	6178223	129	0.6	81	73	50	27.9-39.9	Pallinup	0.5	22.56	106.44	NA	NA	7,600	
WSD9	MB	646359	6181350	125	0.6	117	111	100	29.3-47.3	Pallinup	1	21.19	103.81	NA	NA	5,670	
WSD10	MB	653706	6181045	110	0.5	114	112	100	102-114	Werillup; L	1.4	NA	NA	38.05	71.95		
WSD11	MB	651771	6178334	110	0.6	108	99	100	29.4-47.4	Pallinup	0.4	20.02	89.98	NA	NA	4,317	
Bores Drilled by Rockwater in Dec. 2015																	
WSD12	MB(x2)	645540	6170594	115	0.5	120	114	80	71-77, 101-113	Werillup; U, L	3.5	20.63	94.37	24.88	90.12	5,244	
WSD13P	PB	645521	6170591	115	0.3	120	116	155	74-80, 104-116	Werillup; U, L	5.5	NA	NA	25.26	89.74	5,244	4,520
WSD14	MB(x2)	633173	6182258	141.5	0.5	121	120	80	95-119	Werillup; L	5.9	17.77	123.73	29.02	112.48	44,384	
WSD15P	PB	633190	6182236	142	0.5	122	120	200	89-120	Werillup; L	22	NA	NA	29.47	112.53	45,600	59,500
WSD16P	PB	649613	6183598	118	0.4	116	110	200	95-112	Werillup; L	12.5	NA	NA	31.03	86.97	22,040	21,000
WSD17P	PB	649608	6183595	118	0.4	87	110	155	73-85	Werillup; U	2	NA	NA	28.02	89.95	6,992	6,570
WSD18	MB(x2)	649601	6183590	118	0.4	86	110	80	65-83	Werillup; U	1.2	23.28	94.72	27.62	90.38	6,840	

PB=Production Bore; MB=Monitoring Bore; MB(x2)=Dual monitoring bore with 25mm NB PVC installed in annulus for measuring water levels in the Pallinup Aquifer; SWL=standing water level; TOC=Top of casing; magl = metres above ground level; mbgl = metres below ground level; U=upper; L=Lower; CRT=constant-rate pumping test

7 DRILLING AND BORE CONSTRUCTION

Drilling of the bores at Southdown–Wellstead was conducted by Harrington Drilling during December 2015 using a Versa-Drill V2095-EXP drill rig. Supervision was provided by Rockwater.

Mud-rotary pilot holes with a diameter of 165 mm (for monitoring bores) or 203 mm (for production bores) were drilled to bedrock at sites where the Werillup sand aquifers had already been located by air-core drilling (Rockwater, 2014). Cuttings were taken and described at two metre intervals, and then gamma-ray and resistivity surveys were performed to assist in the identification of aquifer intervals and the quantification of groundwater salinity.

Four production bores and three monitoring bores were drilled at three widely-spaced locations around the proposed Southdown mine (Fig. 3). Production bore WSD13P and its associated monitoring bore, WSD12, were drilled to test the salinity and yield of both Werillup aquifers in the middle reaches of the southern palaeovalley. Production bore WSD15P and its associated monitoring bore, WSD14, were drilled to test the salinity and yield of the Lower Werillup Aquifer in the upper, middle reaches of the central palaeovalley (there being no Upper Werillup Aquifer present this far west within the central palaeovalley).

The three remaining bores (WSD16P, WSD17P, WSD18) were installed nearby to bore WSD4, which had been drilled by Rockwater (2006) into the Upper and Lower Werillup aquifers within the lower, middle reaches of central palaeovalley, about 2.5 km NE of Wellstead (Fig. 3). Production bore WSD16P was installed into the Lower Werillup Aquifer, with (existing) bore WSD4 to be used as its monitoring bore. Production bore WSD17P was drilled into the Upper Werillup Aquifer, and bore WSD18 was drilled into the same aquifer as its accompanying monitoring bore.

As with the Werillup aquifer bores drilled by Rockwater (2006), all monitoring bores (WSD12, WSD14, WSD18) were completed with hand-slotted, 25 mm NB PVC in the upper annulus to allow for the measurement of any drawdowns in the Pallinup Fm caused by extraction from the Werillup aquifers during test-pumping. Bores WSD17P and WSD18 were used in a similar way to monitor drawdowns in the Upper Werillup Aquifer caused by pumping from bore WSD16P, slotted over the Lower Werillup Aquifer.

Composite logs of the monitoring and production bores are shown in Figures 6 to 12 and completion data for the bores are provided in Appendix I. A summary of the drilling data is shown in Table 2. Composite logs for the monitoring bores drilled into the Werillup aquifers by Rockwater (2006) are presented in Appendix II.

7.1 BORE WSD12

Monitoring bore WSD12 was drilled into the Upper and Lower Werillup aquifers within the middle reaches of the southern palaeovalley, on the property of Tony Gorman, about 8 km SE of Southdown (Figs 3–5). A composite log for WSD12 is shown in Figure 6.

Following the installation of a 209 mm ID, 219 mm OD steel surface casing, a 165 mm diameter mud-rotary hole was drilled into weathered bedrock at 114 m depth. The hole intersected about 6 m of upper Werillup sand and 12 m of lower Werillup sand, and was lined with 79 mm ID, 89 mm OD, Class 12 PVC, slotted over the intervals of both sand aquifers. Gravel pack was placed around the slots and a bentonite seal was placed against carbonaceous clay above the aquifers to prevent downward leakage from the Pallinup Fm.

The bore was de-mudded and airlifted until the water was silt-free. The final airlift yield was about 3.5 L/s (limited by the narrow diameter of the air-lift hose), at a field electrical conductivity (EC) of 6.9 mS/cm. The standing water level (SWL) in the Lower and Upper Werillup aquifers was 4.25 m lower than in the Pallinup Fm, indicating that Werillup aquifers are confined.

7.2 BORE WSD13P

Production bore WSD13P was drilled into the Upper and Lower Werillup aquifers about 20 m west of monitoring bore WSD12. A composite log for bore WSD13P is shown in Figure 7.

Following the installation of a 263 mm ID, 273 mm OD steel surface casing, a 203 mm diameter mud-rotary hole was drilled into weathered bedrock at 116 m depth, intersecting a similar sequence of sediments as in WSD12. The hole was then reamed to 254 mm diameter to allow for the insertion a production string comprising 150 mm ID, 168 mm OD, slotted, Class 12 PVC set against the Upper Werillup Aquifer, and a combination of this and 153 mm ID, 166 mm OD, 316-grade, stainless-steel screen, set against the Lower Werillup Aquifer.

Gravel pack was installed to the top of the Werillup Fm and the remainder of the bore's annulus was filled with SG 1.5 cement grout to seal off the Pallinup Fm. The bore was de-mudded and developed by airlifting for about three hours until the water was silt-free. Final airlift yield and EC of the bore were about 5.5 L/s and 6.9 mS/cm, respectively.

7.3 BORE WSD14

Monitoring bore WSD14 was drilled into the Lower Werillup Aquifer within the upper middle reaches of the central palaeovalley, on the property of Mark Slattery, about 8 km NW of Southdown (Figs 3, 4). A composite log for WSD14 is shown in Figure 8.

Following the installation of a 209 mm ID, 219 mm OD steel surface casing, a 165 mm diameter mud-rotary hole was drilled into weathered bedrock at 120 m depth. The hole intersected about 30 m of coarse lower Werillup sand, probably at the deepest part of the palaeovalley, and was lined with 79 mm ID, 89 mm OD, Class 12 PVC, slotted over the sand aquifer. Gravel pack was placed around the slots and an annular bentonite seal was placed against carbonaceous clay above the aquifer to downwards prevent leakage from the Pallinup Fm.

The bore was de-mudded and airlifted until the water was silt-free. The final airlift yield was about 5.9 L/s (again, limited by the narrow diameter of the air-lift hose), at an EC of 58.4 mS/cm. The SWL in the Lower Werillup Aquifer was 11.25 m lower than in the Pallinup Fm, indicating that Werillup aquifer is strongly confined.

7.4 BORE WSD15P

Production bore WSD15P was drilled into the Lower Werillup Aquifer about 30 m south of monitoring bore WSD14. A composite log for bore WSD15P is shown in Figure 9.

Following the installation of a 394 mm ID, 406 mm OD steel surface casing, a 203 mm diameter mud-rotary hole was drilled into weathered bedrock at 120 m depth, intersecting a similar sequence of sediments as in bore WSD14. The hole was then reamed to 343 mm diameter to allow for the insertion a production string comprising 203 mm ID, 225 mm OD, slotted, Class 12 PVC and 202 mm ID, 216 mm OD, 316-grade, stainless-steel screen, set against the Lower Werillup Aquifer.

Gravel pack was installed to the top of the sand aquifer and the remainder of the bore’s annulus was filled with SG 1.5 cement grout to seal off the upper Werillup Fm and the Pallinup Fm. The bore was de-mudded and developed by airlifting for about two hours until the water was silt-free. Final airlift yield and EC of the bore were about 22 L/s and 60 mS/cm, respectively.

7.5 BORE WSD16P

Production bore WSD16P was drilled into the Lower Werillup Aquifer within the lower, middle reaches of the central palaeovalley, on the property of Tony Slattery, about 2.5 km NE of Wellstead (Figs 3, 4). A composite log for bore WSD16P is shown in Figure 10.

Following the installation of a 394 mm ID, 406 mm OD steel surface casing, a 203 mm diameter mud-rotary hole was drilled into weathered bedrock at 110 m depth, intersecting about 8 m of fine Upper Werillup Aquifer sand, and 8 m of coarse Lower Werillup Aquifer sand at its base. Drill logs of nearby bores indicate that the bore is not situated in the deepest part of the palaeovalley and that the thickest section of basal sand was probably not intersected.

The pilot hole was reamed to 343 mm diameter and then lined with 203 mm ID, 225 mm OD, slotted, Class 12 PVC and 202 mm ID, 216 mm OD, 316-grade, stainless-steel screen, set against the Lower Werillup Aquifer.

Gravel pack was installed to just above the top of the basal sand and the remainder of the bore's annulus was filled with SG 1.5 cement grout to fully seal off the Upper Werillup Fm Aquifer and the Pallinup Fm. The bore was de-mudded and developed by airlifting for about two hours until the water was silt-free. Final airlift yield and EC of the bore were about 12 L/s and 29 mS/cm, respectively.

7.6 BORE WSD17P

Production bore WSD17P was drilled into the Upper Werillup Aquifer, about 7 m west of bore WSD16P. A composite log for bore WSD17P is shown in Figure 11.

Following the installation of a 263 mm ID, 273 mm OD steel surface casing, a 203 mm diameter mud-rotary hole was drilled to 2 m below base of the Upper Werillup Aquifer at 85 m depth. The hole was then reamed to 254 mm diameter and lined with 150 mm ID, 168 mm OD, slotted, Class 12 PVC and 153 mm ID, 166 mm OD, 316-grade, stainless-steel screen, set against the aquifer.

Gravel pack was installed to just above the sand and the remainder of the bore's annulus was filled with SG 1.5 cement grout to seal off the upper Werillup Fm and the Pallinup Fm. The bore was de-mudded and developed by airlifting for about five hours, which was not completely successful in removing all of the silt and fine sand from the bore. Further development by airlifting and jetting of the screens is therefore probably required. Final airlift yield and EC of the bore were about 2 L/s and 9.2 mS/cm, respectively.

7.7 BORE WSD18

Monitoring bore WSD18 was drilled into the Upper Werillup Aquifer about 10 m west of bore WSD17P. A composite log for bore WSD18 is shown in Figure 12.

Following the installation of a 209 mm ID, 219 mm OD steel surface casing, a 165 mm diameter mud-rotary hole was drilled to 2 m below the base of the Upper Werillup Aquifer at 84 m depth. The hole was lined with 79 mm ID, 89 mm OD, Class 12 PVC, slotted over the sand aquifer. Gravel pack was placed around the slots and a bentonite seal was placed against carbonaceous clay above the aquifer to prevent downward leakage from the Pallinup Fm.

The bore was de-mudded and airlifted until the water was more or less silt-free. The final airlift yield was about 1.2 L/s, at an EC of 9 mS/cm. The SWL in the Upper Werillup Aquifer was 4.34 m lower than in the Pallinup Fm, indicating that Upper Werillup Aquifer is confined.

8 TEST PUMPING

Test-pumping of production bores WSD13P, WSD15P and WSD16P was performed by Concept Drilling, under the supervision of Rockwater, during March 2016. An attempt was also made to test-pump bore WSD17P, but this resulted in clogging of the submersible pump due to incomplete development of the bore. The bore was therefore airlifted for another five hours and then tested using falling head (slug) tests, instead of a pumping test.

The pumping and slug tests were undertaken to assess the long-term yields and salinity of the bores, and the hydraulic coefficients of the Werillup aquifers for use in groundwater modelling. The tests were also performed to assess the extent to which water levels in the Pallinup Fm are affected by pumping from the Werillup aquifers, which is important because the Pallinup Fm is widely used for farm water supply and contributes to base-flow within some streams and the episodic filling of wetlands.

Each pumping test comprised three parts:

- a step-rate test, with the bore being pumped for at least four, consecutive 60-minute intervals at progressively increasing rates;
- a constant-rate test, with the bore being pumped continuously for at least 24-hours; and
- a recovery-test, with measurement of water level rises following the cessation of pumping.

Pumping rates were measured using a totalising flow meter. Water levels were measured in the production bore and its associated monitoring bore(s) with a pressure transducer and manually. Water from bore WSD13P was discharged to the ground, but owing to the high salinity of bores WSD15P and WSD16P, the water from these bores was discharged to clay pits with a volume of about 1,500 m^3, constructed by SDJV on behalf of the farmers. This limited the duration over which pumping tests could be performed.

8.1 BORE WSD13P

8.1.1 Step-Rate Test

The step-rate test for bore WSD13P, slotted over the Upper and Lower Werillup aquifers in the middle reaches of the southern palaeovalley, comprised five steps with pumping rates (Q) of 2, 4, 6, 8 and 10 L/s. A drawdown (s) of 26.73 m was produced at the end of the last step, starting from a SWL of 25.76 mbtc (m below top of casing). A plot of the step-test results is shown in Figure 13.

The specific capacity (Q/s) of the bore decreased from 0.52 L/s/m at a pumping rate of 2 L/s to 0.37 L/s/m at a pumping rate of 10 L/s, and the head loss resulting from turbulent flow (mostly well loss) increased from 18 to 35% over the range of discharge rates used (Fig. 14). These

parameters indicate that the bore is moderately efficient, especially over the interval of the Lower Werillup Aquifer, which probably contributes most of the water to the bore.

8.1.2 Constant-Rate Test

The constant-rate test for bore WSD13P commenced at a discharge rate of 10 L/s, but was increased to 11.4 L/s (the maximum capacity of the pump in use) after 660 minutes. Drawdowns in the Werillup aquifers for bore WSD13P, and in the Werillup aquifers and Pallinup Fm (separately) for bore WSD12, located 19.6 m east of the pumped bore, are shown in Figure 15.

At the end of the test, the water levels in WSD13P had drawn down by 31.25 m. About 5.6 m of drawdown were recorded in the Werillup aquifers in bore WSD12, and no drawdown occurred in the Pallinup Fm at that bore.

An analysis of the drawdowns in bores WSD13P and WSD12 using the method of Barker, which accounts for well loss in the production bore, indicates that the two Werillup aquifers have an average hydraulic conductivity of about 7.2 m/d and a specific storage of 2.2×10^{-5} (Fig. 16). The low storativity and absence of drawdown in the Pallinup Fm confirms that the Werillup aquifers are confined at this location.

A substantial increase in salinity occurred during the constant-rate test, with the final salinity of the bore being about 4,500 mg/L TDS (Table 2). As the salinity had not stabilised by the end of the test, it may continue to increase somewhat with prolonged pumping.

Extrapolation of the late-time drawdown trend for WSD13P suggests that a drawdown of about 35 m will be produced after 10 years of pumping at a rate of 11 L/s. However, this does not account for the limited width of the palaeovalley aquifer or interference drawdown from any other bores. A more accurate assessment of the long-term yield of the bore will be provided by groundwater modelling.

8.2 BORE WSD15P

8.2.1 Step-Rate Test

The step-rate test for bore WSD15P, slotted over the Lower Werillup Aquifer in the upper, middle reaches of the central palaeovalley, comprised four steps with pumping rates of 6, 9, 12 and 15 L/s. A drawdown of 6.02 m was produced at the end of the last step, starting from a SWL of 30.2 mbtc. A plot of the step-test results is shown in Figure 17.

The specific capacity of the bore decreased slightly from 2.8 L/s/m at a pumping rate of 6 L/s to 2.5 L/s/m at a pumping rate of 15 L/s, and the head loss resulting from turbulent flow (mostly

well loss) increased from 5 to 12% over the range of discharge rates used (Fig. 18). These parameters indicate that the bore is highly efficient.

8.2.2 Constant-Rate Test

The constant-rate test for bore WSD15P was performed at a discharge rate of 15 L/s, being the maximum capacity of the largest pump on hand. Drawdowns in the Lower Werillup Aquifer in bore WSD15P, and the Lower Werillup Aquifer and Pallinup Fm in bore WSD14, located 30 m north of the pumped bore, are shown in Figure 19.

At the end of the test, the water levels in WSD15P had drawn down by 7.85 m. About 3.6 m of drawdown were recorded in the Lower Werillup Aquifer in bore WSD14, and no drawdown occurred in the Pallinup Fm at that bore.

A hydraulic boundary, resulting in steepening of the drawdown curve, occurred after about 6 minutes of pumping. This was probably caused by intersection of the cone of depression with the northern margin of the palaeovalley, which appears to be quite narrow at this location (Fig. 4).

An analysis of the pre-barrier drawdowns in bores WSD15P and WSD14, using the method of Barker, indicates that the Lower Werillup Aquifer has an hydraulic conductivity of about 12 m/d and a specific storage of about 3.6×10^{-5} (Fig. 20). The low storativity and absence of drawdown in the Pallinup Fm confirms that the Lower Werillup Aquifer is also confined at this location.

Salinity in bore WSD15P fluctuated widely during the constant-rate test, with the final salinity of the bore being about 60,000 mg/L TDS (Table 2). This is the highest recorded in any of the bores drilled by Rockwater at Wellstead–Southdown.

Extrapolation of the late-time drawdown trend for bore WSD15P suggests that a drawdown of about 15 m will be produced after 10 years of pumping at a rate of 15 L/s. However, this does not account for additional drawdowns caused by the cone of depression intersecting the southern boundary of the palaeovalley, or the interference of pumping from any other bores. A more accurate assessment of the long-term yield of the bore will be provided by groundwater modelling.

Table 3: Summary of Constant-Rate Test and Slug Test Results

Bore	Test Type	Werillup Aquifer	SWL	Test Duration	Discharge Rate	Final Drawdown	Response	Aquifer Thickness	Transmiss-ivity	Hydraulic Conductivity	Specific Storage^	Storativity
			(mbtc)	(hr)	(L/s)	(m)	(min)	(m)	(m^2/d)	(m/d)	(1/m)	
WSD13P	CRT	Upper & Lower (south palaeovalley)	26.08	25.5	10 (0-660 mins), 11.4 (>660 mins)	31.25	Radial	18 (6 + 12)	130	7.2	2.17×10^{-5} (WSD12, r=20 m)	3.9×10^{-4}
WSD15P	CRT	Lower (central palaeovalley)	30.87	36	15	7.85	Bounded (barrier @ 6 mins)	30	348	11.6	3.57×10^{-5} (WSD14, r=30 m)	1.1×10^{-3}
WSD16P	CRT	Lower (central palaeovalley)	35.10	31	11	20.55	Radial	8	52	6.5	2.5×10^{-4} (WSD4, r=34 m)	2.0×10^{-3}
WSD17P	ST	Upper (central palaeovalley)	29.32	0.5				7	1.47	0.21		
WSD18	ST	Upper (central palaeovalley)	28.80	0.5				7	0.91	0.13		
WSD5*	ST	Upper (central palaeovalley)	31.28	0.5				11	9.79	0.89		
WSD7*	ST	Upper (central palaeovalley)	28.22	0.5				14	4.48	0.32		

Bore drilled by Rockwater (2006)

CRT=constant-rate test; ST=slug test; SWL=standing water level; r=distance from pumping bore

8.3 BORE WSD16P

8.3.1 Step-Rate Test

The step-rate test for bore WSD16P, slotted over the Lower Werillup Aquifer in the lower, middle reaches of the central palaeovalley, comprised five steps with pumping rates of 3, 5, 7, 10 and 11 L/s. A drawdown of 19.16 m was produced at the end of the last step, starting from a SWL of 34.5 mbtc. A plot of the step-test results is shown in Figure 21.

The specific capacity of the bore decreased slightly from 0.63 L/s/m at a pumping rate of 3 L/s to 0.58 L/s/m at a pumping rate of 10 L/s, and the head loss resulting from turbulent flow (mostly well loss) increased from 2 to 6% over the range of discharge rates used (Fig. 22). As with bore WSD15P, the efficiency of this bore is therefore very high.

8.3.2 Constant-Rate Test

The constant-rate test for bore WSD16P was performed at a discharge rate of 11 L/s. Drawdowns in the Lower Werillup Aquifer in bore WSD16P and in bore WSD4, located 34.5 m west of the pumped bore, are shown in Figure 23. Also shown in Figure 23 are drawdowns measured in the Upper Werillup Aquifer in bores WSD17P and WSD18 (located 6.5 and 16.3 m west of the pumped bore, respectively), and drawdowns measured in the Pallinup Fm in bore WSD18.

At the end of the test, the water levels in WSD16P had drawn down by 20.6 m. About 3.5 m of drawdown were recorded in the Lower Werillup Aquifer in bore WSD4, and about 0.5 of drawdown were recorded in Upper Werillup Aquifer in bores WSD17P and WSD18. No drawdown occurred in the Pallinup Fm at bore WSD18. There therefore appears to be some hydraulic connection between the Lower and Lower Werillup Aquifers, but none between the Werillup aquifers and the Pallinup Fm.

An analysis of the drawdowns in bores WSD16P and WSD4, using the method of Barker indicates that the Lower Werillup Aquifer has a hydraulic conductivity of about 6 m/d and a specific storage of about 2.5×10^{-4} (Fig. 24).

Salinity in bore WSD16P increased steadily during the constant-rate test, stabilising at about 21,000 mg/L, possibly as a result of the leakage of low-salinity water from the Upper Werillup Aquifer (Fig. 23). The salinity of bore WSD16P is three times less than the Lower Werillup Aquifer at bore WSD15P, but four times more than in the Lower and Upper Werillup aquifers at bore WSD13P.

Extrapolation of the late-time drawdown trend for bore WSD16P suggests that a drawdown of about 30 m will be produced after 10 years of pumping at a rate of 11 L/s. However, as with the

other bores, groundwater modelling is required to assess the long term yield of the bore in a borefield setting.

8.4 BORE WSD17P

8.4.1 Slug Tests

As mentioned, it was not possible to test-pump bore WSD17P because of incomplete development and excess fine particles remaining in the groundwater. The permeability of the Upper Werillup Aquifer was therefore assessed using two slug (falling-head) tests conducted in each of bores WSD17P and WSD18, as well as single slug-tests conducted in bores WSD5 and WSD7, which had been drilled in the Upper Werillup Aquifer by Rockwater (2006).

Although considerably less accurate than pumping tests, the results of the slug tests, shown in Figure 25, are very consistent and indicate that the hydraulic conductivity of the Upper Werillup Aquifer in the lower, middle reaches of the central palaeovalley, ranges from about 0.2 to 1.0 m/d. A similar permeability is expected for the aquifer in the southern palaeovalley, where the Werillup aquifers were not individually tested.

9 WATER QUALITY ANALYSES

Water samples were collected from the production bores at the end of the constant-rate tests and submitted to ALS, a NATA-accredited laboratory, for comprehensive chemical analyses. Laboratory certificates for the analyses are shown in Appendix III.

Samples collected for dissolved metals were filtered and acidified in the field. An analysis of total iron was also performed on an untreated sample to provide an indication of the presence of iron bacteria (known to be present in the area); the assumption being that the bacteria would be excluded by filtering, resulting in total iron being significantly higher than dissolved iron where the bacteria are present. The results of the chemical analyses are presented in Table 4. Also shown in Table 4 are the results of chemical analyses performed on the Werillup bores drilled by Rockwater (2006).

As discussed, salinity within the Lower Werillup Aquifer ranges from hypersaline (60,000 mg/L) in bore WSD15P, located in the upper, middle reaches of the central palaeovalley; through to saline (~20,000 mg/L) in bores WSD16P and WSD4, located in the lower, middle reaches of the central palaeovalley. Brackish water (~7,000 mg/L) occurs in the Upper Werillup Aquifer in bores WSD17P, WSD5 and WSD7, located in the lower, middle reaches of the central palaeovalley, but the yields of these bores are very low.

Table 4: Water Quality Analyses

	Unit	WSD15P	WSD16P	WSD4*	WSD17P	WSD5*	WSD7*	WSD13P
Werillup Aquifer		Lower	Lower	Upper, Lower	Upper	Upper	Upper	Upper, Lower
Date Sampled		18/3/16	15/3/16	13/1/06	19/3/16	18/1/06	22/1/06	12/3/16
pH	-	6.77	6.75	7	6.57	7	6	6.6
Conductivity @ 25°C	µS/cm	71,800	26,700	44,000	10,900	13,000	13,000	7,290
TDS @ 180 °C	mg/L	59,500	21,000	28,000	6,570	7,200	7,600	4,520
Hardness as $CaCO_3$	mg/L	8,460	3,400		799			834
Hydroxide Alkalinity as $CaCO_3$	mg/L	<1	<1		<1			<1
Carbonate Alkalinity as $CaCO_3$	mg/L	<1	<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as $CaCO_3$	mg/L	199	115	190	38	75	15	92
Total Alkalinity as $CaCO_3$	mg/L	199	115		38			92
Sulphate SO_4	mg/L	4190	1,590	2,100	476	740	620	405
Chloride, Cl	mg/L	26700	10,200	15,000	3,690	3,800	4,200	2230
Calcium, Ca	mg/L	336	160	230	43	27	43	80
Magnesium, Mg	mg/L	1850	729	1,200	168	160	180	154
Sodium, Na	mg/L	16300	5,730	8,000	2,140	2,300	2,300	1360
Potassium, K	mg/L	670	226	190	131	99	94	59
Aluminum, Al	mg/L	<0.10	0.02		<0.01			<0.01
Manganese, Mn	mg/L	0.515	0.252		0.115			0.195
Arsenic, As	mg/L	<0.010	0.016		0.046			0.01
Cadmium, Cd	mg/L	<0.0010	<0.0001		<0.0001			<0.0001
Chromium, Cr	mg/L	<0.010	<0.001		<0.001			<0.001
Lead, Pb	mg/L	<0.010	<0.001		<0.001			<0.001
Selenium, Se	mg/L	<0.10	<0.01		<0.01			<0.01
Zinc, Zn	mg/L	<0.050	0.007		0.005			0.011
Iron, Fe	mg/L	38.2	40.1	0.45?	36.1	0.35?	16	18.2
Iron, Fe (Total)	mg/L	39.8	38.2		40.2			16.9
Mercury, Hg	mg/L	<0.0001	<0.0001		<0.0001			<0.0001
Reactive Silica	mg/L	9.38	34.4		46			37.4
Ammonia as N	mg/L	1.6	1.28		1.14			0.61
Nitrite as NO2	mg/L	<0.01	<0.01		<0.01			<0.01
Nitrate as NO3	mg/L	<0.01	<0.01	0.5	0.01	<0.2	<0.2	0.02
Nitrate + Nitrate as N	mg/L	<0.01	<0.01		0.01			0.02
Total Kjeldahl Nitrogen as N	mg/L	2.4	1.7		1.1			0.6
Total Nitrogen as N	mg/L	2.4	1.7		1.1			0.6
Total Phosphorus, P	mg/L	0.44	0.56		0.3			0.32
Reactive Phosphorus as P	mg/L	<0.01	<0.01		<0.01			<0.01
Ryznar Stability Index (I)**		9.6	10	9.3	12	11	13	10

Bore drilled by Rockwater (2006)

** Encrusting – I < 7, Corrosive – I > 9, or possibly if > 7

The lowest salinity water (~4,500 mg/L) occurs in bore WSD13P, slotted across both Werillup aquifers in the middle reaches of the southern palaeovalley. Presumably, this mainly reflects the salinity of the lower aquifer, which on account of its high thickness and permeability, would have supplied most of the water to the bore.

All of the bores have low concentrations of dissolved metals, apart from iron, which ranges from about 35 to 40 mg/L. Treatment of the bore water to remove iron would therefore be necessary to prevent clogging of the borefield reticulation system. Similarities in the concentration in dissolved and total iron suggest that the high iron concentrations are not due to the presence of iron bacteria.

Another potential problem with the Werillup groundwater is that it is likely to be corrosive, as indicated by calculations of the Ryznar Stability Index (I) being considerably higher than 9 (Table 4).

10 SUMMARY AND RECOMMENDATIONS

A drilling and test-pumping programme was conducted by Rockwater during December 2015 – March 2016 to assess the yield, water quality and aquifer parameters of two, vertically-separated sand aquifers within the Werillup Fm (Upper and Lower Werillup aquifers) that have the potential to supply water for the proposed Southdown magnetite mine.

Four production bores and three monitoring bores were drilled at three widely-spaced locations during the programme. Production bore WSD13P and its associated monitoring bore, WSD12, were drilled into both Werillup aquifers in the middle reaches of a palaeovalley lying to the south of Southdown. Production bore WSD15P and its associated monitoring bore, WSD14, were drilled into the Lower Werillup Aquifer in the upper, middle reaches of a larger, central palaeovalley lying immediately north of Southdown.

The three remaining bores (WSD16P, WSD17P, WSD18) were installed nearby to bore WSD4, which had already been drilled into the Upper and Lower Werillup aquifers within the central palaeovalley, about 2.5 km NE of Wellstead. Production bore WSD16P was installed into the Lower Werillup Aquifer, with (existing) bore WSD4 to be used as its monitoring bore, and production bore WSD17P, and its associated monitoring bore, WSD18, were drilled into the Upper Werillup Aquifer at the same location.

The most productive bores (WSD4, WSD14, WSD15P, WSD16P), with yields of up to 20 L/s and a transmissivity of up to 350 m^2/d, are screened in the Lower Werillup Aquifer situated in the deepest parts of the palaeovalleys. Yields are highest in bores WSD14 and WSD15P, where the central palaeovalley narrows and the Lower Werillup sand becomes thicker and coarser.

However, the salinity of these bores is about 60,000 mg/L, which is probably too high for use at the proposed mine, other than perhaps for dust suppression.

The very high salinity of bores WSD14 and WSD15P probably results from a wedge of hypersaline water extending down the central palaeovalley from a chain of salt lakes located at the foot of the Stirling Range. To the east of bores WSD14 and WSD15P, the salinity of the Lower Werillup Aquifer within the central palaeovalley decreases to about 20,000 mg/L at bore WSD16P, and may decrease further with proximity to the coast.

In the case of the central palaeovalley, much lower salinity water occurs within the Upper Werillup Aquifer than the Lower Werillup Aquifer. For example, the salinity of bores WSD5, WSD7, WSD17P and WSD18 is 6,500 to 7,500 mg/L, whereas the salinity of the Lower Werillup Aquifer bores at these locations (WSD4, WSD16P) is 20,000 to 30,000 mg/L. Yields of the Upper Werillup Aquifer bores are, however, very low (2–4 L/s), so that a large number of bores would be needed to obtain a significant quantity of (brackish) water from this aquifer alone.

The salinity of the Lower Werillup Aquifer appears to be much lower in the southern palaeovalley than in the central palaeovalley. For example, bores WSD12 and WSD13P, which are slotted across both aquifers, have a salinity of about 5,000 mg/L. Although the Lower Werillup Aquifer in the southern palaeovalley is less well-developed than in the central palaeovalley, it is still sufficiently thick and permeable to produce individual bore yields of up to 10 L/s.

Bores screened over both Werillup aquifers in the southern palaeovalley are probably best suited to supplying a moderate quantity of low-salinity groundwater for the Southdown project. Of second priority, might be bores slotted over the Upper Werillup Aquifer within the lower reaches of central palaeovalley, or bores slotted over both aquifers (if the salinity of the lower aquifer continues to decrease towards the coast), although this is somewhat further from Southdown.

Groundwater modelling, using the results of the exploration drilling programmes and pumping tests, is recommended to assess the long-term capacity of the Werillup aquifers under different scenarios of borefield extraction and water supply. The model should be built basin-wide and multi-layer, so that the effects of extraction from the Werillup Fm on groundwater dependent ecosystems, such as streams and wetlands, can be properly evaluated. Dewatering of the proposed Southdown pit could also be included in the model.

The drilling and testing of one or more production bores in the lower reaches of the central and southern palaeovalleys is also recommended, as this region appears is highly prospective for low-salinity groundwater, yet has not been adequately tested by any of the investigations performed to date.

Dated: 24 May 2016 **Rockwater Pty Ltd**

P de Broekert
Principal Hydrogeologist

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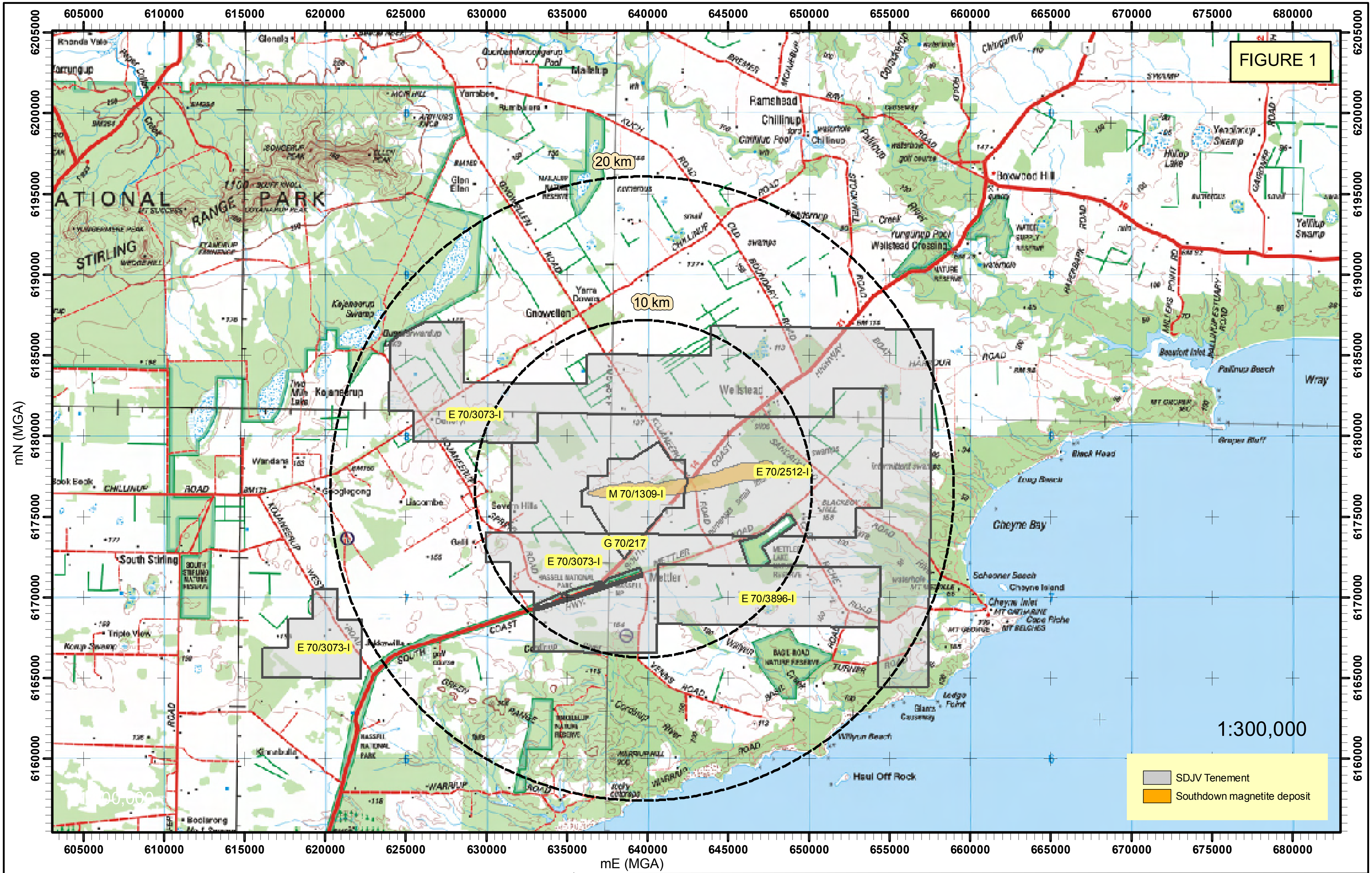
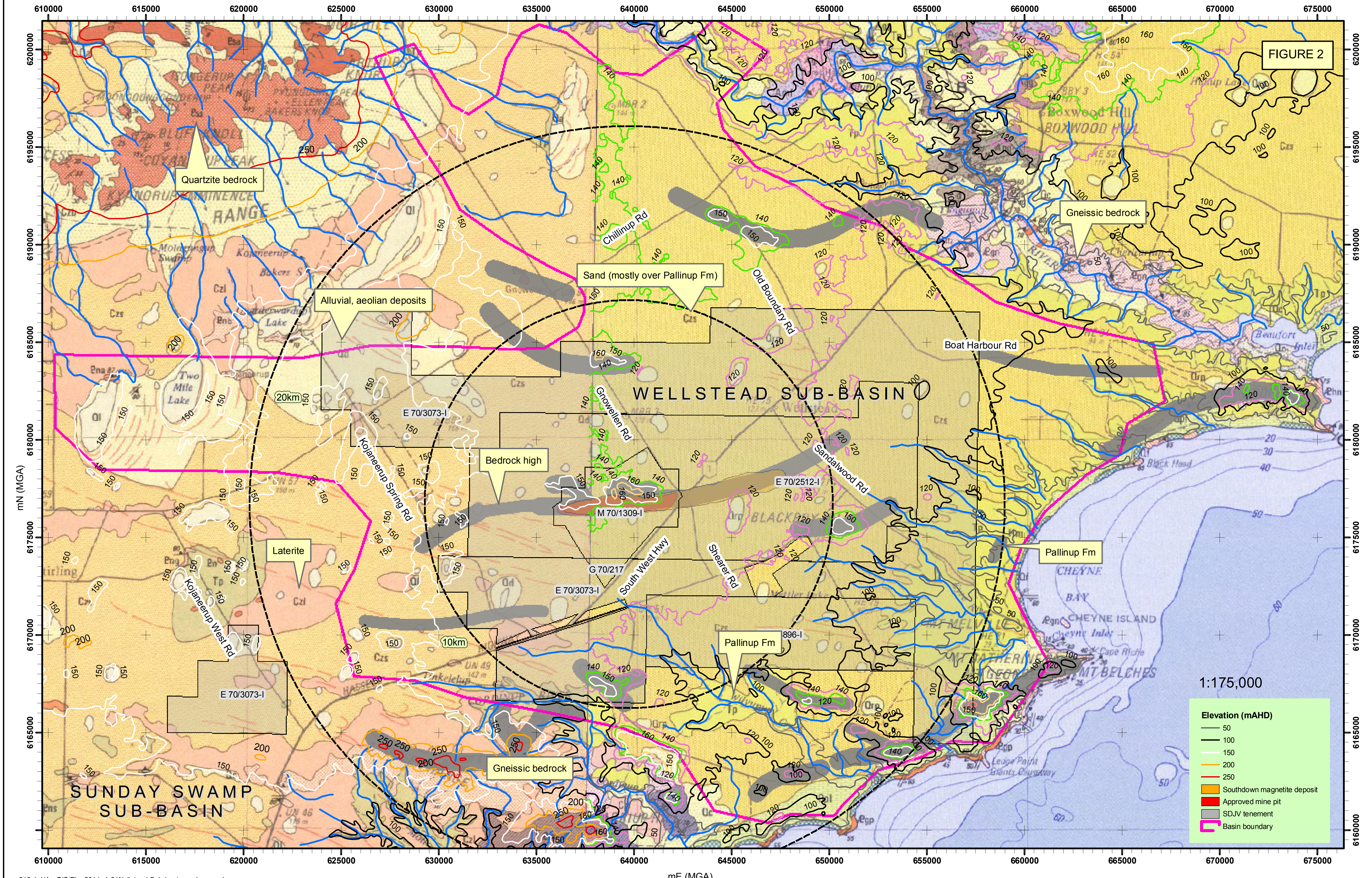
FIGURES



CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: May 2016
Dwg No: 216.1.1/16/1-1

SOUTHDOWN MAGNETITE DEPOSIT, REGIONAL LOCATION

Rockwater Pty Ltd



216-1-1/ArcGIS/Fig. 2014_1-2 Wellstead Sub-basin geology.mxd

CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: May 2016
Dwg No: 216.1.1/16/1-2

WELLSTEAD SUB-BASIN, GEOLOGY, TOPOGRAPHY & DRAINAGE

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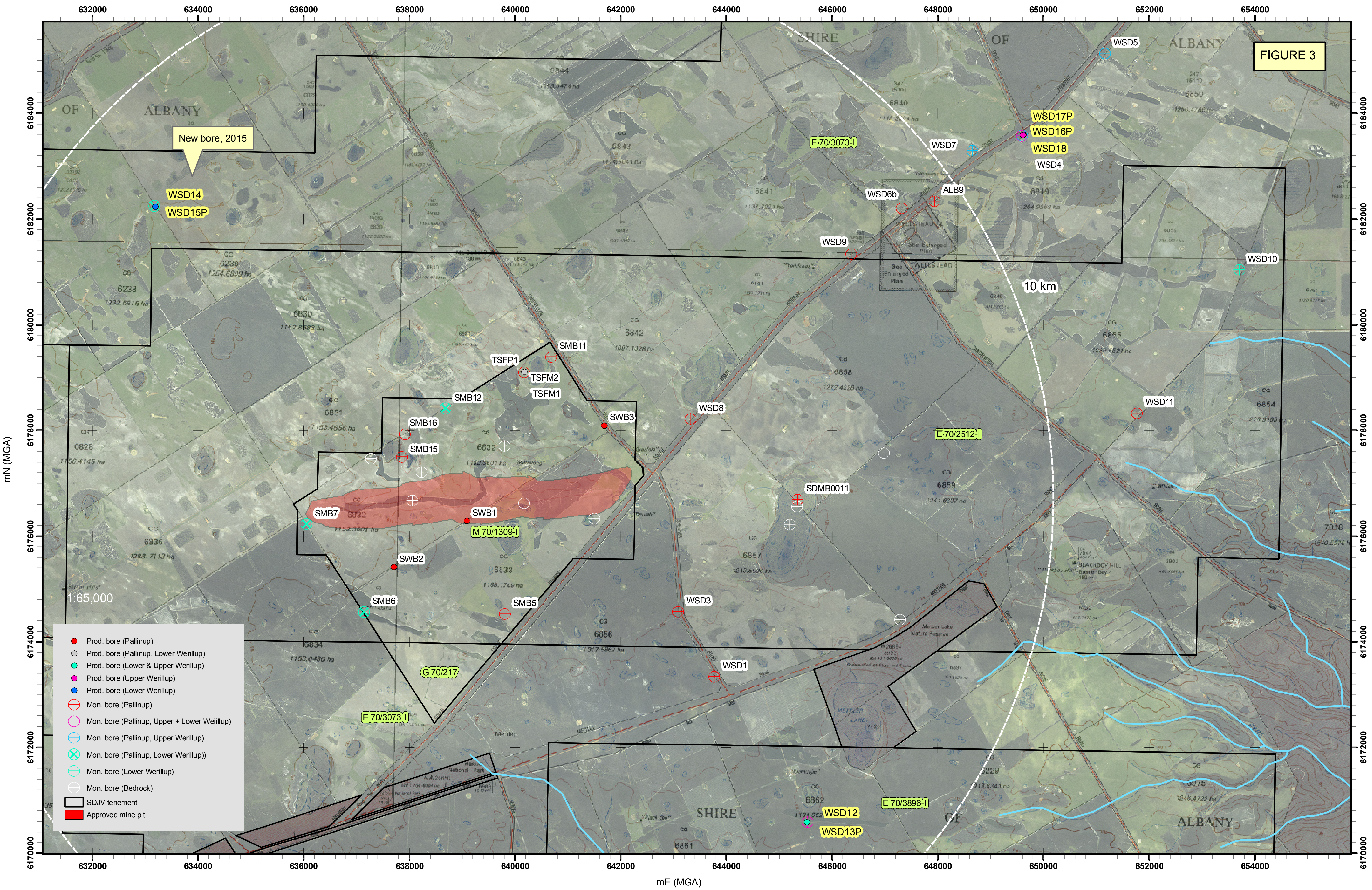

CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: May 2016
Dwg No: 216.1.1/16/1-3

SOUTHDOWN - WELLSTEAD AREA, BORE LOCATIONS

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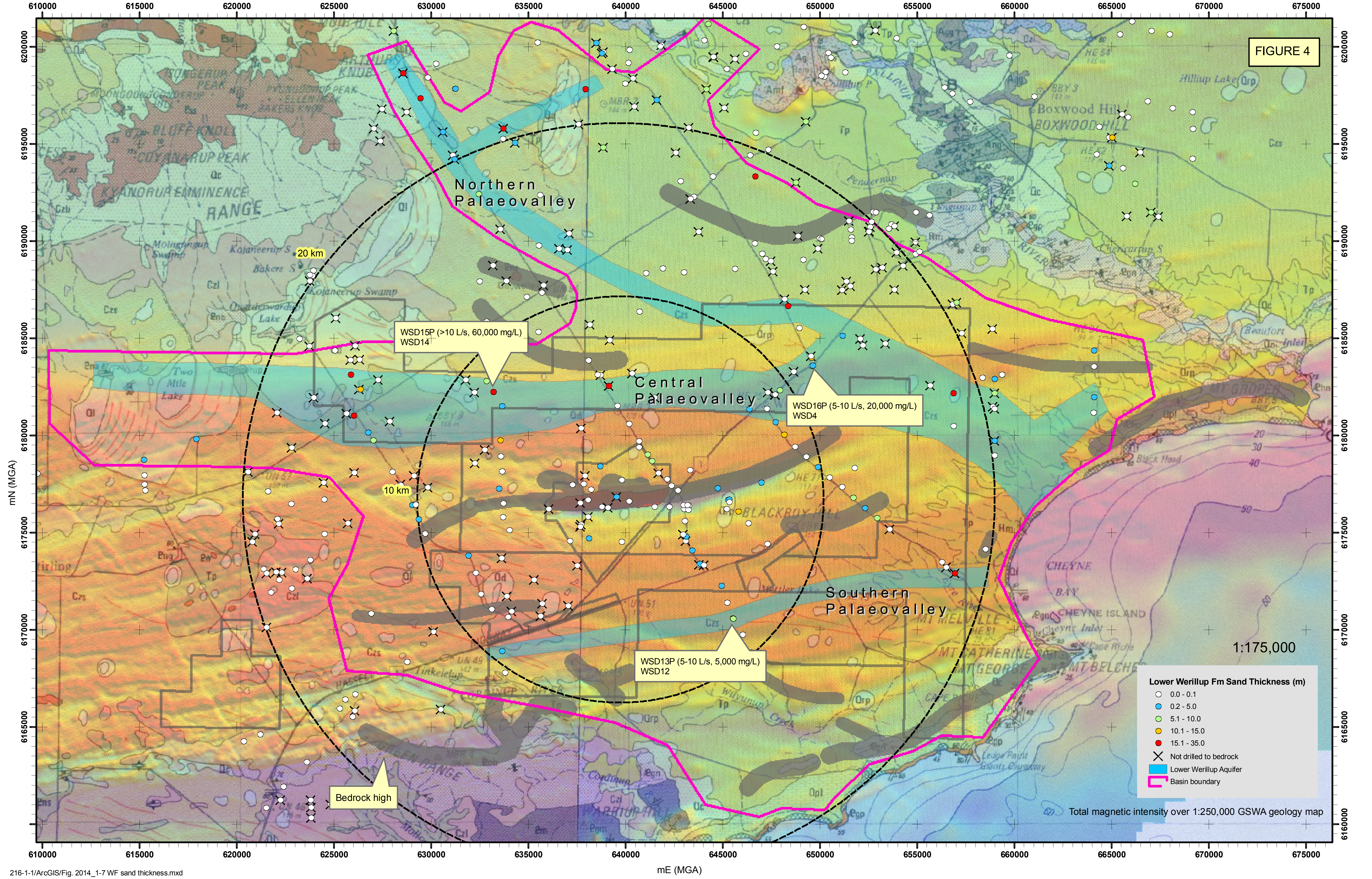

216-1-1/ArcGIS/Fig. 2014_1-7 WF sand thickness.mxd

CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: May 2016
Dwg No: 216.1.1/16/1-4

WELLSTEAD SUB-BASIN, LOWER WERILLUP AQUIFER DISTRIBUTION

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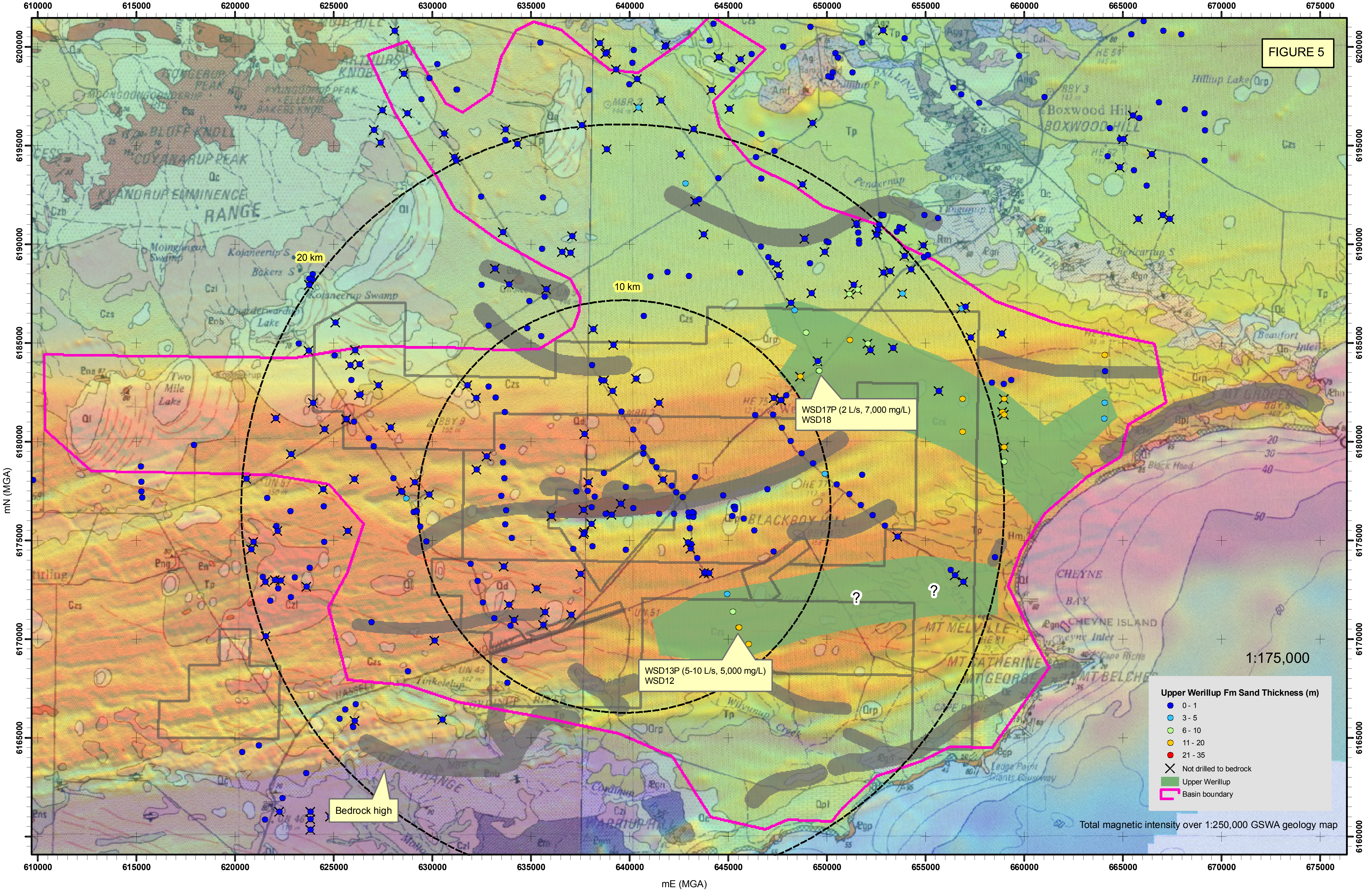
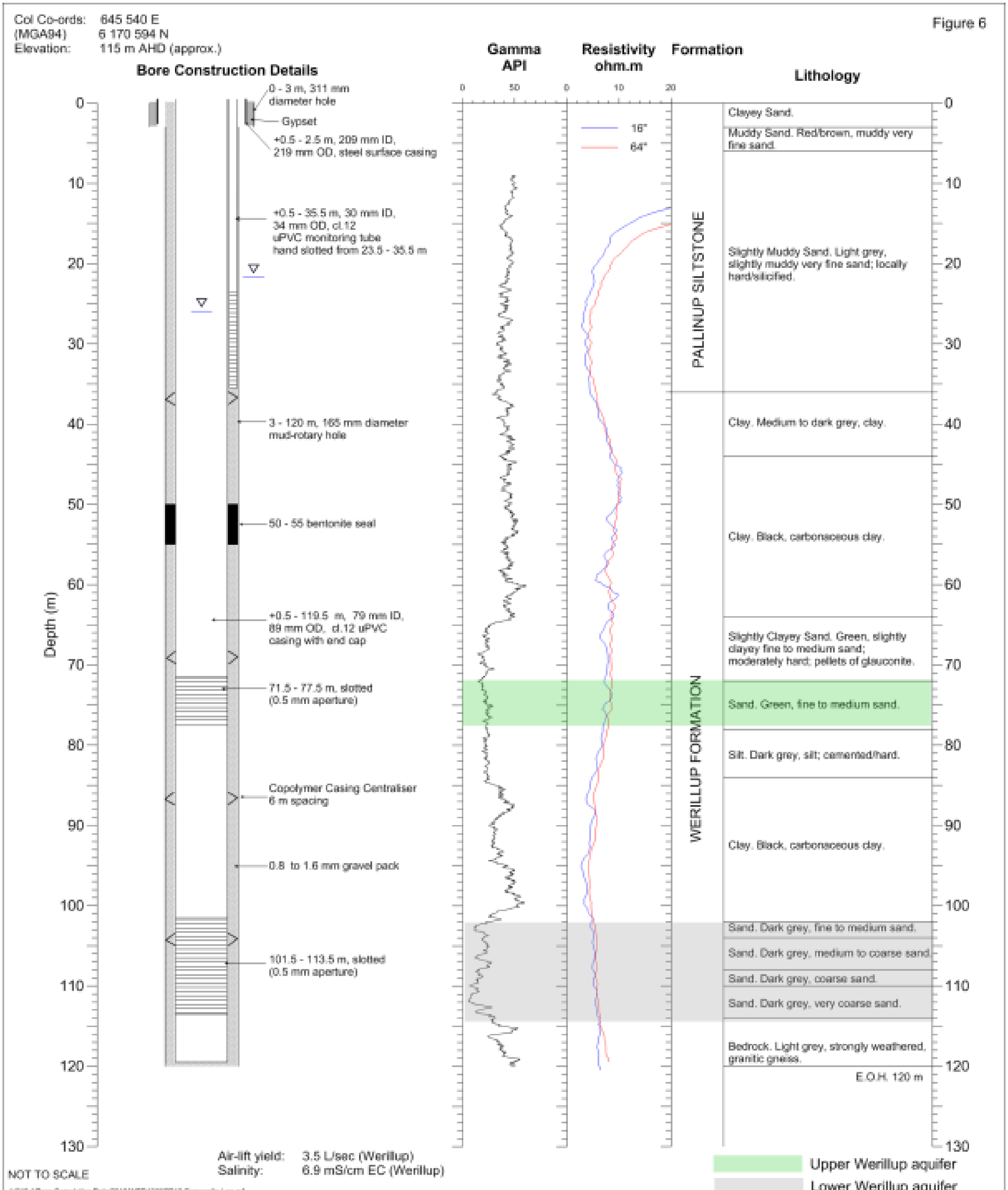


CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: May 2016
Dwg No: 216.1.1/16/1-5

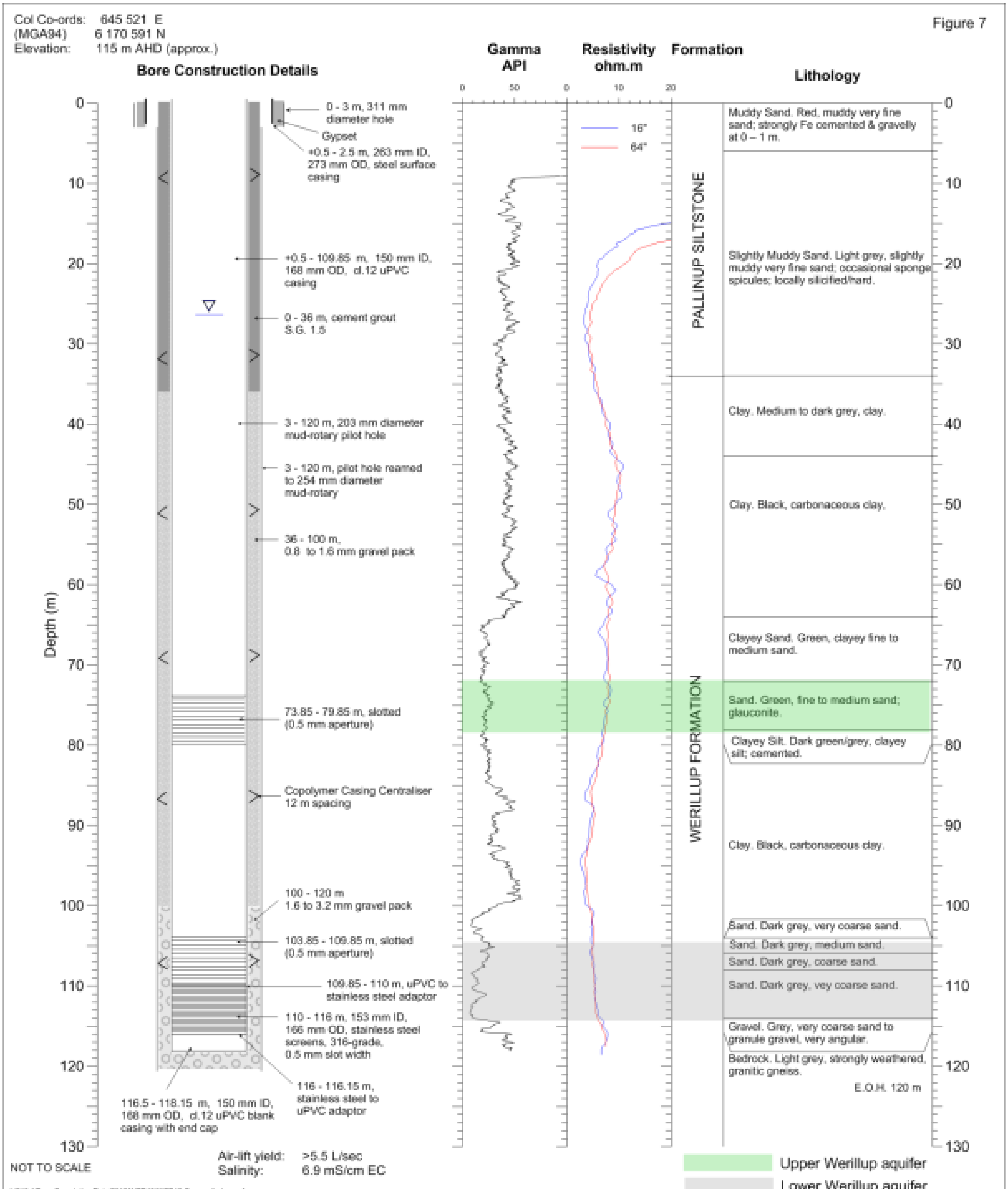
WELLSTEAD SUB-BASIN, UPPER WERILLUP AQUIFER DISTRIBUTION

Rockwater Pty Ltd



Client:	SDJV
Project:	Southdown Water Supply
Date:	May 2016
Drg. No.:	216.1.1/16/1-6

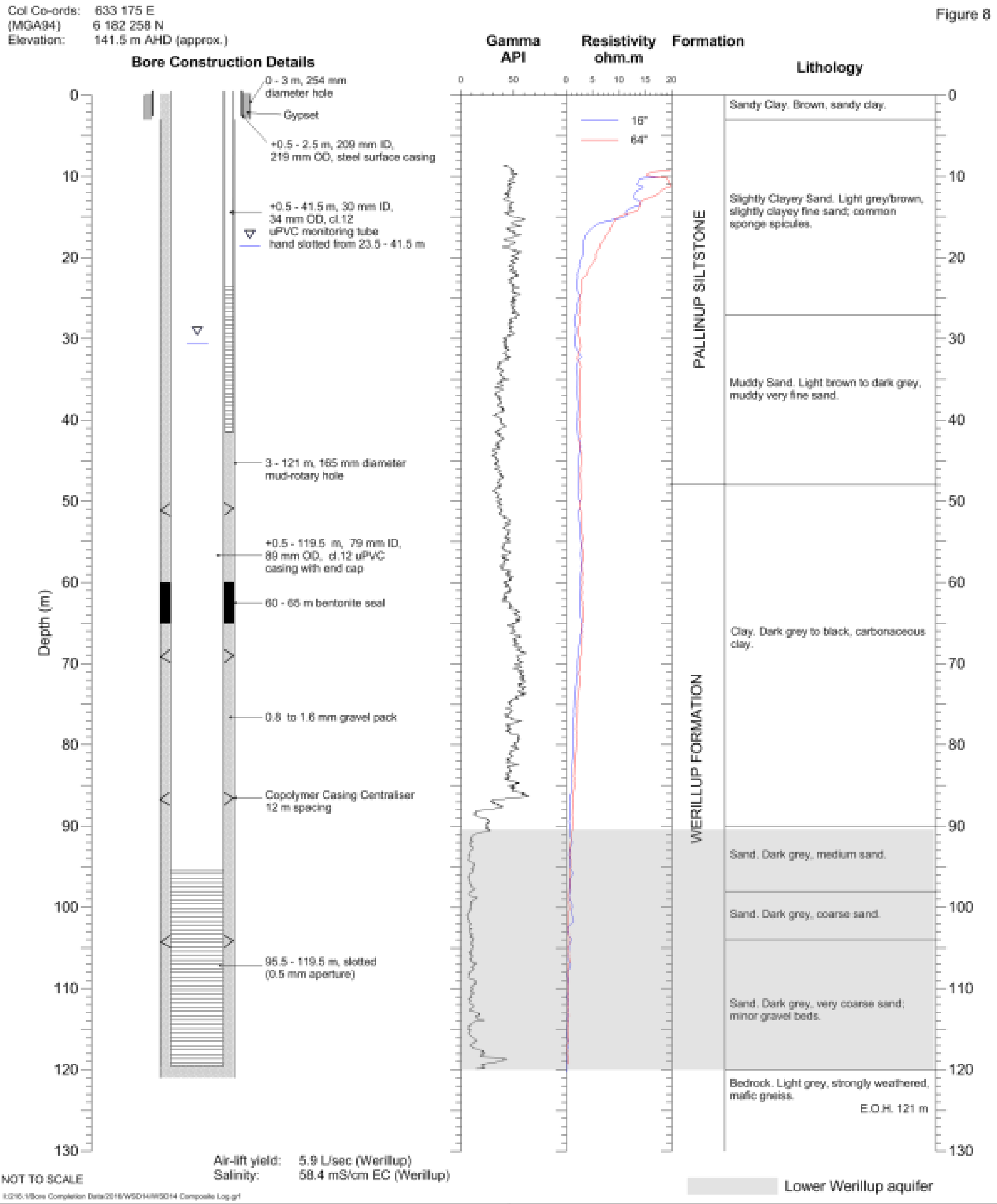
Monitoring Bore WSD12 Composite Log



Client:	SDJV
Project:	Southdown Water Supply
Date:	May 2016
Drg. No.:	216.1.1/16/1-7

Production Bore WSD13P
Composite Log

Figure 8



Client: SDJV

Project: Southdown Water Supply

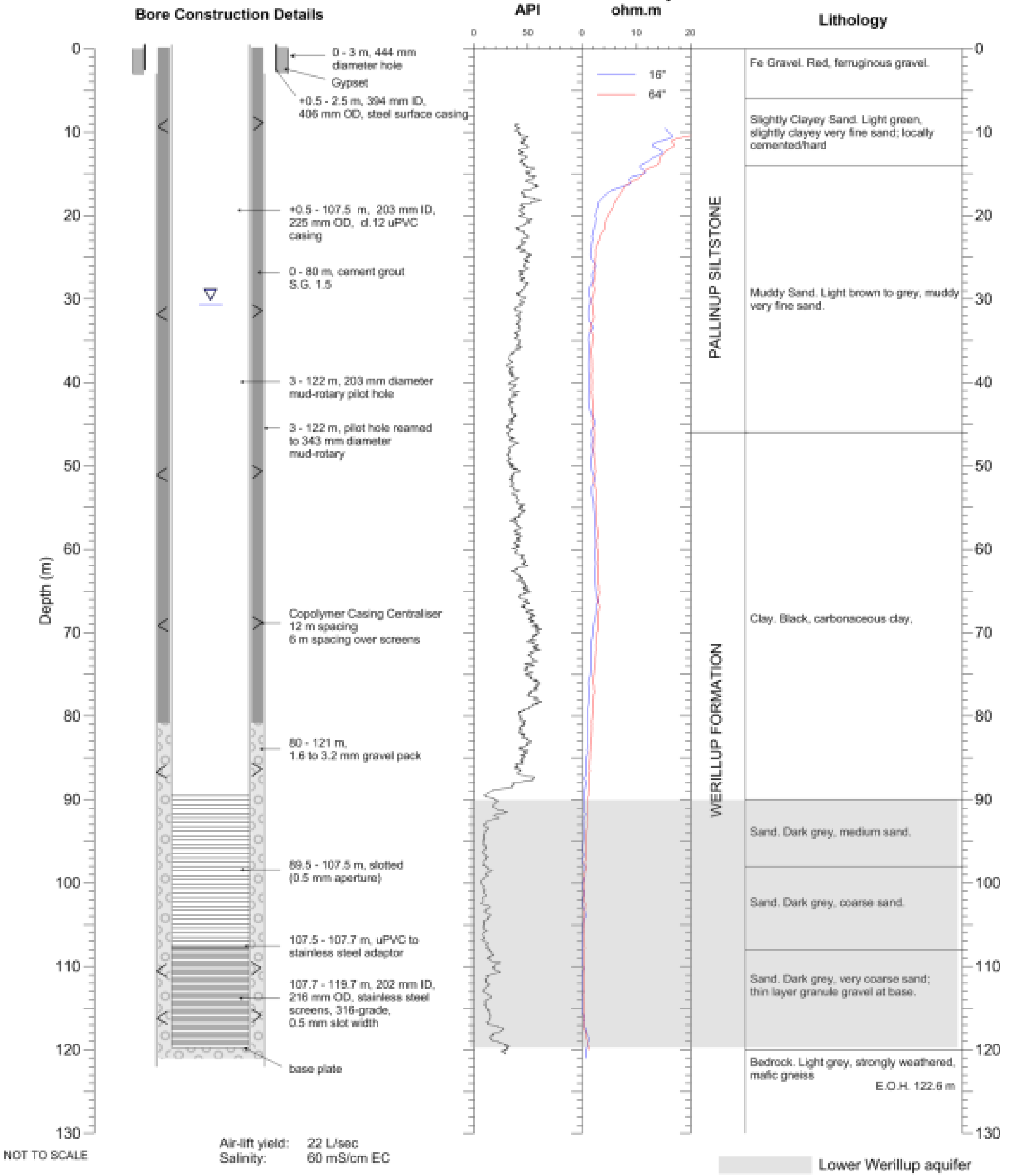
Date: May 2016

Drg. No.: 216.1.1/16/1-8

Monitoring Bore WSD14
Composite Log

Col Co-ords: 633 190 E
(MGA94) 6 182 236 N
Elevation: 142 m AHD (approx.)

Figure 9



NOT TO SCALE

Air-lift yield: 22 L/sec
Salinity: 60 mS/cm EC

I:\216.1\Bore Completion Data\2016\WSD15\WSD15 Composite Log.grf

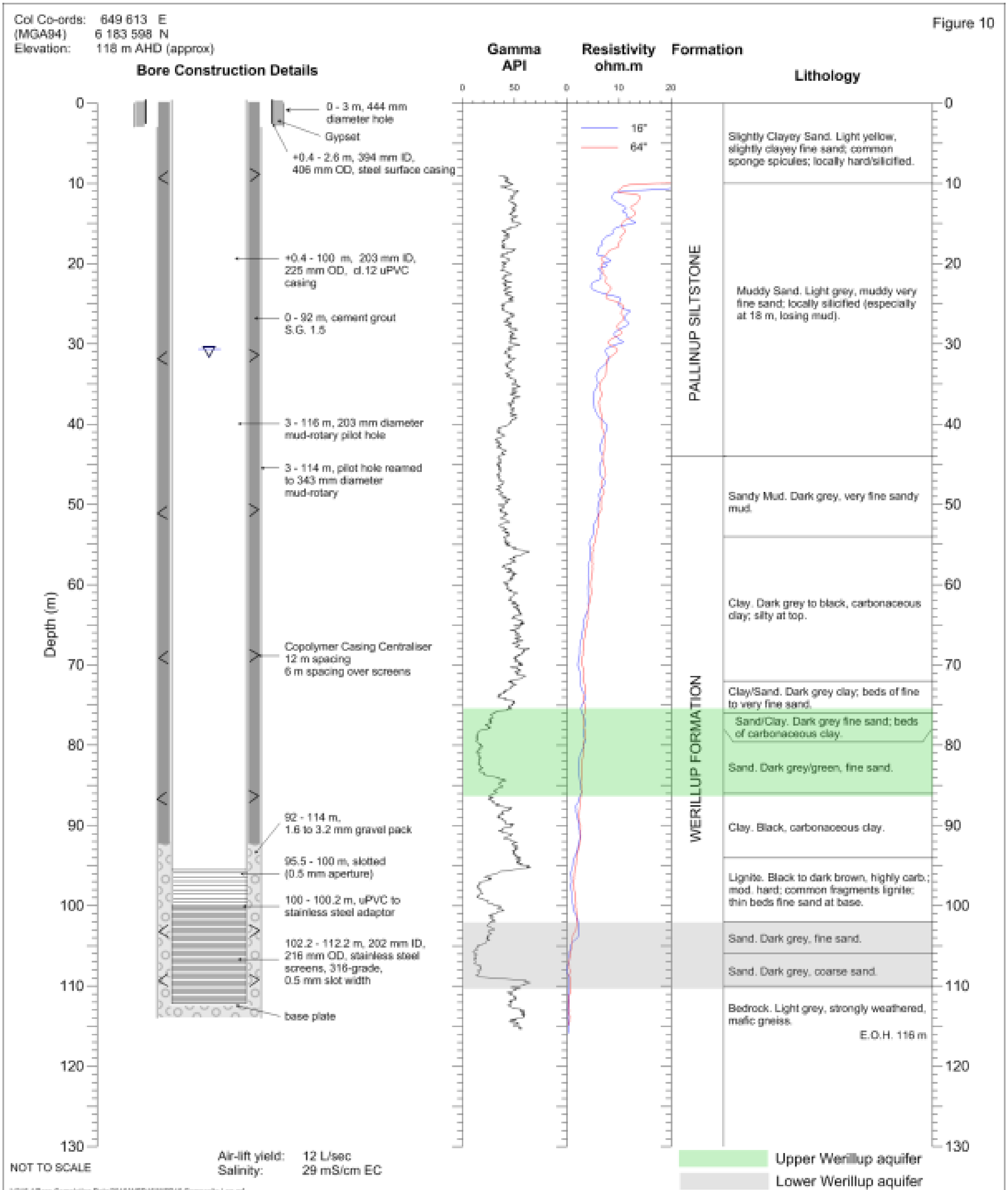
Client: SDJV

Project: Southdown Water Supply

Date: May 2016

Drg. No.: 216.1.1/16/1-9

Production Bore WSD15P Composite Log



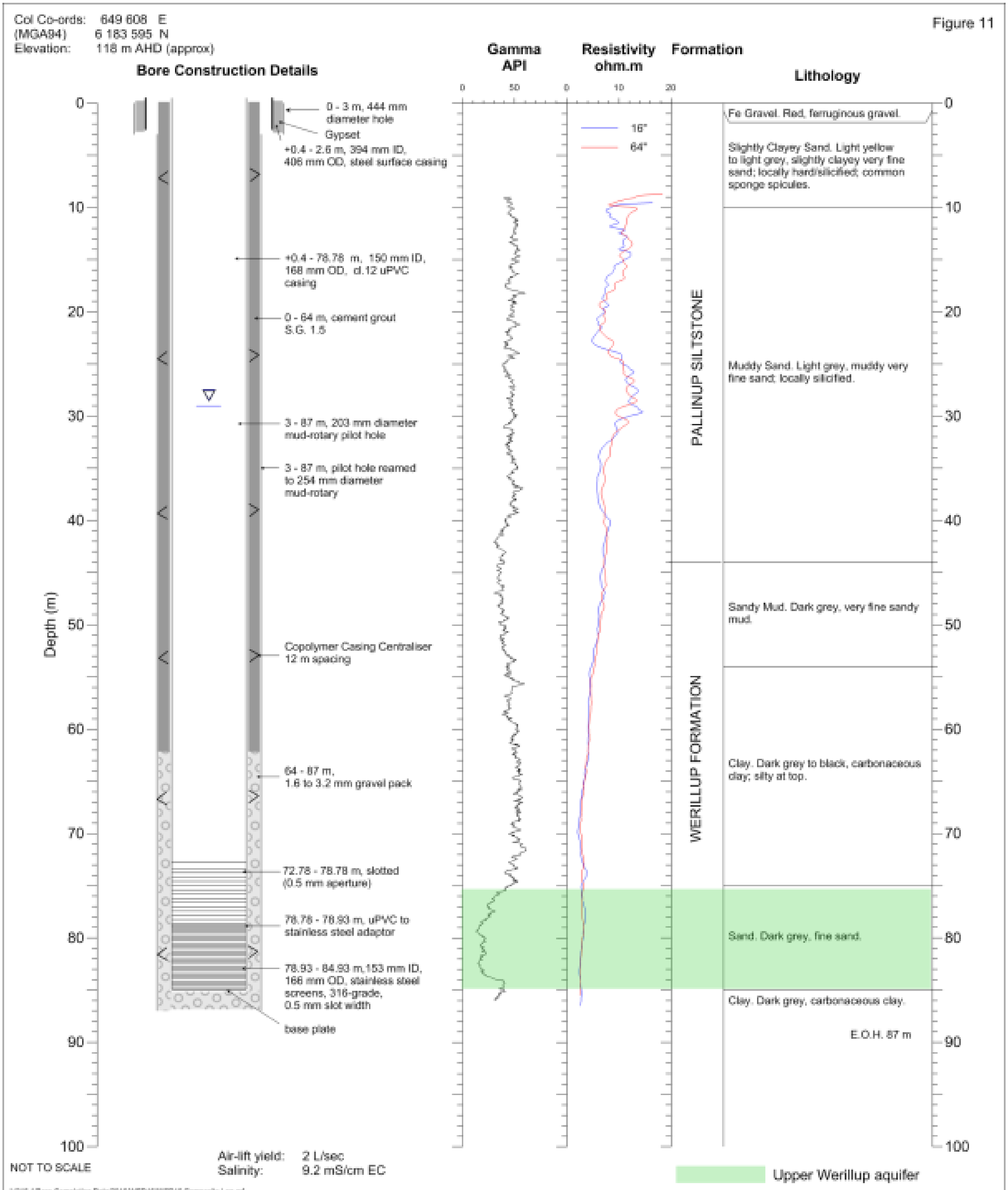
Client: SDJV

Project: Southdown Water Supply

Date: May 2016

Drg. No.: 216.1.1/16/1-10

Production Bore WSD16P Composite Log



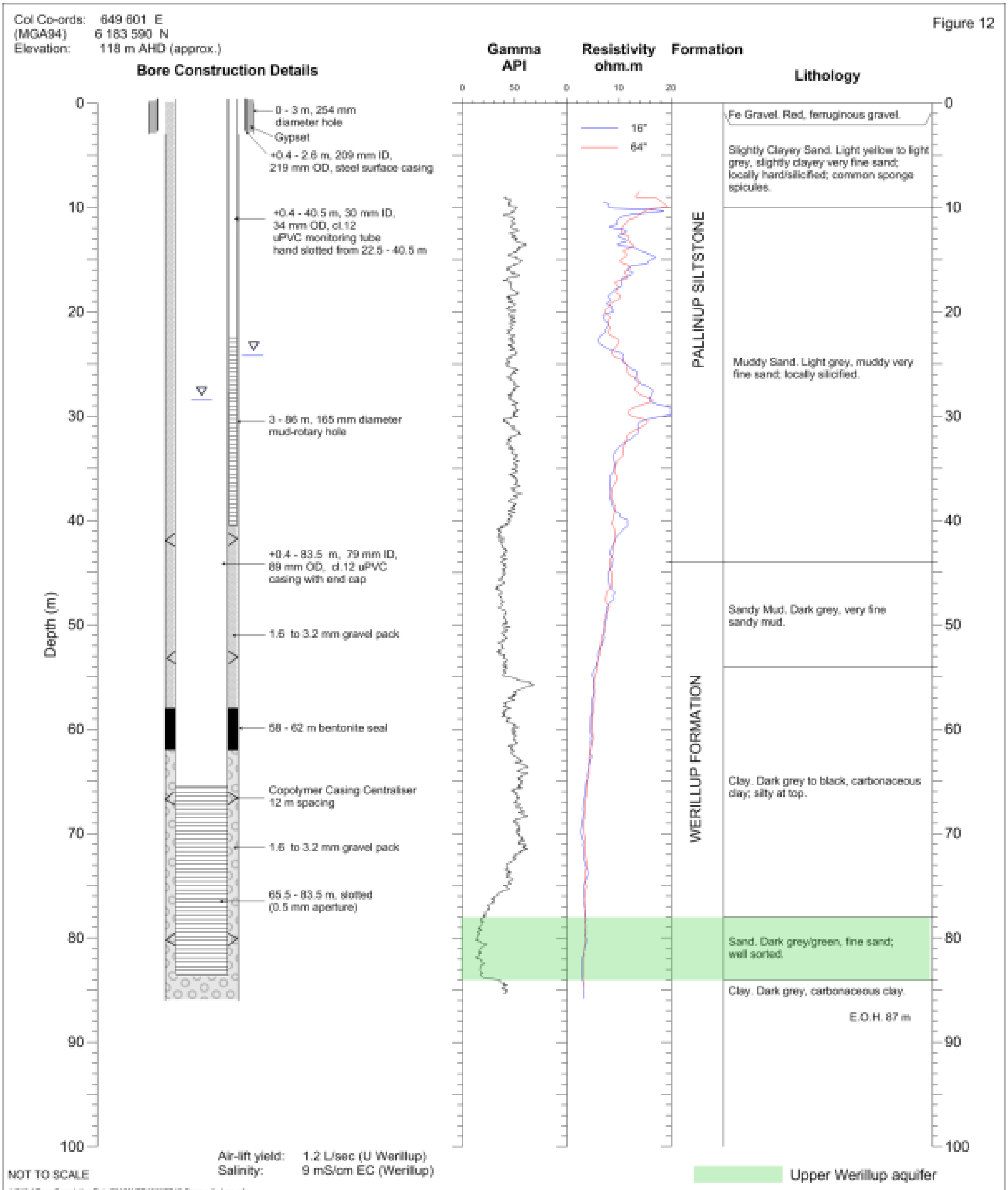
Client: SDJV

Project: Southdown Water Supply

Date: May 2016

Drg. No.: 216.1.1/16/1-11

Production Bore WSD17P Composite Log



Client:	SDJV
Project:	Southdown Water Supply
Date:	May 2016
Drg. No.:	216.1.1/16/1-12

Monitoring Bore WSD18 Composite Log

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: May 2016
Drg. No.: 216.1.1/16/01-13

BORE WSD13P

Step-Rate Test Data

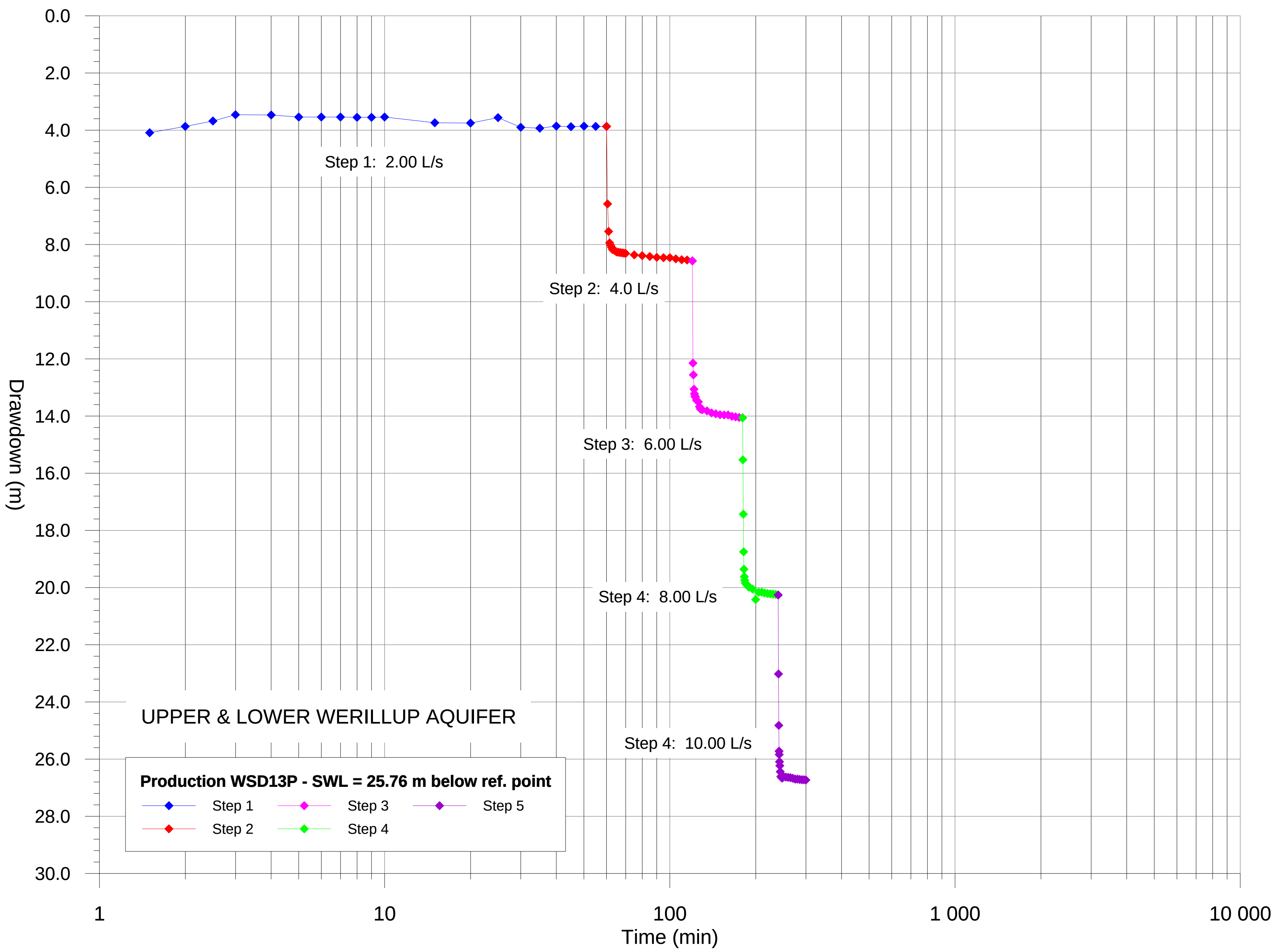
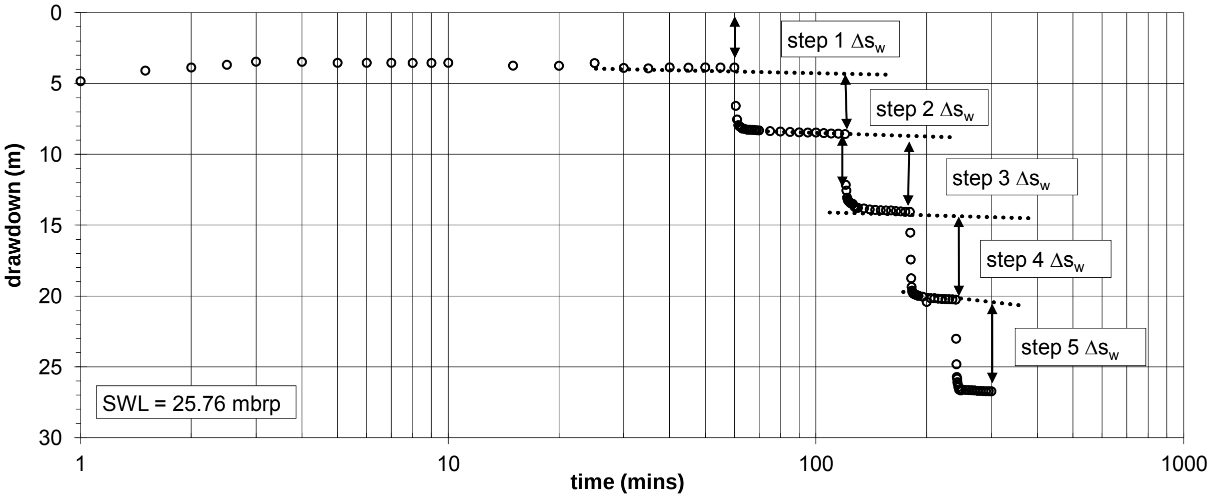


Figure 13

Figure 14

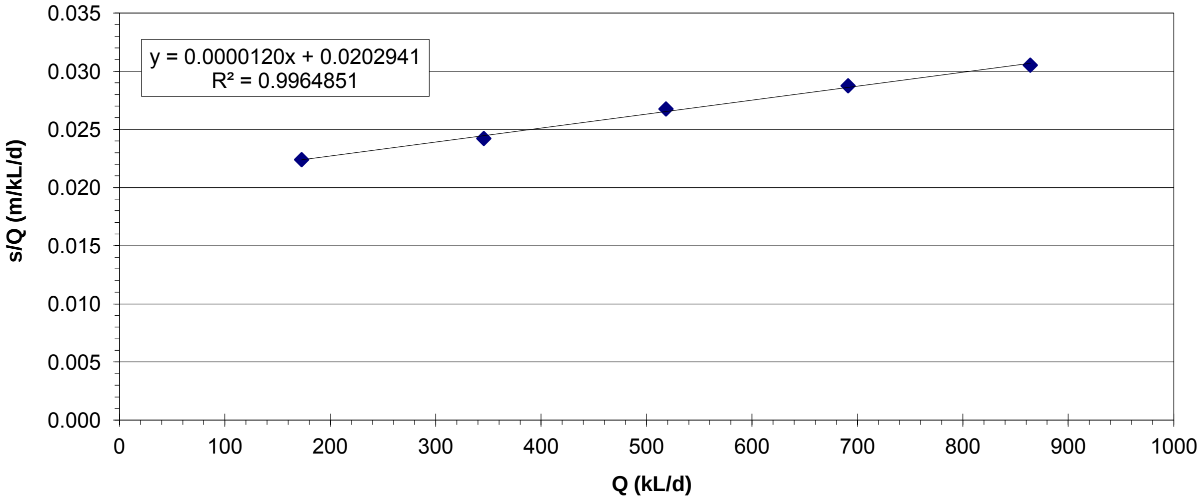


$s=BQ+CQ^2$, where:
BQ is drawdown due to laminar flow
CQ^2 is drawdown due to turbulent flow
s/Q=B+CQ, so in plot of s/Q v. Q, B is the intercept
& C is the slope

B = 0.02013 intercept
C = 1.2E-05 slope

Step	Q		stabilised drawdown (s)		s/Q
	L/s	kL/d	Δs_w (m)	total (m)	m/kL/d
1	2.00	172.80	3.87	3.87	0.022
2	4.00	345.60	4.50	8.37	0.024
3	6.00	518.40	5.50	13.87	0.027
4	8.00	691.20	6.00	19.87	0.029
5	10.00	864.00	6.50	26.37	0.031

predicted drawdown using B & C @ Q=10 L/s, = 26.7 m
actual drawdown from CRT @ t=300 mins & Q=10 L/s, = 26.2 m



Drawdown due to turbulent flow in aquifer and bore (Lt)
$Lt=(CQ^2/(BQ+CQ^2))100$

Lt =	17.7	% at Q =4 L/s
Lt =	24.3	% at Q = 6 L/s
Lt =	30.0	% at Q = 8 L/s
Lt =	34.9	% at Q = 10 L/s

216.1.1\Test Pumping\WSD13\step test - WSD13 Analysis.xls

Client:	Southdown Joint Venture
Project:	Water Supply Investigation
Date	May 2016
Dwg No.	216.1.1/16/1-14

Bore WSD13P Step-rate Test Data Analysis

Rockwater Pty Ltd

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: May 2016
Drg. No.: 216-1-1/16/01-15

Bore WSD13P

Constant-Rate Test Data

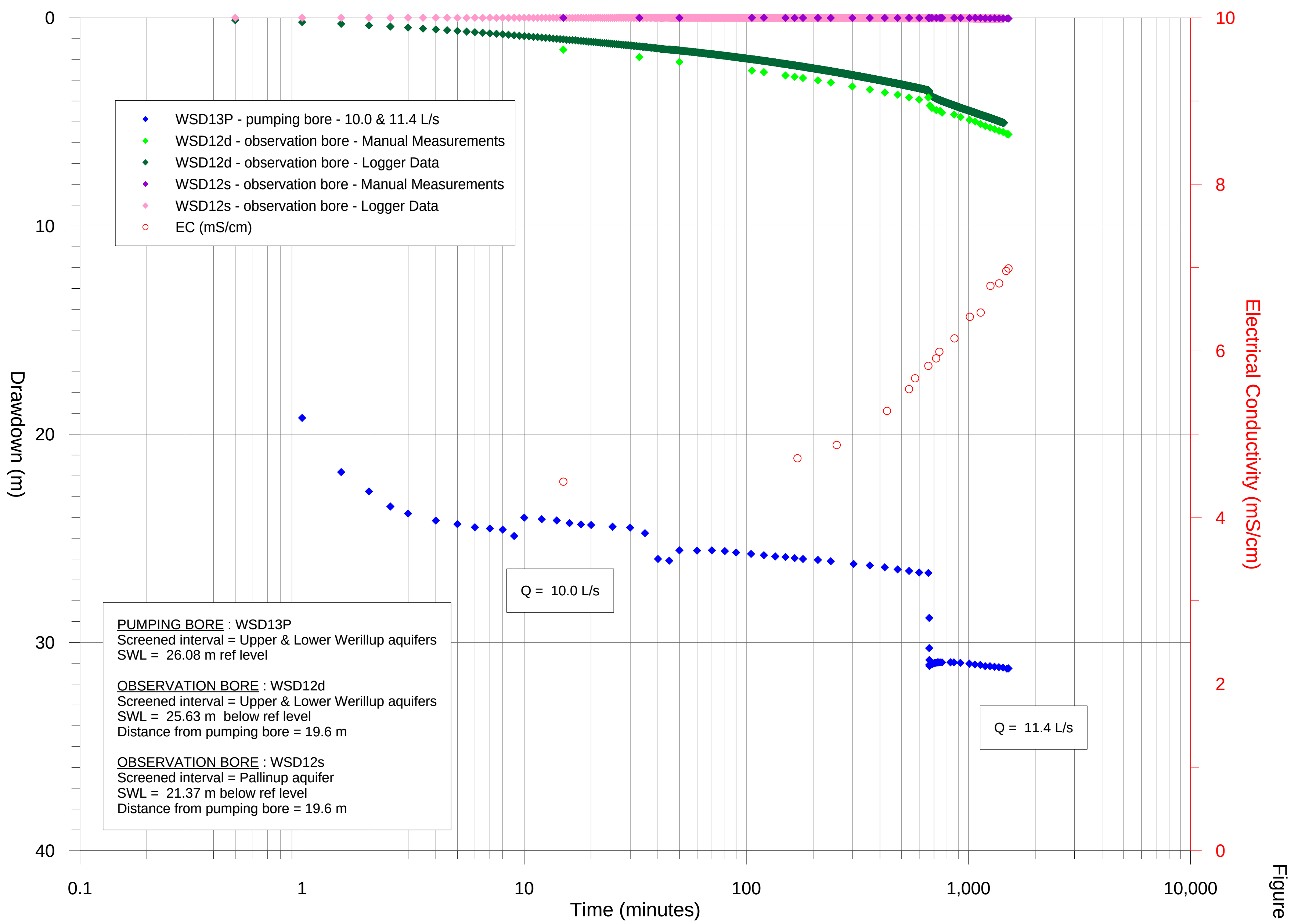
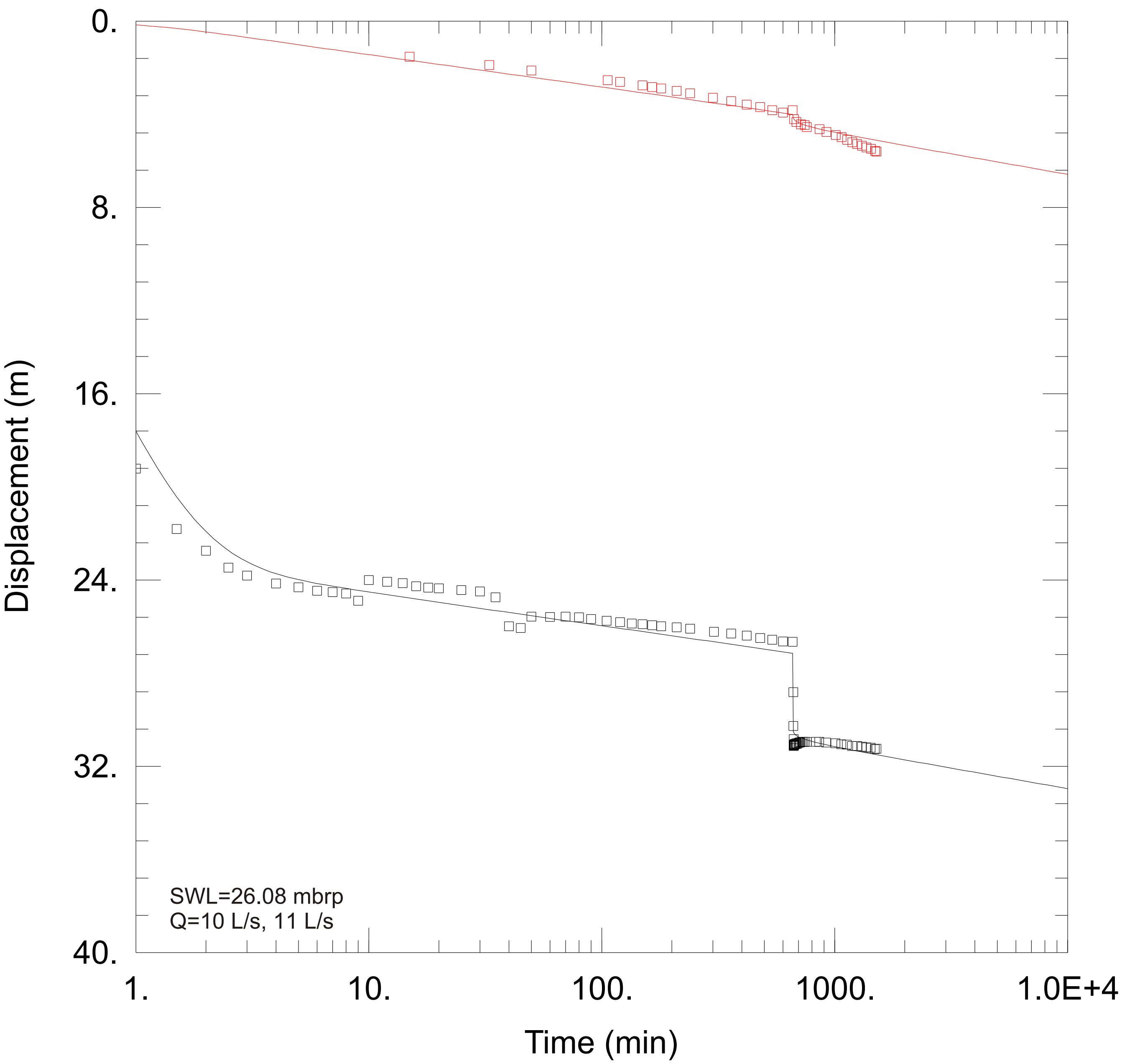


Figure 15

Figure 16



AQUIFER DATA

Saturated Thickness: 18. m

Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
WSD13	0	0

Observation Wells

Well Name	X (m)	Y (m)
WSD13	0	0
WSD12d	19.6	0

SOLUTION

Aquifer Model: Confined

Solution Method: Barker

K = 7.173 m/day
n = 1.96
Sw = 20.
r(c) = 0.075 m

Ss = 2.169E-5
b = 18. m
r(w) = 0.127 m

Client:	Southdown Joint Venture
Project:	Water Supply Investigation
Date:	May 2016
Dwg No:	216.1.1/16/1-16

Bore WSD13P, Constant-Rate Test
Data Analysis

Rockwater Pty Ltd

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: May 2016
Drg. No.: 216.1.1/16/01-17

BORE WSD15P

Step-Rate Test Data

I:/216-1-1/Grapher/WSD15 - SRT.grf

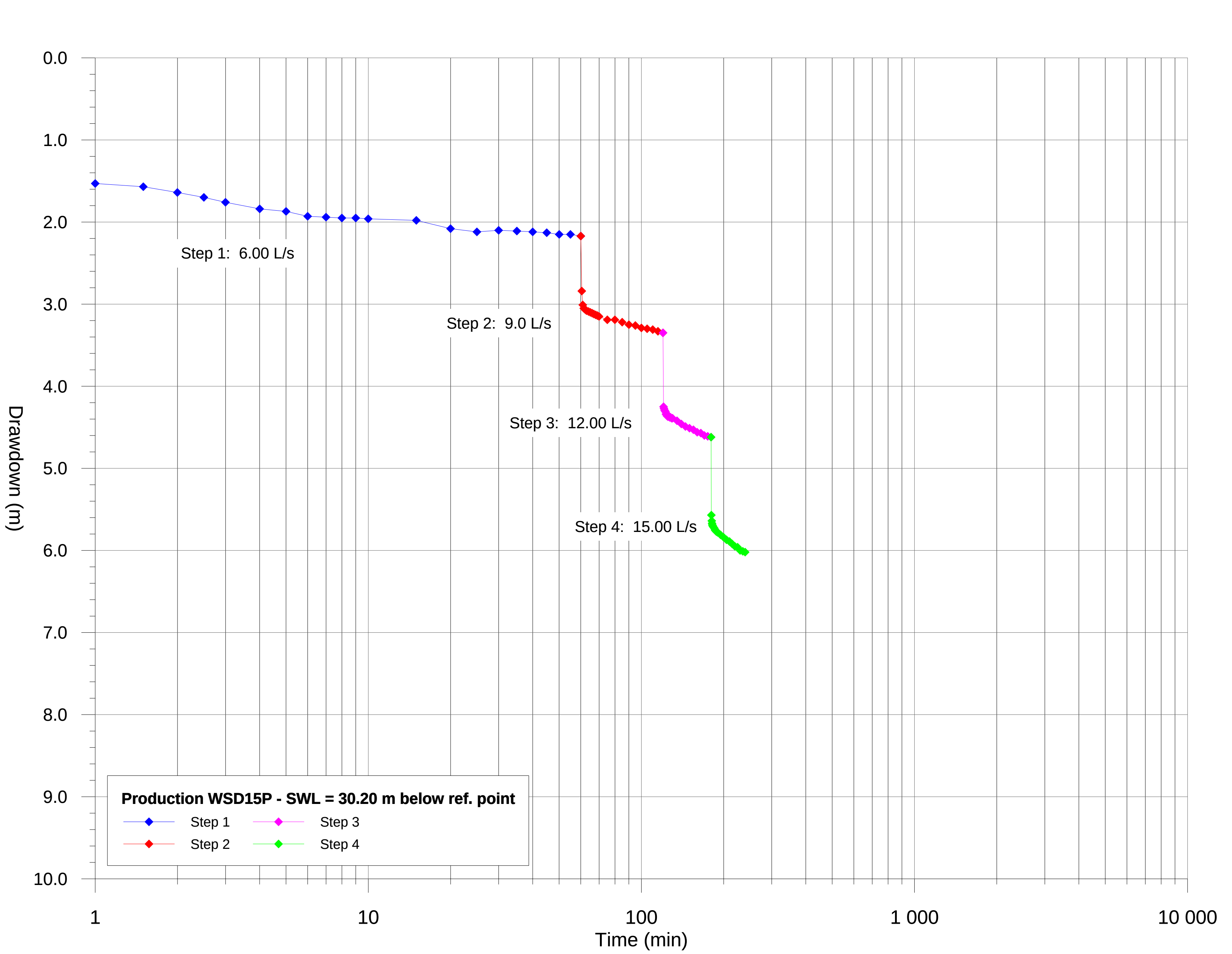
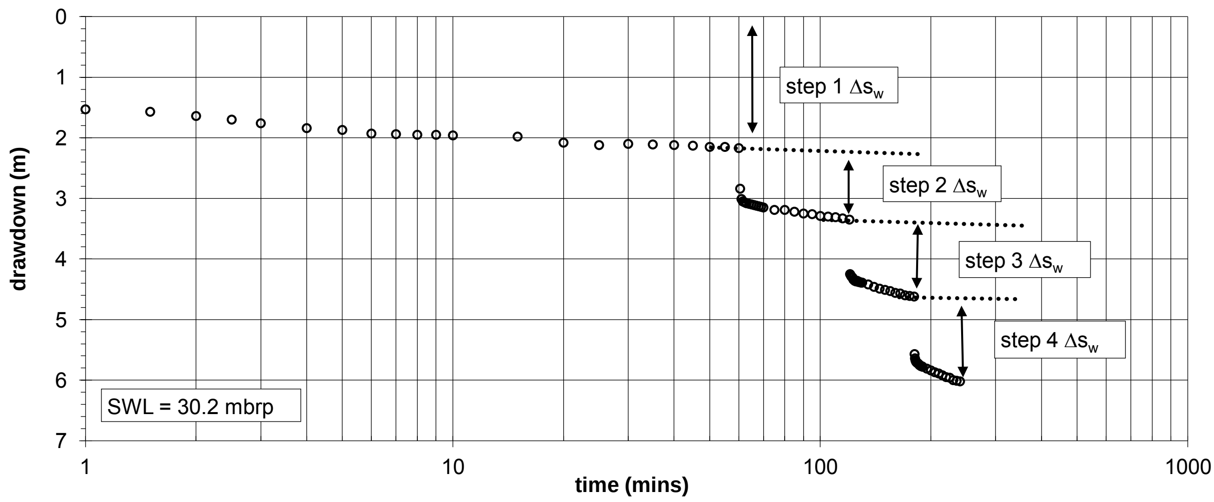


Figure 17

Rockwater



$s=BQ+CQ^2$, where:

BQ is drawdown due to laminar flow

CQ^2 is drawdown due to turbulent flow

s/Q=B+CQ, so in plot of s/Q v. Q, B is the intercept & C is the slope

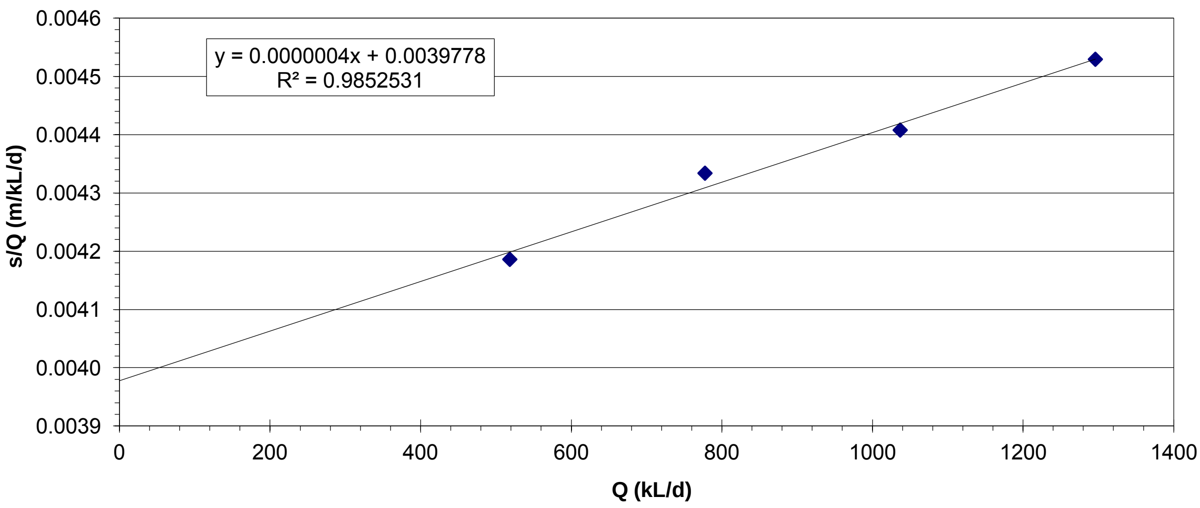
B = 0.00398 intercept

C = 4.3E-07 slope

Step	Q		stabilised drawdown (s)		s/Q
	L/s	kL/d	Δs_w (m)	total (m)	m/kL/d
1	6.00	518.40	2.17	2.17	0.004
2	9.00	777.60	1.20	3.37	0.004
3	12.00	1036.80	1.20	4.57	0.004
4	15.00	1296.00	1.30	5.87	0.005
5	0.00	0.00	0.00	0.00	0.000

predicted drawdown using B & C @ Q=15 L/s, = 5.9 m

actual drawdown from CRT @ t=240 mins & Q=15 L/s, = 5.9 m



Drawdown due to turbulent flow in aquifer and bore (Lt)

$Lt=(CQ^2/(BQ+CQ^2))100$

Lt =	5.3	% at Q =6 L/s
Lt =	7.7	% at Q = 9 L/s
Lt =	10.0	% at Q = 12 L/s
Lt =	12.2	% at Q = 15 L/s

216.1.1\Test Pumping\WSD15\step test - WSD15 Analysis.xls

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date May 2016
Dwg No. 216.1.1/16/1-18

Bore WSD15P Step-rate Test Data Analysis

Rockwater Pty Ltd

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: May 2016
Drg. No.: 216-1-1/16/01-19

Bore WSD15P

Constant-Rate Test Data

Rockwater

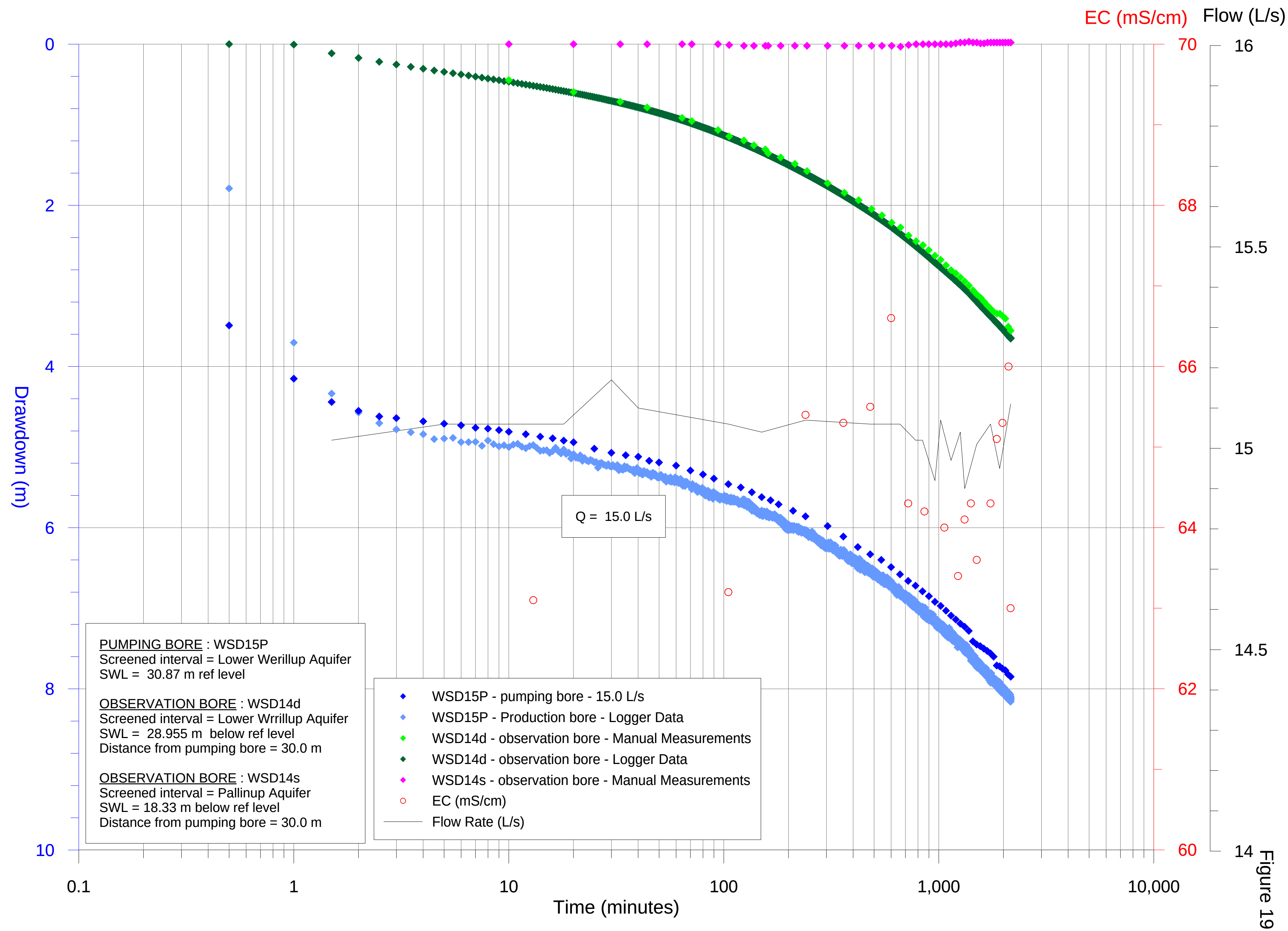
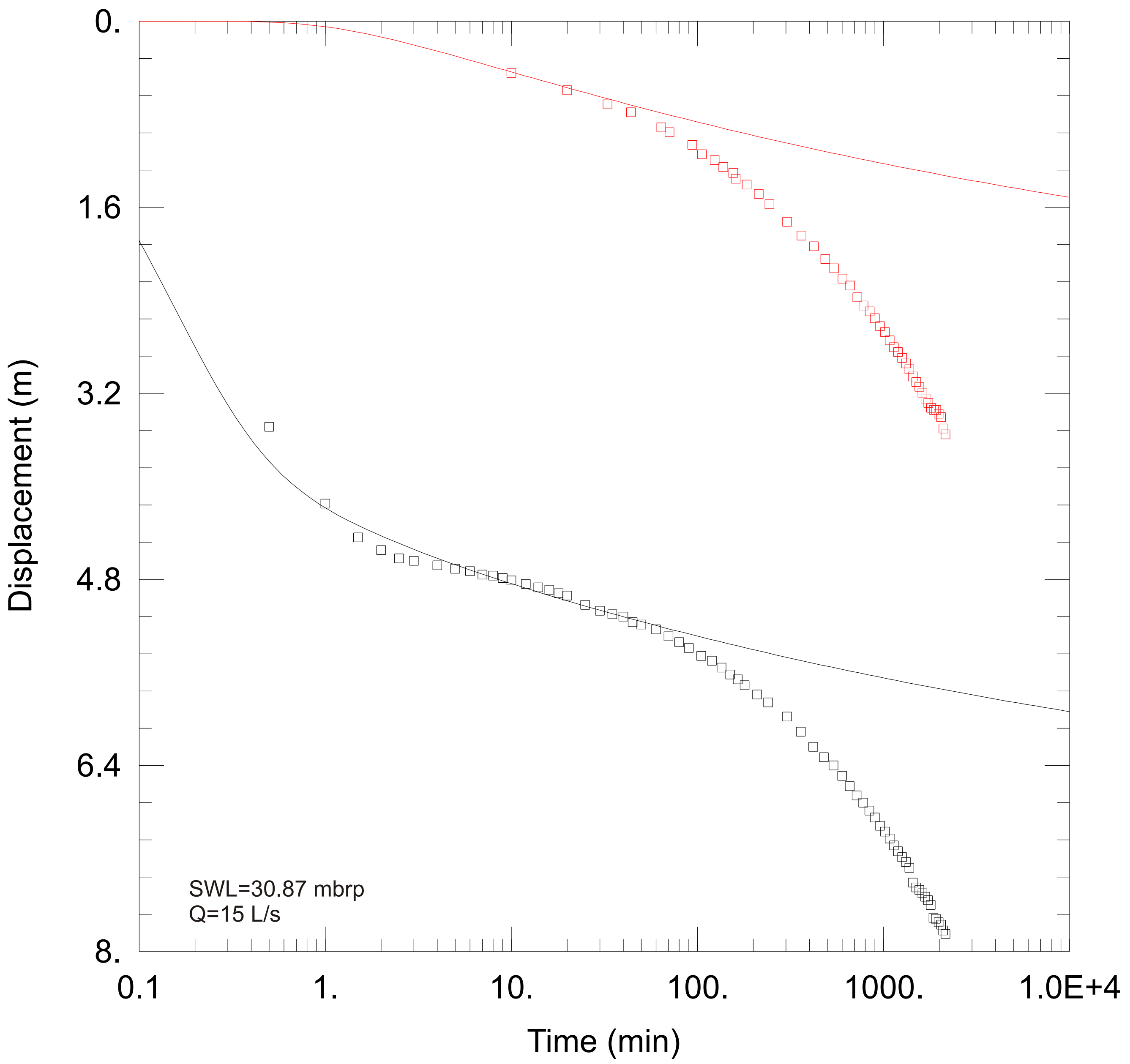


Figure 19



AQUIFER DATA

Saturated Thickness: 30. m

Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
WSD15	0	0

Observation Wells

Well Name	X (m)	Y (m)
WSD15	0	0
WSD14d	30	0

SOLUTION

Aquifer Model: Confined

Solution Method: Barker

K = 11.61 m/day
n = 2.186
Sw = 0.
r(c) = 0.1 m

Ss = 3.569E-5
b = 30. m
r(w) = 0.17 m

Client:	Southdown Joint Venture
Project:	Water Supply Investigation
Date:	May 2016
Dwg No:	216.1.1/16/1-20

Bore WSD15P, Constant-Rate Test
Data Analysis

Rockwater Pty Ltd

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: May 2016
Drg. No.: 216.1.1/16/01-21

BORE WSD16P

Step-Rate Test Data

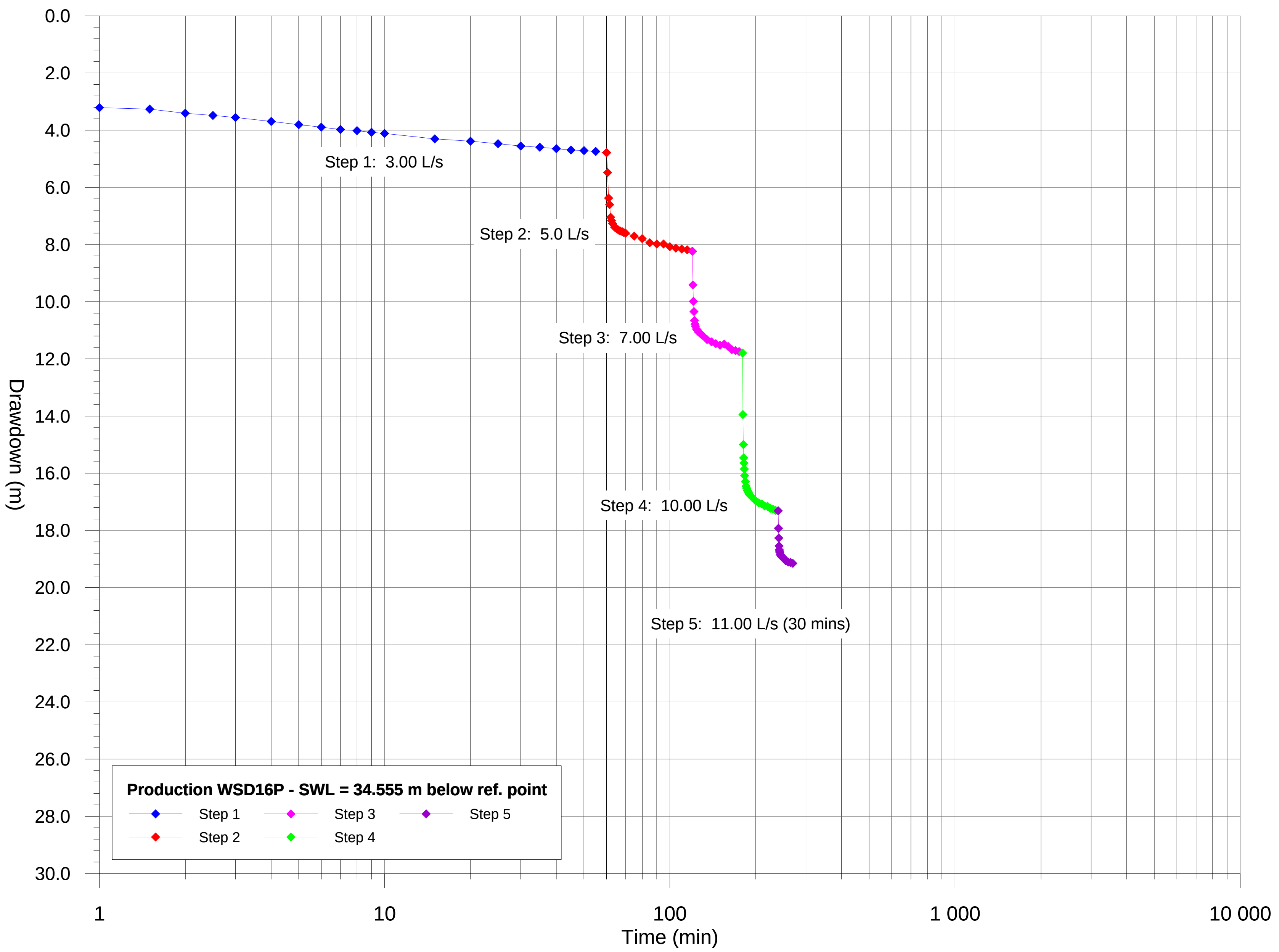
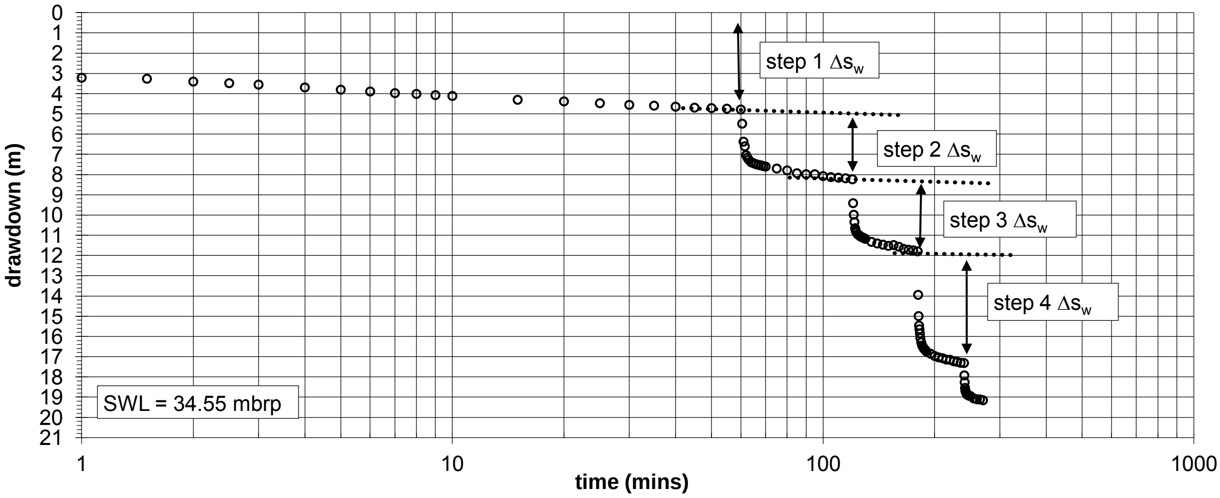


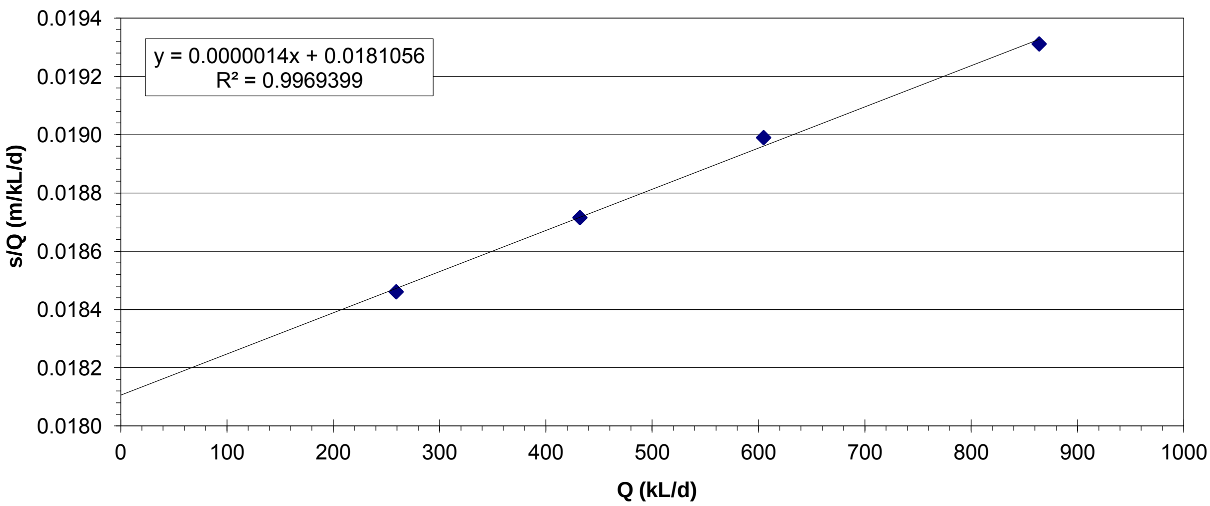
Figure 21



s=BQ+CQ², where:	Step	Q (L/s)	Q (kL/d)	stabilised drawdown (s) Δs_w (m)	stabilised drawdown (s) total (m)	s/Q m/kL/d
BQ is drawdown due to laminar flow						
CQ^2 is drawdown due to turbulent flow	1	3.00	259.20	4.79	4.79	0.018
s/Q=B+CQ, so in plot of s/Q v. Q, B is the intercept	2	5.00	432.00	3.30	8.09	0.019
& C is the slope	3	7.00	604.80	3.40	11.49	0.019
B = 0.018106 intercept	4	10.00	864.00	5.20	16.69	0.019
C = 1.41E-06 slope	5	0.00	0.00	0.00	0.00	0.000

predicted drawdown using B & C @ Q=11 L/s, = 18.5 m

actual drawdown from CRT @ t=240 mins & Q=11 L/s, = 18.7 m



Drawdown due to turbulent flow in aquifer and bore (Lt)
$Lt=(CQ^2/(BQ+CQ^2))100$

Lt =	2.0	% at Q =3 L/s
Lt =	3.3	% at Q = 5 L/s
Lt =	4.5	% at Q = 7 L/s
Lt =	6.3	% at Q = 10 L/s

216.1.1\Test Pumping\WSD16\step test - WSD16 Analysis.xls

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date May-16
Dwg No. 216.1.1/16/1-22

Bore WSD16P Step-rate Test Data Analysis

Rockwater Pty Ltd

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: May 2016
Drg. No.: 216-1-1/16/01-23

Bore WSD16P

Constant-Rate Test Data

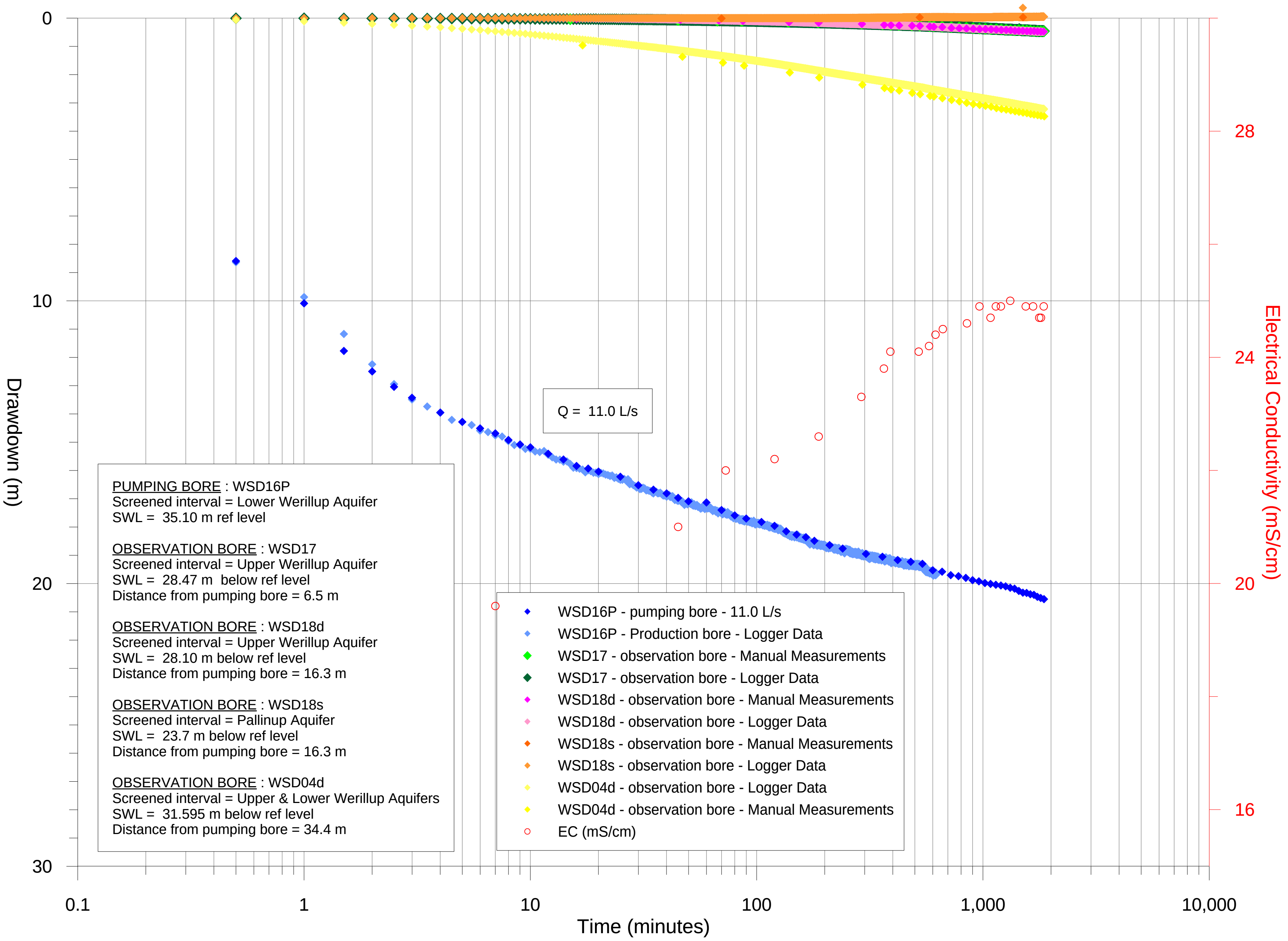
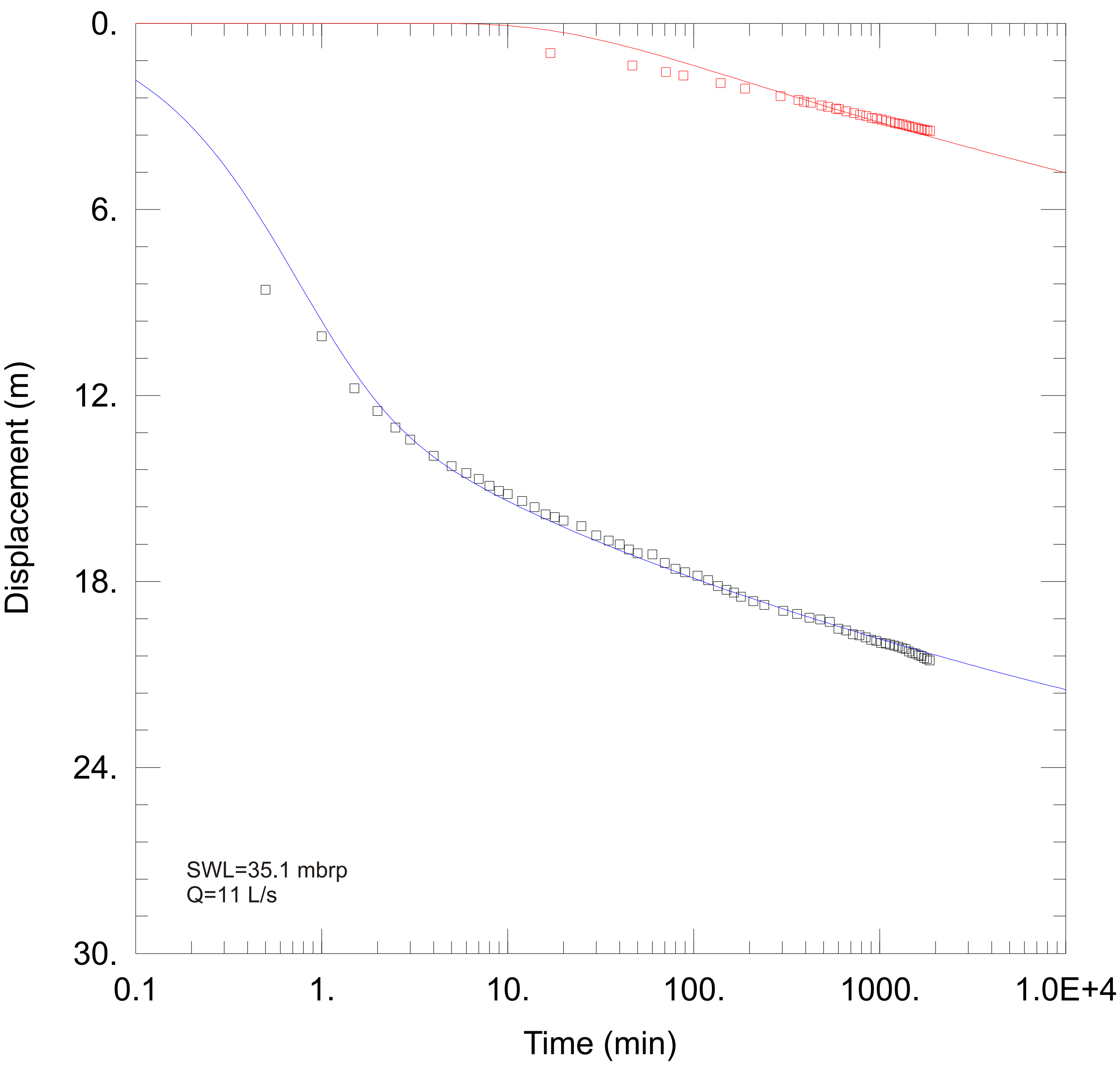


Figure 23

Figure 24



AQUIFER DATA

Saturated Thickness: 8. m

Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
WSD16	0	0

Observation Wells

Well Name	X (m)	Y (m)
WSD16	0	0
WSD04d	34.5	0

SOLUTION

Aquifer Model: Confined

Solution Method: Barker

K = 6.546 m/day
n = 2.153
Sw = 0.
r(c) = 0.1 m

Ss = 0.0002551
b = 8. m
r(w) = 0.17 m

Client:	Southdown Joint Venture
Project:	Water Supply Investigation
Date:	May 2016
Dwg No:	216.1.1/16/1-24

Bore WSD16P, Constant-Rate Test
Data Analysis

Rockwater Pty Ltd

Client: Southdown Joint Venture

Project: Water Supply Investigation

Date: May 2016

Drg. No.: 216-1-1/16/01-25

Upper Werillup Aquifer

Slug Test Data

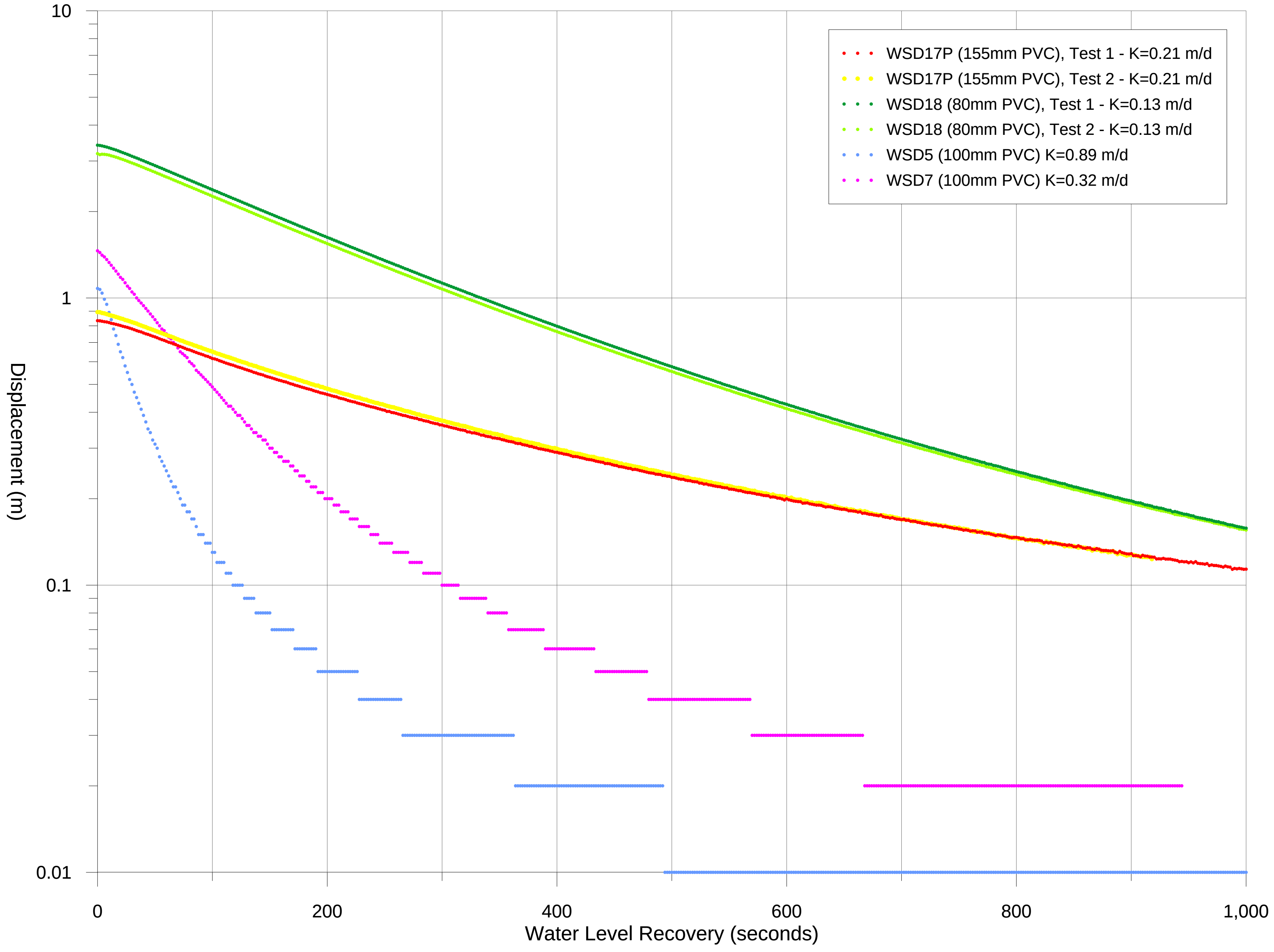


Figure 25

APPENDIX I

BORE COMPLETION DATA

TEST-BORE COMPLETION DATA

Project:	Southdown Water Supply
Bore No:	**WSD12**
Location:	Wellstead, WA
GDA Coordinates:	645 540 mE; 6 170 594 mN (at air-core exp. hole SDAC0322)
Ground Level:	115 m AHD approx.
Status:	Monitoring Bore (Pallinup, U & L Werillup)
Date Commenced:	1 December 2015
Date Completed:	2 December 2015
Drilling Contractor:	Harrington Drilling
Drilling Rig:	Versa-Drill V2095-EXP
Depth Drilled:	120 m
Drilling Details:	0 – 3 m bgl, 254 mm regular-blade air-rotary 0 – 3 m bgl, 311 mm regular-blade air-rotary (ream) 3 – 120 m bgl, 165 mm tricone mud-rotary
Casing Details:	Surface Casing +0.5 – 2.5 m bgl, 209 mm ID, 219 mm OD, steel casing (Gypset annulus) Upper & Lower Werillup Aquifers (80 mm NB PVC) +0.5 – 71.5 m bgl, 79 mm ID, 89 mm OD, Class 12, blank, uPVC casing 71.5 – 77.5 m bgl, 79 mm ID, 89 mm OD Class 12, machine slotted uPVC casing (0.5 mm aperture) 77.5 – 101.5 m bgl, 79 mm ID, 89 mm OD, Class 12, blank, uPVC casing 101.5 – 113.5 m bgl, 79 mm ID, 89 mm OD Class 12, machine slotted uPVC casing (0.5 mm aperture) 113.5 – 119.5 m bgl, 79 mm ID, 89 mm OD, Class 12, blank, uPVC casing with end cap Pallinup Aquifer (25 mm NB PVC) +0.5 – 23.5 m bgl, 30 mm ID, 34 mm OD, Class 12, blank, uPVC casing 23.5 – 35.5 m bgl, 30 mm ID, 34 mm OD, Class 12, hand slotted , uPVC casing with end cap

TEST-BORE COMPLETION DATA
(WSD12, Continued)

Centralisers: co-polymer centralisers at 6 m interval

Annular Fill: 0 – 50 m bgl, 0.8 to 1.6 mm gravel pack
50 – 55 m bgl, ¼" bentonite pellets
55 - 120 m bgl, 0.8 to 1.6 mm gravel pack

Reference Point Description: Top of uPVC casing

Height of Ref. Point.: +0.5 m agl

Final Airlift Yield: 3.5 L/s – 80 mm PVC (U & L Werillup)

Static Water Level: 25.38 m btc (9/03/16) – 80 mm PVC (U & L Werillup)
21.13 m btc (9/03/16) – 25 mm PVC (Pallinup)

Final Water Salinity: 6.9 mS/cm – 80 mm PVC (U & L Werillup)

Lithology:

Depth (m)	Lithology	Description
0 – 3	Clayey Sand	Red, slightly clayey very fine sand; locally Fe cemented & gravelly
3 – 6	Muddy Sand	Red/brown, muddy very fine sand
6 – 36	Slightly Muddy Sand	Light grey, slightly muddy very fine sand; locally hard/silicified
36 – 44	Clay	Medium to dark grey, clay
44 – 64	Carb. Clay	Black, carbonaceous clay
64 – 72	Slightly Clayey Sand	Green, slightly clayey fine to medium sand; moderately hard; pellets of glauconite
72 – 78	Sand	Green, fine to medium sand
78 – 84	Silt	Dark grey, silt; cemented/hard
84 – 102	Carb. Clay	Black, carbonaceous clay
102 – 104	Sand	Dark grey, fine to medium sand
104 – 108	Sand	Dark grey, medium to coarse sand
108 – 110	Sand	Dark grey, coarse sand
110 – 114	Sand	Dark grey, very coarse sand
114 – 120	Bedrock	Light grey, strongly weathered, granitic gneiss
120	EOH	Blade refusal (top fresh bedrock)

TEST-BORE COMPLETION DATA

Project: Southdown Water Supply

Bore No: **WSD13P**

Location: Wellstead, WA

GDA Coordinates: 645 521 mE; 6 170 591 mN (at air-core exp. hole SDAC0322)

Ground Level: 115 m AHD approx.

Status: Production Bore (U & L Werillup)

Date Commenced: 3 December 2015

Date Completed: 6 December 2015

Drilling Contractor: Harrington Drilling

Drilling Rig: Versa-Drill V2095-EXP

Depth Drilled: 120.6 m

Drilling Details:
0 - 3 m bgl, 311 mm regular-blade mud-rotary
3 - 120 m bgl, 203 mm pcd mud-rotary (pilot hole)
3 – 120.6 m bgl, 254 mm tricone mud-rotary (ream)

Casing Details:

Surface Casing
+0.5 – 2.5 m bgl, 263 mm ID, 273 mm OD, steel casing (Gypset annulus)

Upper & Lower Werillup Aquifers (155 mm NB PVC)
+0.5 – 73.85 m bgl, 150 mm ID, 168 mm OD, Class 12, blank, uPVC casing
73.85 – 79.85 m bgl, 150 mm ID, 168 mm OD Class 12, machine slotted uPVC casing (0.5 mm aperture)
79.85 – 103.85 m bgl, 150 mm ID, 168 mm OD, Class 12, blank, uPVC casing
103.85 – 109.85 m bgl, 150 mm ID, 168 mm OD Class 12, machine slotted uPVC casing (0.5 mm aperture)
109.85 – 110 m bgl, adaptor
110 – 116 m bgl, 153 mm ID, 166 mm OD, stainless-steel screens, 316-grade, 0.5 mm slot width, 120 m depth setting
116 – 116.15 m bgl, adaptor
116.15 – 118.15 m bgl, 150 mm ID, 168 mm OD, Class 12, blank, uPVC casing (sump) with external end cap

TEST-BORE COMPLETION DATA
(WSD13P, Continued)

Centralisers: co-polymer centralisers at 12 m interval

Annular Fill: 0 - 36 m bgl, cement grout S.G 1.5
36 – 100 m bgl, 0.8 to 1.6 mm gravel pack
100 - 120 m bgl, 1.6 to 3.2 mm gravel pack

Reference Point Description: Top of uPVC casing

Height of Ref. Point.: +0.5 m agl

Final Airlift Yield: 5.5 L/s (minimum); strong Fe staining

Static Water Level: 25.56 m btc (9/03/16)

Final Water Salinity: 6.9 mS/cm

Lithology:

Depth (m)	Lithology	Description
0 - 6	Muddy Sand	Red, muddy very fine sand; strongly Fe cemented & gravelly at 0 – 1 m.
6 – 34	Slightly Muddy Sand	Light grey, slightly muddy very fine sand; occasional sponge spicules; locally silicified/hard
34 –44	Clay	Medium to dark grey, clay
44 – 64	Carb. Clay	Black, carbonaceous clay
64 – 72	Clayey Sand	Green, clayey fine to medium sand
72 – 78	Sand	Green, fine to medium sand; glauconite
78 – 80	Clayey Silt	Darg green/grey, clayey silt; cemented
80 –103.5	Carb. Clay	Black, carbonaceous clay
103.5 –104	Sand	Dark grey, very coarse sand
104 – 106	Sand	Dark grey, medium sand
106 – 108	Sand	Dark grey, coarse sand
108 – 114	Sand	Dark grey, very coarse sand
114 – 116	Gravel	Grey, very coarse sand to granule gravel, very angular
116 – 120	Bedrock	Light grey, strongly weathered, granitic gneiss
120	EOH	Blade refusal (top fresh bedrock)

TEST-BORE COMPLETION DATA

Project:	Southdown Water Supply
Bore No:	**WSD14**
Location:	Wellstead, WA
GDA Coordinates:	633 175 mE; 6 182 258 mN (at air-core exp. hole SDAC0313)
Ground Level:	141.5 m AHD approx.
Status:	Monitoring Bore (Pallinup, L Werillup)
Date Commenced:	6 December 2015
Date Completed:	8 December 2015
Drilling Contractor:	Harrington Drilling
Drilling Rig:	Versa-Drill V2095-EXP
Depth Drilled:	121 m
Drilling Details:	0 – 3 m bgl, 254 mm regular-blade air-rotary 3 – 121 m bgl, 165 mm tricone mud-rotary
Casing Details:	Surface Casing +0.5 – 2.5 m bgl, 209 mm ID, 219 mm OD, steel casing (Gypset annulus) Lower Werillup Aquifer (80 mm NB PVC) +0.5 – 95.5 m bgl, 79 mm ID, 89 mm OD, Class 12, blank, uPVC casing 95.5 – 119.5 m bgl, 79 mm ID, 89 mm OD Class 12, machine slotted uPVC casing (0.5 mm aperture) with end cap Pallinup Aquifer (25 mm NB PVC) +0.5 – 23.5 m bgl, 30 mm ID, 34 mm OD, Class 12, blank, uPVC casing 23.5 – 41.5 m bgl, 30 mm ID, 34 mm OD, Class 12, hand slotted, uPVC casing with end cap
Centralisers:	co-polymer centralisers at 12 m interval

TEST-BORE COMPLETION DATA
(WSD14, Continued)

Annular Fill: 0 – 60 m bgl, 0.8 to 1.6 mm gravel pack
60 – 65 m bgl, ¼” bentonite pellets
65 – 121 m bgl, 0.8 to 1.6 mm gravel pack

Reference Point Description: Top of uPVC casing

Height of Ref. Point.: +0.5 m agl

Final Airlift Yield: 5.9 L/s – 80 mm PVC (Werillup)

Static Water Level: 29.52 m btc (16/03/16) – 80 mm PVC (Lower Werillup)
18.27 m btc (16/03/16) – 25 mm PVC (Pallinup)

Final Water Salinity: 58.4 mS/cm – 80 mm PVC (Lower Werillup)

Lithology:

Depth (m)	Lithology	Description
0 – 3	Sandy Clay	Brown, sandy clay
3 – 27	Slightly Clayey Sand	Light grey/brown, slightly clayey fine sand; common sponge spicules
27 – 48	Muddy Sand	Light brown to dark grey, muddy very fine sand
48 – 90	Carb. Clay	Dark grey to black, carbonaceous clay
90 – 98	Sand	Dark grey, medium sand
98 – 104	Sand	Dark grey, coarse sand
104 – 120	Sand	Dark grey, very coarse sand; minor gravel beds
120 – 121	Bedrock	Light grey, strongly weathered, mafic gneiss
121	EOH	Not blade refusal

TEST-BORE COMPLETION DATA

Project:	Southdown Water Supply
Bore No:	**WSD15P**
Location:	Wellstead, WA
GDA Coordinates:	633 190 mE; 6 182 236 mN (at air-core exp. hole SDAC0313)
Ground Level:	142 m AHD approx.
Status:	Production Bore (Lower Werillup)
Date Commenced:	8 December 2015
Date Completed:	11 December 2015
Drilling Contractor:	Harrington Drilling
Drilling Rig:	Versa-Drill V2095-EXP
Depth Drilled:	122 m
Drilling Details:	0 – 3 m bgl, 311 mm regular-blade air-rotary 0 – 3 m bgl, 444 mm regular-blade air-rotary (ream) 3 – 122 m bgl, 203 mm pcd mud-rotary (pilot hole) 3 – 122 m bgl, 343 mm tricone mud-rotary (ream)
Casing Details:	<u>Surface Casing</u> +0.5 – 2.5 m bgl, 394 mm ID, 406 mm OD, steel casing (Gypset annulus) <u>Lower Werillup Aquifer (200 mm NB PVC)</u> +0.5 – 89.5 m bgl, 203 mm ID, 225 mm OD, Class 12, blank, uPVC casing 89.5 – 107.5 m bgl, 203 mm ID, 225 mm OD Class 12, machine slotted uPVC casing (0.5 mm aperture) 107.5 – 107.7 m bgl, adaptor 107.7 – 119.7 m bgl, 202 mm ID, 216 mm OD, stainless-steel screens, 316-grade, 0.5 mm slot width, 120 m depth setting, with base plate
Centralisers:	co-polymer centralisers at 12 m interval; 6 m over screens
Annular Fill:	0 – 80 m bgl, cement grout S.G 1.5 80 – 121 m bgl, 1.6 to 3.2 mm gravel pack

TEST-BORE COMPLETION DATA
(WSD15P, Continued)

Reference Point Description: Top of uPVC casing

Height of Ref. Point.: +0.5 m agl

Final Airlift Yield: 22 L/s (minimum); Fe staining

Static Water Level: 29.97 m btc (16/03/16)

Final Water Salinity: 60 mS/cm

Lithology:

Depth (m)	Lithology	Description
0 – 2	Fe Gravel	Red, ferruginous gravel
2 – 14	Slightly Clayey Sand	Light green, slightly clayey very fine sand; locally cemented/hard
14 – 46	Muddy Sand	Light brown to grey, muddy very fine sand
46 – 90	Carb. Clay	Dark grey to black, carbonaceous clay
90 – 98	Sand	Dark grey, medium sand
98 – 108	Sand	Dark grey, coarse sand
108 – 120	Sand	Dark grey, very coarse sand; thin layer granule gravel at base
120 – 122.6	Bedrock	Light grey, strongly weathered, mafic gneiss
122.6	EOH	Not blade refusal

TEST-BORE COMPLETION DATA

Project:	Southdown Water Supply
Bore No:	**WSD16P**
Location:	Wellstead, WA
GDA Coordinates:	649 613 mE; 6 183 598 mN (near WSD4)
Ground Level:	118 m AHD approx.
Status:	Production Bore (Lower Werillup)
Date Commenced:	12 December 2015
Date Completed:	14 December 2015
Drilling Contractor:	Harrington Drilling
Drilling Rig:	Versa-Drill V2095-EXP
Depth Drilled:	116 m
Drilling Details:	0 – 3 m bgl, 311 mm regular-blade mud-rotary 0 – 3 m bgl, 444 mm regular-blade mud-rotary (ream) 3 – 116 m bgl, 203 mm pcd mud-rotary (pilot hole) 3 – 114 m bgl, 343 mm tricone mud-rotary (ream)
Casing Details:	Surface Casing +0.4 – 2.6 m bgl, 394 mm ID, 406 mm OD, steel casing (Gypset annulus) Lower Werillup Aquifer (200 mm NB PVC) +0.4 – 95.5 m bgl, 203 mm ID, 225 mm OD, Class 12, blank, uPVC casing 95.5 – 100 m bgl, 203 mm ID, 225 mm OD Class 12, machine slotted uPVC casing (0.5 mm aperture) 100 – 100.2 m bgl, adaptor 100.2 – 112.2 m bgl, 202 mm ID, 216 mm OD, stainless-steel screens, 316-grade, 0.5 mm slot width, 120 m depth setting, with base plate
Centralisers:	co-polymer centralisers at 12 m interval; 6 m over screens
Annular Fill:	0 – 92 m bgl, cement grout S.G 1.5 92 – 114 m bgl, 1.6 to 3.2 mm gravel pack

TEST-BORE COMPLETION DATA
(WSD16P, Continued)

Reference Point Description: Top of uPVC casing

Height of Ref. Point.: +0.4 m agl

Final Airlift Yield: 12 L/s (minimum)

Static Water Level: 31.43 m btc (16/03/16)

Final Water Salinity: 29 mS/cm

Lithology:

Depth (m)	Lithology	Description
0 – 10	Slightly Clayey Sand	Light yellow, slightly clayey fine sand; common sponge spicules; locally hard/silicified
10 – 44	Muddy Sand	Light grey, muddy very fine sand; locally silicified (especially at 18 m, losing mud)
44 – 54	Sandy Mud	Dark grey, very fine sandy mud
54 – 72	Carb. Clay	Dark grey to black, carbonaceous clay; silty at top
72 – 76	Clay/Sand	Dark grey clay; beds of fine to very fine sand
76 – 78	Sand/Clay	Dark grey fine sand; beds of carbonaceous clay
78 – 86	Sand	Dark grey/green, fine sand
86 – 94	Carb. Clay	Black, carbonaceous clay
94 – 102	Lignite	Black to dark brown, highly carbonaceous clay; moderately hard; common fragments lignite; thin beds fine sand at base
102 – 106	Sand	Dark grey, fine sand
106 – 110	Sand	Dark grey, coarse sand
110 – 116	Bedrock	Light grey, strongly weathered, mafic gneiss
116	EOH	Not blade refusal

TEST-BORE COMPLETION DATA

Project:	Southdown Water Supply
Bore No:	**WSD17P**
Location:	Wellstead, WA
GDA Coordinates:	649 608 mE; 6 183 595 mN (near WSD4)
Ground Level:	118 m AHD approx.
Status:	Production Bore (Upper Werillup)
Date Commenced:	15 December 2015
Date Completed:	16 December 2015
Drilling Contractor:	Harrington Drilling
Drilling Rig:	Versa-Drill V2095-EXP
Depth Drilled:	87 m
Drilling Details:	0 – 3 m bgl, 311 mm regular-blade air-rotary 3 – 87 m bgl, 203 mm pcd mud-rotary 3 – 87 m bgl, 254 mm blade mud-rotary (ream)
Casing Details:	Surface Casing +0.4 – 2.6 m bgl, 263 mm ID, 273 mm OD, steel casing (Gypset annulus) Upper Werillup Aquifer (155 mm NB PVC) +0.4 – 72.78 m bgl, 150 mm ID, 168 mm OD, Class 12, blank, uPVC casing 72.78 – 78.78 m bgl, 150 mm ID, 168 mm OD, Class 12, machine slotted, uPVC casing (0.5 mm aperture) 78.78 – 78.93 m bgl, adaptor 78.93 – 84.93 m bgl, 153 mm ID, 166 mm OD, stainless-steel screens, 316-grade, 0.5 mm slot width, 120 m depth setting, with base plate
Centralisers:	co-polymer centralisers at 12 m interval,
Annular Fill:	0 – 64 m bgl, cement grout, SG 1.5 (loss of grout into Pallinup Fm) 64 – 87 m bgl, 1.6 to 3.2 mm gravel pack

TEST-BORE COMPLETION DATA
(WSD17P, Continued)

Reference Point Description: Top of uPVC casing

Height of Ref. Point.: +0.4 m agl

Final Airlift Yield: 2 L/s

Static Water Level: 28.42 m btc (12/03/16)

Final Water Salinity: 9.2 mS/cm

Lithology:

Depth (m)	Lithology	Description
0 – 1	Fe Gravel	Red, ferruginous gravel
1 – 10	Slightly Clayey Sand	Light yellow to light grey, slightly clayey very fine sand; locally hard/silicified; common sponge spicules
10 – 44	Muddy Sand	Light grey, muddy very fine sand; locally silicified
44 – 54	Sandy Mud	Dark grey, very fine sandy mud
54 – 75	Carb. Clay	Dark grey to black, carbonaceous clay; silty at top
75 – 85	Sand	Dark grey, fine sand
85 – 87	Carb. Clay	Dark grey, carbonaceous clay
87	EOH	

TEST-BORE COMPLETION DATA

Project:	Southdown Water Supply
Bore No:	**WSD18**
Location:	Wellstead, WA
GDA Coordinates:	649 601 mE; 6 183 590 mN (near WSD4)
Ground Level:	118 m AHD approx.
Status:	Monitoring Bore (Pallinup, Upper Werillup)
Date Commenced:	16 December 2015
Date Completed:	18 December 2015
Drilling Contractor:	Harrington Drilling
Drilling Rig:	Versa-Drill V2095-EXP
Depth Drilled:	86 m
Drilling Details:	0 – 3 m bgl, 254 mm regular-blade air-rotary 3 – 86 m bgl, 165 mm pcd mud-rotary
Casing Details:	Surface Casing +0.4 – 2.6 m bgl, 209 mm ID, 219 mm OD, steel casing (Gypset annulus) Upper Werillup Aquifer (80 mm NB PVC) +0.4 – 65.5 m bgl, 79 mm ID, 89 mm OD, Class 12, blank, uPVC casing 65.5 – 83.5 m bgl, 79 mm ID, 89 mm OD Class 12, machine slotted uPVC casing (0.5 mm aperture) with end cap Pallinup Aquifer (25 mm NB PVC) +0.4 – 22.5 m bgl, 30 mm ID, 34 mm OD, Class 12, blank, uPVC casing 22.5 – 40.5 m bgl, 30 mm ID, 34 mm OD, Class 12, hand slotted, uPVC casing with end cap
Centralisers:	co-polymer centralisers at 12 m interval

TEST-BORE COMPLETION DATA
(WSD18, Continued)

Annular Fill: 0 – 58 m bgl, 1.6 to 3.2 mm gravel pack
58 – 62 m bgl, ¼" bentonite pellets
62 – 86 m bgl, 1.6 to 3.2 mm gravel pack

Reference Point Description: Top of uPVC casing

Height of Ref. Point.: +0.4 m agl

Final Airlift Yield: 1.2 L/s – 80 mm PVC (Upper Werillup)

Static Water Level: 28.02 m btc (12/03/16) – 80 mm PVC (Upper Werillup)
23.68 m btc (12/03/16) – 25 mm PVC (Pallinup)

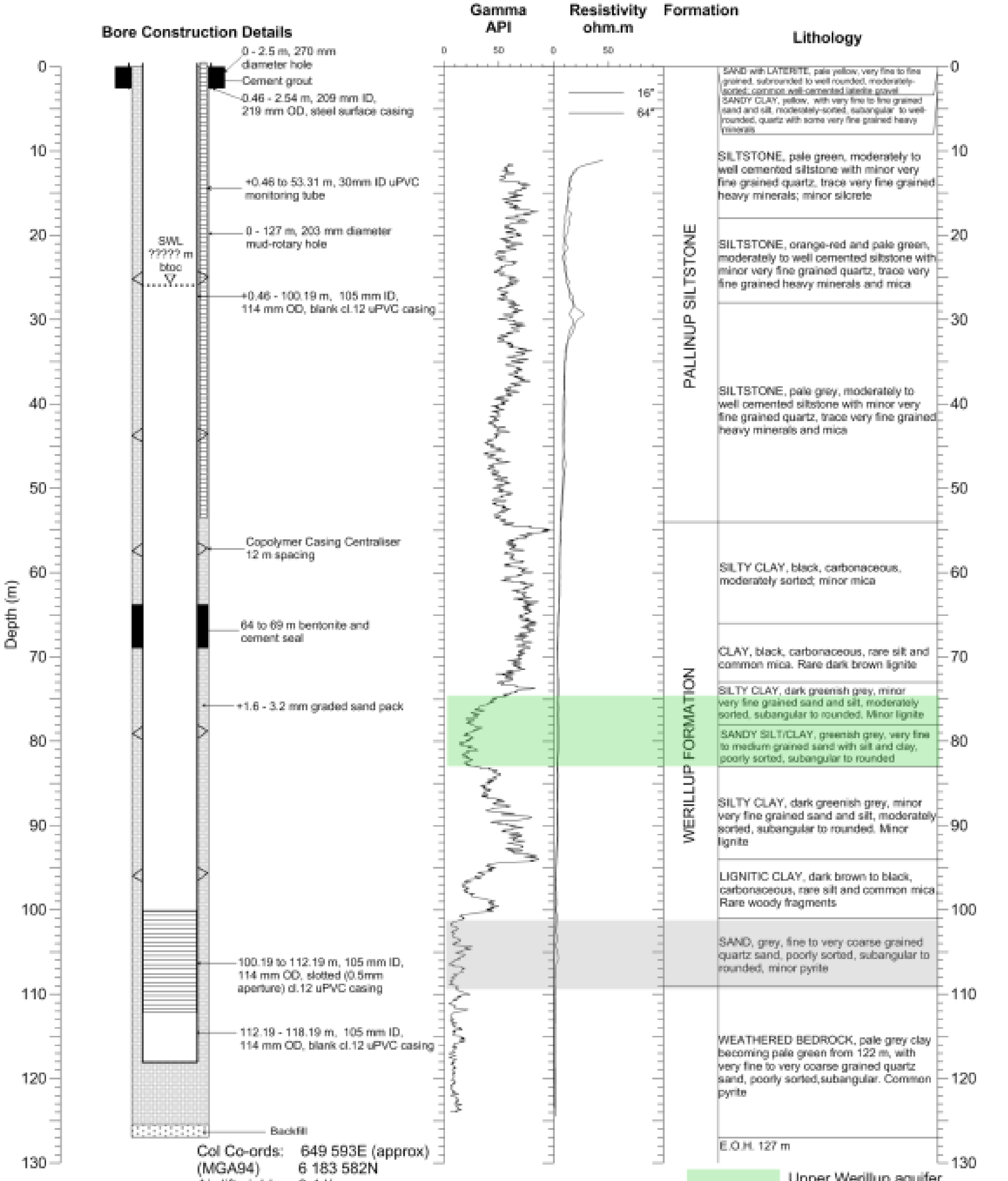
Final Water Salinity: 9 mS/cm – 80 mm PVC (Werillup)

Lithology:

Depth (m)	Lithology	Description
0 – 1	Fe Gravel	Red, ferruginous gravel
1 – 10	Slightly Clayey Sand	Light yellow to light grey, slightly clayey very fine sand; locally hard/silicified; common sponge spicules
10 – 44	Muddy Sand	Light grey, muddy very fine sand; locally silicified
44 – 54	Sandy Mud	Dark grey, very fine sandy mud
54 – 78	Carb. Clay	Dark grey to black, carbonaceous clay; silty at top
78 – 84	Sand	Dark grey/green, fine sand; well sorted
84 – 86	Carb. Clay	Dark grey, carbonaceous clay
87	EOH	

APPENDIX II

COMPOSITE LOGS
BORES WSD4, WSD5, WSD7



Col Co-ords: 649 593E (approx)
(MGA94) 6 183 582N
Air-lift yield: 9.4 l/sec
Salinity: 28,500 mg/L TDS

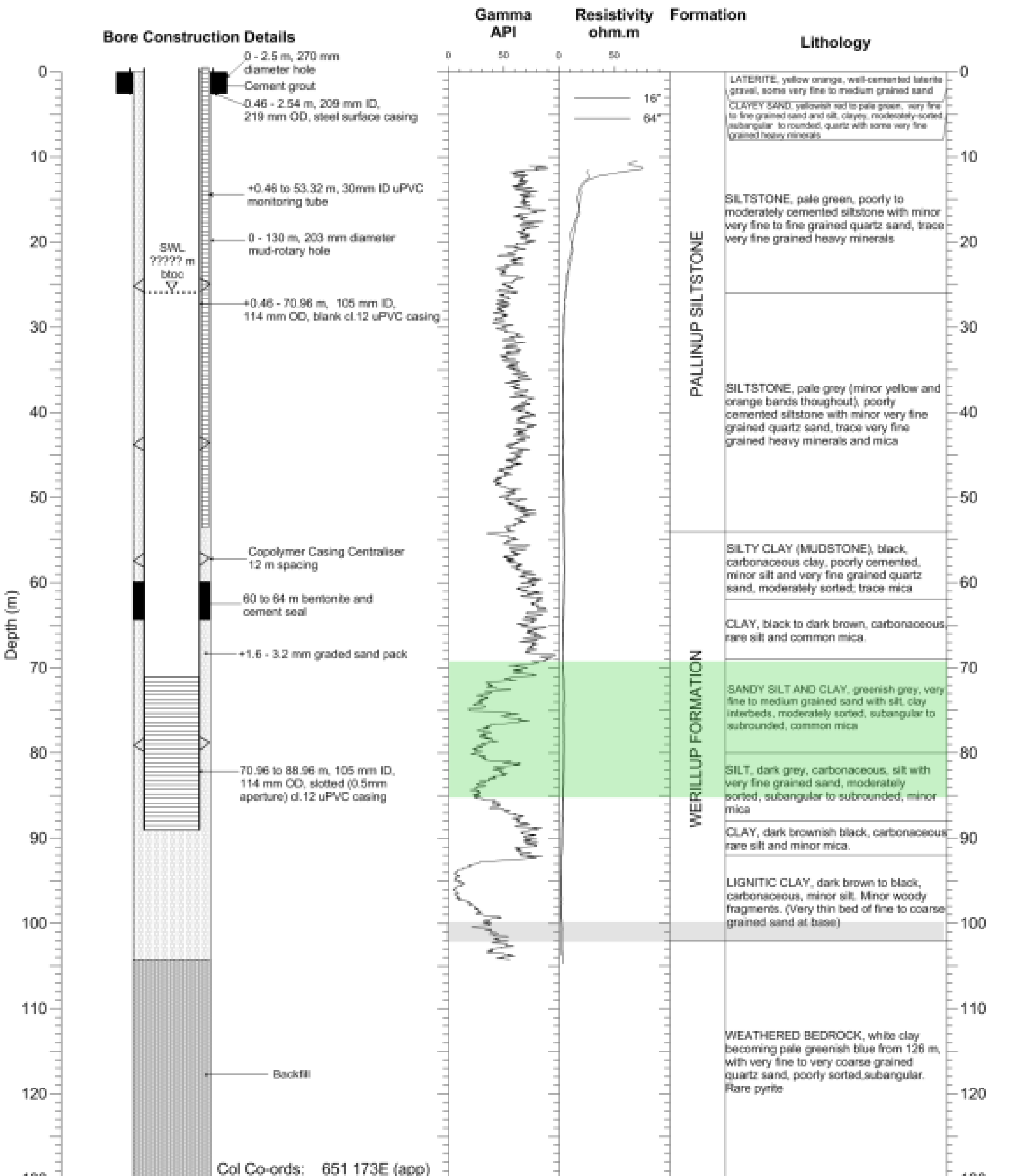
I:\216.1\Project Files\Drilling Results\WSD4 Composite Log.grf

Client:	SDJV
Project:	Southdown Water Supply
Date:	May 2016
Drg. No.:	216.1.1/16/

Monitoring Bore WSD4 Composite Log

R Rockwater Pty Ltd

Figure X

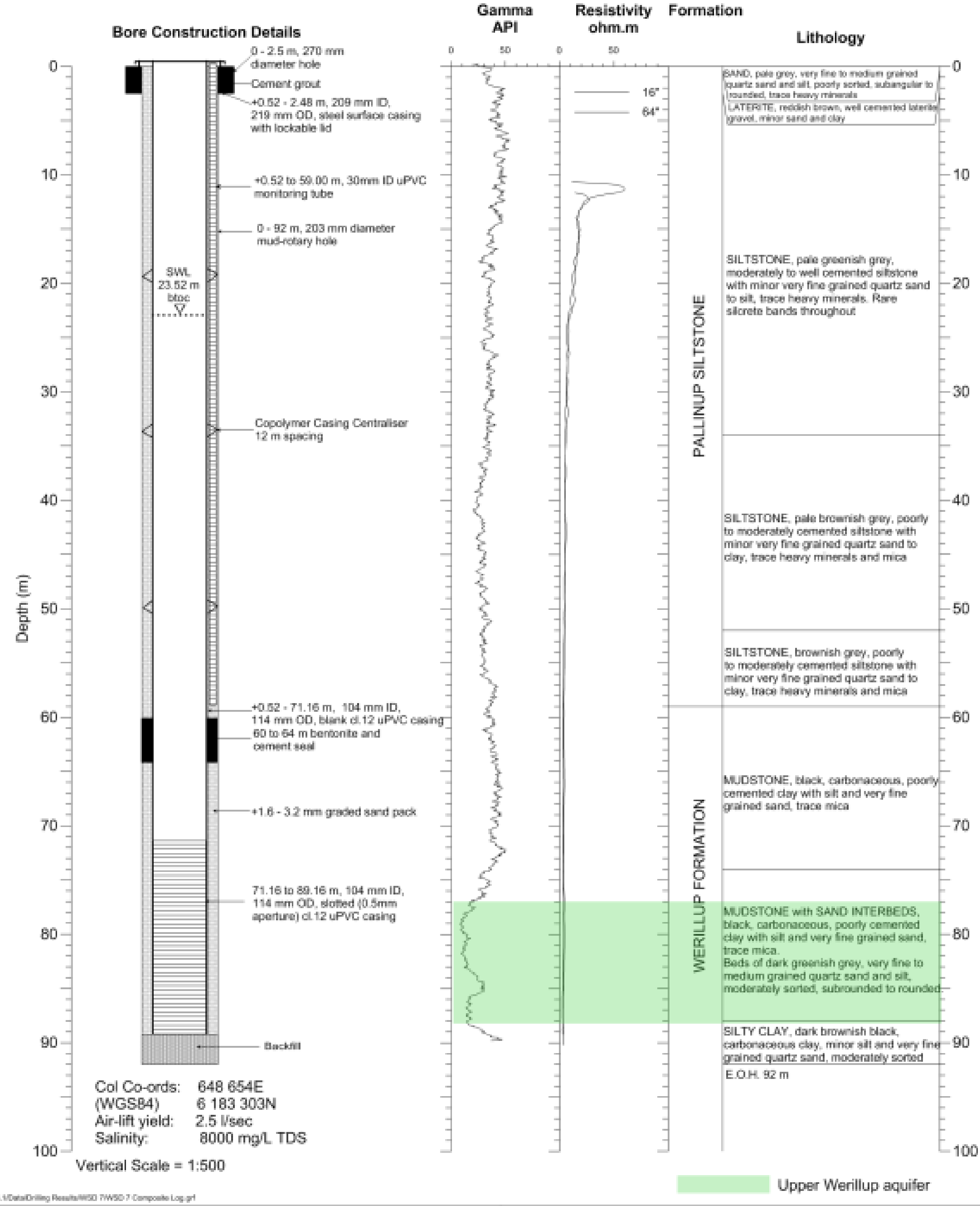


Col Co-ords: 651 173E (app)
(MGA94) 6 185 141N
Air-lift yield: 3.4 l/sec
Salinity: 7500 mg/L TDS

Client:	SDJV
Project:	Southdown Water Supply
Date:	May 2016
Drg. No.:	216.1.1/16/

Monitoring Bore WSD5
Composite Log

R Rockwater Pty Ltd



I:\216.1\Data\Drilling Results\WSD 7\WSD 7 Composite Log.grf

Client:	SDJV
Project:	Southdown Water Supply
Date:	May 2016
Drg. No.:	216.1.1/16/

Monitoring Bore WSD7 Composite Log

Rockwater Pty Ltd

APPENDIX III

WATER QUALITY LABORATORY CERTIFICATES

CERTIFICATE OF ANALYSIS

Work Order	: **EP1602437**	Page	: 1 of 4
Client	: **ROCKWATER PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: PETER DEBROEKERT	Contact	: Customer Services EP
Address	: 1ST FLOOR, 76 JERSEY ST WEMBLEY WA, AUSTRALIA 6014	Address	: 10 Hod Way Malaga WA Australia 6090
Telephone	: +61 08 9284 0222	Telephone	: +61-8-9209 7655
Project	: WELLSTEAD TEST PUMPING	Date Samples Received	: 21-Mar-2016 16:47
Order number	: ----	Date Analysis Commenced	: 21-Mar-2016
C-O-C number	: ----	Issue Date	: 30-Mar-2016 20:49
Sampler	: DAISY SCOTT		
Site	: ----		
Quote number	: ----		
No. of samples received	: 4		
No. of samples analysed	: 4		

NATA Accredited Laboratory 825
Accredited for compliance with
ISO/IEC 17025.

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Metals Instrument Chemist	Perth Inorganics, Malaga, WA
Efua Wilson	Metals Chemist	Perth Inorganics, Malaga, WA
Jeremy Truong	Laboratory Supervisor	Perth Inorganics, Malaga, WA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.

- EG020: Metals LOR raised due to high TDS content.
- EG020: It is recognised that total concentration is less than dissolved for some metal analytes. However, the difference is within experimental variation of the methods
- It is recognised that Total Kjeldahl Nitrogen (EK061G) is less than Ammonia (EK055G) for various samples. However, the difference is within experimental variation of the methods.
- TDS by method EA-015 may bias high due to the presence of fine particulate matter, which may pass through the prescribed GF/C paper.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	WSD13	WSD15	WSD16	WSD17	----
			Client sampling date / time	12-Mar-2016 06:30	18-Mar-2016 18:00	15-Mar-2016 15:00	19-Mar-2016 14:20	----
Compound	CAS Number	LOR	Unit	EP1602437-001	EP1602437-002	EP1602437-003	EP1602437-004	--------
				Result	Result	Result	Result	Result
EA005P: pH by PC Titrator								
pH Value	----	0.01	pH Unit	6.60	6.77	6.75	6.57	----
EA010P: Conductivity by PC Titrator								
Electrical Conductivity @ 25°C	----	1	µS/cm	7290	71800	26700	10900	----
EA015: Total Dissolved Solids dried at 180 ± 5 °C								
Total Dissolved Solids @180°C	----	10	mg/L	4520	59500	21000	6570	----
EA065: Total Hardness as CaCO3								
Total Hardness as CaCO3	----	1	mg/L	834	8460	3400	799	----
ED037P: Alkalinity by PC Titrator								
Hydroxide Alkalinity as CaCO3	DMO-210-001	1	mg/L	<1	<1	<1	<1	----
Carbonate Alkalinity as CaCO3	3812-32-6	1	mg/L	<1	<1	<1	<1	----
Bicarbonate Alkalinity as CaCO3	71-52-3	1	mg/L	92	199	115	38	----
Total Alkalinity as CaCO3	----	1	mg/L	92	199	115	38	----
ED041G: Sulfate (Turbidimetric) as SO4 2- by DA								
Sulfate as SO4 - Turbidimetric	14808-79-8	1	mg/L	405	4190	1590	476	----
ED045G: Chloride by Discrete Analyser								
Chloride	16887-00-6	1	mg/L	2230	26700	10200	3690	----
ED093F: Dissolved Major Cations								
Calcium	7440-70-2	1	mg/L	80	336	160	43	----
Magnesium	7439-95-4	1	mg/L	154	1850	729	168	----
Sodium	7440-23-5	1	mg/L	1360	16300	5730	2140	----
Potassium	7440-09-7	1	mg/L	59	670	226	131	----
EG020F: Dissolved Metals by ICP-MS								
Aluminium	7429-90-5	0.01	mg/L	<0.01	<0.10	0.02	<0.01	----
Arsenic	7440-38-2	0.001	mg/L	0.010	<0.010	0.016	0.046	----
Cadmium	7440-43-9	0.0001	mg/L	<0.0001	<0.0010	<0.0001	<0.0001	----
Chromium	7440-47-3	0.001	mg/L	<0.001	<0.010	<0.001	<0.001	----
Lead	7439-92-1	0.001	mg/L	<0.001	<0.010	<0.001	<0.001	----
Manganese	7439-96-5	0.001	mg/L	0.195	0.515	0.252	0.115	----
Selenium	7782-49-2	0.01	mg/L	<0.01	<0.10	<0.01	<0.01	----
Zinc	7440-66-6	0.005	mg/L	0.011	<0.050	0.007	0.005	----
Iron	7439-89-6	0.05	mg/L	18.2	38.2	40.1	36.1	----
EG020T: Total Metals by ICP-MS								
Iron	7439-89-6	0.05	mg/L	16.9	39.8	38.2	40.2	----

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	WSD13	WSD15	WSD16	WSD17	----
			Client sampling date / time	12-Mar-2016 06:30	18-Mar-2016 18:00	15-Mar-2016 15:00	19-Mar-2016 14:20	----
Compound	CAS Number	LOR	Unit	EP1602437-001	EP1602437-002	EP1602437-003	EP1602437-004	--------
				Result	Result	Result	Result	Result
EG035F: Dissolved Mercury by FIMS								
Mercury	7439-97-6	0.0001	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	----
EG052G: Silica by Discrete Analyser								
Reactive Silica	----	0.05	mg/L	**37.4**	**9.38**	**34.4**	**46.0**	----
EK055G: Ammonia as N by Discrete Analyser								
Ammonia as N	7664-41-7	0.01	mg/L	**0.61**	**1.60**	**1.28**	**1.14**	----
EK057G: Nitrite as N by Discrete Analyser								
Nitrite as N	14797-65-0	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
EK058G: Nitrate as N by Discrete Analyser								
Nitrate as N	14797-55-8	0.01	mg/L	**0.02**	<0.01	<0.01	**0.01**	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.02**	<0.01	<0.01	**0.01**	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	**0.6**	**2.4**	**1.7**	**1.1**	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ Total Nitrogen as N	----	0.1	mg/L	**0.6**	**2.4**	**1.7**	**1.1**	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	**0.32**	**0.44**	**0.56**	**0.30**	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	<0.01	<0.01	<0.01	<0.01	----
EN055: Ionic Balance								
Total Anions	----	0.01	meq/L	**73.2**	**844**	**323**	**115**	----
Total Cations	----	0.01	meq/L	**77.3**	**895**	**323**	**112**	----
Ionic Balance	----	0.01	%	**2.75**	**2.90**	**0.04**	**1.05**	----

APPENDIX B
Borefield Modelling Report
(Rockwater 2017)

SOUTHDOWN MAGNETITE PROJECT

NUMERICAL MODELLING OF GROUNDWATER SUPPLY FROM THE WELLSTEAD SUB-BASIN

REPORT FOR
SOUTHDOWN JOINT VENTURE

OCTOBER 2017

Report No. 216.1.1/17/02

Rockwater
HYDROGEOLOGICAL AND ENVIRONMENTAL CONSULTANTS

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(continued)

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REVISION	AUTHOR	REVIEW	AUTHORISED	ISSUED
0	PdeB	MJT	PdeB	30/10/17

1. INTRODUCTION

The Southdown Joint Venture (SDJV), a consortium between Grange Resources Ltd and SRT Australia Pty Ltd, is planning to mine the Southdown magnetite iron-ore deposit, located nearby to Wellstead, about 90 km north-east of Albany. The total mineral resource at Southdown is currently 1.25 Bt at 33.7% DTR (Davis Tube Recovery). At a concentrate production rate of 10 Mtpa, it is expected that the mine life will be 15 years. Possibilities exist for extending the mine life to 30 years by halving the processing rate or doubling the pit length (subject to additional approvals), or even up to 60 years by adopting both of these measures.

A water balance for the base-case, 10 Mtpa/15 year mining scenario, was developed by MAGJV (2012) as part of the Definitive Feasibility Study (DFS) for the Southdown magnetite project. The DFS indicates that up to 13,500 kL/d (156 L/s) of water will be required for the mine construction phase, which is expected to last 36 months. Thereafter, an even larger supply of about 28,600 kL/d (330 L/s) will be required for dust suppression, beneficiation of the ore and transport of the concentrate via a slurry pipeline to the port of Albany. Importantly, about 80% (266 L/s) of this needs to be fresh with a TDS (Total Dissolved Solids) content of <600 mg/L.

A reverse osmosis (RO) desalination plant will be constructed at Cape Riche to supply the bulk of the water for the operational phase, as the chance of obtaining such a large quantity of fresh (or saline) water from local aquifers is negligible. However, local groundwater sources could be used to support the construction phase (before the RO plant becomes operational), and then also be used to supply most, if not all, of the water needed for dust suppression during the operational phase, which does not need to have a low salinity.

Exploration drilling performed by Rockwater (2006, 2010, 2014), followed by the drilling and test-pumping of four production bores by Rockwater (2016), has revealed the presence of two sand aquifers within the Werillup Formation, of the Plantagenet Group in the Bremer Basin, that have the potential to supply at least some of the water required during construction and on-going operation of the mine.

Using data from the drilling and test-pumping programmes, a numerical groundwater model has been constructed to assess what the maximum capacities of the Werillup aquifers are likely to be over mine lives of 15 and 60 years. A report summarising the main results of the groundwater modelling has been prepared by Rockwater (2017). The purpose of this report is to provide additional details on the construction and calibration of the model, which will enable the model to be modified or formally reviewed at a later time.

2. LOCATION

The Southdown magnetite deposit is situated immediately north of the South Coast Highway, about 90 km north-east of Albany and 8 km south-west of Wellstead (Fig. 1). The deposit has a length of about 12 km and strikes in an east-west direction, straddling the intersection between the South Coast Hwy and Gnowellen Rd, although only that part of the orebody which lies within M70/1309, to the west of this intersection, is currently approved for mining.

Exploration lease E70/3073 and miscellaneous licences L70/185 and L70/186 (all held by SDJV) surround the Southdown magnetite deposit and occupy a large part of the area between Kojaneerup

Spring Rd in the west and the South Coast in the east (Fig. 1). The miscellaneous licences were primarily obtained for groundwater exploration.

3. WATER LICENCES

The SDJV mineral tenements do not lie within a Groundwater Area proclaimed under the *Rights in Water and Irrigation Act 1914*, and the aquifers being investigated are not artesian (free-flowing at the land-surface). Licensing of the drilling of water bores and the extraction of groundwater is therefore not required by the Department of Water and Environmental Regulation.

Under Ministerial Statement 816, issued by the Environmental Protection Authority (dated 25 November 2009), SDJV is required to ensure that groundwater extraction does not adversely affect native vegetation or other beneficial users outside the mine site. Water table drawdowns, as predicted by the groundwater model, are therefore relevant from a regulatory point of view.

4. CLIMATE

The climate at Southdown is mild Mediterranean, with monthly average maximum temperatures ranging from 16 to 25° C (Table 1). Average annual rainfall at Mettler (Fig. 1) is about 610 mm, 72 % of which falls between May and October. Potential evaporation, obtained from gridded (interpolated) data, is about 1,600 mm/yr and exceeds rainfall during every month except June and July.

Within the Southdown study area, it is likely that rainfall decreases significantly with increasing distance from the coast, reaching a minimum of about 470 mm at Kojaneerup, nearby to the foot of the Stirling Range (Fig. 1). To a lesser extent, rainfall probably also decreases in an easterly direction, as the annual rainfall at Manypeaks (located 49 km south-west of Southdown) is 727 mm, and the annual rainfall at Boxwood Hill (located 27 km north-east of Southdown) is 503 mm

Table 1: Long-Term Monthly Climate Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Rainfall (mm)^	28	25.9	40.7	50.5	65.2	67	71.3	66.6	60.2	54.9	43.9	31.6	604.9
Pot. Evaporation (mm)*	233.8	193.7	168.9	110.1	74.2	56.4	58.9	73.1	93.6	132.0	170.2	218.3	1,583.4
Max. Daily Temp. (°C)#	25.1	25.1	23.9	22	19.2	17	16.2	16.4	17.8	19.7	21.8	23.8	-

^ BOM data for Mettler [Stn 009754] (1966-2014)
* Data Drill Dataset, QLD Dept of Environment and Resource Management (1950-2014)
# BOM data for Mettler [Stn 009754] (1966-1997)

5. LANDFORMS AND DRAINAGE

The land-surface at Southdown largely comprises a fairly flat and featureless plain, underlain by marine sediments of the Pallinup Formation (to be discussed in Sect. 6). It slopes gently downwards in a south-easterly direction from about 200 mAHD at the foot of the Stirling Range, to about 100 mAHD approximately 5 km inland from the coast (Fig. 2). Seawards of the 100 mAHD topographic contour, the land-surface slopes more steeply downward at a gradient of about 1.6% to the coast.

Local highpoints, with an elevation of about 160 mAHD and a relief of 25–30 m above the plain occur at the Southdown magnetite deposit, Blackboy Hill, and an un-named hill located about 7 km north of the deposit (Figs 2, 3). These are underlain by shallow bedrock and therefore form palaeo-topographic highs within the basin that were not been completely buried by the sedimentary cover. Along the coast, many of these bedrock highs – generally of lower relief than at Southdown – have been exhumed by erosion to form rocky headlands (Fig. 2).

Drainage lines discharging to the sea are largely limited to the narrow, steeply-sloping coastal zone; although two drainages (Cordinup River and Willyun Creek) extend almost as far inland as the South Coast Hwy (Fig. 2). The north-eastern part of the area is bounded by the Pallinup River, which drains a large area north of the Stirling Range, and has been sufficiently active to erode through the sedimentary cover and expose the bedrock along most of its length.

It is likely that the more deeply incised drainages, such as Cordinup River, Willyun Creek and Pallinup River, are sustained by groundwater discharge from the sedimentary strata. In the case of the Cordinup River, this is clearly demonstrated by perennial flows in its headwater tributaries.

Numerous closed, semi-circular depressions, with a relief of up to about 15 m, lie scattered across the inland plain (Fig. 2). These form ephemeral wetlands (Yate swamps) that are filled to a shallow depth by surface water run-off and possibly also by the inflow of perched groundwater during particularly wet winters. The wetlands are situated above the water table, as demonstrated by drilling conducted at a wetland nearby to the proposed Southdown pit, where the base of the wetland lies at about 112 mAHD, whereas the water table lies at about 104 mAHD (GHD 2012).

Several large salt lakes, bordered by lunate dunes on their eastern side, occur along the foot of the Stirling Range (Fig 2). These receive large volumes of runoff from the range, which evaporate and becomes highly saline.

6. GEOLOGY AND HYDROGEOLOGY

6.1. WELLSTEAD SUB-BASIN

Bedrock in the region is composed of high-grade metamorphic rocks of the Proterozoic-age Albany-Fraser Orogen. Felsic gneiss is dominant in the Southdown study area, but to the north the bedrock comprises sandstone, quartzite and schist that crop out to form the Stirling Range (Fig. 3). The Proterozoic bedrock has been intensely deformed, resulting in the widespread development of faults and shears that typically trend in an easterly and north-westerly direction (Thom and Chin 1984, Muhling and Brakel 1985). Several of these intersect and displace the Southdown magnetite ore-body (GHD 2010).

Unconformably overlying the Proterozoic bedrock are Middle to Late Eocene-aged strata of the Plantagenet Group (Cockbain 1968). The sediments are widely distributed along the South Coast of Western Australia between Walpole and Esperance, where they occupy shallow basins developed within the Proterozoic basement. The basins are interconnected, and in combination with a much thicker accumulation of Tertiary sediments offshore, are termed the Bremer Basin.

At Southdown, the Eocene strata are bounded by outcrops of bedrock along the Green Range in the south, the Stirling Range in the north and the valley of the Pallinup River in the north-east (Fig. 3). In

view of their isolation from the remainder of the Bremer Basin, these sediments are referred to as the Wellstead sub-basin (Rockwater 2005).

The western margin of the Wellstead sub-basin is poorly defined, but drilling data suggest that it merges across a broad bedrock high with a smaller sub-basin containing sediments that reach their greatest thickness at Sunday Swamp, and is hence referred to as the Sunday Swamp sub-basin.

On its north-eastern side, the Wellstead sub-basin is bounded by the Bremer Bay sub-basin. The two basins probably merge across a (buried) bedrock high that lies to the east of the Pallinup River. However, as the Pallinup River has cut through the basin sediments to impermeable bedrock, the river valley effectively forms the north-eastern boundary of the Wellstead Sub-basin from a hydrogeological (groundwater flow) point of view.

6.2. WERILLUP FORMATION

The basal unit of the Plantagenet Group is the Werillup Formation (Fm), which is composed of fine- to coarse-grained sand, variably carbonaceous clay and silt, and minor lignite, deposited in a low-relief, coastal plain environment that was considerably wetter and warmer than at present.

The logs of over 400 water bores and mineral and groundwater exploration holes (locations shown in Figure 4) were used to generate the cross-sections shown in Figures 5A to 10. These reveal that the sand beds form two vertically-isolated aquifers within the Werillup Fm (Rockwater 2014).

The lower Werillup sand aquifer comprises fine- to very coarse-grained, poorly sorted sand that is mainly restricted to the base of three main palaeovalleys which drained the basin in easterly direction, following the strike of the Proterozoic bedrock. These are referred to as the northern, central and southern palaeovalleys (Fig. 4), although the existence of the northern palaeovalley is somewhat speculative. On the basis of its coarse grain size, poor sorting and basal position within the palaeovalleys, it is inferred that the lower Werillup sand aquifer was deposited in a high-energy, fluvial environment, very similar to the “palaeochannels” on the Yilgarn Craton (Commander *et al*. 1991).

The lower Werillup sand aquifer is (hydraulically) confined below by crystalline bedrock, locally weathered to a depth of up 10 m; and above by thick carbonaceous clay, which is the main facies of the Werillup Fm. In the central palaeovalley, the lower Werillup sand aquifer attains a maximum known thickness of about 30 m in production bore WSD15P (Figs. 4, 6). Elsewhere in the central palaeovalley, the sand has an average thickness of about 25 m (Figs 5A, 8A, 9). Limited intersections of the lower Werillup aquifer in the southern palaeovalley indicate that is thinner, reaching a maximum thickness of 13 m in production bore WSD13P (Figs 4, 8B).

A long-section of the central palaeovalley, shown in Figure 10, suggests that the base of the lower Werillup aquifer has an elevation of about -45 mAHD at the coast. This is similar to the Sunday Swamp and Bremer-Bay Sub-basins, where the base of the lower Werillup aquifer occurs at about -45 and -50 mAHD, respectively. Figure 10, and a cross-section of the central palaeovalley shown in Figure 9, also suggest that the clay facies of the Werillup Fm crops out along the South Coast and along the valley of the Pallinup River. However, such outcrops do not appear in the relevant 1:250,000-scale geological maps (Fig. 3; Thom and Chin 1984, Muhling and Brakel 1985), so this aspect of the basin geology requires further verification.

Coarse-grained sand at the base of the Werillup Fm also occurs along the flanks of major bedrock highs, such as the ridge incorporating the Southdown magnetite deposit (Figs 5A, 7, 8A). As these “marginal aquifers” are localised, they would probably not be suitable for long-term groundwater supply. In any case, dewatering of the aquifers before mining may be required where they are to be intersected by the proposed pit, as shown for example in Figure 7.

The other sand unit, referred to as the upper Werillup aquifer, occurs about 20 m above the lower Werillup aquifer. It is typically composed of 5 to 15 m of green (glauconitic), slightly clayey, fine- to medium-grained sand. This sand is restricted to lower (coastal) reaches of the palaeovalleys (Fig. 4) and appears to have been deposited by a partial marine incursion into the sedimentary basin.

The upper Werillup sand aquifer is confined above and below by thick carbonaceous clay. In the southern palaeovalley, it attains a maximum known thickness of 14 m in bore WSD13P (Figs 4, 8B) and thins rapidly in a westerly (up-valley) direction. In the central palaeovalley, it has a maximum known thickness of 17 m in hole SDAC0326 (Fig. 10).

Substantial differences in the elevation of the upper Werillup aquifer suggest that it was deposited over an uneven topography, which was lowest along the central part of the basin, by then partly filled with sand and carbonaceous clay. As with the lower Werillup aquifer, it is likely that the upper aquifer crops out below current sea level (Fig. 10).

The pumping-test results of production bores WSD13P, 15P and 16P (Fig. 4) indicate that the hydraulic conductivity of lower, coarse-grained Werillup sand aquifer ranges from about 7 to 12 m/d, and that the aquifer is confined (Rockwater 2016). Air-lift yields from these production bores range from 5 to 20 L/s.

No pumping tests have been conducted to assess the hydraulic properties of the upper Werillup aquifer. However, the results of slug tests suggest that it has a hydraulic conductivity of 0.2 to 1 m/d, possibly increasing towards the basin centre. There is also some indication that the upper aquifer is less permeable in the southern palaeovalley. This may be because of the palaeovalley’s relatively small width, which would have restricted marine circulation during deposition of the upper aquifer. Air-lift yields from bores slotted in the upper Werillup aquifer are fairly low (<3.5 L/s).

As far as is known, no bores have been drilled to exploit the lower Werillup aquifer other than those installed by Rockwater (2006, 2010, 2016). However, the upper Werillup aquifer is probably locally used for farm-water supply, especially in the coastal part of its extent, as this aquifer is shallower and considerably less saline than the lower Werillup aquifer.

6.3. PALLINUP FORMATION

The other main stratigraphic unit of the Plantagenet Group is the Pallinup Fm (formally defined as the Pallinup Siltstone), which conformably overlies the upper carbonaceous clay facies of the Werillup Fm with a gradational contact. The Pallinup sediments were deposited by a major marine transgression along the South Coast of WA, which in the Wellstead Sub-basin reached as far inland as the Stirling Range.

At Southdown, the Pallinup Fm is mostly composed of a coarsening-upwards sequence of muddy, very fine-grained sand, grading upwards into slightly clayey, fine-grained sand. Siliceous sponge spicules are a characteristic component of the Pallinup Fm, but are not abundant at Southdown.

The upper surface of the Pallinup Fm is a low-relief ramp that slopes gently from the Stirling Range to the coast (Fig. 2) and its lower surface takes the form of that part of the Wellstead Sub-basin that had not been filled by the Werillup sediments. Consequently, the formation thickens towards the axes of the palaeovalleys and the coastal part of the basin where it reaches a thickness of about 70 m (Fig. 11). In higher, peripheral parts of the basin, the Pallinup Fm is thin and commonly directly overlies Proterozoic bedrock. In these areas, the Pallinup Fm may also be unsaturated.

Yields from bores slotted in the Pallinup Fm are typically low (<0.5 L/s). No pumping tests have been conducted to assess its permeability, but the results of slug tests indicate that this is about 0.5 m/d.

Owing to the fairly shallow depth to groundwater in the Pallinup Fm aquifer and its low salinity (to be discussed below), the aquifer is widely exploited for farm supply. An important aim of the groundwater model is therefore to predict the extent of drawdown that will occur in the Pallinup Fm as a result of extraction from the underlying Werillup aquifers, although strong confinement of the Werillup aquifers makes this possibility unlikely.

7. WATER LEVELS

Water level depths and elevations for 262 bores located throughout the Wellstead Sub-basin are shown in Figures 12 and 13, respectively. The water levels are not grouped according to the aquifer in which the bores are screened, but as most are from farm bores they are likely mostly to be of the Pallinup Fm.

As expected, the water levels decrease in elevation from the upland, northern and western parts of the Wellstead Sub-basin, to the coast, where the groundwater discharges to the ocean (Fig. 10). Water levels in the Pallinup Fm are also controlled (lowered) by discharge to deeply incised streams, such as Pallinup River (Fig. 9), Cordinup River (Fig. 5B) and Willyun Creek (Fig. 8B), as is evidenced by perennial flows in these drainages.

Deep water levels and a lack of farm bores in the coastal part of the central palaeovalley indicate that the Pallinup Fm is unsaturated in this area (Fig. 10). Consequently, it is likely that the upper reaches of small ephemeral streams. such as Eyre River (Fig 2), are sustained by surface water run-off and perched groundwater, rather than baseflow from the Pallinup Fm.

A possible cause for unsaturation of the Pallinup Fm in the coastal part of the central palaeovalley is downwards leakage into the Werillup Fm aquifers, induced by lower heads in these aquifers as a result of their active discharge to the ocean. For example, at bore WSD16P, shown in Figure 9, the water level in the lower Werillup aquifer is about 3.5 m lower than in the upper Werillup aquifer, which in turn has a water level that is 4.5 m lower than in the Pallinup Fm. Downward heads of similar magnitude occur in the southern palaeovalley (Fig. 8B). However, the downwards head between the Pallinup Fm and the lower Werillup aquifer appears to be much greater in the upper to middle reaches of the central palaeovalley, reaching about 11 m at bore WDS15P (Fig. 6).

Along with baseflow to streams, leakage from the Pallinup Fm into the underlying Werillup aquifers is probably a major source of water loss from the Pallinup aquifer that needs to be replicated during model calibration. This is especially the case for the current model, which was biased to the calibration of heads in the Pallinup Fm.

A brief review of time-series water level data indicates that water levels in the Werillup Sub-basin are rising because of increased recharge following clearing of the native vegetation. On average, the rate of

rise is about 0.25 m/yr in the Pallinup Fm, 0.1 m/yr for the Werillup aquifers, and 0.06 m/yr for bores slotted in weathered bedrock (Fig. 12).

Rising water levels in the Pallinup Fm are highly undesirable because of their potential to intersect the base of wetlands, thereby causing salinisation and waterlogging, and eventual death of the native vegetation. Limited drawdowns in the Pallinup Fm arising from extraction from the Werillup aquifers would therefore assist in arresting this rising water level trend.

8. SALINITY

The salinity of the Werillup aquifers is particularly important because, along with bore yields, it will govern potential use of the aquifers to supply water for the construction and operational phases of the Southdown project.

As shown in Figure 14, the groundwater salinity varies vertically, as a function of aquifer, and then also laterally within each aquifer, as a function of distance from the coast.

The salinity of the lower Werillup aquifer in the central palaeovalley, which is the highest yielding of the aquifers, decreases markedly in a down-valley direction from about 60,000 mg/L TDS (Total Dissolved Solids) in bores SDAC0303 and WSD15P (Figs 5A and 6, respectively), to about 21,000 mg/L in bore WSD16P (Fig. 9). The very high salinity of the lower Werillup aquifer in the upper to middle reaches of the central palaeovalley probably results from a plume of dense brine entering the aquifer from Two Mile (salt) Lake (Fig. 14).

The salinity of the upper Werillup aquifer in the lower reaches of the central palaeovalley is about 7,000 mg/L, which is about one-third of that in the lower aquifer (Fig. 14). Additional drilling is required to test if either Werillup aquifer becomes even less saline closer to the coast, which would be of benefit for supplying water for the Southdown project.

Salinity data from the coastal reaches of the southern palaeovalley are also lacking. However, limited data from further up-valley indicate that the upper and lower Werillup aquifers have a salinity of 4,000-5,000 mg/L (Fig 14). Geophysical logs indicate that the upper aquifer is less saline than the lower aquifer, but not to the extent which occurs in the central palaeovalley (Rockwater 2016).

The salinity of the Pallinup Fm varies widely from 300 to 7,000 mg/L, with no pattern in the salinity distribution clearly evident (Fig. 14). Some of the variation may arise from differences in bore construction (e.g., sealing of the bore annulus to prevent surface water inflow), bore placement (e.g., proximity to bedrock highs producing surface water runoff), and perhaps also an increase in salinity with depth.

9. POTENTIAL BOREFIELDS

Three main water supply borefields could be established for the Southdown project based on the yield and salinity of the Werillup aquifers (Table 2, Fig. 15). The lower Werillup aquifer in the middle to lower reaches of the central palaeovalley could be used to supply a large volume of hypersaline water for dust suppression. The salinity of the lower Werillup aquifer in the upper reaches of the central palaeovalley is probably too high to be of any use for the project.

Table 2: Werillup Aquifers and their Potential Application

Palaeo-valley	Reach	Aquifer	Yield	Salinity	Borefield	Potential application
Central	middle	upper	not present			
		lower	high	v. high	1	dust suppression
	lower	upper	low	moderate	2	RO feed (low to moderate volume)
		lower	high	high	1	dust suppression
Southern	middle	upper	low	low	3	RO feed (moderate volume)
		lower	moderate	low	3	
	lower	upper	low	v. low?	3	
		lower	moderate	v. low?	3	

In the lower reaches of the central palaeovalley, the upper Werillup aquifer could be developed independently as a low to moderate volume source of feed water for an RO plant, or other mining operations for which high salinity water cannot be used (Table 2). This would require the drilling of two bores at each location – one deep, large-diameter bore to extract hypersaline water from the lower aquifer and another shallow, small-diameter bore to extract moderate salinity water from the upper aquifer (Fig. 15).

The third water source and potential borefield would involve screening of production bores over both Werillup aquifers in the southern palaeovalley. This water could be used as a moderate-volume source of feed water for a RO plant, or other mining operations for which low salinity water is required (Table 2).

No groundwater is likely to exist within the Werillup aquifers that has a low enough salinity for direct use in concrete production or camp supply (<600 mg/L). Current plans are to truck potable water to Southdown from a similar palaeovalley aquifer borefield located at Redmond – King River, nearby to Albany (Rockwater 2011). An alternate option would be desalinate low-salinity water from the second or third borefields, described above.

10. PREVIOUS GROUNDWATER MODELS

Groundwater modelling of the Southdown area has been performed by Golder Assoc. (2006a, 2015), Rockwater (2008) and GHD (2010, 2012). These models were all primarily constructed to predict rates of inflow to the proposed mine pit and drawdowns in the Pallinup Fm that will be produced by dewatering, with the models of GHD (2012) and Golder Assoc. (2015) also being used to predict water levels in and around the pit after mine closure.

The models were all based on very limited bore data, largely concentrated around the Southdown deposit, which resulted in an over-simplification of the geometry and stratigraphy of the Wellstead Sub-basin. The Werillup Fm was included in the models of GHD (2010, 2012) and Golder Assoc. (2015), but then only as a flat layer of low permeability situated between a tabular layer of Pallinup Fm above and three or four other tabular layers, representing decreases in bedrock weathering and permeability with depth, below. For example, the GHD (2010, 2012) models used permeabilities of 0.1 m/d for the

Pallinup Fm, 0.01 m/d for the Werillup Fm, 0.001 m/d for weathered bedrock, and 0.0001 m/d for fresh bedrock. Fresh bedrock permeability was increased to 0.004-0.3 m/d along faults that intersect the Southdown ore-body, which in the case of the latter GHD model where (unrealistically) extended from the pit to the model boundaries.

The models did not recognise the full extent of the Wellstead Sub-basin and nature of its hydraulic boundaries. For example, in all cases, constant head cells of 120-140 mAHD were placed along the western model boundary, whereas this should be a groundwater divide (no-flow boundary); and in the case of the GHD (2010, 2012) models, river cells were permitted to recharge the Pallinup Fm, whereas they should only be receiving (draining) water from the water table.

Steady-state calibration of the GHD (2010, 2012) and Golder Assoc. (2006a) models necessitated the application of very low recharge rates, being 0.04 and 0.01 % of annual rainfall, respectively. This is partly due to the low permeability of the Pallinup Fm that was used (0.1 m/d for GHD (2010. 2012); 0.086 m/d for Golder Assoc. (2006a)), and the absence of the upper and lower Werillup aquifers, which receive downwards leakage from the Pallinup Fm.

11. CONCEPTUAL FLOW SYSTEM

A conceptual model of the groundwater flow system in the Wellstead Sub-basin is shown in Figure 16. Water enters the flow system solely through rainfall, which infiltrates the Pallinup Fm until it recharges the water table. The recharge rate probably decreases slightly with distance inland as a result of declining rainfall and increasing evaporation. Surface run-off and perched groundwater collected in wetland basins may locally and temporarily increase the recharge rate, as may runoff from exposed bedrock highs, but these were not explicitly included in the model. Also not included in the model is the recharge of brine from salt lakes, which would be largely density-driven.

To maintain equilibrium and prevent the water table from rising (now temporarily upset by clearing of the native vegetation), an equal amount of water must leave the Pallinup Fm as arrives by recharge. Along the coast and Pallinup River, a considerable amount of groundwater is lost from the Pallinup Fm to streams. As the water table is too deep for evapotranspiration, and the Pallinup Fm is bounded by impermeable bedrock along all margins of the Wellstead Sub-basin (except for along the coast and Pallinup River), all remaining water loss from the Pallinup Fm must occur through downward leakage to the Werillup aquifers, which discharge to the ocean. The Werillup aquifers are separated from the Pallinup Fm by thick beds of low-permeability clay (aquitards), so this process must take place very slowly and diffusely.

Limited seepage from the Werillup clay aquitards may take place where they crop-out along the coast and Pallinup River (Figs 9, 10), although, as noted, the existence of such outcrops requires further verification.

12. MODEL DESCRIPTION, GEOMETRY AND BOUNDARY CONDITIONS

The model used to simulate groundwater flow in the Wellstead Sub-basin was Processing Modflow (PMWIN) Pro Version 8, which incorporates MODFLOW, the industry-standard finite-difference groundwater model designed by the U.S. Geological Survey (McDonald and Harbaugh 1988).

The model domain comprised a 60 x 40 km rectangle, incorporating the entire Wellstead Sub-basin, except the upper part of the northern palaeovalley which remains poorly explored and is not likely to be used for water supply (Fig. 15). The model grid was formed of 302 rows and 489 columns, with the rows aligned in an east-north-east direction, roughly parallel to the orientation of the central and southern palaeovalleys. A grid cell size of 75 x 75 m was used at locations of the proposed production bores, and also at the Southdown magnetite deposit to enable dewatering of the pit to be modelled at a later stage. For the remainder of the model, a grid cell size of 150 x 150 m was used.

To reduce computation time, cells were set as inactive where they occur over the ocean or exposed or shallow bedrock, such as Green Range and the foot of the Stirling Range. Inactive cells were also used on the eastern side of the Pallinup River, which has incised to fresh bedrock and partitions groundwater flow in the Wellstead Sub-basin (Fig. 15). Excluding the inactive cells, the model domain had an area of about 12,500 km^2.

Five model layers were used to simulate flow in the basin: layer 1 for the Pallinup Fm, layer 2 for the upper Werillup aquitard, layer 3 for the upper Werillup aquifer, layer 4 for the lower Werillup aquitard, and layer 5 for the lower Werillup aquifer (Fig. 9). A sixth model layer of very low permeability bedrock was also included (but set as inactive) to allow for future modelling of pit dewatering.

Hydraulic parameters, to be discussed in the following section, were assigned to spatial zones within each model layer according to variations in the material represented (Fig. 17). For example, layer 3 was set to have a high permeability only in the region of the upper Werillup aquifer. Throughout the remainder of the model, layer 3 was set to have a lower permeability to represent Werillup clay or weathered bedrock.

Much of the need to assign zones with different hydraulic properties within each model layer arose from the MODFLOW requirement for each layer to extend with some thickness to the model boundary. This is not well suited to the complex stratigraphic situations, such as the Wellstead Sub-basin, where the lower Werillup aquifer is restricted to the base of palaeovalleys, the upper Werillup aquifer pinches-out inland, and the Pallinup Fm and Werillup aquitards terminate against intra-basin bedrock highs.

The following method was used to construct the model layer geometry required by MODFLOW.

- Manual contours of the elevation of the base of the Pallinup Fm were first constructed using the available bore data (Fig. 18). Contours were projected through bedrock highs to permit continuity of the Pallinup Fm layer (1) across the model domain. A zone of low permeability was created to account for the presence of bedrock in the layer where the bedrock high extends above the water table, as occurs at the Southdown magnetite deposit (Fig. 17).

- The second surface to be manually contoured was the base of layer 4 (Fig. 19). This represents the contact between Werillup clay and the top of the lower Werillup aquifer along the palaeovalley floors, and the contact between Werillup clay and bedrock along the palaeovalley flanks (Fig. 19). The contours were once again projected through bedrock highs, at a lower elevation than the base of Pallinup contours, to enable continuity of this (temporary) layer across the model domain.

- The last surface to be manually contoured was the elevation of the base of the lower Werillup aquifer (Fig. 20), which was projected from palaeovalley to palaeovalley through the intervening bedrock (Fig. 17).

- Lastly, the volume between the first and second surfaces contoured was split into three layers (model layers 2, 3 and 4), each initially set with a very low permeability to represent the Werillup Fm aquitards. A zone with a high permeability and thickness of 10 m was then established within the coastal part of layer 3, to account for flow within the upper Werillup aquifer (Figs. 17, 19).

No-flow cells were placed at the margins of all model layers, except in layers 3 and 5 at the coast where constant-head cells were used (Fig. 15). The constant-head cells were assigned an elevation of 25 mAHD in the case of layer 3, and 20 mAHD in the case of layer 5, to simulate discharge to the ocean from the upper and lower Werillup aquifers, respectively (Fig. 10).

Discharge from the Pallinup Fm to the Pallinup River and deeply incised streams along the coast was simulated by the use of drain cells (Figs 15). The base of the drain cells where set an elevation of 1-10 m above the base of layer 1 and the cells were assigned a high conductance to allow an unrestricted inflow of groundwater, at least where the water level in the aquifer remains above the base of the drain.

The only source of water input to the model was recharge. This was applied at progressively lower rates in three zones located sequentially inland from the coast (Fig. 15). The rates of recharge were established during steady-state calibration of the model, to be discussed below.

13. MODEL STEADY-STATE CALIBRATION

Calibration of the model was mainly performed in steady-state mode, which essentially involved the adjustment, by trial and error, of boundary conditions, external stresses (recharge and drain flows), and horizontal and vertical hydraulic conductivity, until the predicted steady-state water level elevations matched those that are observed as closely as possible. Initial water level elevations used in the model calibration were those shown in Figure 13. A list of the hydraulic parameters giving the closest match between predicted and observed water levels is shown in Table 3.

Initially set on the basis of pumping and slug test results, and not allowed to vary widely during the steady-state calibration, were the horizontal hydraulic conductivities (Kh) of the upper and lower Werillup aquifers and the Pallinup Fm (Golder Assoc. 2006b, Rockwater 2015). However, the Kh of the Pallinup Fm used in the present model was 1.0 m/d, which is somewhat higher than the average of 0.4 m/d returned by field investigations at Southdown, and considerably higher than that used in previously modelling, especially by Golder Assoc. (2006a) [0.086 m/d] and GHD (2010, 2012) [0.1 m/d].

A higher Kh for the Pallinup Fm was needed in this case to enable a recharge rate of about 2.5 to 4 % of rainfall to be applied (Table 3), which is considered more realistic than the very low recharge rates of 0.01, 0.04 and 0.8% of rainfall used by Golder Assoc. (2006a), GHD (2010, 2012) and Golder Assoc. (2015), respectively. A secondary reason for use of very low recharge rates in these models is probably that they did not account for any leakage from the Pallinup Fm to the Werillup aquifers during the steady-state calibrations.

Table 3: Steady-state Hydraulic Parameters

			SEDIMENT			BEDROCK
			AQUIFER		AQUITARD	
LAYER 1 (unconfined)	min	max	PF, Sand fine			Weathered
Top (mAHD)	34.7	191.2				
Bott (mAHD)	13.2	150.9				
Kh (m/d)			1.00			0.05
Kv (m/d)			0.10			0.05
Sy			0.15			0.01
LAYER 2					WF Clay	Weathered
Bott (mAHD)	-6.6	132.0				
Kh (m/d)					0.00005	0.01
Kv (m/d)					0.00002	0.01
Ss (1/m)					0.001	0.00001
Sy					0.02	0.01
LAYER 3			WF Sand, fine (C p-v, N p-v)	WF Sand, fine (S p/v)	WF Clay	Weathered
Bott (mAHD)	-16.6	122.9				
Kh (m/d)			1.00	0.50	0.00005	0.01
Kv (m/d)			0.10	0.05	0.00002	0.01
Ss (1/m)			0.0005	0.0005	0.001	0.00001
Sy			0.20	0.20	0.02	0.01
CHB (coast)			25.00	25.00	25.00	25.00
LAYER 4					WF Clay	Weathered
Bott (mAHD)	-26.6	114.3				
Kh (m/d)					0.00005	0.01
Kv (m/d)					0.00002	0.01
Ss (1/m)					0.001	0.00001
Sy					0.02	0.01
LAYER 5			WF Sand, coarse (C p-v, N p-v)	WF Sand, coarse (S p-v)		Transitional
Bott (mAHD)	-46.3	66.6				
Kh (m/d)			7.5, [5.0]	5.0, [3.0]		0.005
Kv (m/d)			0.75, [0.5]	0.5, [0.3]		0.005
Ss (1/m)			0.0005	0.0005		0.00001
Sy			0.25	0.25		0.005
CHB (coast)			20.00	20.00		20.00
RECHARGE			(mm/yr)	(% basin average rainfall [560 mm/yr])		
NW Zone			14.60	2.61		
Central Zone			18.25	3.26		
SE Zone			21.90	3.91		

Kh=horizontal hydraulic conductivity; Ky=vertical hydraulic conductivity; Ss=specific storage; Sy=specific yield, CHB=constant head boundary (at coast); PF=Pallinup Fm; WF=Werillup Fm, N p-v=northern palaeovalley; C p-v=central palaeovalley; S p-v=southern palaeovalley, [ ] Kh & Kv in lower (costal) reaches of palaeovalleys.

A plot of observed and predicted water level elevations for 77 bores used to calibrate the steady-state model is shown in Figure 21. The bores are nearly all in the Pallinup Fm, which strongly biases the calibration to that layer. It was assumed that observed water levels represent equilibrium conditions (i.e., are stable), which, owing to increased recharge following clearing of the native vegetation, is not strictly the case. The root mean square (RMS) error of the calibration using all 77 bores is 8.2 m, which reduces to 4.8 m if 32 of the bores with the most reliable water levels are used.

The spatial distribution of steady-state residuals for the 77 calibration bores, that is the difference between predicted and observed water level elevations, is shown in Figure 22. Over-predicted and under-predicted water levels are distributed fairly randomly, indicating no systematic error in the model geometry, although the over-predicted water levels close to the Pallinup River suggest that more drain cells are required in that area.

The most significant parameters assessed in the steady-state calibration were recharge and the hydraulic conductivity of the Pallinup Fm; these having the most direct influence on water levels in the Pallinup layer 1. This is clearly demonstrated by the results of a sensitivity analysis (Figure 23), which shows large variations in the RMS error resulting from fairly small changes in recharge and hydraulic conductivity of the Pallinup Fm. Success of the steady-state calibration therefore largely depended on achieving the right balance between these two parameters.

On the other hand, the results of the sensitivity analysis show that the steady-state model is poorly suited to the calibration of the Kh of the Werillup aquifers and the vertical hydraulic conductivity (Kv) of the overlying Werillup aquitards. These parameters have a strong influence on the supply-capacity of the Werillup aquifer and are therefore of central importance to current investigation. Also exerting a major control on the supply-capacity of Werillup aquifers, but not assessed at all by the steady-state calibration, were the storage properties of the Werillup aquitards and aquifers.

Fairly accurate independent estimates of the Kh and storage properties of the Werillup aquifers for use in the predictive model (see Sect. 14) were obtained from the results of the pumping tests and slug tests. However, no field measurements of the Kv and storage properties of the Werillup aquitards were available for use in the predictive model. These parameters were therefore assessed by a separate transient, five-layer, MODFLOW model (not reported on here), which was calibrated using the pumping-test results of production bore WSD16P (Fig. 9). During the constant-rate test of this bore, about 11 L/s were extracted from the lower Werillup aquifer for 31 hours, resulting in 20.5 m of drawdown in the target aquifer, but only 0.5 m of drawdown in the upper Werillup aquifer and no drawdown in the Pallinup Fm, as measured in an adjacent monitoring bore (Rockwater 2015). The results of the calibrated transient model indicate that the Kv of the Werillup Fm clay is about 0.00002 m/d, (which is very low, but in keeping with published values for clay) and that the specific storage of the Werillup aquitard is about 0.001 m^{-1}.

A water balance for the steady-state flow model is provided in Table 4. As expected, the main source of water entering the system is recharge, although a small volume is also supplied by flow from the constant head boundary in the upper Werillup aquifer to the constant head boundary in the lower Werillup aquifer, which were set to have a head difference of 5 m (Fig. 10). Outflow from the system occurs more or less equally as discharge to streams from the Pallinup Fm (via the drain cells) and discharge to the ocean from the upper and lower Werillup aquifers (via the constant head boundaries).

Table 4: Steady-State Water Balance

Parameter	Rate (kL/d)	Rate (L/s)
INFLOW		
Recharge	6,245	72
Constant head	859	10
Drains	0.0	0
Total	7,104	82
OUTFLOW		
Recharge	0.0	0
Constant head	3,480	40
Drains	3,624	42
Total	7,104	82
INFLOW-OUTFLOW	0.0	0.0

14. MODEL PREDICTIONS

14.1. MAXIMUM EXTRACTION FOR 15 YEARS

The calibrated groundwater model was first used to assess the maximum rate of extraction that can be sustained by the upper and lower Werillup aquifers for 15 years, which is the expected life of the Southdown mine at a processing rate of 10 Mtpa.

Extraction was simulated from the three borefields as outlined in Table 2. Further details are presented below.

- The first borefield comprised 10 production bores screened in the lower Werillup aquifer within the middle to lower reaches of the central palaeovalley. These bores are labelled 1-6 and 7A-10A in Figure 15. Each bore was pumped at a rate of 15 L/s for a total extraction of 150 L/s.
- The second borefield comprised four bores screened in the upper Werillup aquifer in the lower reaches of the central palaeovalley. These are labelled 7B-10B in Figure 15. Each bore was pumped at 3 L/s for a total extraction of 12 L/s.
- The third borefield comprised four bores screened over both Werillup aquifers in the southern palaeovalley. These are labelled 11 to 14 in Figure 15. Each bore was pumped at 10 L/s from the lower Werillup aquifer and 2 L/s from the upper Werillup aquifer, for a total extraction of 48 L/s.

Figure 24 shows a longitudinal section of the central palaeovalley with the water levels produced by extraction at the rates described above for 15 years. An equivalent section for the southern palaeovalley is shown in Figure 25. Final water levels (potentiometric heads) are in both cases still above the top of each aquifer, and no significant drawdowns are produced in the Pallinup that could reduce baseflow to streams.

It is important to note that the model concentrates on the capacity of the aquifer and presents results for a whole model cell, rather than the bores. Actual pumping water levels in the bores will be somewhat lower (deeper) than shown in the sections because of inefficiencies in bore construction (well-loss) and the relatively coarse grid cell size of 75 x 75 m used. The difference between modelled and actual water levels will be greater for the upper Werillup aquifer, where the cone of depression produced by pumping will be fairly deep and narrow on account of the aquifer's low permeability. If the difference becomes excessive, more bores than used in the model may in reality be required to extract the volume of water modelled.

14.2. MAXIMUM EXTRACTION FOR 60 YEARS

By halving the processing rate to 5 Mtpa and doubling the pit size, mining of the Southdown deposit could be extended to a maximum of 60 years. A second modelling scenario was therefore performed to assess the maximum volume of water that can be extracted from the upper and lower Werillup aquifers over this period.

The bores used for the 60 year mining scenario were the same as used for the 15 year mining scenario, except that the lower Werillup aquifer bores in the central palaeovalley were pumped at 8 L/s each for a total of 80 L/s, the upper Werillup aquifer bores in the central palaeovalley were pumped at 1 L/s each for a total of 4 L/s, and the lower and upper Werillup aquifer bores in the southern palaeovalley were pumped at 7 L/s each for a total of 28 L/s.

Longitudinal sections of the water levels produced by pumping at the above rates for 60 years are shown for the central and southern palaeovalleys in Figures 26 and 27, respectively. The modelled extraction rates are once again well within the capacity of the aquifers, notwithstanding that actual pumping water levels in the production bores will be somewhat deeper than shown. As with the 15 year mining scenario, no drawdowns are produced in the Pallinup Fm that could have a detrimental impact on the environment.

15. UNCERTAINTY ANALYSIS

No quantitative analysis of the uncertainty of the model's predictions with respect to supplying the water required for the Southdown mining project has been performed. This may be required if the model is to be formally assessed for environmental approvals, although in that case the effect of extraction from the Werillup aquifers on water levels in the Pallinup Fm would be of greater concern.

The main parameter governing the capacity of the Werillup aquifers to supply groundwater is probably the storage of the Werillup Fm clay, as this releases most of the water extracted from the lower Werillup aquifer. Storage did not form part of the steady-state calibration and was set, based on modelling of the pumping test results of bore WSD16P, as a specific storage of 0.001 m^{-1}. This is on the high side of the range for plastic clay (0.0018-0.00023 m^{-1}) and higher than the range for stiff clay (0.00012-0.00024 m^{-1}). A lower specific storage would result in considerably higher drawdowns in the Werillup aquifers and a reduction in their capacity to supply water for the Southdown project. It is therefore recommended that additional long-term pumping tests should be performed and that the results be evaluated in MODFLOW, as has been done for bore WSD16P.

All other non-field-assessed parameters in the model have been set fairly conservatively (low). For example, a higher vertical hydraulic conductivity for the Werillup clay would lead to more leakage from

the Pallinup Fm to the lower Werillup aquifer, thereby decreasing drawdowns in the aquifer. Other factors that could decrease drawdowns in the lower Werillup aquifer, and increase its supply-capacity, are inflows from bedrock fracture zones and tributaries to the main palaeovalleys, which were not accounted for in the present model.

16. WATER SUPPLY AND DEMAND

For the base-case, 15 year mining scenario, the results of the model indicate that about 150 L/s of high salinity water can be extracted from the central palaeovalley, and that 60 L/s of moderate to low salinity water can be extracted from central and southern palaeovalleys. Modelled extraction rates for the maximum-case, 60 year mining scenario, are 80 L/s of high-salinity water from central palaeovalley and 32 L/s of moderate to low salinity water from central and southern palaeovalleys.

Table 5 provides a comparison of the modelled supply rates with the rates of demand that are likely to be required during the construction and operational phases of the Southdown mine for periods of 15 and 60 years. It is important to note that the demand values for the 60-year scenario have been estimated from the 15 year scenario and that even these are likely to change.

In the case of the 15 year mining scenario, extraction from the lower Werillup aquifer in the central palaeovalley should be able to meet the requirement for saline water during the construction phase, which peaks at 148 L/s (Fig. 28). The aquifer should be more readily able to meet the on-going demand for saline water during the operation phase, as this falls to about 65 L/s.

The demand for fresh water during the operation phase of the 15 year mining scenario is very high (266 L/s), which clearly cannot be met by any of the aquifers at Southdown, especially given that an even larger volume will be required to allow for the low recovery rate of RO desalination. However, the demand for fresh water during construction phase (0.5-9 L/s) could be met by the desalination of low-salinity water from the lower and upper Werillup aquifers in the southern palaeovalley.

The Werillup aquifers appear to be less capable of supplying the water needed for the 60 year mining scenario (Fig. 29). This is probably because of the much larger volume of water extracted over 60 years than 15 years (159 GL compared to 77 GL in the case of the central palaeovalley), and because most water will come from storage in the Werillup Fm.

Nevertheless, is should still be possible to supply the demand for saline water during the construction and operational phases for the 60-year scenario by utilising both aquifers in both palaeovalleys, or by adjusting the pumping rate from the lower Werillup aquifer in the central palaeovalley to more closely match the rate of demand. The demand for fresh water during the mine construction phase could be met by the desalination of low-salinity water from the upper and lower Werillup aquifers in the southern palaeovalley. The demand for fresh water during the operational phase is very high (136 L/s), which as with the 15 year mining scenario, would require the construction of the sea-water desalination plant at Cape Riche.

Table 5: Summary of Water Demand and Supply

	10 Mtpa/APPROVED PIT, 15 YEARS							5 Mtpa/EXTENDED PIT, 60 YEARS					
	DEMAND			SUPPLY (MODELLED)				DEMAND			SUPPLY (MODELLED)		
Month	Saline (L/s)	Fresh (L/s)		Central p/v, L. Werillup, Hi TDS (L/s)	Central p/v, U. Werillup, Mod TDS (L/s)	South p/v, U & L Werillup, Lo TDS (L/s)		Saline (L/s)	Fresh (L/s)		Central p/v, L. Werillup, Hi TDS (L/s)	Central p/v, U. Werillup, Mod TDS (L/s)	South p/v, U & L Werillup, Lo TDS (L/s)
Construction Phase													
1	2.3	0.5		150	12	48		2	0.4		80	4	28
2	2.3	0.5		150	12	48		2	0.4		80	4	28
3	2.3	0.5		150	12	48		2	0.4		80	4	28
4	2.3	0.8		150	12	48		2	0.6		80	4	28
5	2.3	0.8		150	12	48		2	0.6		80	4	28
6	19.7	0.8		150	12	48		16	0.6		80	4	28
7	19.7	0.8		150	12	48		16	0.6		80	4	28
8	19.7	2.0		150	12	48		16	1.6		80	4	28
9	19.7	2.3		150	12	48		16	1.8		80	4	28
10	19.7	2.0		150	12	48		16	1.6		80	4	28
11	19.7	5.5		150	12	48		16	4.4		80	4	28
12	19.7	5.5		150	12	48		16	4.4		80	4	28
13	43.4	7.2		150	12	48		35	5.8		80	4	28
14	55.0	7.2		150	12	48		44	5.8		80	4	28
15	55.0	7.2		150	12	48		44	5.8		80	4	28
16	55.0	7.2		150	12	48		44	5.8		80	4	28
17	55.0	7.2		150	12	48		44	5.8		80	4	28
18	55.0	8.9		150	12	48		44	7.2		80	4	28
19	55.0	8.9		150	12	48		44	7.2		80	4	28
20	138.0	8.9		150	12	48		110	7.2		80	4	28
21	138.0	8.9		150	12	48		110	7.2		80	4	28
22	138.0	8.9		150	12	48		110	7.2		80	4	28
23	138.0	8.9		150	12	48		110	7.2		80	4	28
24	122.9	8.7		150	12	48		98	6.9		80	4	28
25	147.6	8.7		150	12	48		118	6.9		80	4	28
26	147.6	8.7		150	12	48		118	6.9		80	4	28
27	147.6	8.7		150	12	48		118	6.9		80	4	28
28	147.6	6.9		150	12	48		118	5.6		80	4	28
29	147.6	6.9		150	12	48		118	5.6		80	4	28
30	147.6	6.9		150	12	48		118	5.6		80	4	28
31	147.6	6.9		150	12	48		118	5.6		80	4	28
32	147.6	6.9		150	12	48		118	5.6		80	4	28
33	147.6	6.9		150	12	48		118	5.6		80	4	28
34	147.6	6.9		150	12	48		118	5.6		80	4	28
35	147.6	6.9		150	12	48		118	5.6		80	4	28
36	147.6	6.9		150	12	48		118	5.6		80	4	28
Operation Phase													
37	65.0	266.7		150	12	48		52	136.2		80	4	28
38	65.0	266.7		150	12	48		52	136.2		80	4	28
180	65.0	266.7		150	12	48		52	136.2		80	4	28
720								52	136.2		80	4	28

Notes:

- Demand for construction phase, 10 Mtpa/15 year scenario, from spreadsheet developed by Ross Carpenter (Oct 2014)
- Demand for operation phase, 10 Mtpa/15 year scenario, from Table 11.2.1 in MAGJV (2012)
- Demand for construction phase, 5 Mtpa/60 year scenario, assumed to be 80% of that during construction phase of 10 Mtpa/15 year scenario
- Demand of saline for dust suppression during operation phase. 5 Mtpa/60 year scenario, assumed to be 80% of that in 10 Mtpa/15 year scenario
- Demand of fresh for process plant during operation phase, 5 Mtpa/60 year scenario, assumed to be 50% of that in 10 Mtpa/15 year scenario
- Demand of fresh for drinking/concreting during operation phase, 5 Mtpa/60 year scenario, assumed to be 80% of that in 10 Mtpa/15 year scenario

17. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The Southdown Joint Venture is planning to mine the Southdown magnetite iron-ore deposit, located nearby to Wellstead. At a concentrate production rate of 10 Mtpa, it is expected that the mine life will be 15 years, but this could be extended to 60 years if the mining rate is halved and the size of the pit doubled.

A water balance for the base-case, 10 Mtpa operation indicates that up to 156 L/s of water will be required for the mine construction phase, which is expected to last 36 months. Thereafter, an even larger supply of about 330 L/s will be required for dust suppression, beneficiation of the ore and transport of the concentrate via a slurry pipeline to the port of Albany. Importantly, about 80% (266 L/s) of this needs to be fresh, with a TDS of <600 mg/L.

Exploration drilling performed by Rockwater (2006, 2010, 2014), followed by the drilling and test-pumping of four production bores by Rockwater (2016), has revealed the presence of two sand aquifers that have the potential to supply at least some of the water required during construction and on-going operation of the mine. The sand aquifers occur within the Werillup Fm, which fills the base of several small, interconnected, sedimentary basins along the South Coast, known as the Bremer Basin.

The lower Werillup aquifer is a fluvial deposit, restricted to the base of the three main palaeovalleys which formerly drained the Wellstead Sub-basin (of the Bremer Basin), and the upper Werillup aquifer is restricted to the coast, having been deposited by a subsequent partial marine incursion into the Wellstead Sub-basin. Both aquifers are strongly confined – the lower aquifer, below by crystalline bedrock and above by carbonaceous clay, and the upper aquifer below and above by the clay. Extraction from the Werillup aquifers therefore has no or very little effect on water levels in the overlying Pallinup Fm, which is widely used for farm water supply and sustains several perennial streams along the coast.

Much higher bore yields can be obtained from the lower Werillup aquifer than the upper Werillup aquifer, but the salinity of the lower aquifer is much higher, particularly in the central of the three palaeovalleys, where it attains it greatest thickness and permeability.

Three main borefields could be established based on the yield and salinity of the Werillup aquifers. The lower Werillup aquifer in the middle to lower reaches of the central palaeovalley could be used to supply a large volume of hypersaline water for dust suppression. In the lower reaches of the central palaeovalley, the upper Werillup aquifer could be developed independently as a low to moderate volume source of feed water for an RO plant, or other mining operations for which high salinity water cannot be used. The third potential borefield would involve screening production bores over both Werillup aquifers in the southern palaeovalley. This water could be used as a moderate-volume source of feed water for a RO plant, or other mining operations for which low salinity water is required.

Using data from the drilling and test-pumping programmes, a numerical groundwater model was constructed to assess what the maximum capacities of the Werillup aquifers are likely to be over mine lives of 15 and 60 years. Earlier groundwater models for the Southdown project, developed by Golder Assoc. (2006a, 2015), Rockwater (2008) and GHD (2010, 2012), concentrated on pit dewatering rates and were based on a limited understanding of the stratigraphy and hydrogeology of the Wellstead Sub-basin.

The new model comprises five layers to simulate flow in the Pallinup Fm, an upper Werillup aquitard, the upper Werillup aquifer, a lower Werillup aquitard and the lower Werillup aquifer. Discharge from the Pallinup Fm to deeply incised streams along the coast was simulated by the use of drain cells and the only source of water input to the model was recharge. This was applied at progressively lower rates in three zones located sequentially inland from the coast.

Calibration of the model was mainly performed in steady-state mode. Initially set on the basis of pumping and slug test results, and not allowed to vary widely during the steady-state calibration, were the hydraulic conductivities of the upper and lower Werillup aquifers and the Pallinup Fm. However, the hydraulic conductivity of the Pallinup Fm used in the present model was 1.0 m/d, which is somewhat higher than the average of 0.4 m/d returned by field investigations at Southdown, and considerably higher than that used in previously modelling.

A higher hydraulic conductivity for the Pallinup Fm was needed in this case to enable a recharge rate of about 2.5-4 % of rainfall to be applied, which is considered more realistic than the very low recharge rates of 0.01- 0.8% of rainfall used by the earlier models. A secondary reason for use of very low recharge rates in these models is probably that they did not account for any leakage from the Pallinup Fm to the Werillup aquifers during the steady-state calibrations.

A satisfactory correlation between observed and modelled water levels was achieved in the steady-state calibration. However, an analysis of parameter sensitivity showed that the success of the calibration was almost entirely dependent on recharge and the hydraulic conductivity of the Pallinup Fm, these having the greatest influence on water levels in the model layer where most of the observation bores used in the calibration were located.

On the other hand, the results of the sensitivity analysis showed that the steady-state model is poorly suited to the calibration of the hydraulic conductivity of the Werillup aquifers and aquitards, which will have a strong influence on the water supply-capacity of the Werillup aquifer. Also exerting a major control on the supply-capacity of Werillup aquifers, but not assessed at all by the steady-state calibration, were the storage properties of the Werillup aquitards and aquifers.

Fairly accurate independent estimates of the hydraulic conductivity and storage properties of the Werillup aquifers for use in the predictive model were obtained from the results of pumping tests and slug tests. However, no field measurements of the hydraulic conductivities and storage properties of the Werillup aquitards were available for use in the predictive model. These parameters were therefore assessed by a separate groundwater model, which was calibrated using the results of a constant-rate pumping-test in which water levels in all aquifers were recorded.

The calibrated groundwater model was then used to predict the maximum rate of extraction that can be sustained by the upper and lower Werillup aquifers for periods 15 and 60 years.

For the base-case, 15 year mining scenario, the results of the predictive model indicate that about 150 L/s of high salinity water can be extracted from the central palaeovalley, and that 60 L/s of moderate to low salinity water can be extracted from central and southern palaeovalleys. Modelled extraction rates for the maximum-case, 60 year mining scenario, are 80 L/s of high-salinity water from central palaeovalley and 32 L/s of moderate to low salinity water from central and southern palaeovalleys.

The modelled extraction rates should be sufficient to meet the demand for saline water during the construction and operational phases of the mine for both of the 15 and 60 year scenarios. The demand

for fresh water during the construction phase could also be met by desalination of the lower-salinity water from the upper Werillup aquifer in the central palaeovalley, and the upper and lower Werillup aquifers in the southern palaeovalley. However, the demand for fresh water during the operational phase of either mining scenario is probably too high to be met by any of the aquifers at Southdown.

The lower reaches of the central and southern palaeovalleys are poorly known and require further exploration by air-core drilling, followed in each case by the drilling and testing of at least one production bore in each of the Werillup aquifers. It is likely that the groundwater salinity will decrease further with proximity to the coast, making the lower reaches of the palaeovalleys particularly attractive, especially as sources of feed water for desalination.

It is likely that the groundwater model will need be up-dated and re-run to incorporate the results of the additional drilling. A quantitative analysis of the uncertainty of the model predications should also be performed at that time, which was only addressed qualitatively as part of this investigation.

Dated: 30 October 2017 **Rockwater Pty Ltd**

P de Broekert

Principal Hydrogeologist

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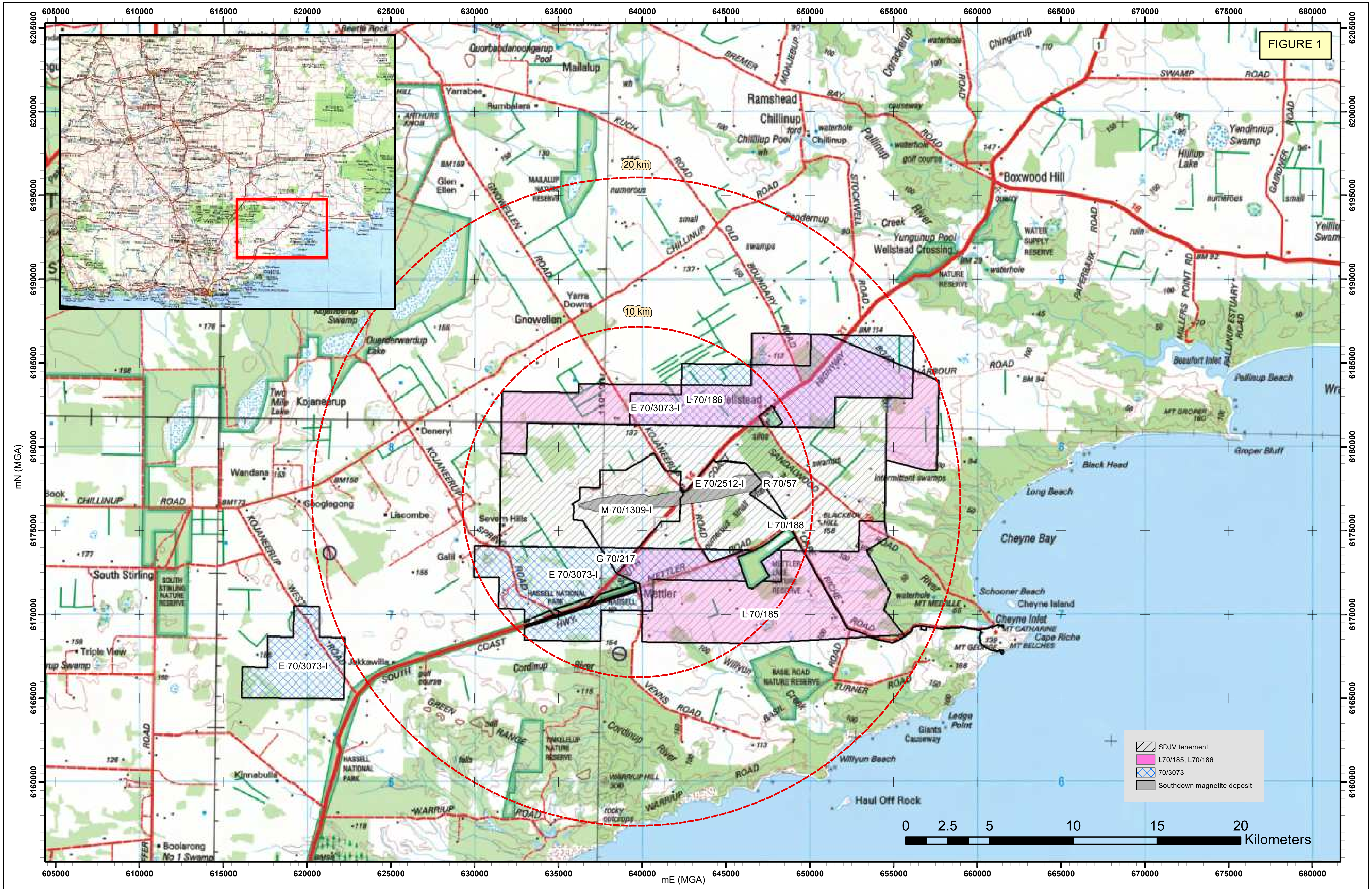
FIGURES



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PROJECT: Water Supply Investigation
DATE: Sept. 2017
Dwg No: 216.1.1/17/2-1

SOUTHDOWN LOCATION & TENEMENTS

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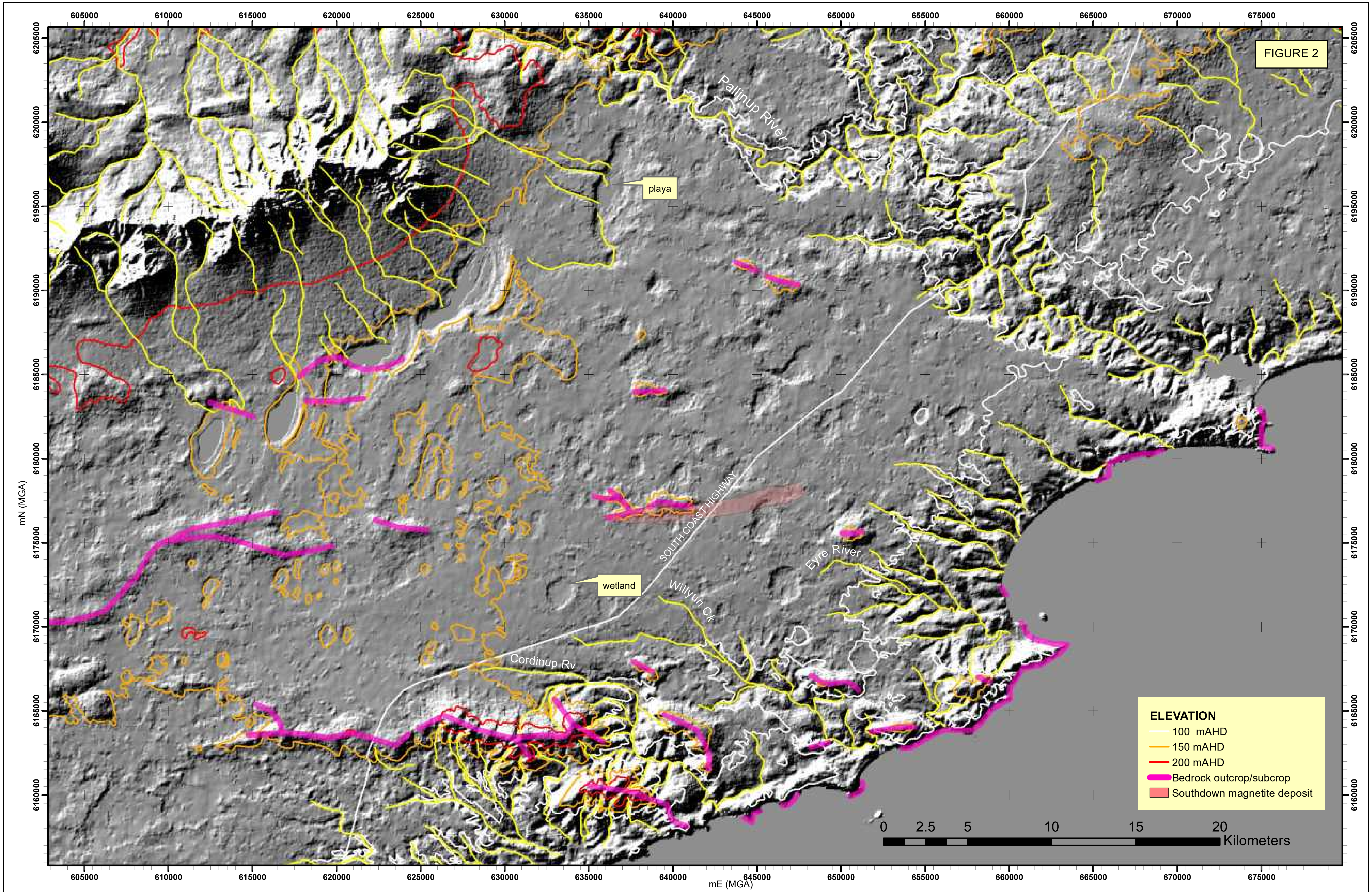

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TOPOGRAPHY AND DRAINAGE

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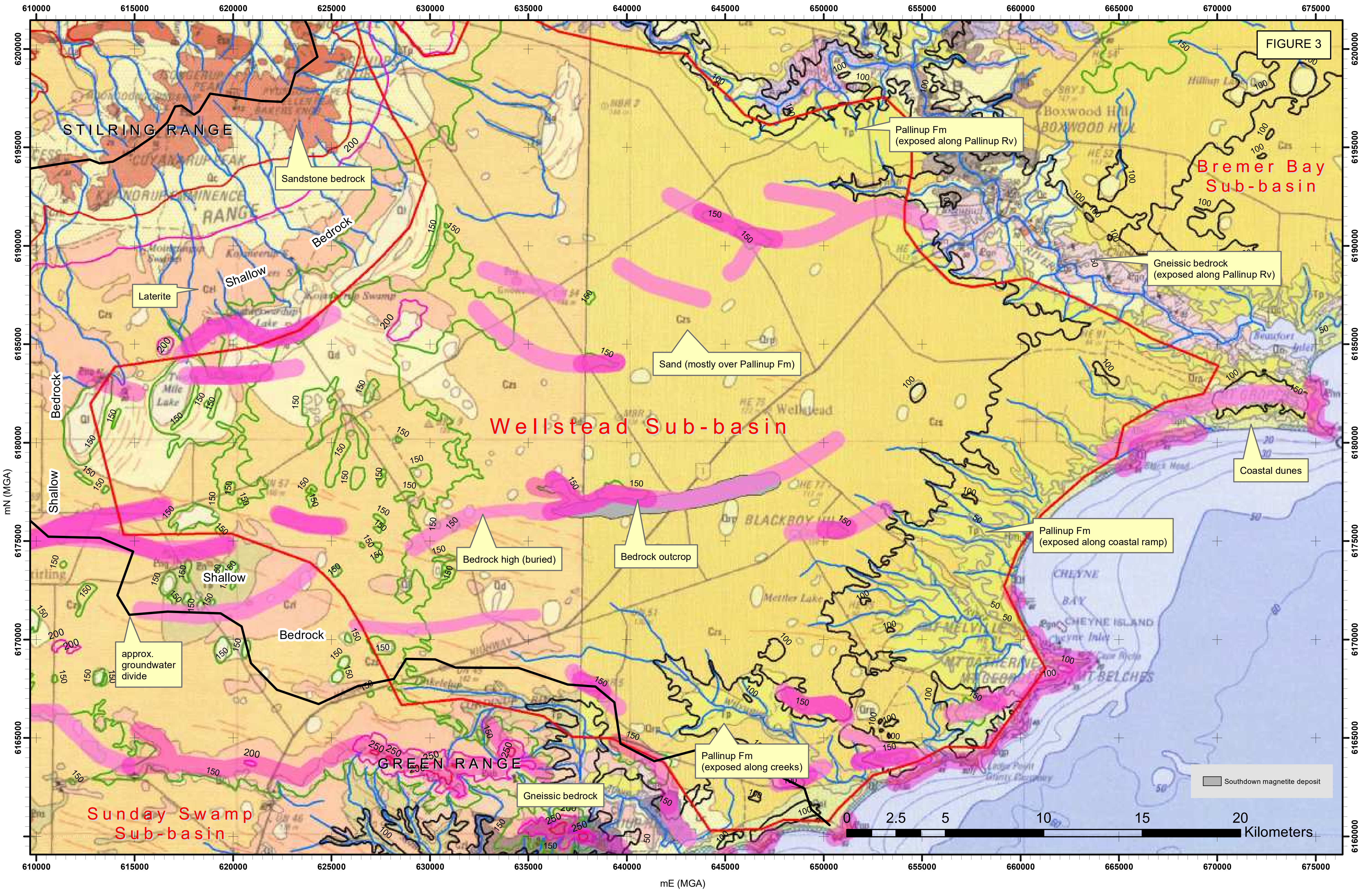

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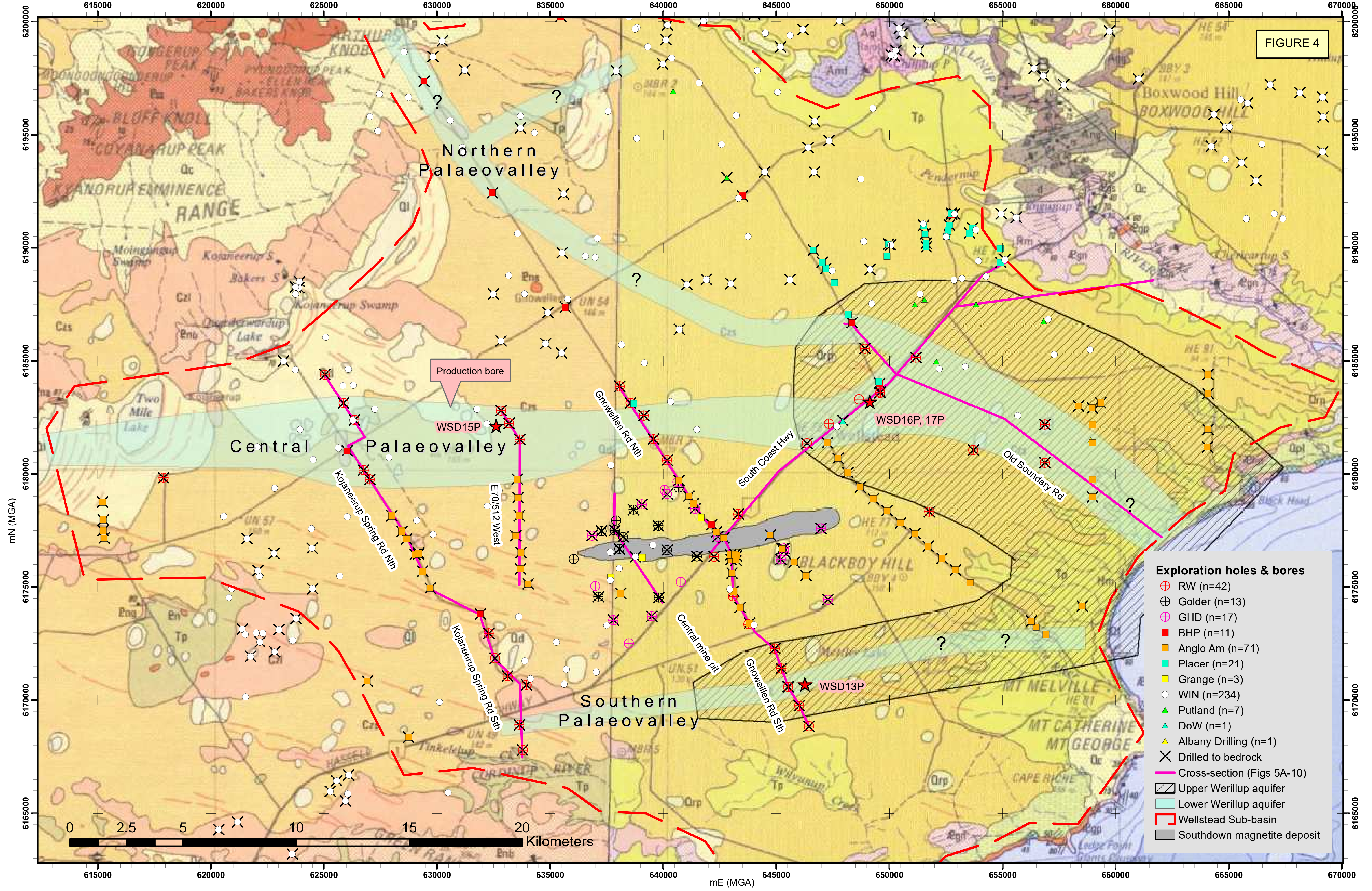
PROJECT: Water Supply Investigation
DATE: Sept. 2017
Dwg No: 216.1.1/17/2-3

WELLSTEAD SUB-BASIN

Rockwater Pty Ltd



CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: Sept. 2017
Dwg No: 216.1.1/17/2-4

BORES, PALAEOVALLEYS AND WERILLUP AQUIEFRS

Rockwater Pty Ltd

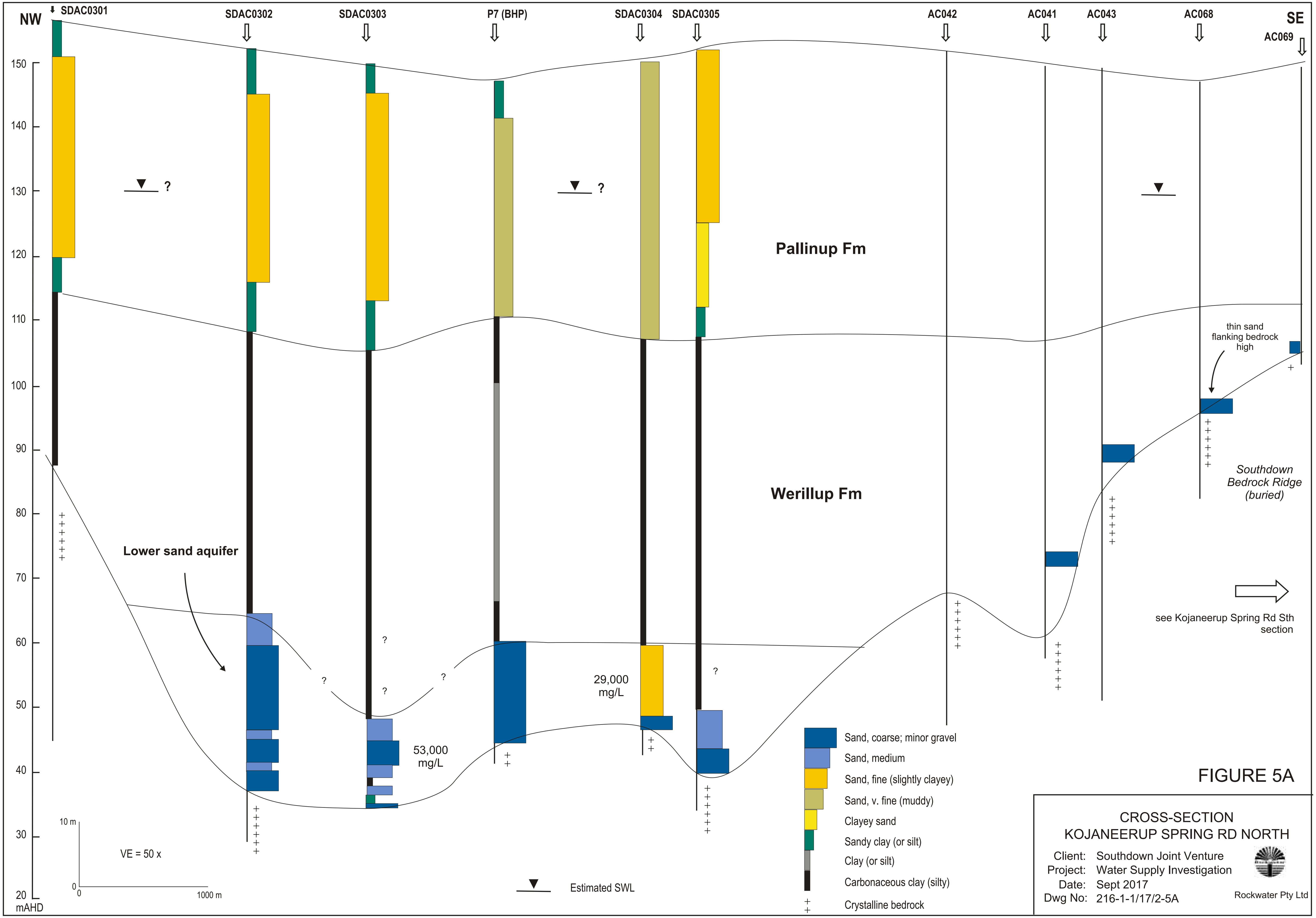


FIGURE 5A

CROSS-SECTION
KOJANEERUP SPRING RD NORTH

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept 2017
Dwg No: 216-1-1/17/2-5A

Rockwater Pty Ltd

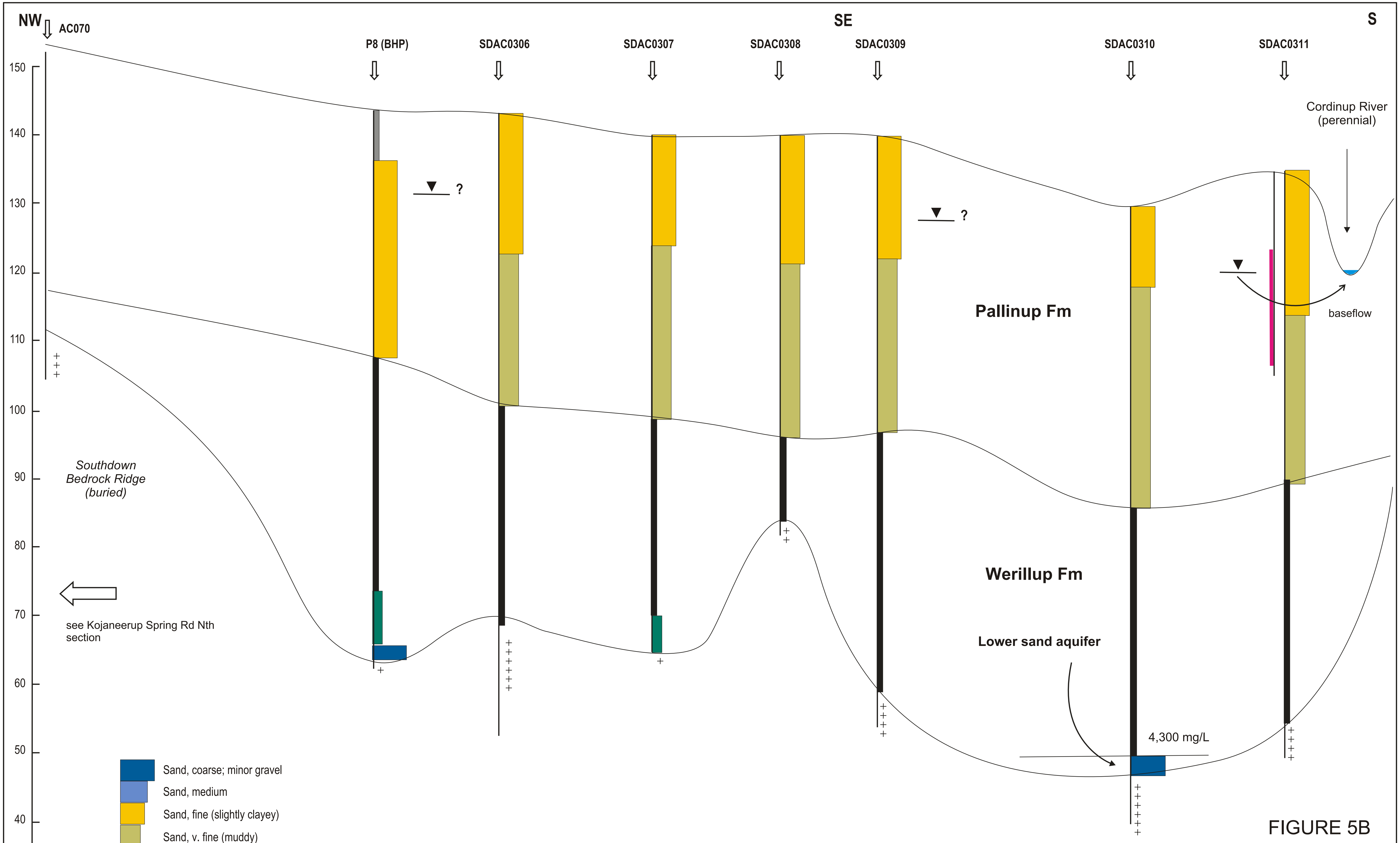
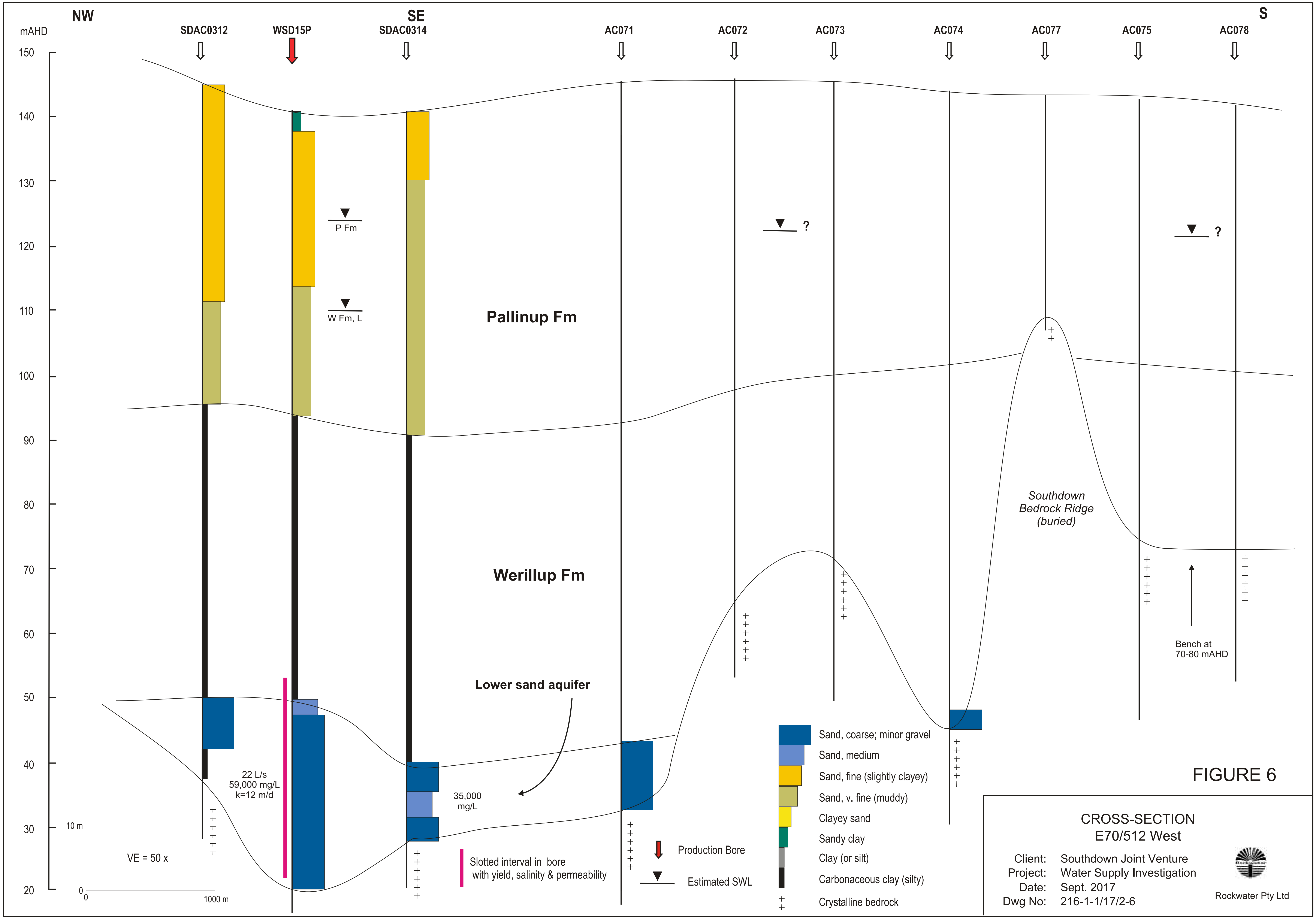


FIGURE 5B

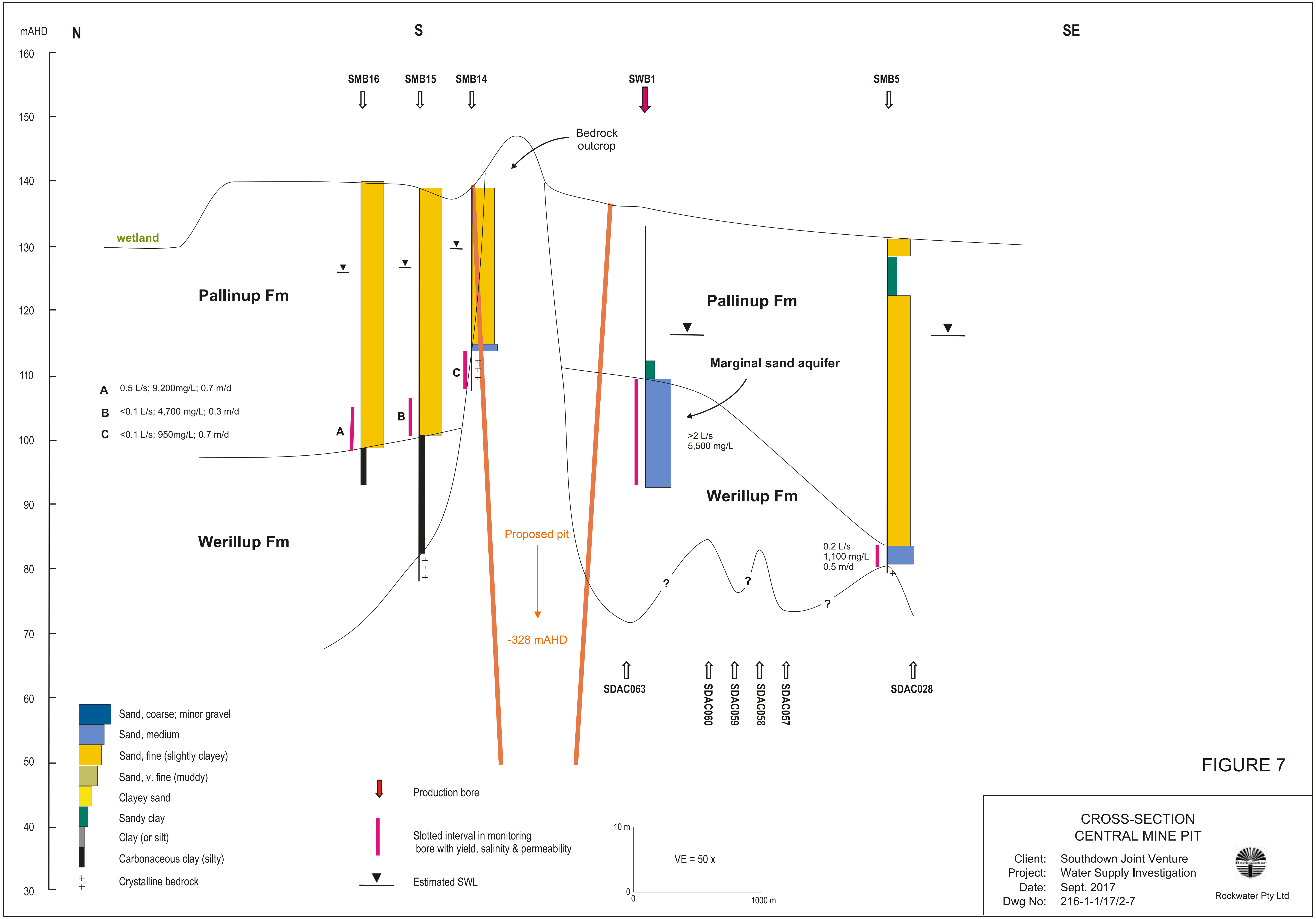
CROSS-SECTION
KOJANEERUP SPRING RD SOUTH

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept 2017
Dwg No: 216-1-1/17/2-5B

Rockwater Pty Ltd



NW
SE
S
mAHD
SDAC0312
WSD15P
SDAC0314
AC071
AC072
AC073
AC074
AC077
AC075
AC078
150
140
130
120
110
100
90
80
70
60
50
40
30
20
P Fm
W Fm, L
?
?
Pallinup Fm
Werillup Fm
Southdown Bedrock Ridge (buried)
Bench at 70-80 mAHD
Lower sand aquifer
22 L/s
59,000 mg/L
k=12 m/d
35,000 mg/L
10 m
0
0
1000 m
VE = 50 x
Slotted interval in bore with yield, salinity & permeability
Production Bore
Estimated SWL
Sand, coarse; minor gravel
Sand, medium
Sand, fine (slightly clayey)
Sand, v. fine (muddy)
Clayey sand
Sandy clay
Clay (or silt)
Carbonaceous clay (silty)
Crystalline bedrock
FIGURE 6
CROSS-SECTION
E70/512 West
Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept. 2017
Dwg No: 216-1-1/17/2-6
Rockwater Pty Ltd


mAHD
N
S
SE
160
150
140
130
120
110
100
90
80
70
60
50
40
30
SMB16
SMB15
SMB14
SWB1
SMB5
Bedrock outcrop
wetland
Pallinup Fm
Pallinup Fm
Marginal sand aquifer
Werillup Fm
Werillup Fm
A 0.5 L/s; 9,200mg/L; 0.7 m/d
B <0.1 L/s; 4,700 mg/L; 0.3 m/d
C <0.1 L/s; 950mg/L; 0.7 m/d
A
B
C
>2 L/s
5,500 mg/L
0.2 L/s
1,100 mg/L
0.5 m/d
Proposed pit
-328 mAHD
?
SDAC063
SDAC060
SDAC059
SDAC058
SDAC057
SDAC028
Sand, coarse; minor gravel
Sand, medium
Sand, fine (slightly clayey)
Sand, v. fine (muddy)
Clayey sand
Sandy clay
Clay (or silt)
Carbonaceous clay (silty)
Crystalline bedrock
Production bore
Slotted interval in monitoring bore with yield, salinity & permeability
Estimated SWL
10 m
0
0
1000 m
VE = 50 x
FIGURE 7
CROSS-SECTION
CENTRAL MINE PIT
Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept. 2017
Dwg No: 216-1-1/17/2-7
Rockwater Pty Ltd

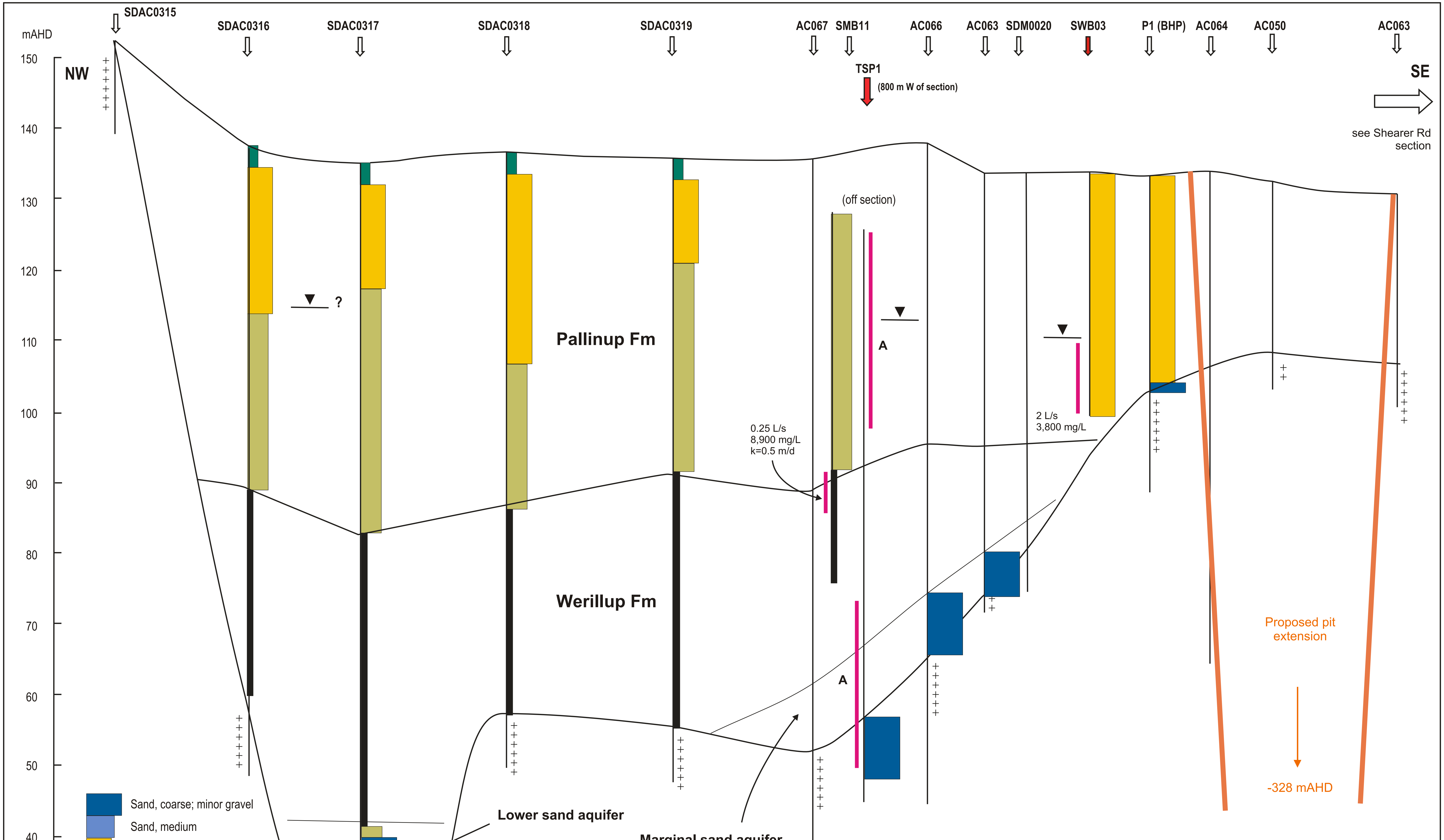


FIGURE 8A

CROSS-SECTION
GNOWELLEN RD

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept. 2017
Dwg No: 216-1-1/17/2-8A

Rockwater Pty Ltd

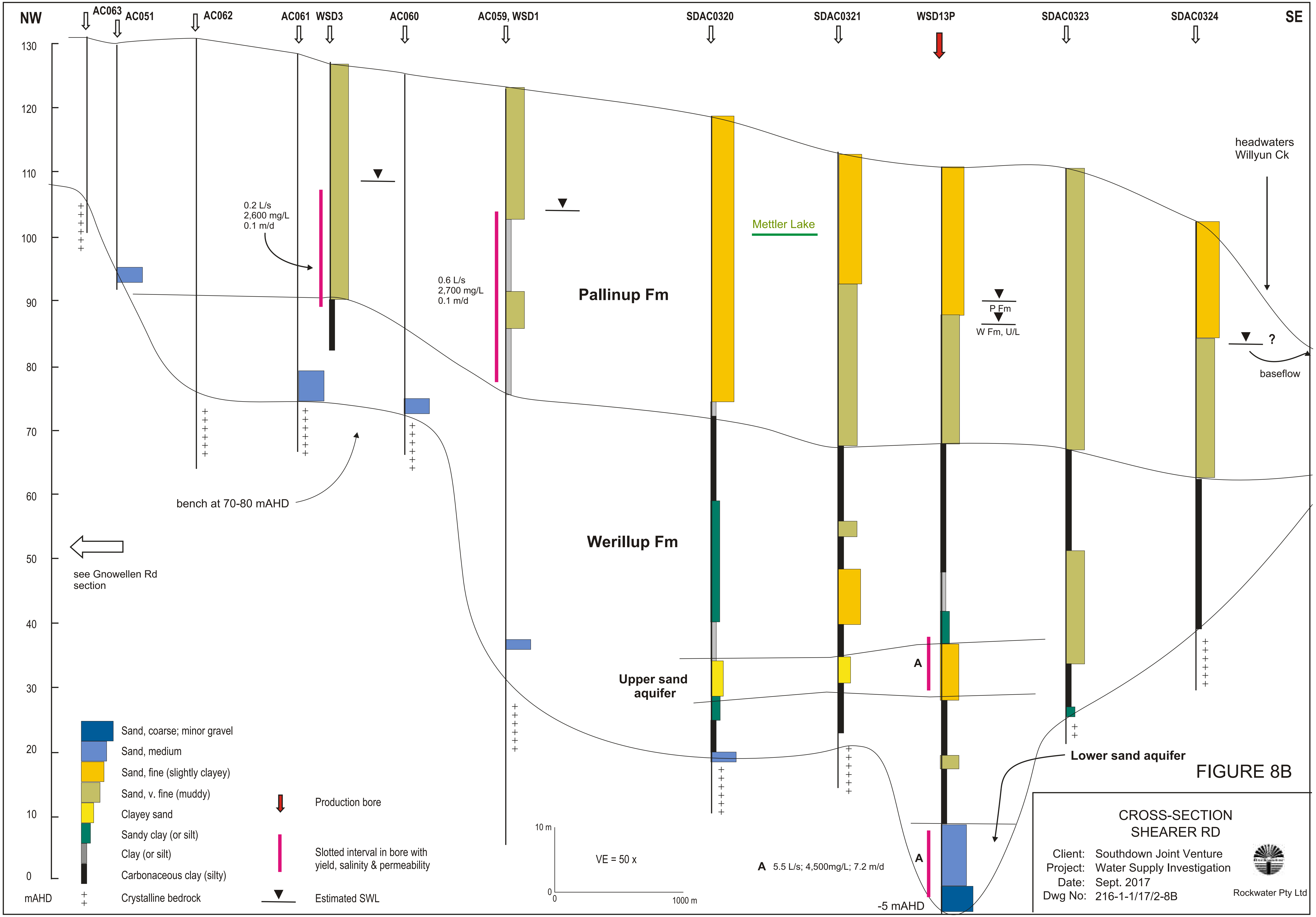
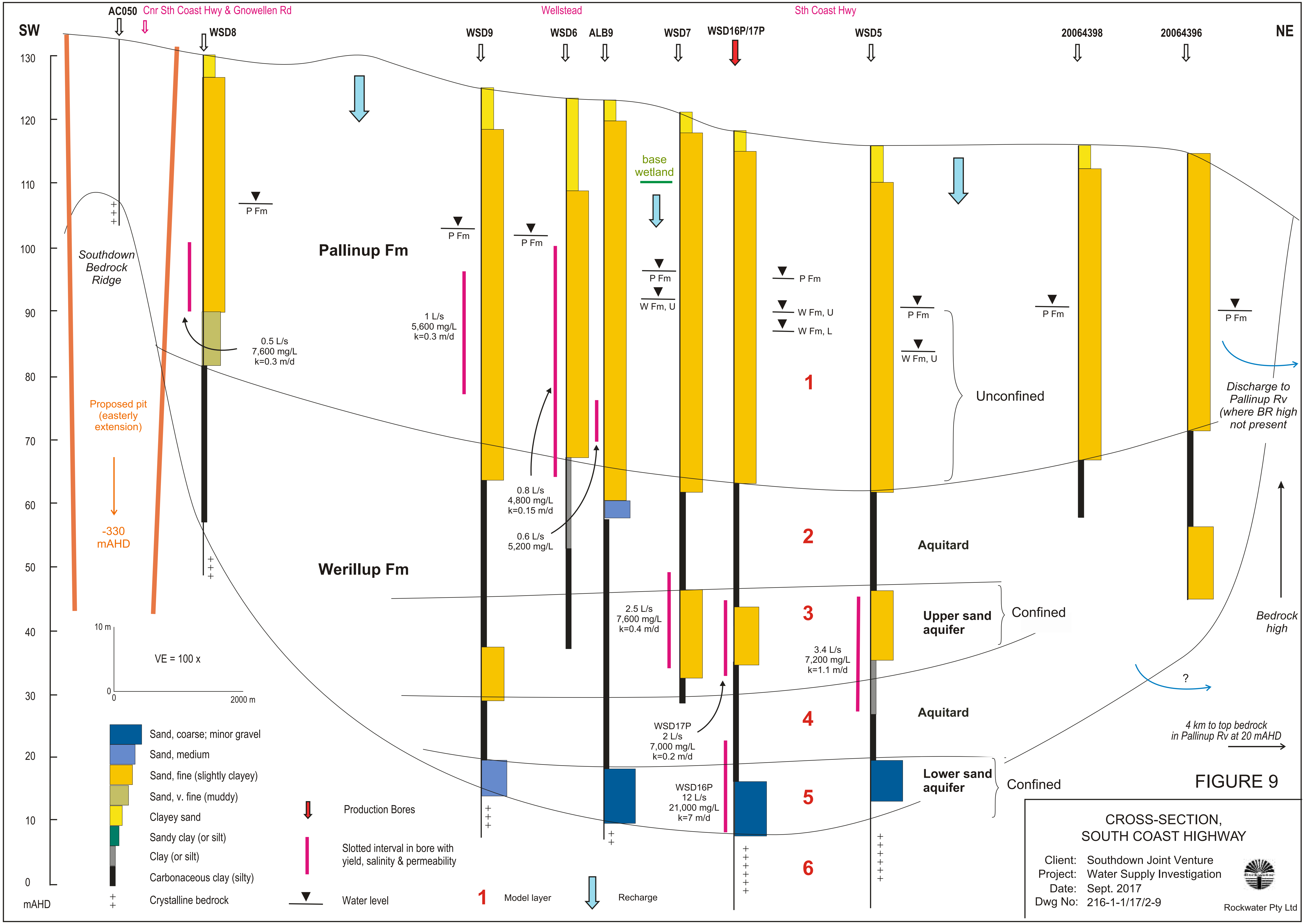


FIGURE 8B

CROSS-SECTION
SHEARER RD

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept. 2017
Dwg No: 216-1-1/17/2-8B

Rockwater Pty Ltd


SW
NE
AC050
Cnr Sth Coast Hwy & Gnowellen Rd
WSD8
Wellstead
Sth Coast Hwy
WSD9
WSD6
ALB9
WSD7
WSD16P/17P
WSD5
20064398
20064396
Southdown Bedrock Ridge
Proposed pit (easterly extension)
-330 mAHD
Pallinup Fm
Werillup Fm
base wetland
P Fm
W Fm, U
W Fm, L
0.5 L/s 7,600 mg/L k=0.3 m/d
1 L/s 5,600 mg/L k=0.3 m/d
0.8 L/s 4,800 mg/L k=0.15 m/d
0.6 L/s 5,200 mg/L
2.5 L/s 7,600 mg/L k=0.4 m/d
WSD17P 2 L/s 7,000 mg/L k=0.2 m/d
WSD16P 12 L/s 21,000 mg/L k=7 m/d
3.4 L/s 7,200 mg/L k=1.1 m/d
1
2
3
4
5
6
Unconfined
Aquitard
Upper sand aquifer
Confined
Aquitard
Lower sand aquifer
Confined
Discharge to Pallinup Rv (where BR high not present
Bedrock high
?
4 km to top bedrock in Pallinup Rv at 20 mAHD
10 m
0
0
2000 m
VE = 100 x
mAHD
Sand, coarse; minor gravel
Sand, medium
Sand, fine (slightly clayey)
Sand, v. fine (muddy)
Clayey sand
Sandy clay (or silt)
Clay (or silt)
Carbonaceous clay (silty)
Crystalline bedrock
Production Bores
Slotted interval in bore with yield, salinity & permeability
Water level
Model layer
Recharge
FIGURE 9
CROSS-SECTION, SOUTH COAST HIGHWAY
Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept. 2017
Dwg No: 216-1-1/17/2-9
Rockwater Pty Ltd

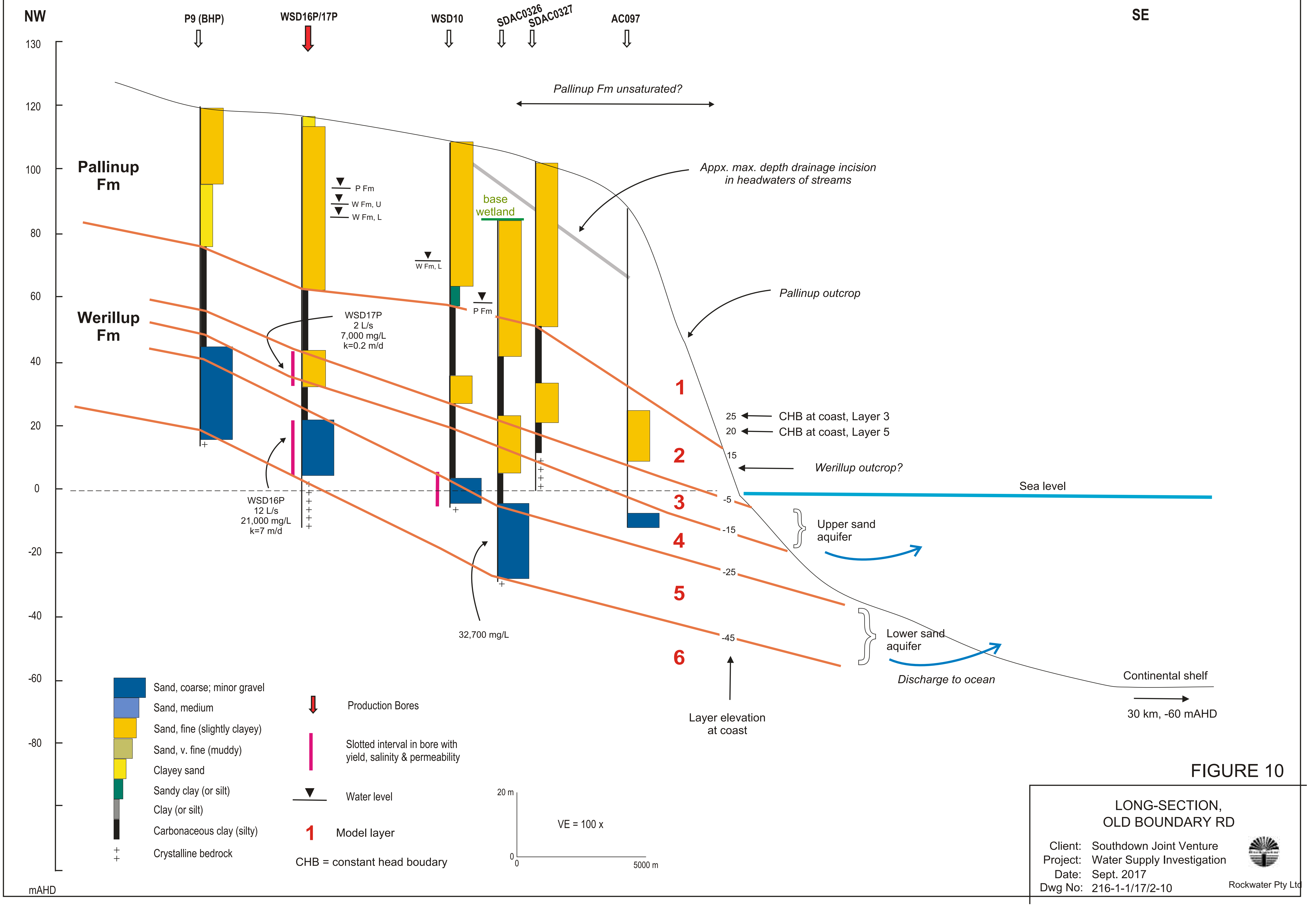
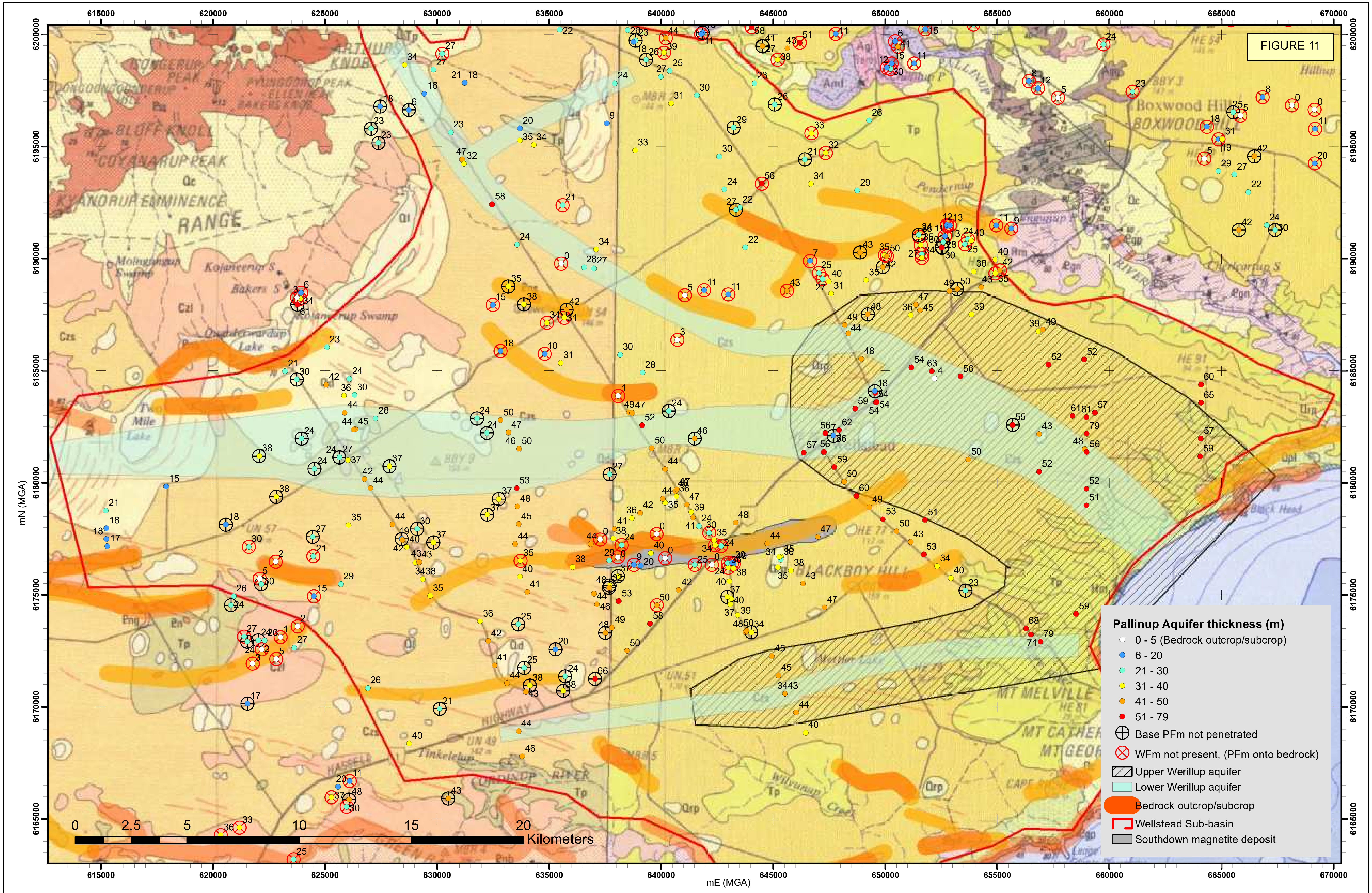


FIGURE 10

LONG-SECTION, OLD BOUNDARY RD

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept. 2017
Dwg No: 216-1-1/17/2-10

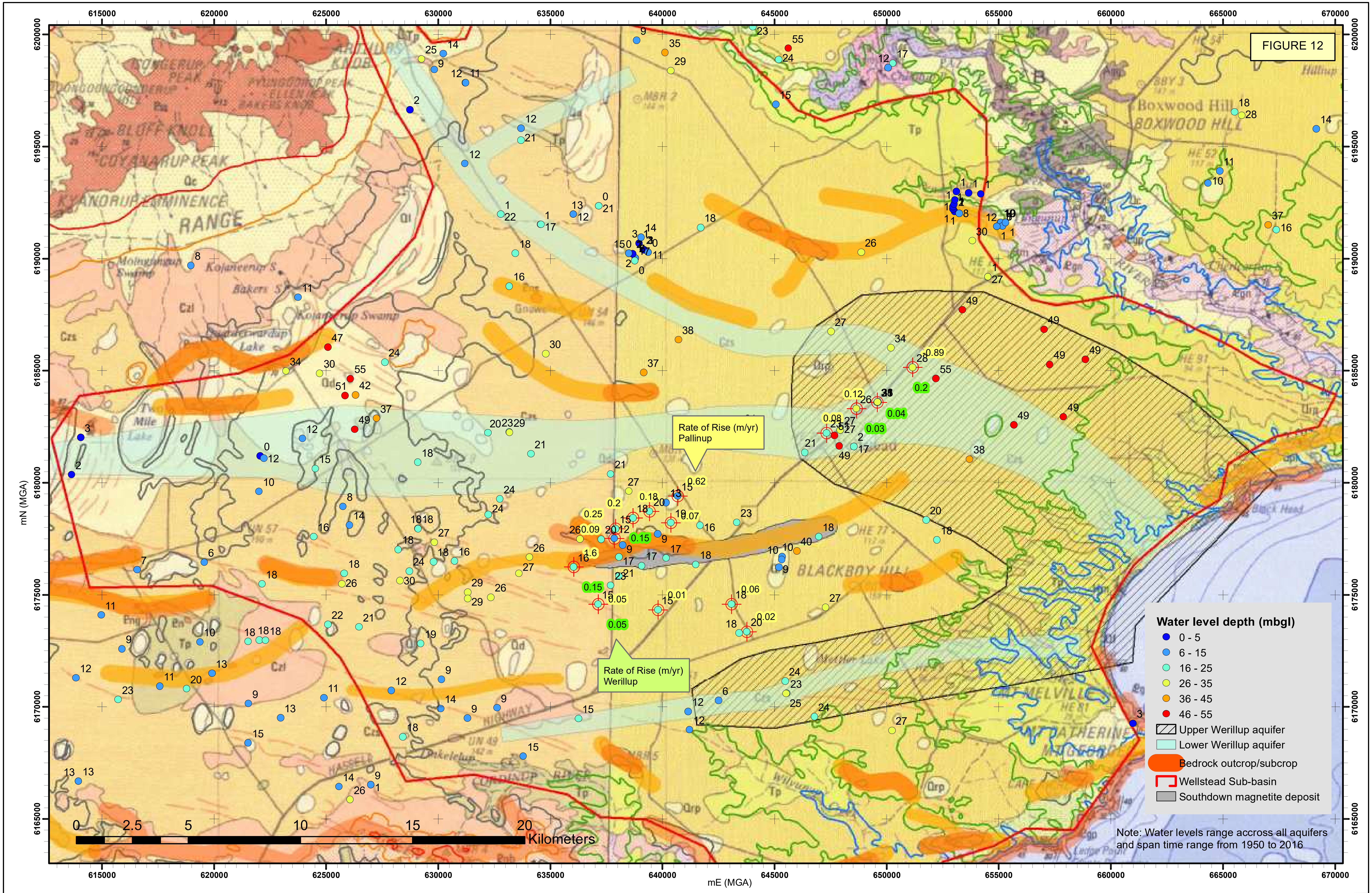
Rockwater Pty Ltd



CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: Sept. 2017
Dwg No: 216.1.1/17/2-11

THICKNESS OF PALLINUP FORMATION

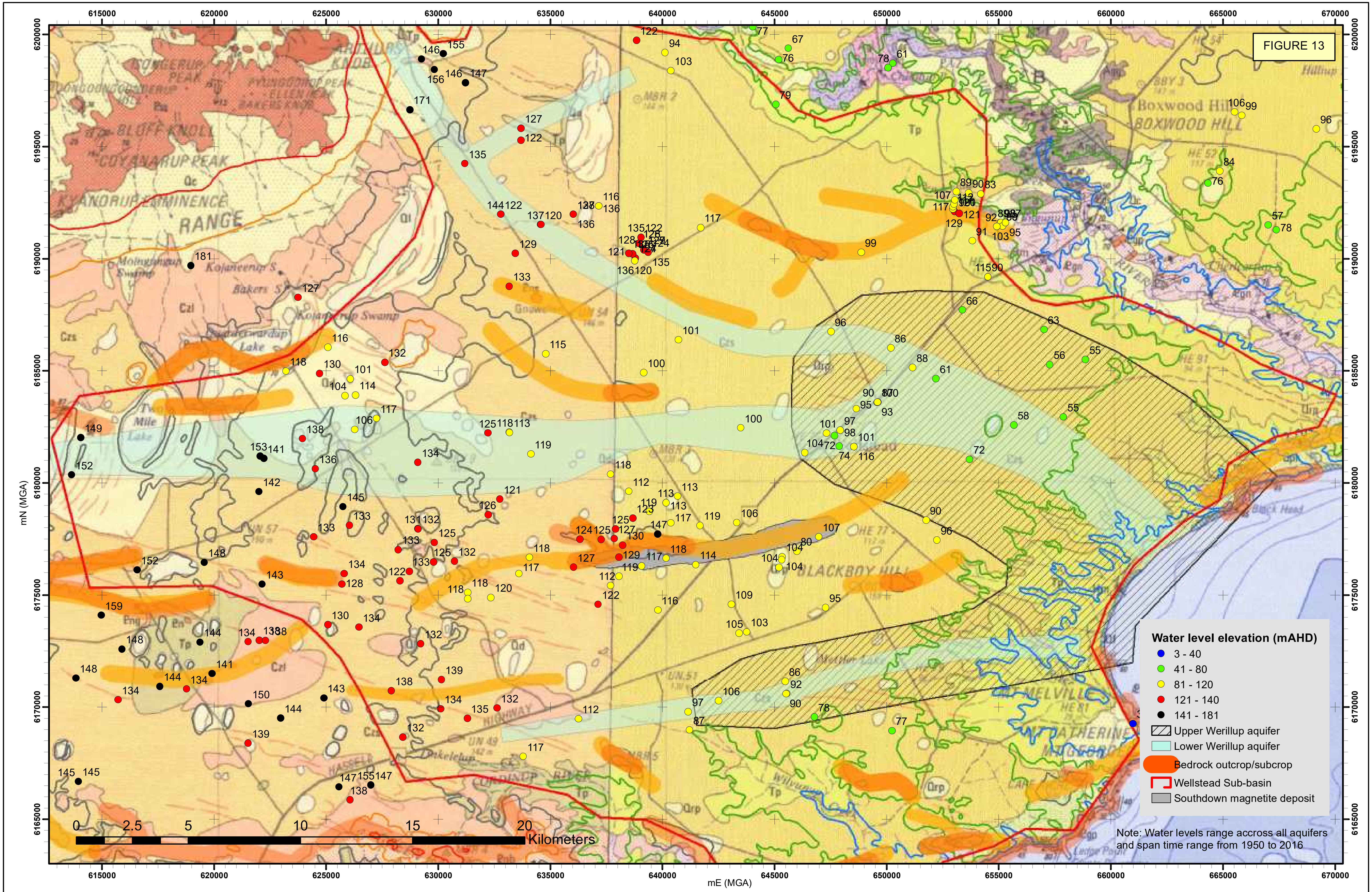
Rockwater Pty Ltd



CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: Sept. 2017
Dwg No: 216.1.1/17/2-12

GROUNDWATER LEVEL DEPTH AND RATE OF RISE

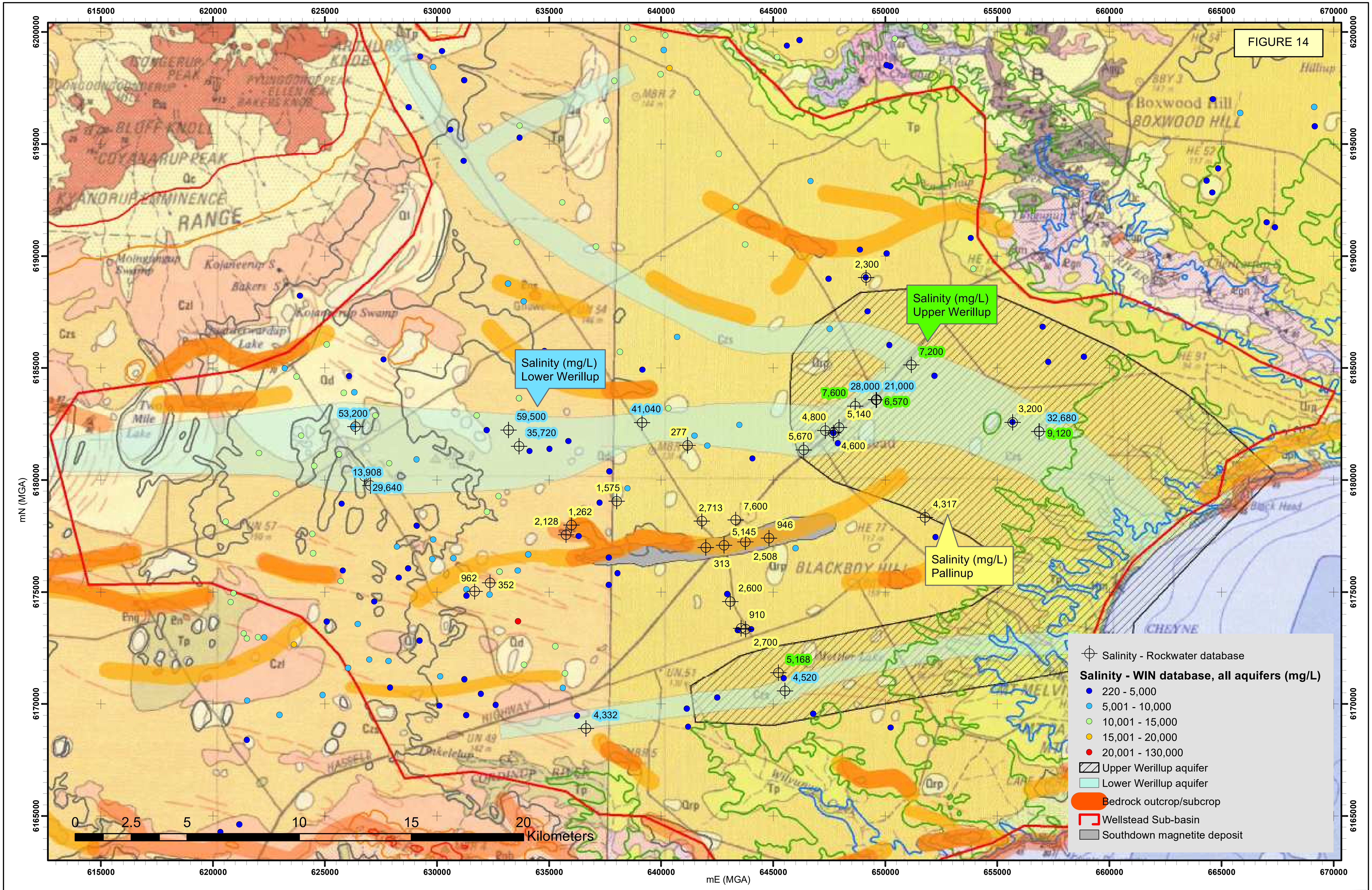
Rockwater Pty Ltd



CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: Sept. 2017
Dwg No: 216.1.1/17/2-13

GROUNDWATER LEVEL ELEVATION

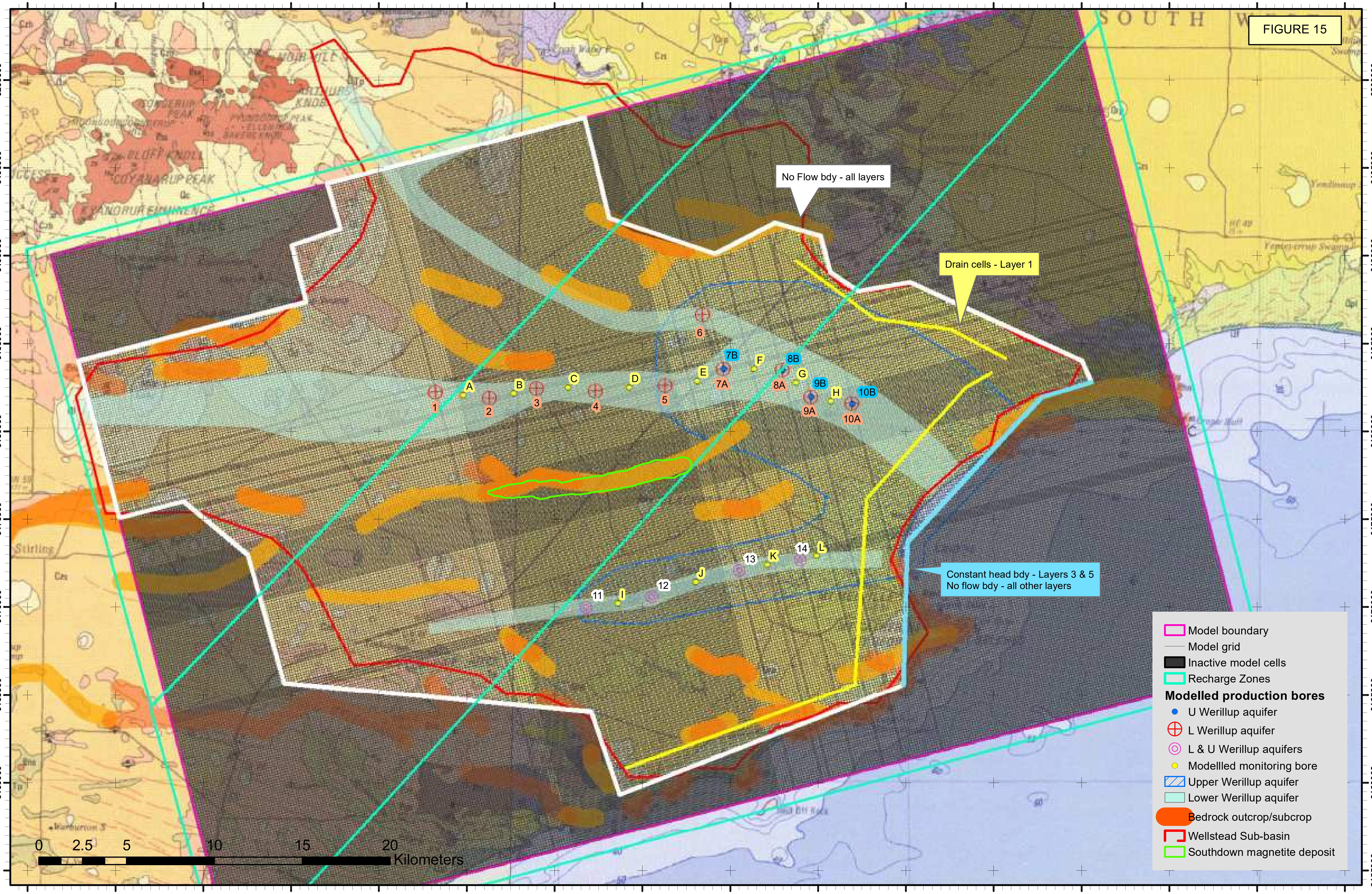
Rockwater Pty Ltd



CLIENT:	Southdown Joint Venture
PROJECT:	Water Supply Investigation
DATE:	Sept. 2017
Dwg No:	216.1.1/17/2-14

GROUNDWATER SALINITY

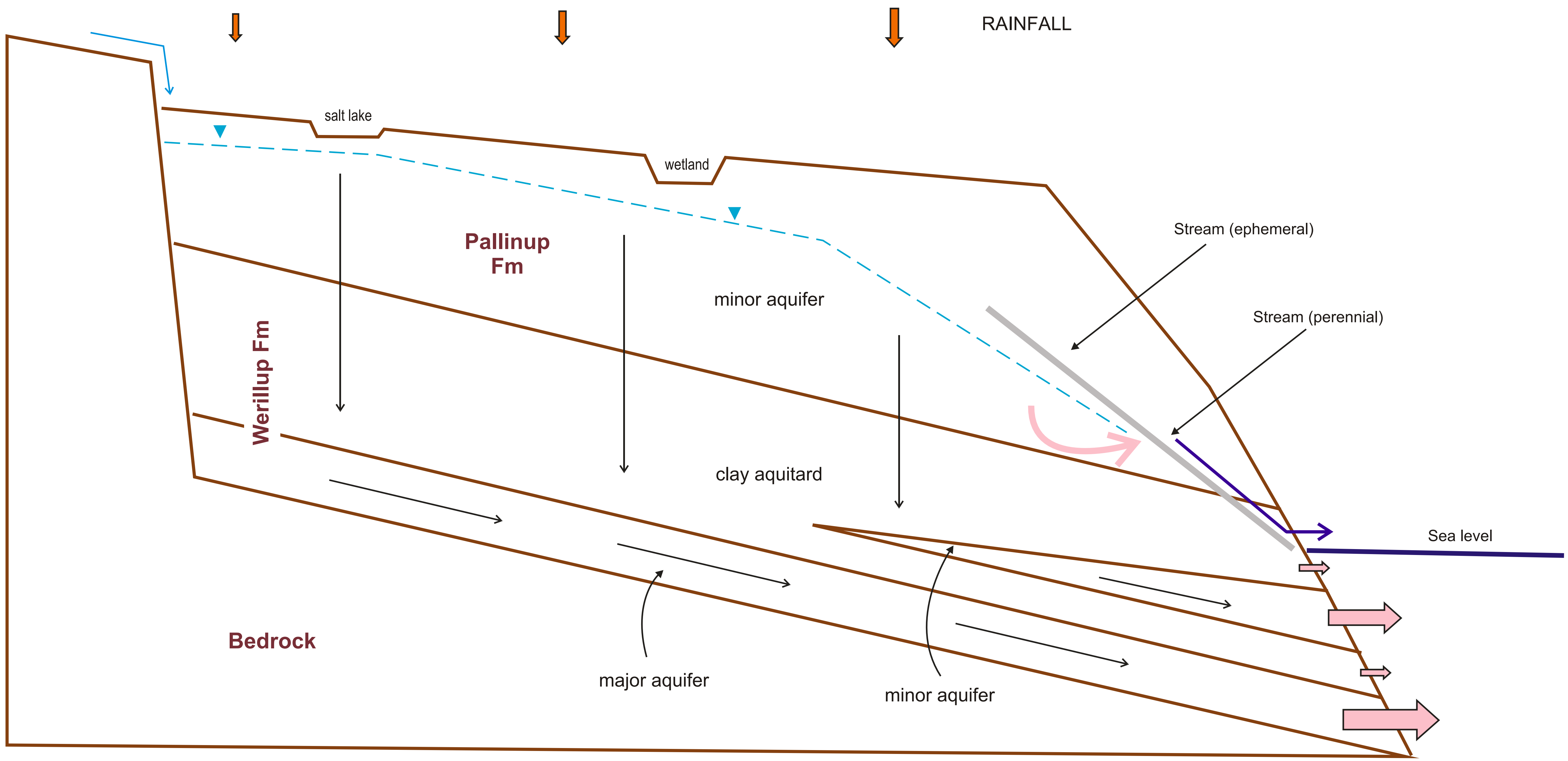
Rockwater Pty Ltd



CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: Sept. 2017
Dwg No: 216.1.1/17/2-15

MODEL DOMAIN AND BORE LOCATIONS

Rockwater Pty Ltd



NOT TO SCALE

FIGURE 16

CONCEPTUAL GROUNDWATER FLOW SYSTEM

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept. 2017
Dwg No: 216-1-1/17/2-16

Rockwater Pty Ltd

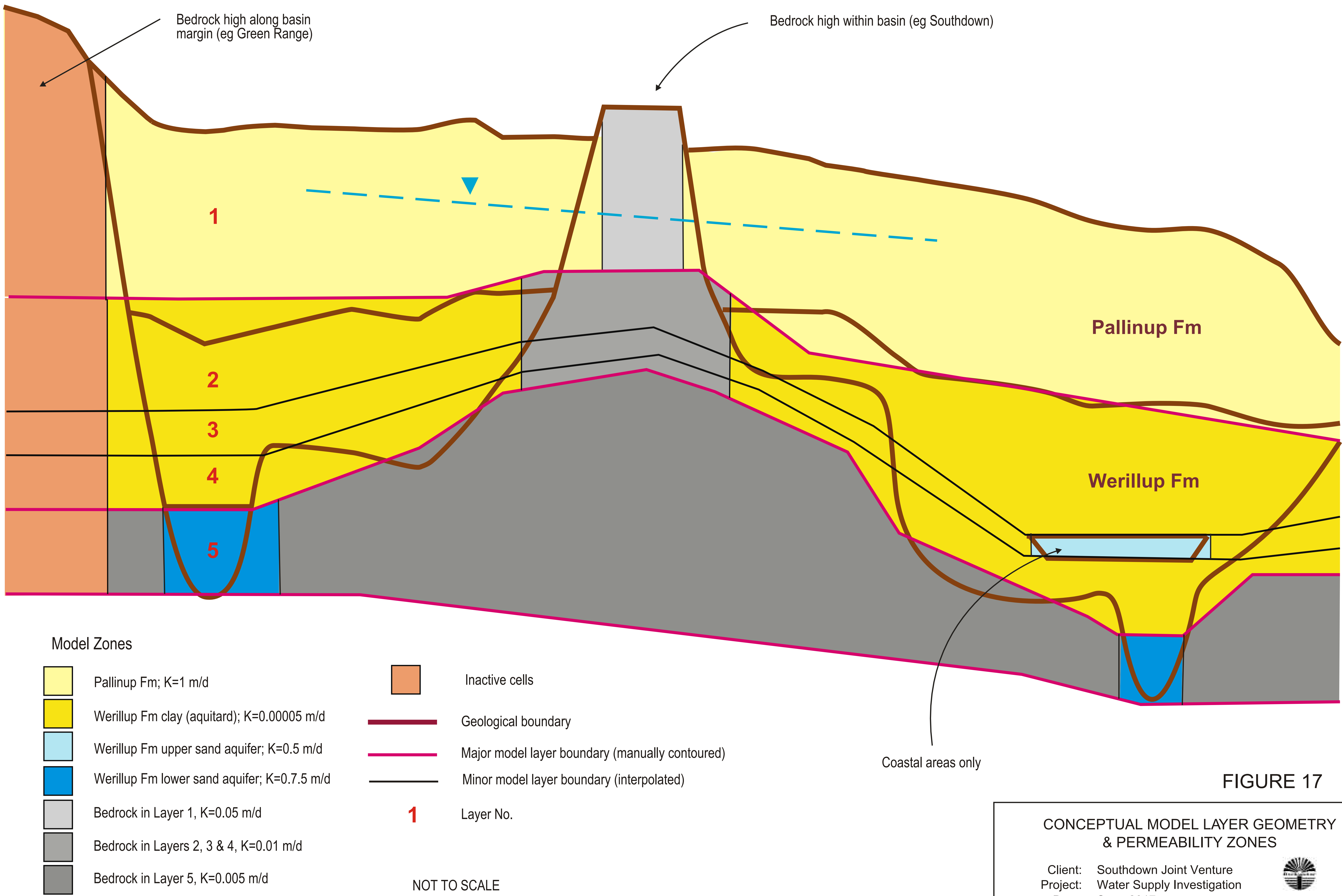
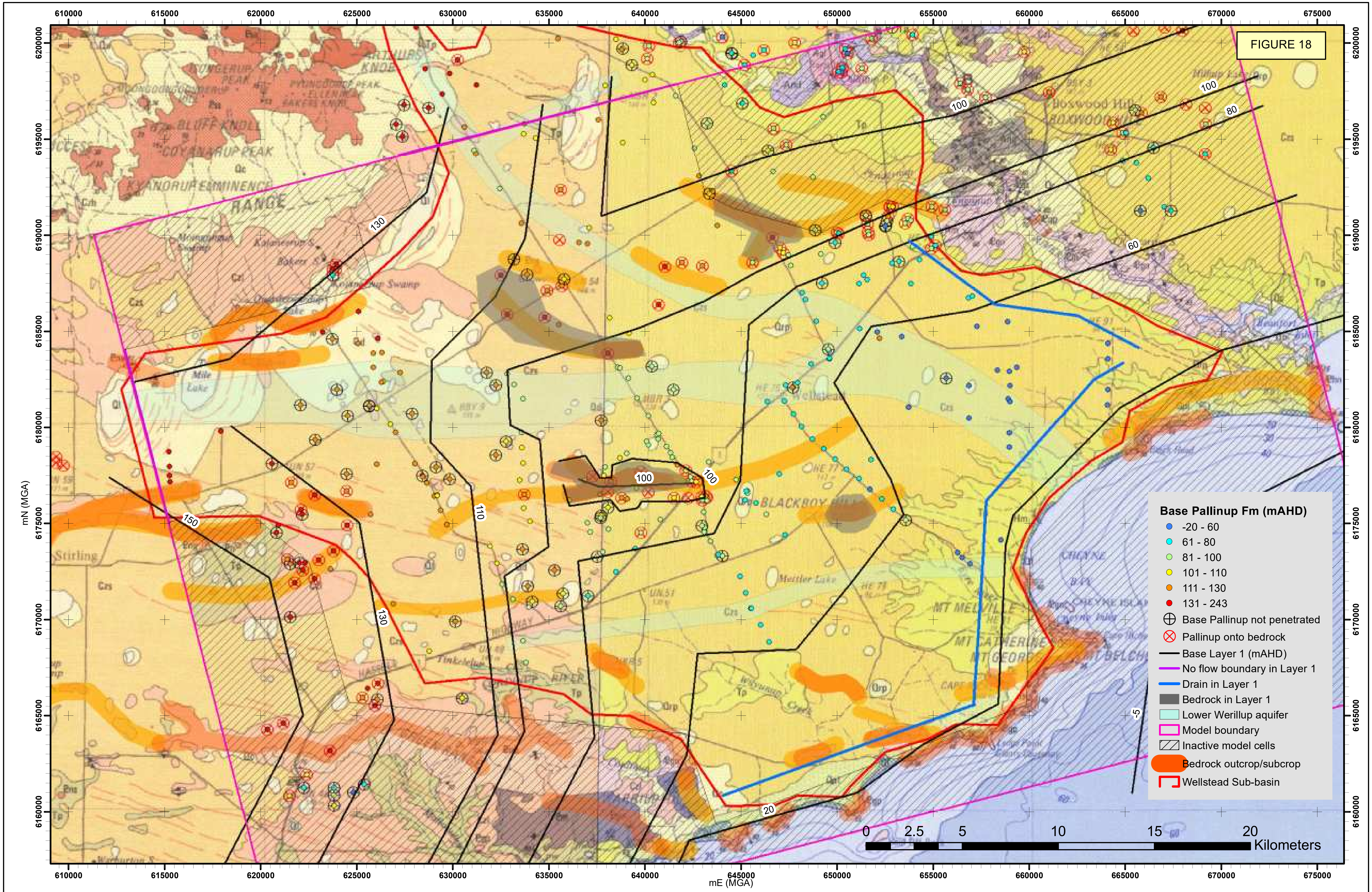


FIGURE 17

CONCEPTUAL MODEL LAYER GEOMETRY & PERMEABILITY ZONES

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept. 2017
Dwg No: 216-1-1/17/2-17

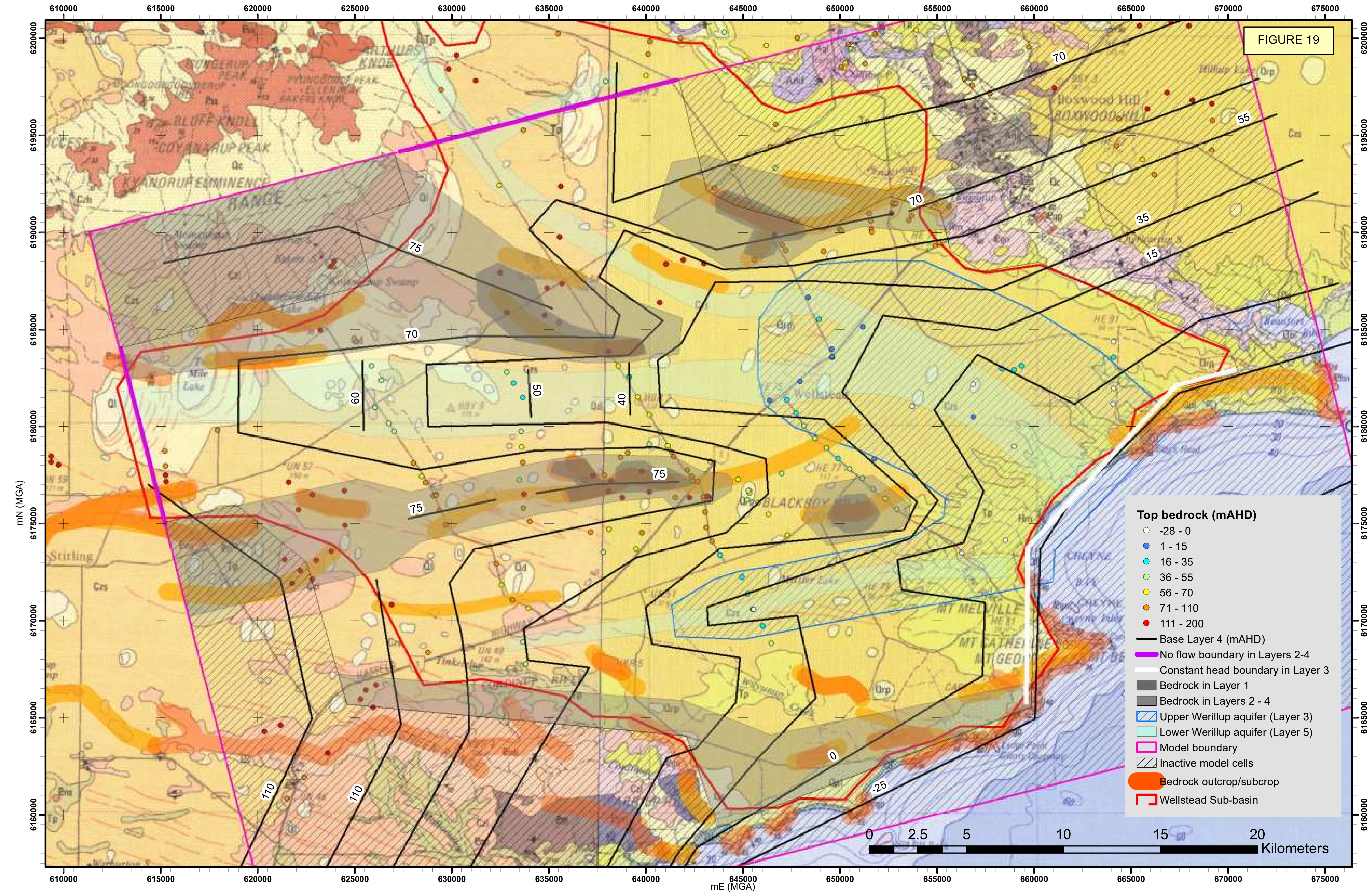
Rockwater Pty Ltd



CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: Sept. 2017
Dwg No: 216.1.1/17/2-18

DETAILS OF MODEL LAYER 1

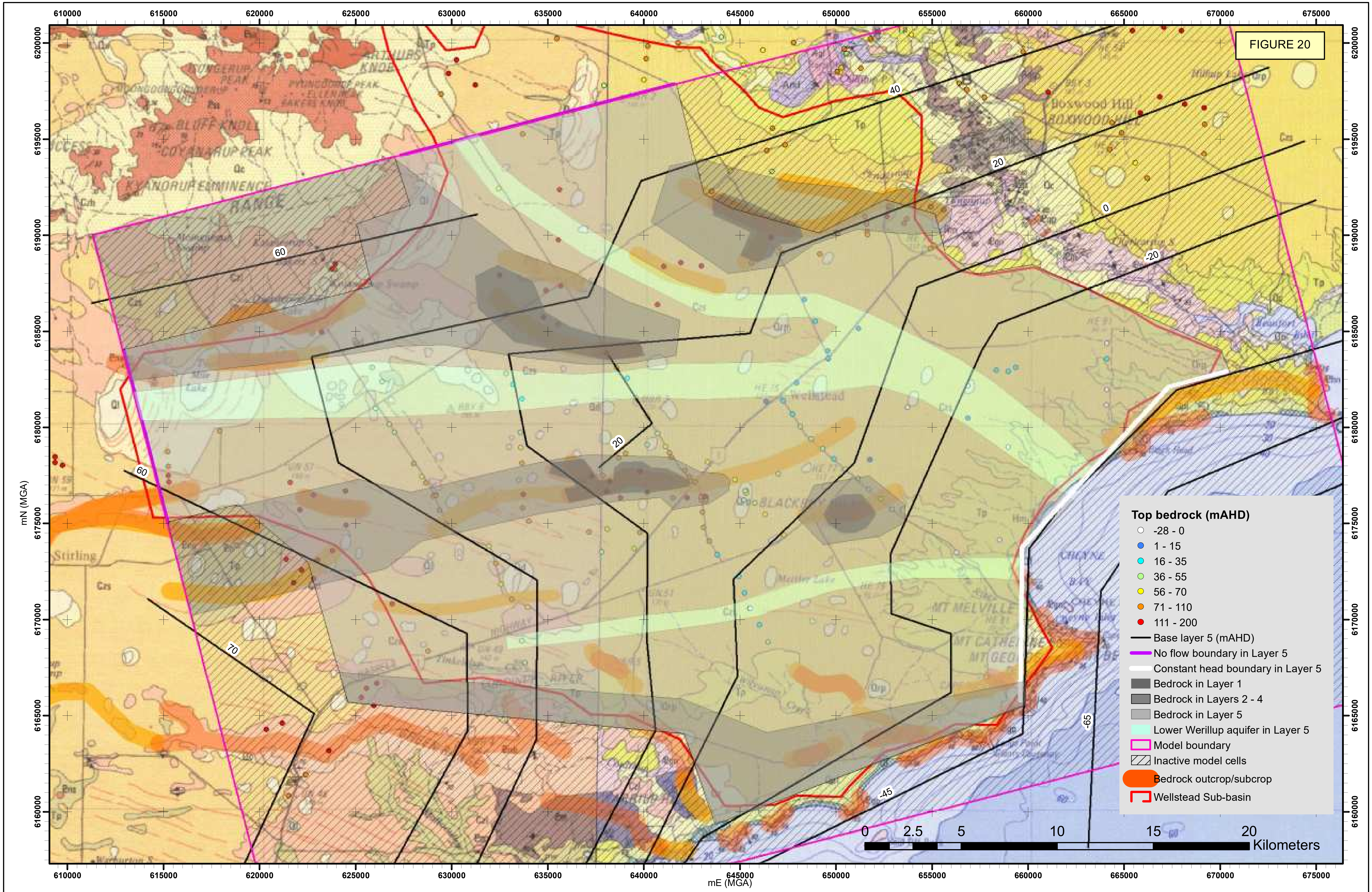
Rockwater Pty Ltd



CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: Sept. 2017
Dwg No: 216.1.1/17/2-19

DETAILS OF MODEL LAYERS 2, 3 AND 4

Rockwater Pty Ltd

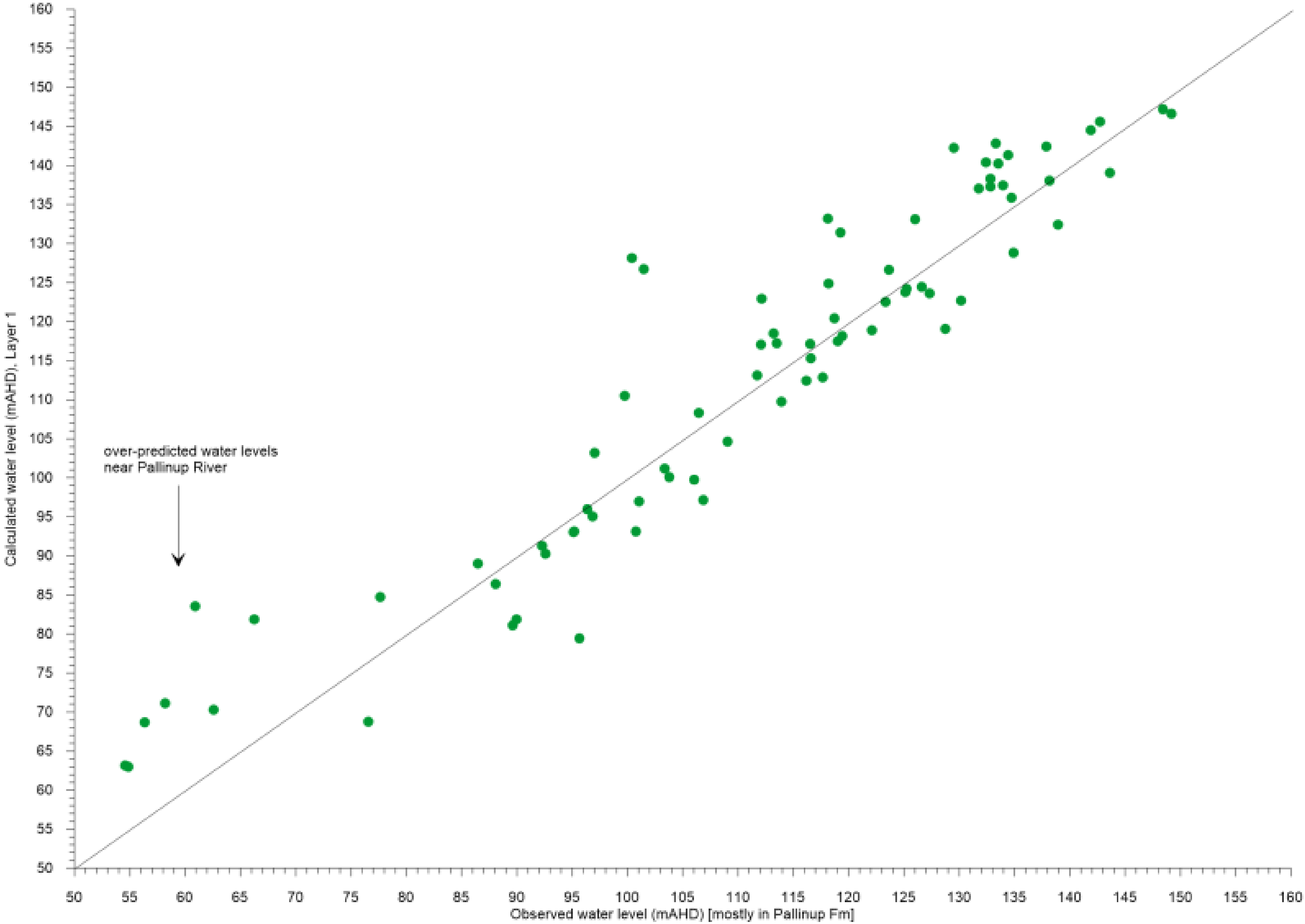


CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: Sept. 2017
Dwg No: 216.1.1/17/2-20

DETAILS OF MODEL LAYER 5

Rockwater Pty Ltd

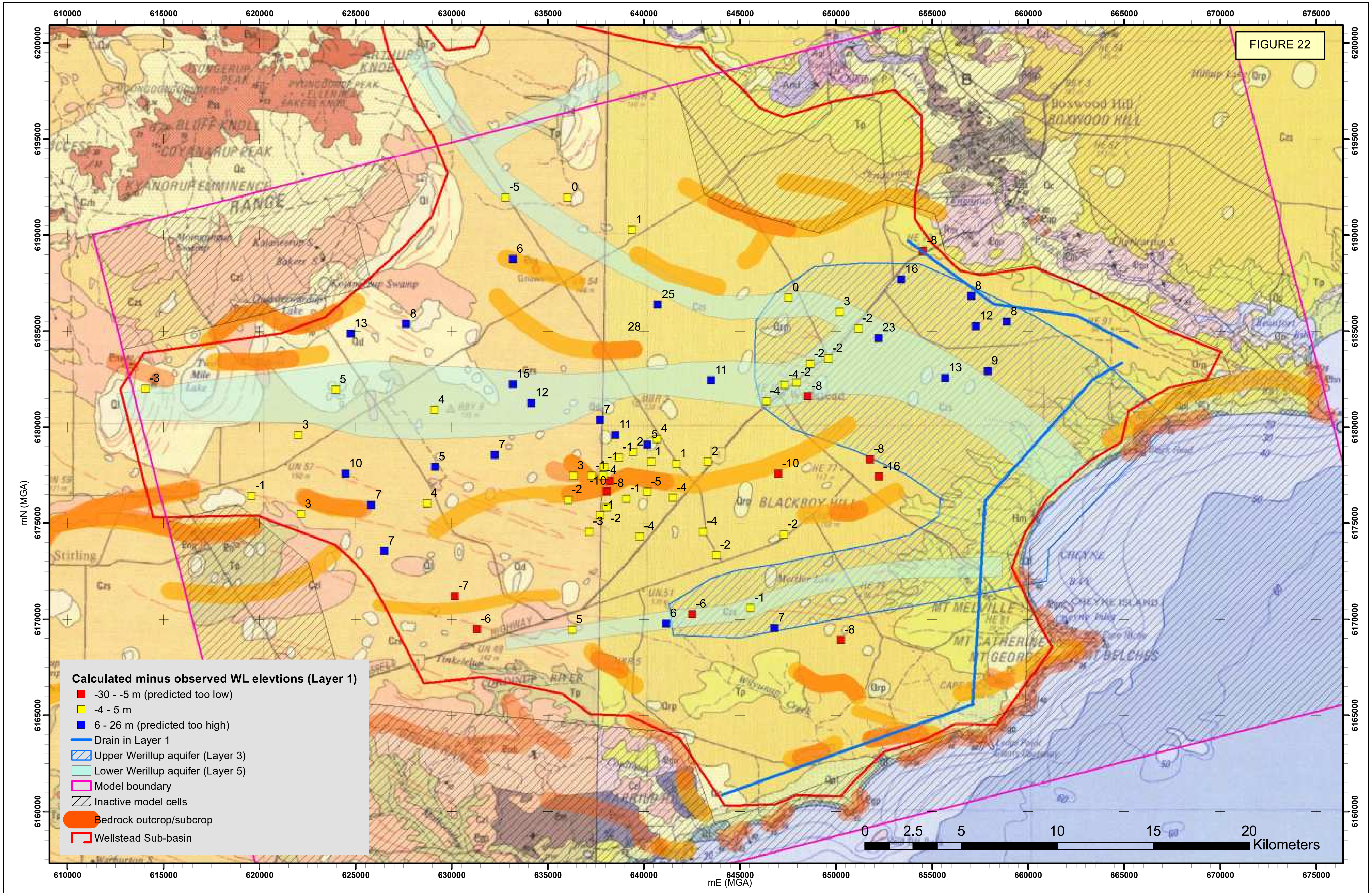
FIGURE 21



STEADY-STATE CALIBRATION PLOT

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept. 2017
Ref: 216.1.1/17/2-21

Rockwater Pty Ltd

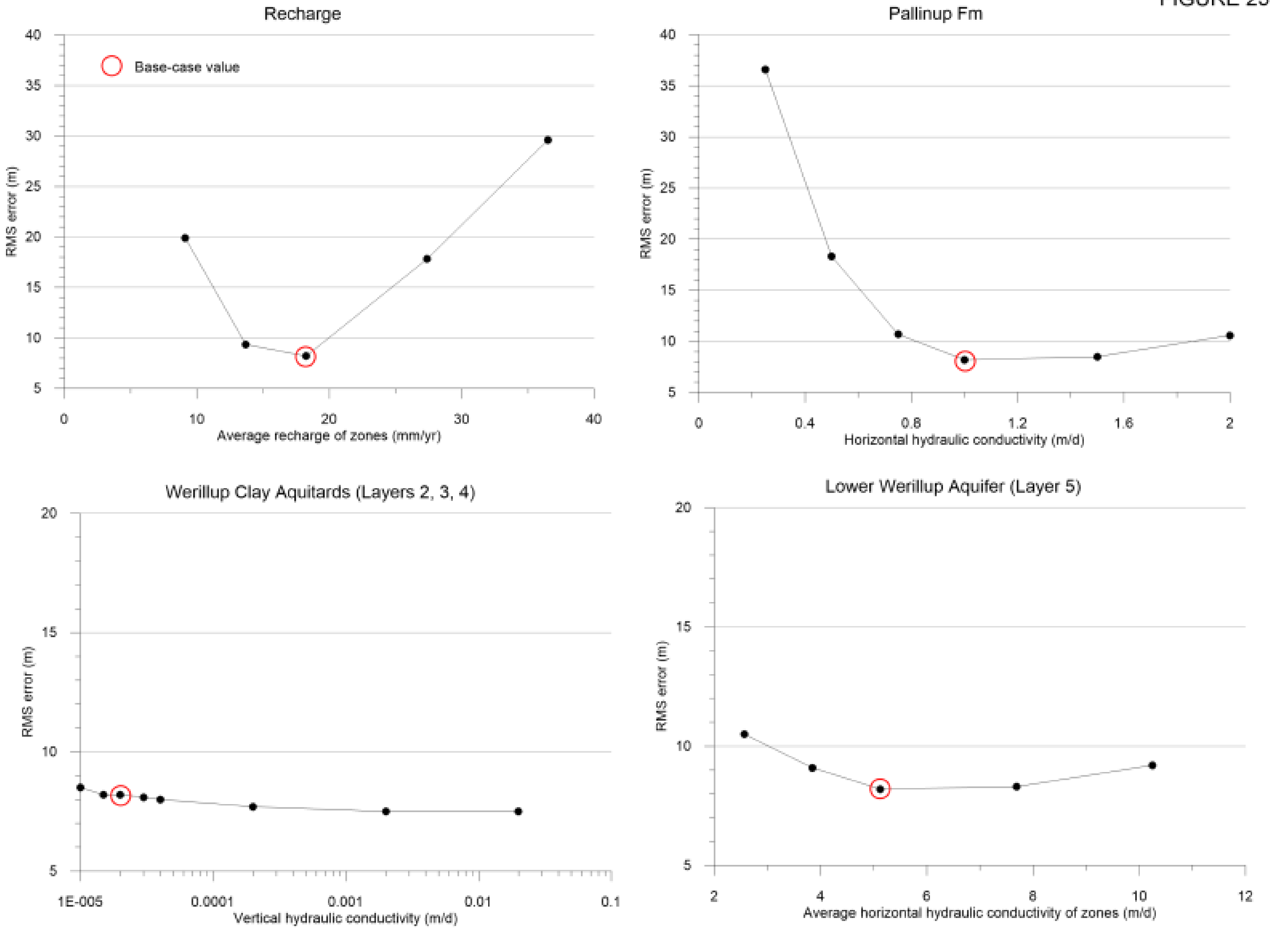


CLIENT:	Southdown Joint Venture
PROJECT:	Water Supply Investigation
DATE:	Sept. 2017
Dwg No:	216.1.1/17/2-22

SPATIAL DISTRIBUTION OF STEADY-STATE RESIDUALS

Rockwater Pty Ltd

FIGURE 23



SENSITIVITY OF PARAMETERS IN STEADY-STATE CALIBRATION

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept. 2017
Ref: 216.1.1/17/2-23

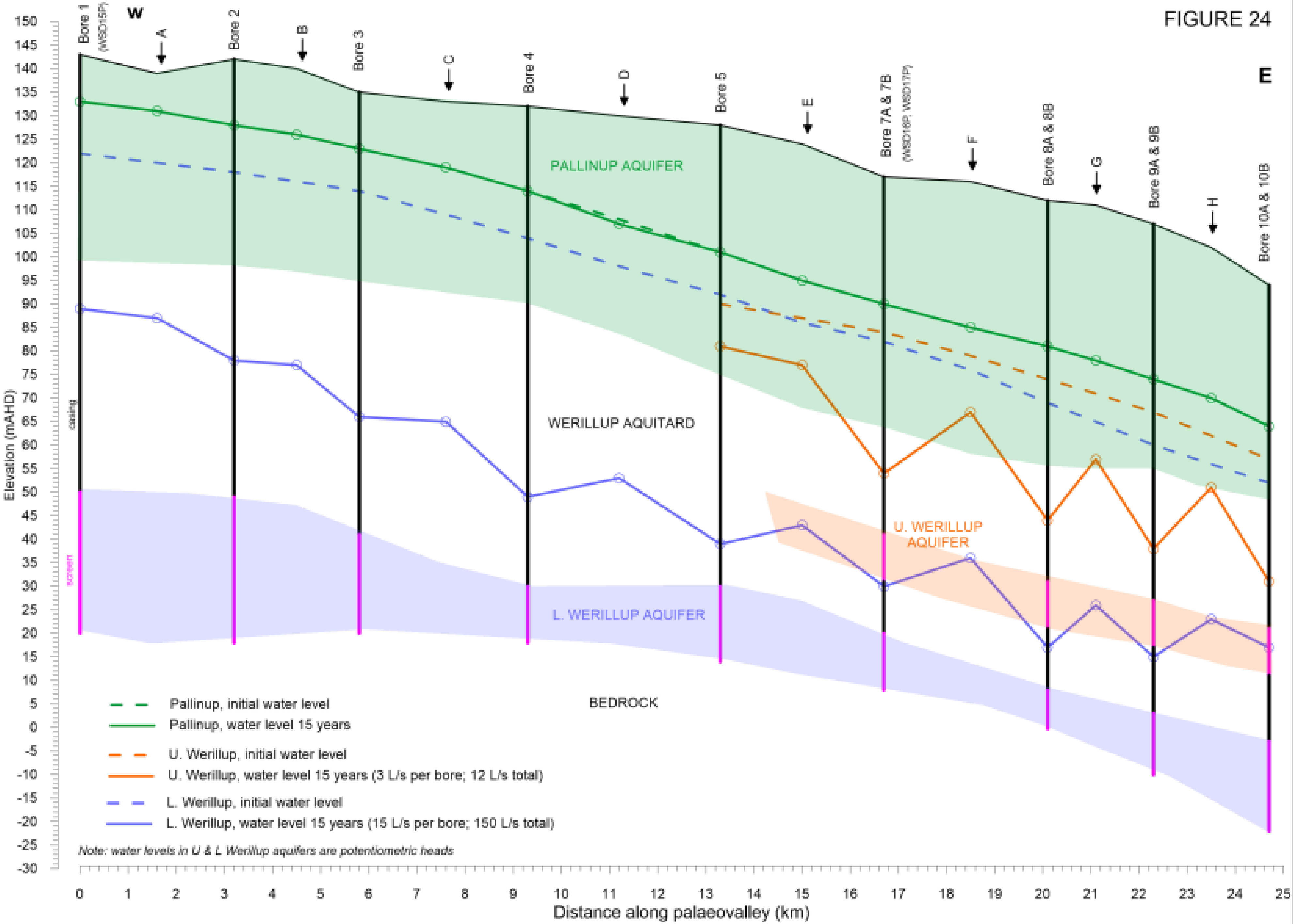
Rockwater Pty Ltd

Client: SDJV
Project: Water Supply Investigation
Date: Sept 2017
Ref: 216.1.1/17/2-24

CENTRAL PALAEOVALLEY,
MODELLED WATER LEVELS AFTER 15 YEARS

Rockwater Pty Ltd

FIGURE 24

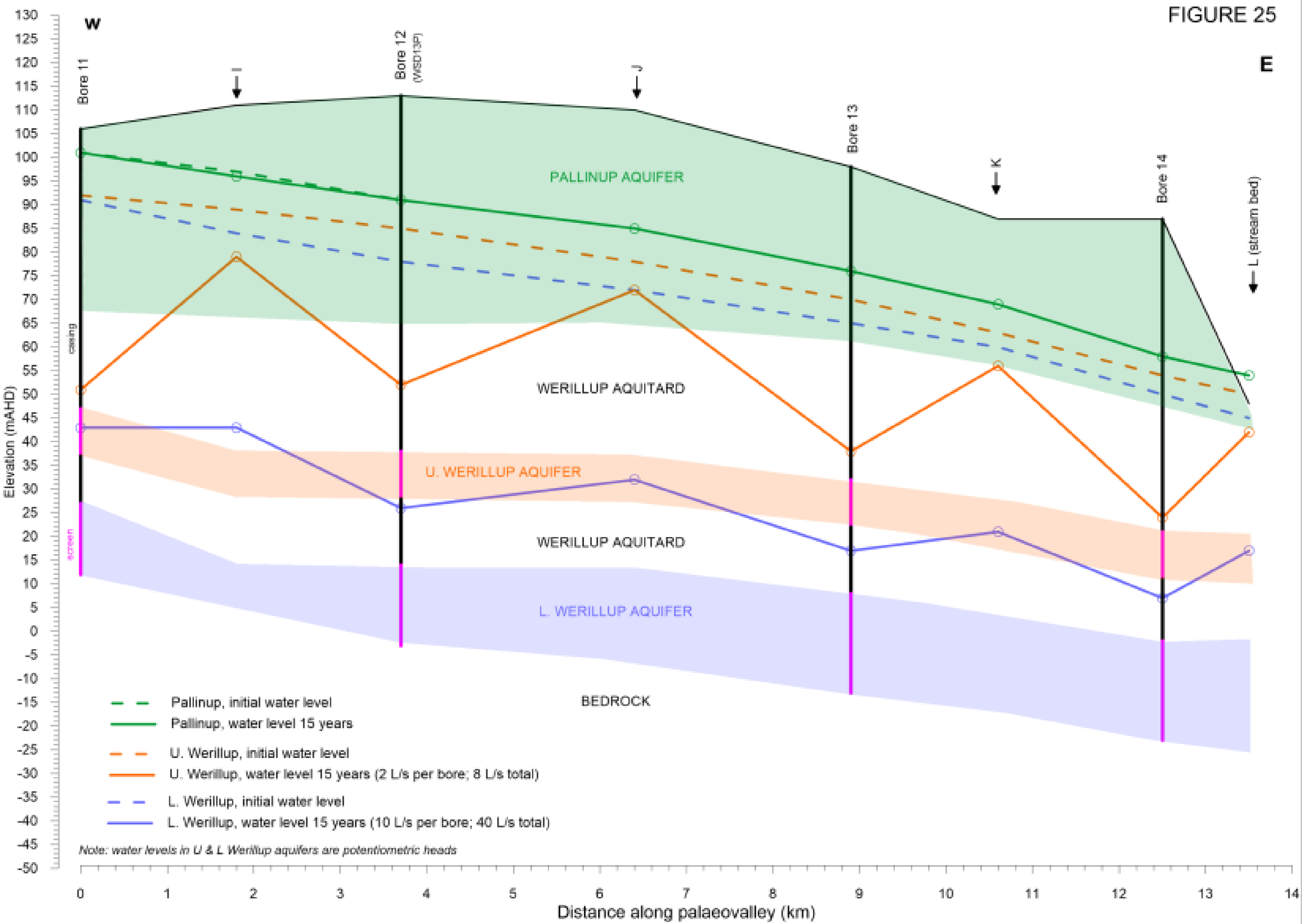


Client: SDJV
Project: Water Supply Investigation
Date: Sept. 2017
Ref: 216.1.1/17/2-25

SOUTHERN PALAEOVALLEY,
MODELLED WATER LEVELS AFTER 15 YEARS

Rockwater Pty Ltd

FIGURE 25



Client: SDJV
Project: Water Supply Investigation
Date: Sept. 2017
Ref: 216.1.1/17/2-26

CENTRAL PALAEOVALLEY,
MODELLED WATER LEVELS AFTER 60 YEARS

Rockwater Pty Ltd

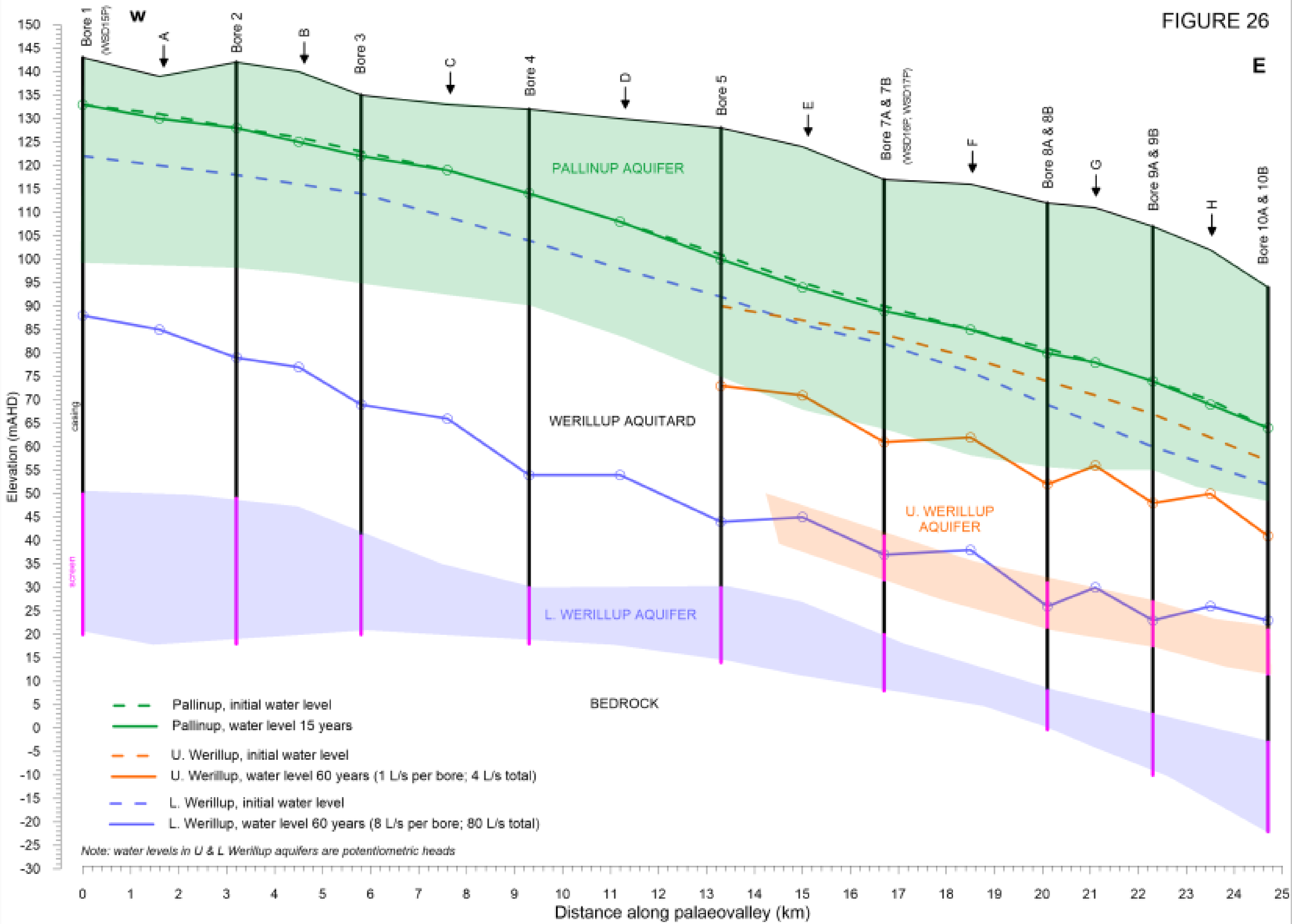
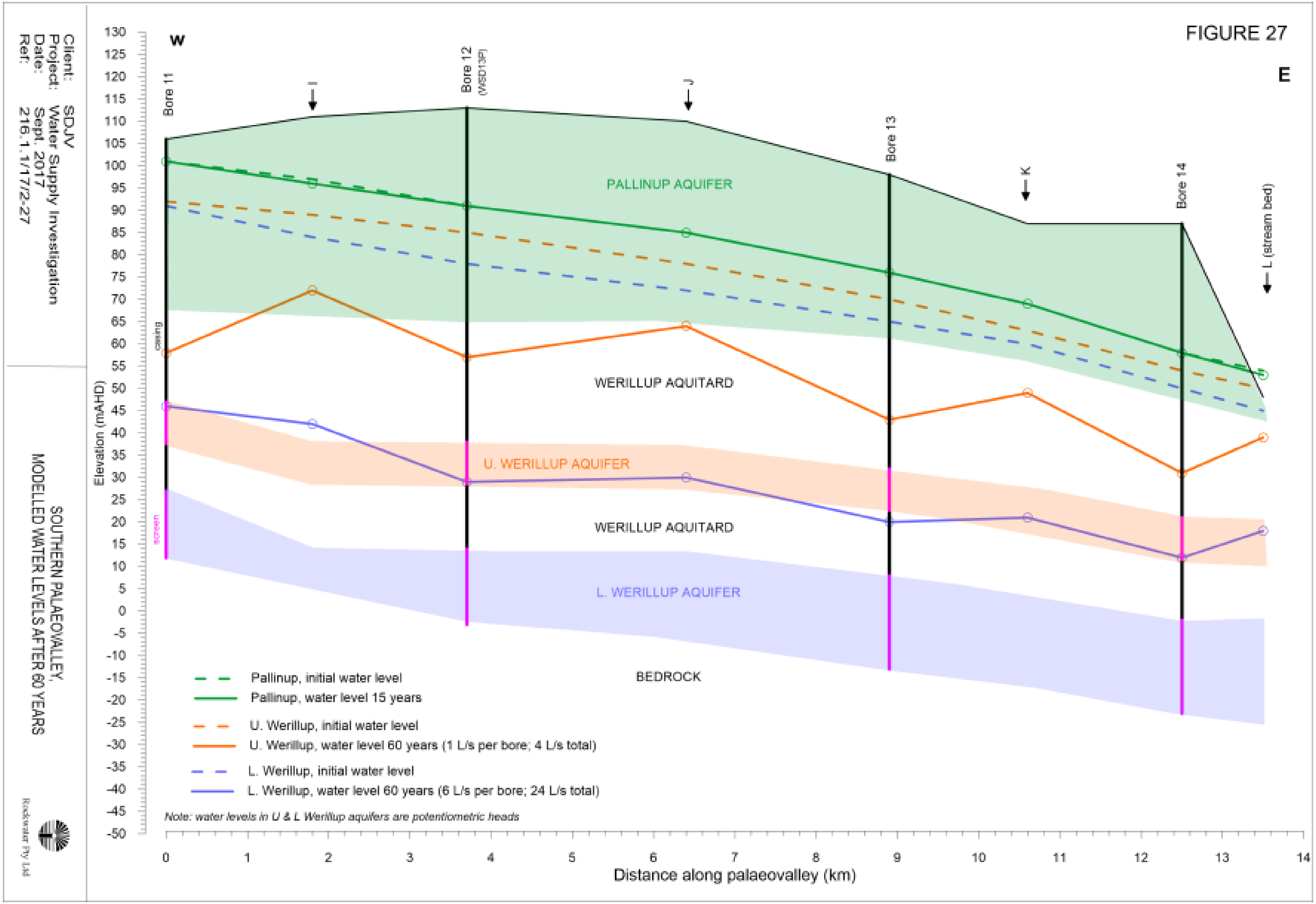


FIGURE 26

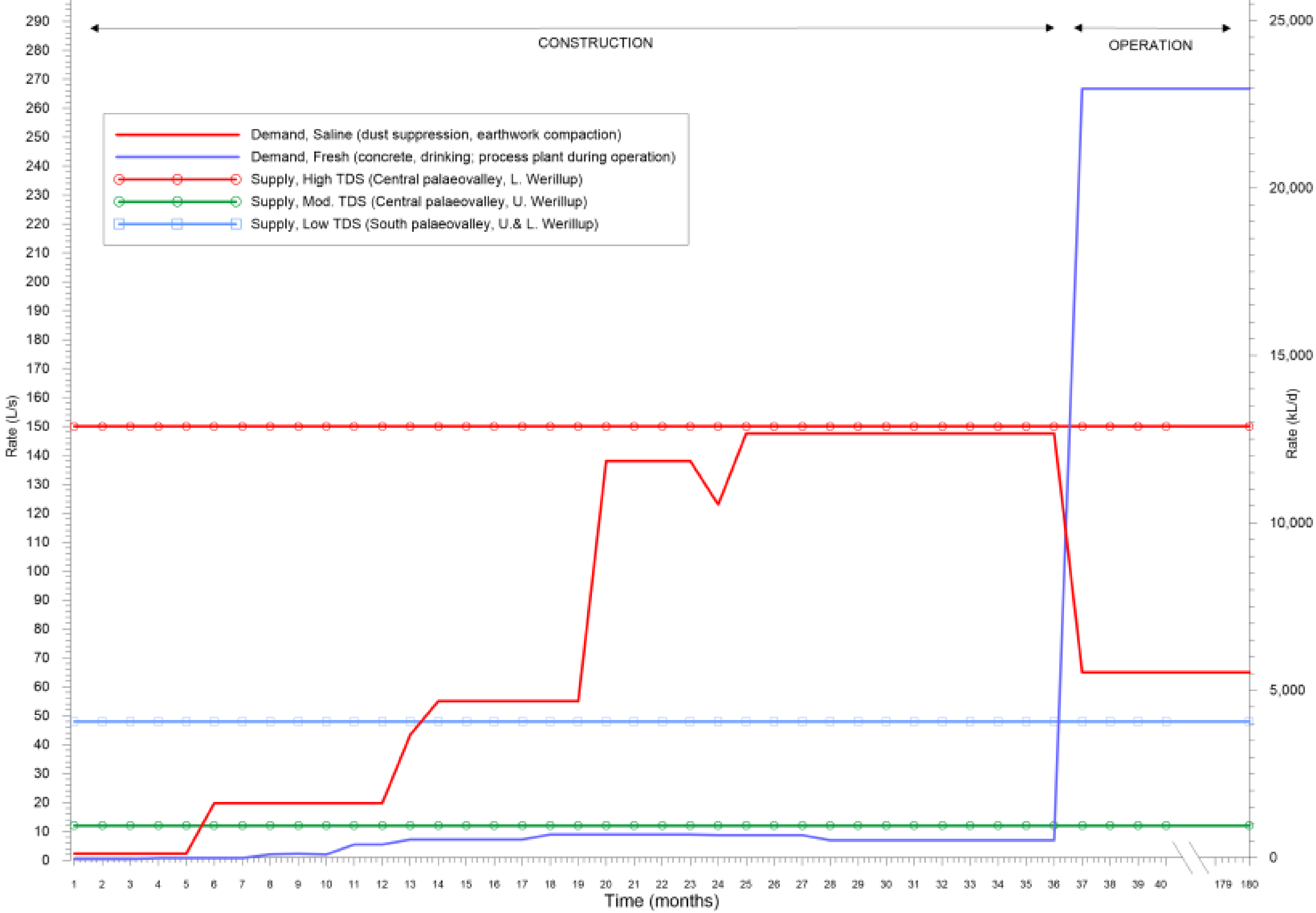

Client: SDJV
Project: Water Supply Investigation
Date: Sept. 2017
Ref: 216.1.1/17/2-27
SOUTHERN PALAEOVALLEY,
MODELLED WATER LEVELS AFTER 60 YEARS
Rockwater Pty Ltd
FIGURE 27
W
E
Bore 11
I
Bore 12 (WSD13P)
J
Bore 13
K
Bore 14
L (stream bed)
casing
screen
PALLINUP AQUIFER
WERILLUP AQUITARD
U. WERILLUP AQUIFER
WERILLUP AQUITARD
L. WERILLUP AQUIFER
BEDROCK
Elevation (mAHD)
Distance along palaeovalley (km)
Pallinup, initial water level
Pallinup, water level 15 years
U. Werillup, initial water level
U. Werillup, water level 60 years (1 L/s per bore; 4 L/s total)
L. Werillup, initial water level
L. Werillup, water level 60 years (6 L/s per bore; 24 L/s total)
Note: water levels in U & L Werillup aquifers are potentiometric heads

Client: SDJV
Project: Water Supply Investigation
Date: Sept 2017
Ref: 216.1.1/17/2-28

WATER SUPPLY AND DEMAND, 10 MTPA/15 YEAR SCENARIO

Rockwater Pty Ltd

FIGURE 28



Client: SDJV
Project: Water Supply Investigation
Date: Sept. 2017
Ref: 216.1.1/17/2-29

WATER SUPPLY AND DEMAND, 5 MTPA/60 YEAR SCENARIO

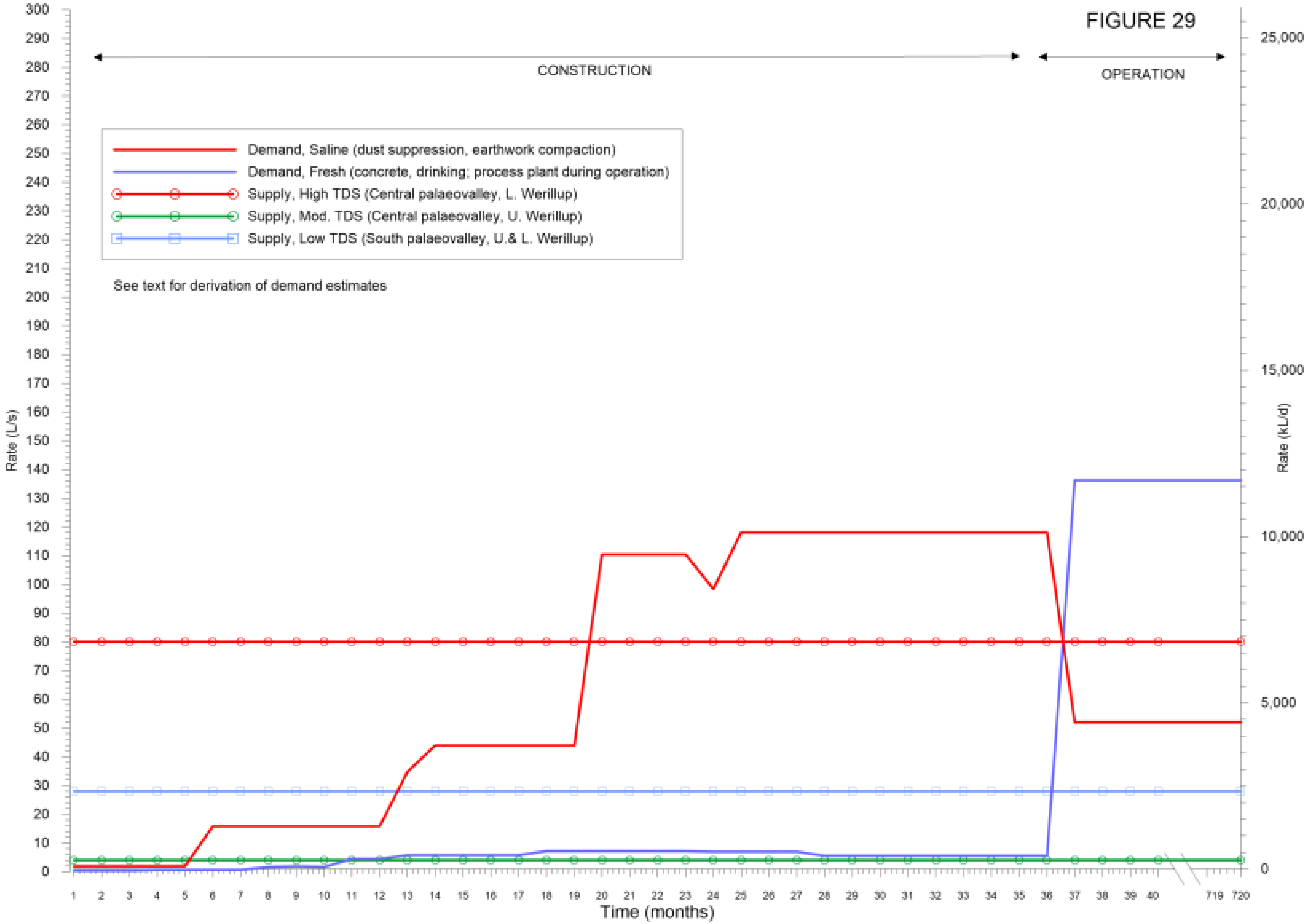


FIGURE 29

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APPENDIX C
Pit Dewatering Report
(Golder 2006)

Golder Associates Pty Ltd
A.B.N. 64 006 107 857

1 Havelock Street, West Perth, WA 6005 Australia
(PO Box 1914, West Perth, WA 6872 Australia)
Telephone (08) 9213 7600
Fax (08) 9213 7611
http://www.golder.com

REPORT ON

ESTIMATES OF GROUNDWATER INFLOW INTO AND DRAWDOWN AROUND THE PROPOSED OPEN PIT SOUTHDOWN IRON ORE PROJECT

Submitted to:

Grange Resources Limited
Level 11, Mount Newman House
200 St Georges Terrace
PERTH WA 6000

DISTRIBUTION:

2	Copies	-	Grange Resources Pty Ltd (+1 Electronic)
2	Copies	-	Golder Associates Pty Ltd

July 2006 05641009-R16

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1.0 INTRODUCTION

Grange Resources Ltd (Grange) is undertaking studies for the future development of the Southdown Magnetite Project situated approximately 90 km east of Albany in the south-west of Western Australia. Based on the conceptual mine planning work prepared by Golder Associates Pty Ltd (Golder) for input to the Public Environmental Review (PER), the proposed pit will be approximately 6,000 m long, 600 m wide, and about 300 m deep. The life of mine is expected to be about 22 years. Portions of the mine waste will be returned to the mine on a progressive basis

The report presents a summary of hydrogeological investigations and groundwater modelling to estimate potential groundwater inflows into and groundwater drawdown around the open pit.

2.0 SCOPE OF WORK

The work undertaken as part of the proposed study to date has consisted of the following activities:

- Identification of existing groundwater wells within 5 km radius from the proposed mine site.
- Site visit including review of the existing water wells at the project site.
- Hydraulic conductivity testing program in selected geotechnical drill holes.
- Evaluation of the *in situ* test data and preparation of a conceptual hydrogeological model for the proposed open pit.
- Preparation of a numerical groundwater model for the Southdown open pit for estimates of groundwater inflows and drawdown.

3.0 GROUNDWATER LEVEL SURVEY

Information on the depth to groundwater table in the project area was obtained from the groundwater database, maintained by the Department of Water, survey of wells at the Site and from selected geotechnical drill holes.

3.1 Regional Water Well Survey

Groundwater wells have been identified from the groundwater database within 5 km radius from the proposed mine site. A total of 21 wells were identified within the set radius but only four of these contained information on static water level measurements, and an additional three wells providing information on interception of water table during drilling. These wells

were completed over a period of 1964 to 1975 to depths ranging from about 27 to 47 m below ground surface. Only three of them include elevation datum. Locations of the regional water wells with groundwater information are shown in Figure 1.

Based on the information from the regional well survey, the static water table within a 5 km radius around the project site varies from approximately 17 to 27 m below ground surface. The limited survey data indicate water table elevations from about 111 to 124 m (Table 1).

3.2 Site Well Survey

Based on the information provided by Grange several stock water supply wells are known at the site but no well completion details or yield information is available on these wells. The poor conditions of the well casings did not allow a proper water level survey and no information on water table elevation is available for these locations. In addition to the old farm wells, three new wells were completed at the project site in 2005 by Grange as part of the exploration drilling program to depths ranging from 33 to 40 m. Water level measurements from February 2005 indicate depth to water table in the site wells between 16 and 23 m (112 and 119 m elevation). Summary of the water level measurements are shown in the Table 1 and Figure 1.

3.3 Geotechnical Drill Holes

A water level survey was conducted in selected geotechnical drill holes completed in the western part of the deposit in August 2005 as part of the *in situ* hydraulic testing program. Groundwater level measurements were collected from five open holes at four locations. At drill site SDD-121 water levels were measured in a shallow and deep well completed at this location providing limited information on groundwater gradient at the project site. The total length of the surveyed drill holes varied from 38 to 330 m, but as these holes were drilled at an angle the actual depth was somewhat reduced. The vertical depth to groundwater measured in the selected geotechnical drill holes was between 10 and 20 m. Groundwater level elevation at these locations ranged from 125 to 148 m asl (Table 1, Figure 1).

Table 1: Water Level Data

Hole No	Coordinates		Elevation	TD (m)	SWL	
	E	N			m bgs	Elevation
Regional Water Wells (5 km radius)						
20060355	637675	6175313	139	47.55	27.45	111.55
20060347	637702	6180384	142	27.43	21.34	120.66
20060374	636323	6177482	150	32.00	25.90	124.10
20064160	638068	6175830	N/A	36.58	22.34	N/A
20064162	642949	6174908	N/A	36.58	17.39	N/A
20064164	638507	6179616	N/A	33.50	27.40	N/A
20064428	641488	6181969	N/A	45.72	24.40	N/A
Grange Res. Water Wells						
SWB-1	639084	6176294	133.298	39.60	16.70	116.60
SWB-2	637701	6175419	135.463	32.50	23.30	112.16
SWB-3	641684	6178069	135.003	34.00	16.00	119.00
Grange Res. Geotechnical Holes						
SDD-121	636982.11	6176445.16	145.449	150.00	19.57	125.88
SDD121A	636982.11	6176445.16	145.449	37.50	14.94	130.51
SDD-124	637665.33	6176879.25	157.518	330.00	9.35	148.17
SDD-125	637718.98	6176385.08	138.573	320.00	13.16	125.41
SDD-128	638586.08	6177011.12	147.267	260.00	16.58	130.69

Note: Total depth (TD) of geotechnical holes is measured along the drill hole.

4.0 HYDRAULIC CONDUCTIVITY TESTING

Hydraulic conductivity testing has been conducted in selected geotechnical drill holes over the period of 19 to 25 August 2005 as part of the geotechnical drilling program carried out at the project site. A total of 12 tests were carried out in four drill holes completed in the western section of the proposed open pit (Figure 1). The test hole selection was based on their location and orientation with respect to the proposed pit walls to provide information on hydraulic parameters of the rock mass within the hanging wall and footwall of the deposit. Some of the test holes were also selected from their orientation towards the brittle crosscutting structures identified at the project site to allow hydraulic characterisation of these structures.

The hydraulic testing was carried out using a single pneumatic packer suspended on a wireline through HQ size drill rods. The relatively tight hydraulic conditions within the bedrock at the project site allowed use of a single packer where the test interval was increased in stages by moving the packer that formed the upper boundary of the test zone. Falling head tests consisting of adding water to the drill rods above the isolated test interval and

monitoring the recovery to the pre-test level over time were used to obtain data required for calculation of hydraulic conductivity. Hvorslev (1951) time-lag analyses were used to calculate hydraulic conductivity of the individual test intervals. In some cases where the results of the previous test showed low hydraulic conductivity, the length of the new test interval was reduced by using the upper bound of the previous test as the lower boundary of the new one.

Based on the results of the August 2005 testing program the hydraulic conductivity in the proposed open pit area varies from about 1×10^{-6} m/s in the saturated overburden and shallow weathered bedrock above +60 m elevation, to relatively low hydraulic conductivity of 1×10^{-9} m/s in the lower fresh bedrock below -60 m elevation. The hydraulic conductivity of the crosscutting structures was estimated to be in the order of 1×10^{-6} m/s. Results of the individual tests are shown in the Table 2 below.

Table 2: Hydraulic Conductivity Test Results

Hole No	Incl. (deg.)	Test Interval (m)**	Test Length (m)	K Value (m/s)	Comments
SDD124	60	172.4-330.6	158.2	1×10^{-9}	test WL 6.85 m BTC
		079.4-330.6	251.2	3×10^{-8}	test WL 7.6 m BTC
		079.4-172.4	93.0*	1×10^{-8}	
		014.40-172.4	158.0	5×10^{-7}	test WL 8.5 m BTC
		014.40-079.4	65.0*	1×10^{-6}	
SDD125	60	271.6-320.9	49.3	failed test	test WL 12.08 m BTC
		211.6-320.9	109.3	7×10^{-10}	test WL 13.83 m BTC
		151.6-320.9	169.3	5×10^{-9}	test WL 14.3 m BTC
		151.6-211.6	60.0*	1×10^{-8}	
		091.6-320.9	229.3	2×10^{-8}	test WL 14.45 m BTC
		091.6-211.6	120.0*	4×10^{-8}	
		037.6-151.6	114.0*	2×10^{-7}	
		037.6-091.6	54.0*	3×10^{-7}	
SDD121A	80	019.7-037.5	17.8	4×10^{-8}	test WL 10.7 m BTC
SDD128	60	205.7-259.8	54.1	1×10^{-7}	test WL 10.2 m BTC
		148.7-259.8	111.1	8×10^{-7}	test WL 18.93 m BTC
		052.7-148.7	96.0*	1×10^{-7}	test WL 19.75m BTC

* length of test interval adjusted based on results of previous tests
** test interval along the hole axis
K = hydraulic conductivity

5.0 CONCEPTUAL HYDROGEOLOGIC MODEL

5.1 Water Table Elevations

Based on the combined information from the regional water well survey, the site well survey, and selected geotechnical drill holes, the static water table around the project site varies from approximately 10 to 27 m below ground surface. With a topographic relief around the pit area varying from about 138 to 147 m AHD, the range of water table elevations is expected between 125 and 148 m in the immediate pit area, and from about 111 to 124 m in the wider radius around the proposed pit. Because of lack of long-term data it is unclear whether the differences in water table elevations are representative of the actual groundwater conditions or are the result of seasonal fluctuations at the time the individual measurements were taken.

5.2 Hydraulic Conductivity

Based on the results of the August 2005 testing program, the near surface hydrostratigraphic unit of saturated overburden and shallow weathered bedrock above +60 m elevation has relatively high bulk hydraulic conductivity of about 1×10^{-6} m/s. In the area of the proposed open pit the hydraulic conductivity is decreasing with depth to about 1×10^{-9} m/s in the lower fresh bedrock below -60 m elevation. The hydraulic conductivity of the brittle crosscutting structures was estimated from test conducted in the geotechnical drill hole SDD128 over an interval of 150 to 260 m along the borehole axis (+20 to -80 m elevation). As this structure is approximately 10 to 20 m wide, majority of the material within the test interval was represented by the relatively tight lower fresh bedrock hydrostratigraphic unit.

Table 3: Estimated Distribution of Hydraulic Conductivity

Hydrostratigraphic Unit	K
Saturated overburden and weathered bedrock	1×10^{-6} m/s
Upper fresh bedrock above +60 m elevation	1×10^{-7} m/s
Middle fresh bedrock between +60 and -60 m elevation	1×10^{-8} m/s
Lower fresh bedrock below -60 m elevation	1×10^{-9} m/s
Crosscutting structures (10 identified)	1×10^{-6} m/s

5.3 Preliminary Pit Design and Life of Mine Schedule

The preliminary design of the proposed Southdown open pit suggests that it will be approximately 6,000 m long, 600 m wide, and about 300 m deep. The life of mine is expected to be over 22 years but for groundwater modelling purposes we have assumed a 20 year life of mine. It is expected that the narrow Southdown pit will be mined in a series of blocks starting at the western end and progressing towards the east throughout the mine life.

The mining schedules were developed based on the results of the pit optimisation study. The proposed design also includes split waste disposal with partial surface dumping and partial waste disposal back into the pit on a progressive basis. It has been assumed that the earliest that the backfill could start is towards the end of Year 5 with an increasing proportion of waste going to backfill after that time.

The estimated progress of the pit face and the pit backfill from the West end of the proposed open pit will be as follows.

Table 4: Life of Mine

Life of Mine	Pit Face	Backfill
Year 5	2,000 m	0 m
Year 10	3,000 m	2,200 m
Year 15	4,500 m	3,300 m
Year 20	6,000 m	4,400 m

6.0 NUMERICAL HYDROGEOLOGIC MODEL

6.1 Model Construction

The hydrogeological model for the proposed Southdown open pit was constructed using FEFLOW version 5.1 (WASY 2004) modelling software. FEFLOW is a three-dimensional finite-element groundwater flow model, and is widely used for simulating groundwater flow, including dewatering and drawdown.

The FEFLOW model consisted of 35,958 nodes and 58,990 elements. The model incorporated elements with distance between the nodes ranging from 850 m along the edges of the modelling area to less than 100 m at the proposed pit faces. The finite element mesh (with mesh refinement at the pit) is shown in Figure 2. Vertically, the model was divided into five layers. The bottom of the model was set 750 m below the ground surface.

The model represents an area of approximately 552.8 km^2, which incorporates several catchment areas around the proposed open pit. The model incorporates parts of the Willyun Creek and Eyre River catchments, and extends to the coastline. The modelled proposed pit has a length of ~6000 m, width of ~600 m and depth of ~300 m. The ground surface layer was prepared based on the topography map available for the project site.

The top layer (Layer 1) represents the surficial saturated overburden, and weathered bedrock. Based on the current geological model, this layer was assumed to be 18 m thick. The second layer from the top (Layer 2) represents the upper fresh bedrock zone, which was assumed to be 70 m thick. The third layer from the top (Layer 3) represents the middle fresh bedrock

zone and was assumed to be 120 m thick. The two bottom layers (Layers 4 and 5) represent the lower fresh bedrock zone. An approximate thickness of 550 m was adopted for this zone.

For hydrogeologic modelling purposes it was assumed that the open pit will be mined in four stages. The duration of mining and size of the pit for each section is shown in Table 5.

Table 5: Life of Mine

	Life of Mine	Length Open
Section 1	Year 5	2,000 m
Section 2	Year 10	800 m
Section 3	Year 15	1,200 m
Section 4	Year 20	1,600 m

It has been assumed that placement of backfill will start towards the end of Year 5 with an increasing proportion of waste going to backfill after that time.

6.2 Boundary Conditions

A recharge boundary condition was applied to the top of the model representing rainfall recharge. This parameter was varied during the initial model runs to achieve calibration. Acceptable model calibration was achieved using an apparent rainfall recharge rate of 0.073 mm/yr (~0.01% of rainfall).

Rainfall recharge for a typical farmland region could vary between 3% and 10%. This rainfall infiltrates the groundwater and then typically discharges along waterways (creeks and rivers). The hydrological setting in the modelling region is unique because there are very few well defined waterways. Groundwater probably discharges along natural drains or ponds in low lying regions in the wet season, and as a result, the net rainfall recharge is much lower than is typical for a farmland region.

A constant head boundary of 140 m AHD was placed along the western model boundary to simulate inflow from the upper catchment. A constant head boundary of 0 m AHD was applied along the coast to represent the ocean.

Perennial streams were represented by constant head boundaries which simulated the approximate water level in the river. A constraint was placed on the stream, to prevent the non-perennial stream contributing water to the aquifer if the groundwater level falls below the base of the river.

The pit floor was represented by constant head boundary conditions. These boundary conditions represented the proposed sumps in each pit section, and simulate groundwater inflow into the pit and into the sumps.

A constraint has been placed on the pit floor, to prevent the pit contributing water to the aquifer if the groundwater level falls below the pit floor elevation.

The mining sequence in the pit was simulated using 16 constant head boundary functions, each representing 375 m of the pit face. As mining progresses from west to east, groundwater levels are lowered. It was assumed that when the in-pit dump is placed in the pit, dewatering operations for this part of the pit will cease. This was represented in the model by constraining the constant head boundary when the in-pit dumps are placed in the pits.

6.3 Input Parameters

The hydraulic properties adopted in the numerical models are summarised in Table 6, and are based on the results of recent *in situ* testing program conducted in the proposed pit area.

Table 6: Adopted Hydraulic Parameters

Material	Hydraulic Conductivity, K (m/s)	Anisotropy	Specific Yield	Specific storage (1/m)
Saturated overburden and weathered bedrock	1×10^{-6}	1	5%	-
Upper fresh bedrock	1×10^{-7}	1	0.5%	1×10^{-4}
Middle fresh bedrock	1×10^{-8}	1	0.5%	1×10^{-4}
Lower fresh bedrock	1×10^{-9}	1	0.5%	1×10^{-4}
Fault zones	1×10^{-6}	1	-	1×10^{-4}

For modelling of groundwater inflows, it was assumed that the hydraulic conductivity of the various hydrostratigraphic units could be 5 times higher or lower than estimated, thus allowing for uncertainty of model input parameters.

6.4 Discrete Feature Elements

Discrete feature elements have been applied in the area of the proposed pit. These elements simulate angled brittle crosscutting structures identified at the project site that were for modelling purposes assumed to be vertical. A total of ten crosscutting structures were identified. Locations of these structures at 0 m elevation are shown in Figure 1 and 2. For identification purposes they were labelled A to J in the direction from West to East. Their properties are based on the results of *in situ* field tests conducted across structure B in the western section of the proposed open pit, and are summarised in Table 7. For modelling purposes it has been assumed that all the identified structures have the same properties.

Table 7: Adopted Properties of Discrete Feature Elements

	A	C,D,F,G,H,J	I	E	B
Thickness (m)	0.5	1.0	5.0	10.0	15.0
Hydraulic conductivity (m/s)	1×10^{-6}	1×10^{-6}	1×10^{-6}	1×10^{-6}	1×10^{-6}
Specific storage (1/m)	1×10^{-4}	1×10^{-4}	1×10^{-4}	1×10^{-4}	1×10^{-4}
Specific yield	0.15	0.15	0.15	0.15	0.15

7.0 GROUNDWATER LEVELS AND DRAWDOWN

Water table elevations and corresponding drawdown contours were estimated for 5-year time segments over a 20 year life of mine period (5, 10, 15, and 20 years of mining). The groundwater contours are shown in Figures 3 to 6, while the drawdown contours are shown in Figures 7 to 10. Development of the drawdown cone as mining progresses is summarised in Table 8.

Table 8: Extent of Drawdown Cone as Mining Progresses

Mining Year	Drawdown Cone Area (km^2)
5	3.2
10	5.9
15	8.8
20	12.2

As the mining will start at the western end of the proposed pit, the impact of the pit dewatering activities will be most pronounced in this area. However, the results of the hydrogeological model indicate only a limited extent of the drawdown cone after the first five years of mining (Figure 7). After 10 years of mining, the drawdown cone is expected to develop around the western end of the proposed pit to about 700 m distance (Figure 8). With the additional pit development the drawdown cone will continue expanding with the pit, and is expected to reach about 1,100 m distance from the pit crest at the end of the 20 year life of mine period. Development of the drawdown cone however will be slower than the rate of mining, resulting in a limited impact on the pre-mining groundwater conditions in the eastern end of the proposed pit (Figures 9 and 10).

An appropriate groundwater monitoring network will assist with monitoring of the expansion of the drawdown cone as mining progresses.

8.0 GROUNDWATER INFLOW ESTIMATES

Groundwater inflows were estimated considering the uncertainty of model input parameters, in particular the uncertainty of hydraulic conductivity of the respective hydrostratigraphic units.

Based on the results of the groundwater model developed for the project site, groundwater inflows into the proposed Southdown open pit after 1 year of mining are expected to be between 5 and 10 L/s. After five years of mining, the groundwater inflows are expected to increase gradually to between 30 and 62 L/s as the pit is developed over a length of approximately 2,000 m without backfill. After the initial 5 year mining period the total groundwater inflows into the proposed pit are expected to decrease as a result of in-pit deposition of waste rock, before increasing to between 34 and 70 L/s at year 10. This increase is due to the additional inflow contribution from the fracture zones that will be intercepted by the pit during that mining period. After a stabilisation period of about one year, the total groundwater inflows are expected to gradually decrease to between 18 to 37 L/s at the end of the 22 year mine life. The expected groundwater inflows for the proposed pit development throughout the life of mine for the 20 years mine schedule are presented in the Table 9 below and Figure 11.

Table 9: Expected Groundwater Inflows during Life of Mine

Mine Year	Groundwater Inflow (L/s)		
	5%	50%	95%
1	5	8	10
2	21	34	44
3	26	43	55
4	29	47	60
5	30	48	62
6	28	45	58
7	25	41	53
8	25	40	52
9	26	42	55
10	34	55	70
11	36	59	77
12	35	57	74
13	30	49	63
14	27	44	57
15	26	42	54
16	25	41	53
17	24	39	51
18	23	37	48
19	21	34	44
20	20	33	42
21	19	32	41
22	18	29	37

9.0 CONCLUSIONS AND RECOMMENDATIONS

9.1 Groundwater Inflow Rates

There is inevitable uncertainty associated with the groundwater model predictions and actual groundwater inflow rates could be different from those predicted. The hydraulic conductivity values used in the model were obtained from tests limited to the western section of the proposed pit, and additional permeable structures might be identified during mine development.

A monitoring program should be put in place during the mining operations to measure both groundwater level and inflow rates. These could be compared to the modelled predicted values, the model recalibrated, re-run and, at times, some adjustments to the dewatering strategy can be anticipated.

9.2 Seepage from the Backfill

After year 5 of mining operation, waste rock and tailings will be backfilled in the mined out portion of the open pit. Groundwater seepage is expected at the toe of the backfill material caused by groundwater inflow and rainfall recharge into the backfill. This seepage has not been considered in the groundwater inflow estimations.

9.3 Dewatering Rates

The dewatering requirements from the proposed open pit should take into account both groundwater inflow and rainfall runoff. Rainfall runoff has not been considered in this study because it did not form part of the scope. Seepage from the backfill has also not been considered in the dewatering requirements.

In addition, evaporation has not been considered, for example, if it is assumed that groundwater inflow will cover 30% of the pit walls, average evaporation losses could be more than 17 L/s (assuming the pit wall covers an area of 121 ha).

It is recommended that a hydrological study be carried out to estimate the potential rainfall runoff into the proposed open pit. This study should also include the design, at feasibility level, of diversion drains around the open pit if and where required, and the sizing of sump pump infrastructure capable to remove storm water from the pit floor in sufficient time so that mining operations are not significantly affected.

9.4 Groundwater Quality

Groundwater quality samples in the fractured bedrock have been collected during the installation of the monitoring bores and are discussed in detail by Golder (July 2008). Groundwater pH varies between 6.4 and 7.2 while total dissolved solids ranges between 1300

and 3700 mg/L. However, these samples were taken from relatively shallow depths and groundwater salinities typically increase with depth.

It is possible that the pumped groundwater chemistry could change with time as a consequence of geochemical processes, in particular sulphide oxidation in the dewatered formations. It is also possible that seepage from the proposed waste rock dumps and tailings storage facilities could flow towards the open pit and affect the quality of dewatering water.

It is recommended that the quality of the dewatering water be monitored during mining operations and that dewatering water be pumped to the Impacted Water Storage Facility if the quality of dewater water is not acceptable for discharge to the environment.

9.5 Seepage from Waste Rock Dumps

The scope of this study did not include any groundwater-related impacts from seepage associated with the proposed waste rock dumps and tailings storage facilities. It is likely that water could seep from both of these facilities into the groundwater. Since the quality of this seepage water would probably be different from the groundwater quality, it could also affect pumped groundwater quality.

The current groundwater model can, with a few adjustments, be used to assess groundwater impacts related to the waste rock and tailings facilities, off-site groundwater impacts and post-closure groundwater and pit water impacts.

9.6 Post-closure Impacts

After the mine has closed, groundwater levels are expected to recover and the section of the pit not backfilled with waste rock would fill up with water. The post-closure impacts related to the pit water level recovery rates or pit lake water qualities were not addressed as part of this study.

GOLDER ASSOCIATES PTY LTD

Jan Vermaak
Associate

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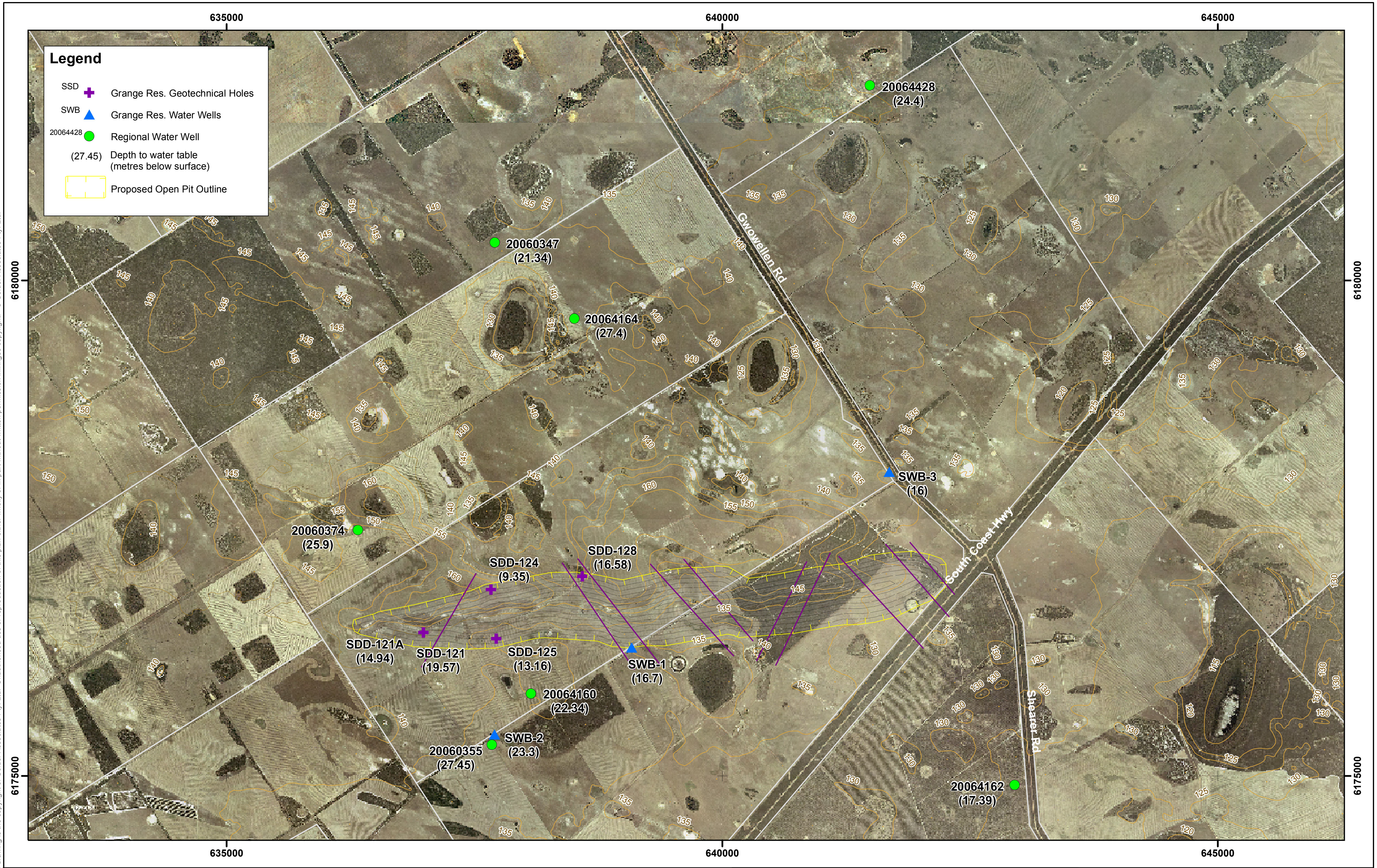

NOTE:
1. Base map copyright Mapinfo Australia Pty Ltd.
2. Datum GDA94, Projection MGA94, Zone 50.
3. Aerial photography provided by client

0 300 600 1,200 1,800 2,400 3,000
metres

N

Golder Associates

CLIENT: GRANGE RESOURCES Ltd		PROJECT: Southdown Project	
DRAWN: DFH	DATE: 22-11-2005	TITLE: LOCATION OF GROUNDWATER LEVEL SURVEY POINTS	
CHECKED: JJV	DATE: 05-07-2006		
SCALE: 1:35,000	A3	PROJECT No: 05641009-R16	FIGURE No: 1

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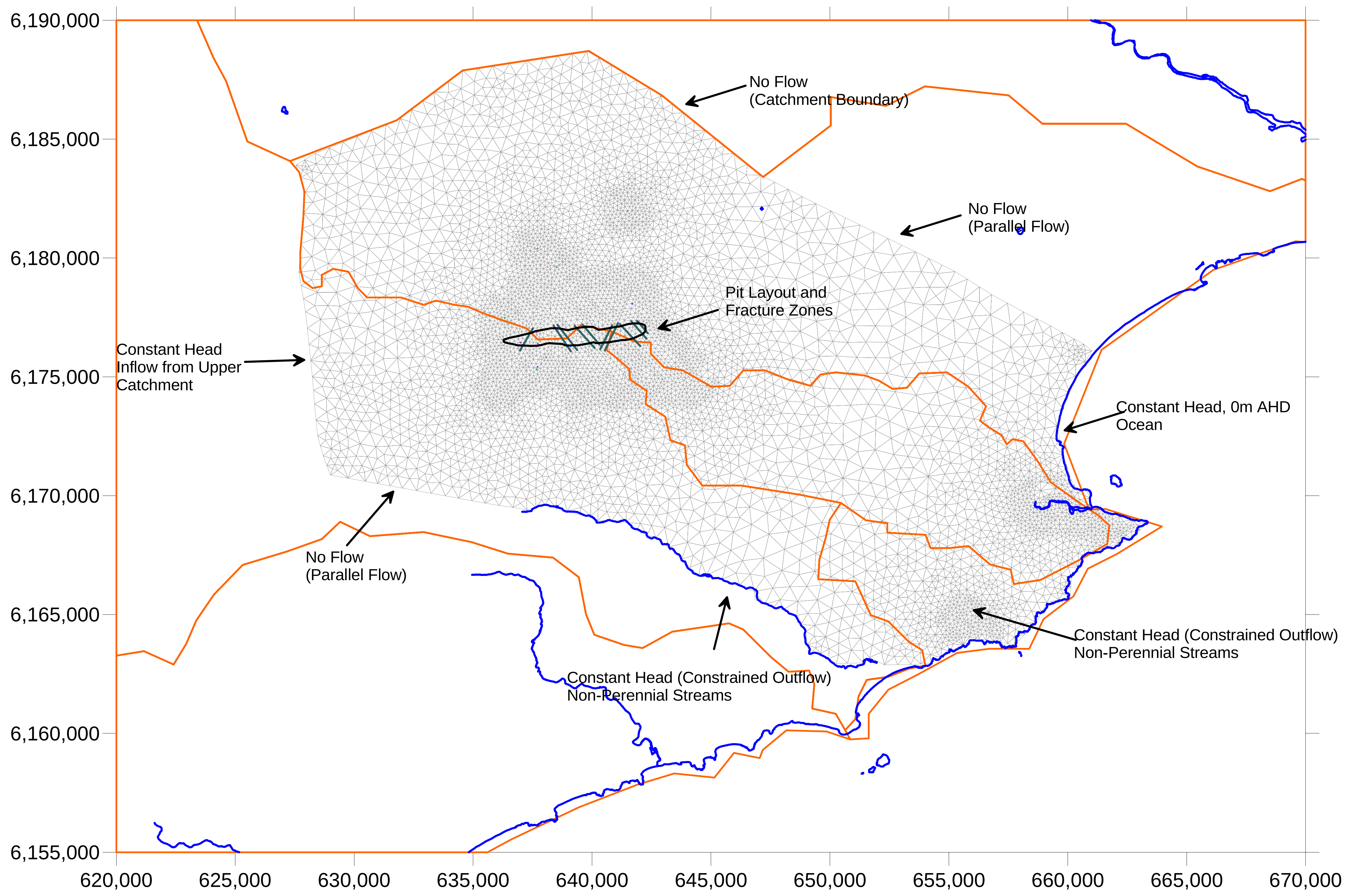

Golder Associates

CLIENT	Grange Resources			PROJECT	Dewatering
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CHECKED	RF	DATE	July 2006		
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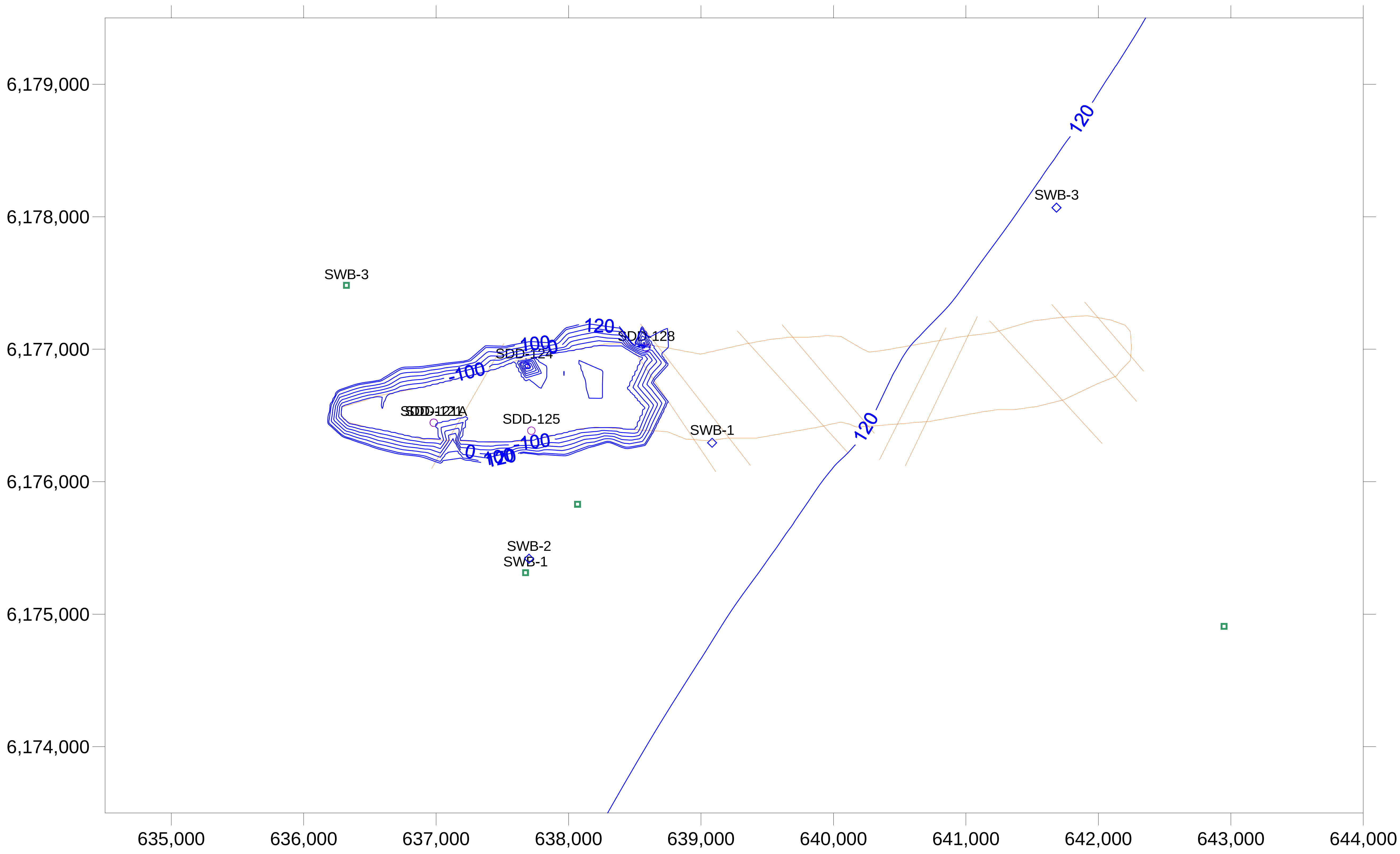

Refer to Groundwater Levels in Weathered Zone

CLIENT: Grange Resources			PROJECT: Dewatering	
DRAWN: JJV	DATE: November 2005		TITLE: MODELLED GROUNDWATER LEVELS AFTER 5 YEARS (m AHD)	
CHECKED: RF	DATE: July 2006			
SCALE: NOT TO SCALE		A3	PROJECT No: 05641009-16	FIGURE No: 3

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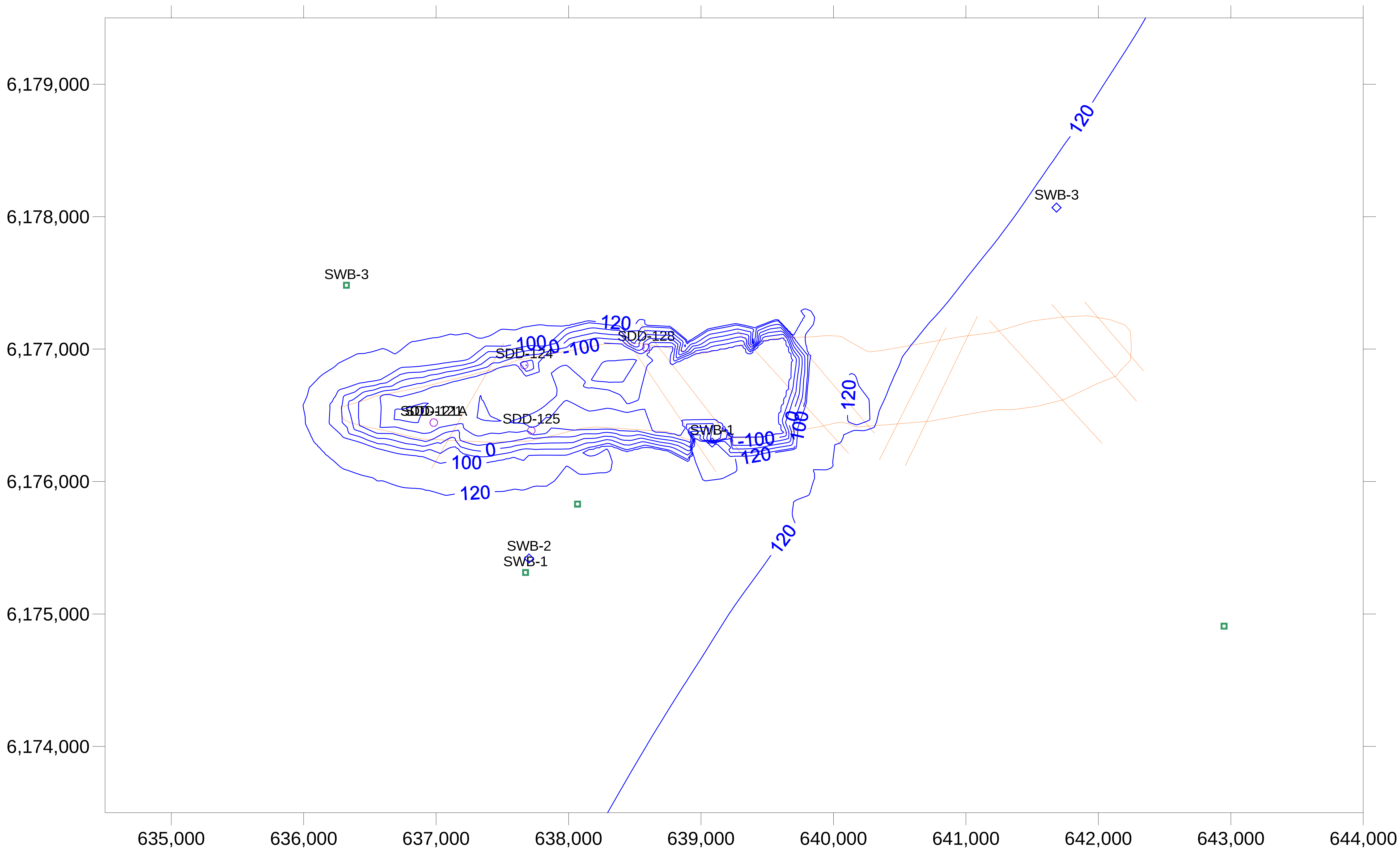

Refer to Groundwater Levels in Weathered Zone

CLIENT	Grange Resources	PROJECT	Dewatering
DRAWN JJV	DATE November 2005	TITLE	MODELLED GROUNDWATER LEVELS AFTER 10 YEARS (m AHD)
CHECKED RF	DATE July 2006		
SCALE NOT TO SCALE	A3	PROJECT No 05641009-16	FIGURE No 4

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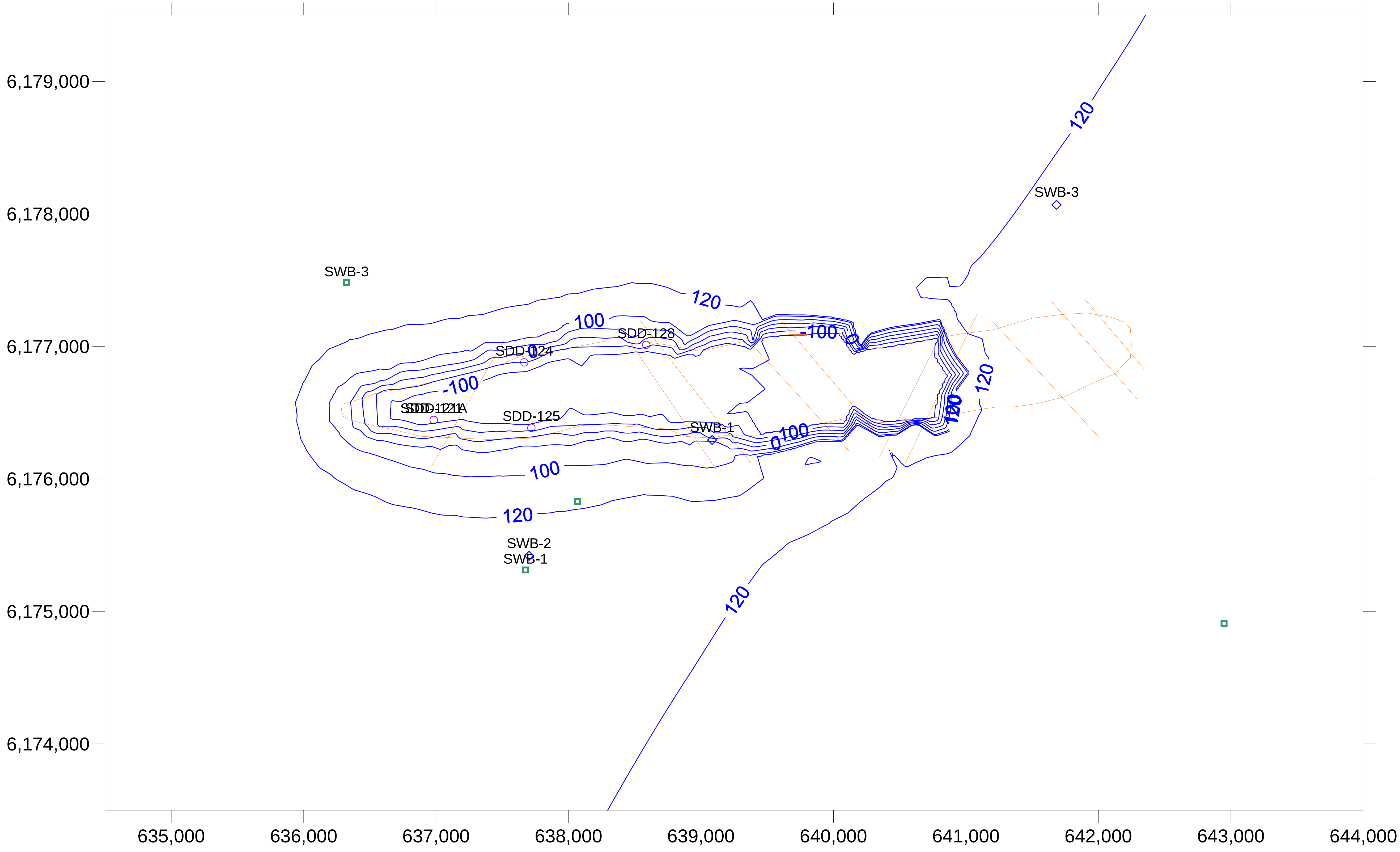

Refer to Groundwater Levels in Weathered Zone

CLIENT Grange Resources			PROJECT Dewatering	
DRAWN JJV	DATE November 2005		TITLE MODELLED GROUNDWATER LEVELS AFTER 15 YEARS (m AHD)	
CHECKED RF	DATE July 2006			
SCALE NOT TO SCALE	A3		PROJECT No 05641009-16	FIGURE No 5

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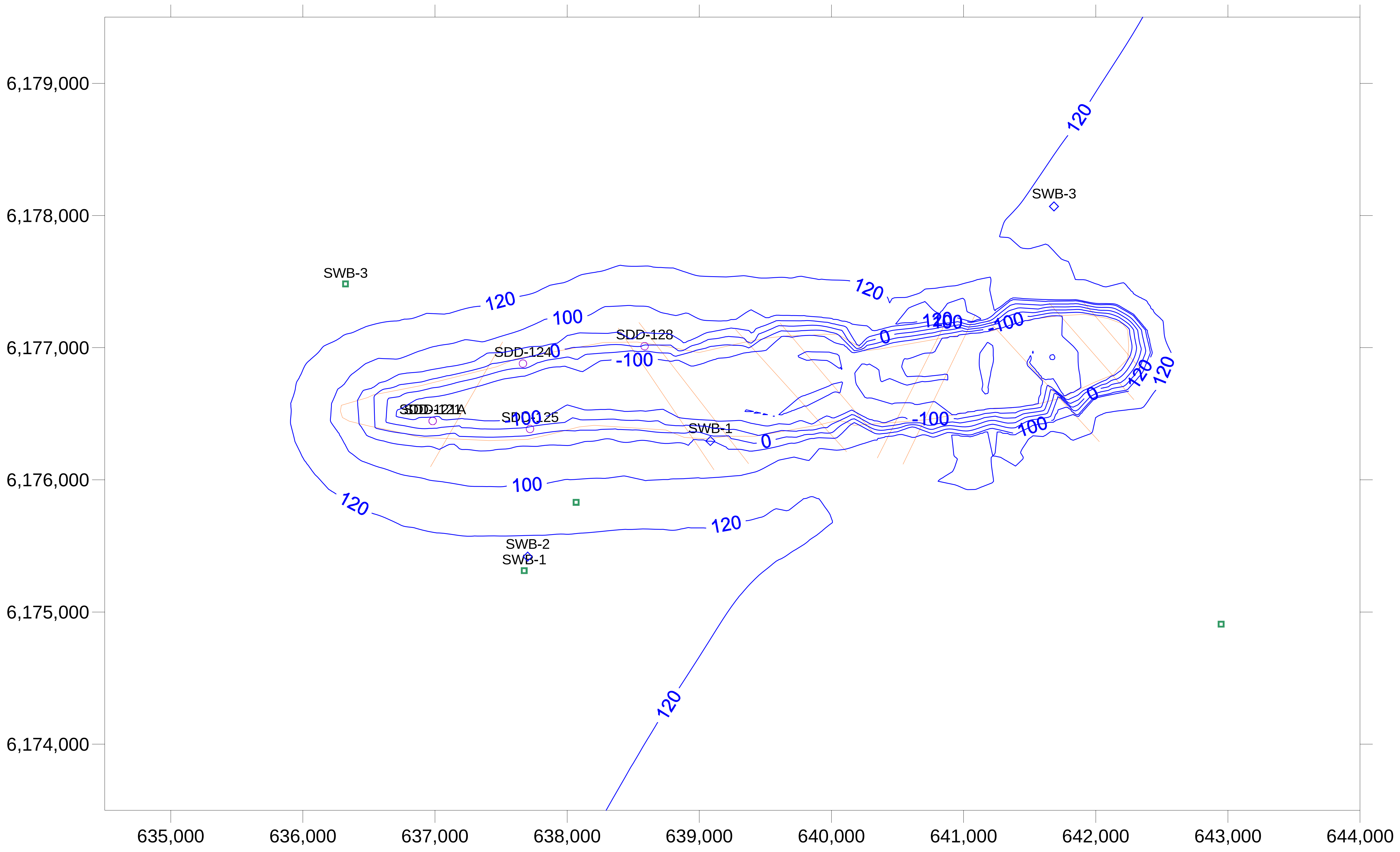

Refer to Groundwater Levels in Weathered Zone

Golder Associates	CLIENT Grange Resources			PROJECT Dewatering	
	DRAWN JJV	DATE November 2005		TITLE MODELLED GROUNDWATER LEVELS AFTER 20 YEARS (m AHD)	
	CHECKED RF	DATE July 2006			
	SCALE NOT TO SCALE		A3	PROJECT No 05641009-16	FIGURE No 6

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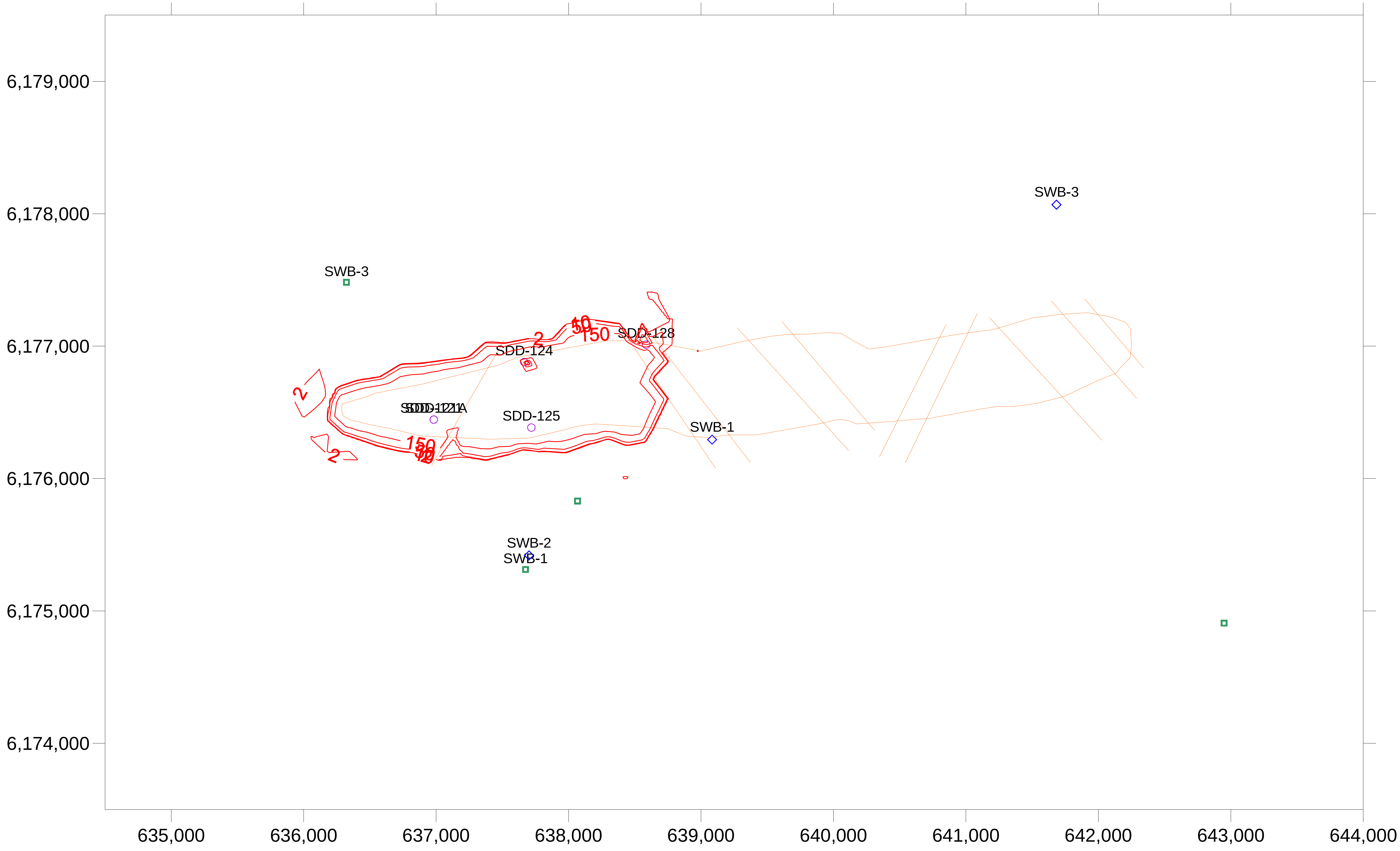

Refer to Groundwater Drawdown in Weathered Zone

Golder Associates	CLIENT Grange Resources		PROJECT Dewatering	
	DRAWN JJV	DATE November 2005	TITLE **MODELLED GROUNDWATER DRAWDOWN AFTER 5 YEARS (m)**	
	CHECKED RF	DATE July 2006		
	SCALE NOT TO SCALE	A3	PROJECT No **05641009-16**	FIGURE No **7**

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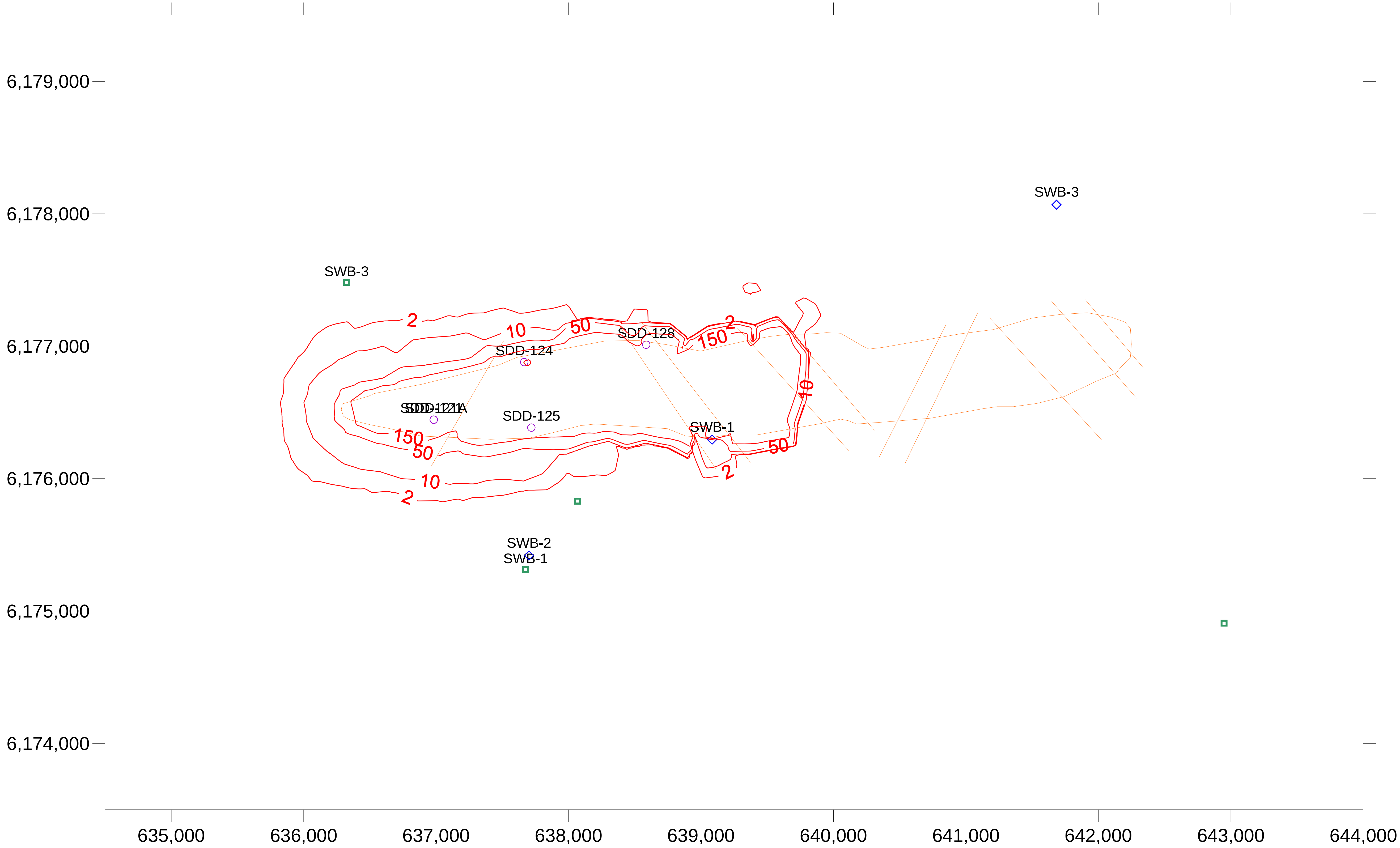

Refer to Groundwater Drawdown in Weathered Zone

Golder Associates	CLIENT Grange Resources		PROJECT Dewatering	
	DRAWN JJV	DATE November 2005	TITLE **MODELLED GROUNDWATER DRAWDOWN AFTER 10 YEARS (m)**	
	CHECKED RF	DATE July 2006		
	SCALE NOT TO SCALE	A3	PROJECT No **05641009-16**	FIGURE No **8**

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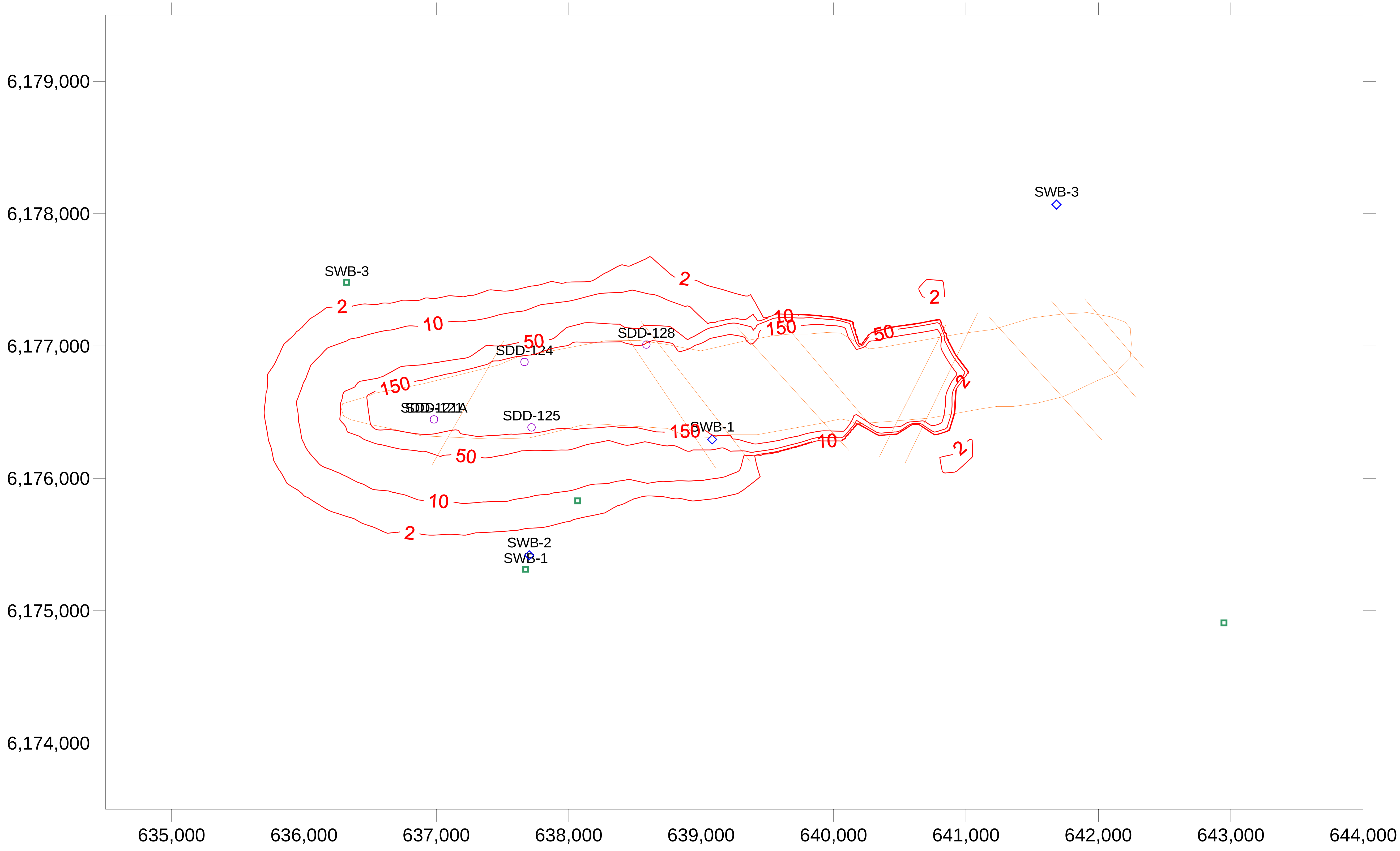

Refer to Groundwater Drawdown in Weathered Zone

Golder Associates	CLIENT	Grange Resources	PROJECT	Dewatering
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	CHECKED RF	DATE July 2006		
	SCALE NOT TO SCALE	A3	PROJECT No 05641009-16	FIGURE No 9

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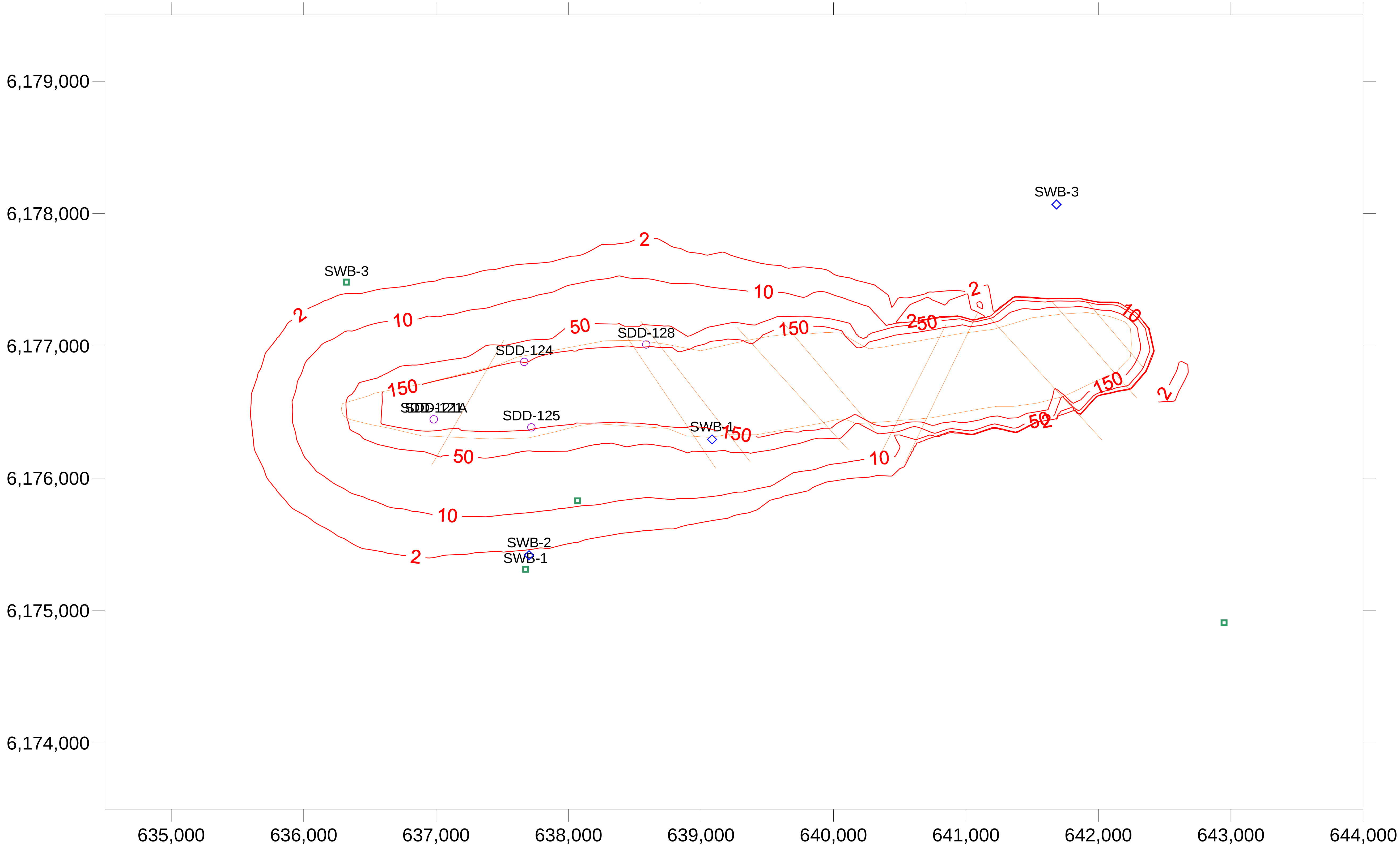

Refer to Groundwater Drawdown in Weathered Zone

Golder Associates	CLIENT: Grange Resources		PROJECT: Dewatering	
	DRAWN: JJV	DATE: November 2005	TITLE: MODELLED GROUNDWATER DRAWDOWN AFTER 20 YEARS (m)	
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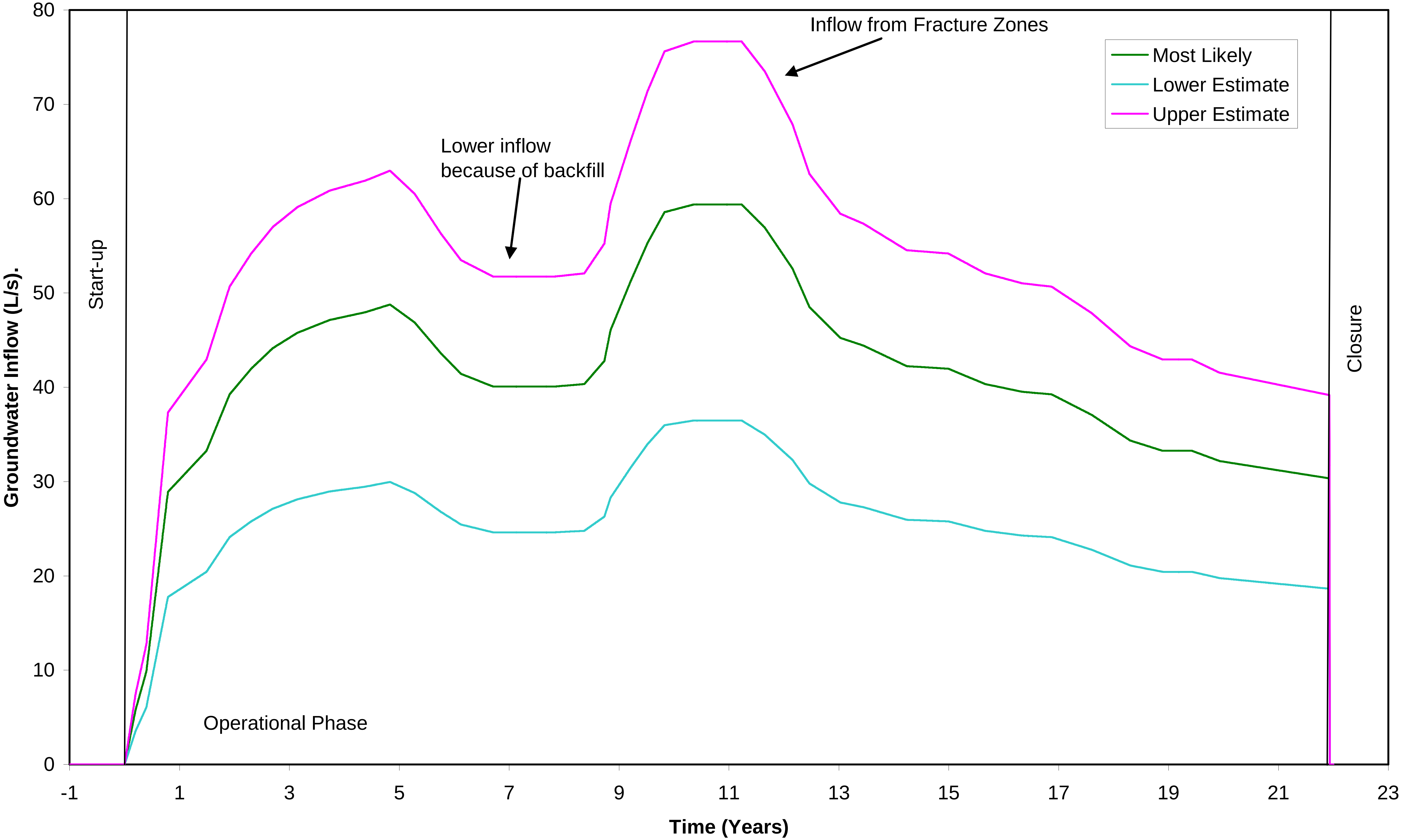

Golder Associates	CLIENT Grange Resources			PROJECT Dewatering	
	DRAWN JJV	DATE November 2005		TITLE **MODELLED GROUNDWATER INFLOWS**	
	CHECKED RF	DATE July 2006			
	SCALE NOT TO SCALE		A3	PROJECT No **05641009-16**	FIGURE No **11**

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Appendix 3
Southdown Joint Venture Southdown Magnetite Project - Review of Matters of National Environmental Significance (MNES); mine and desalination pipeline for the assessment of de-watering impacts (Bamford 2015)

Southdown Joint Venture
Southdown Magnetite Project
Review of Matters of National Environmental Significance (MNES); mine and desalination pipeline for the assessment of de-watering impacts

Prepared for: Southdown Joint Venture
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21st April 2015

1 Introduction

Grange Resources Limited (Grange), as listed proponent and Feasibility Study Manager on behalf of the Southdown Joint Venture (SDJV) (Grange 70% and SRT Australia Pty Ltd 30%), is proposing to develop the Southdown Magnetite Project, near Wellstead east of Albany. Previous studies have identified a suite of species of conservation significance that may be present or have been recorded in the project area, including some listed under the federal *Environment Protection and Biodiversity Conservation Act (1999)* (EPBC Act). Those species listed under the EPBC Act are Matters of National Environmental Significance (MNES). One of these MNES, Carnaby's Black-Cockatoo *Calyptorhynchus latirostris,* was recorded consistently and it was concluded that this was the only MNES requiring assessment under the EPBC Act. Bamford Consulting Ecologists (BCE) was asked to review the status of MNES in the project area and immediate surrounds as a means to determine what management actions might be required to mitigate potential impacts. The project area and sites immediately around it are illustrated in Appendix 1.

2 Methods

The review of MNES carried out by BCE was based upon previous studies, databases and a site inspection. The results of previous studies included an assessment of the fauna values of the project area by Ecologia Environment (2006), investigations of part of the project area in 2012 by GHD (2012), and an impact assessment by Strategen (2009) specifically for Carnaby's Black-Cockatoo.

While Ecologia Environment (2006) included a review of databases such as the EPBC Act protected matters database, Naturebase and Birdata, the protected matters database was also accessed in April 2014. In addition, some species were included based upon known patterns of general distribution.

For the site inspection, the project area was visited by Dr Mike Bamford of BCE from 22nd to 24th April 2014. The project area and many areas of remnant native vegetation in the surrounding district to at least 15km from the site were inspected. This inspection included the mine area and the desalination pipelines route, and allowed the suitability of habitat for significant species known from the general region to be assessed. During the site inspection, searching was carried out for signs of significant species such as the dreys of the Western Ring-tailed Possum, foraging holes of Woylies and scats of the Chuditch.

Species lists generated from the review of sources of information were generous as they included records drawn from a large region and possibly from environments not represented in the survey area. Even records made in the project area may not be representative of the status of the species in the area, as fauna are highly mobile. Therefore, interpretation of lists of significant species generated through the desktop review and site inspections included assigning an expected status within the survey area to species of conservation significance. This gives an indication of the likely importance of the area to the species. The status categories used are:

- Resident: species with a population permanently present in the survey area;

- Regular migrant or visitor: species that occur within the survey area regularly in at least moderate numbers, such as part of annual cycle;
- Irregular Visitor: species that occur within the survey area irregularly such as nomadic and irruptive species. The length of time between visitations could be decades but when the species is present, it uses the survey area in at least moderate numbers and for some time
- Vagrant: species that occur within the survey area unpredictably, in small numbers and/or for very brief periods. Therefore, the survey area is unlikely to be of importance for the species; and
- Locally extinct: species that has not been recently recorded in the local area and therefore is almost certainly no longer present in the survey area.

3 Results

Species returned from the review that are MNES include up to 20 bird and nine mammal species (Table 1). Four of the bird species and eight of the mammal species are locally extinct with no recent records and little if any suitable habitat due to clearing for agriculture. Only one significant mammal is expected, the Chuditch, and then only as an irregular visitor south of the proposed mine, in the vicinity of the desalination pipelines. This species has declined in the region due to habitat loss and impacts of feral species. It has not been recorded in any of the surveys carried out as part of this project.

Among birds of MNES returned from the review, the Malleefowl and Australasian Bittern are thought to have been resident but are now unlikely except as vagrants or irregular visitors due to habitat loss. Wetlands in the area are mostly small, seasonal and with a canopy of eucalypts over low sedges, rather than the extensive rushbeds favoured by the bittern. Migratory waterbirds are also expected only as vagrants as the wetlands lack the areas of open water, shallows and extensive emergent vegetation that are favoured by such species. Figure 1 illustrates a typical wetland in the region. Note there are large salt lakes to the north which may be utilised by migratory waterbirds but they are outside the area of impact.

The Forest Red-tailed Black-Cockatoo has been seen infrequently in the area by residents (M. & M. Gorman pers. comm.) and the region is at the eastern limit of the sub-species' range. A key food plant is the Marri *Corymbia calophylla* and this is absent from the project area, but present along the South Coast Highway to the west. It is therefore expected only as an irregular visitor. The Fork-tailed Swift is also expected only irregularly and furthermore is largely aerial in Australia, so is unlikely to be affected by localised development as proposed.

Of the species that are expected, only Carnaby's Black-Cockatoo and the Rainbow Bee-eater are expected to be present regularly.

The Rainbow Bee-eater is a breeding migrant to the region but was not recorded by Ecologia (2006) although it was predicted to be likely to be present. The species is widespread and digs its nesting burrows in disturbed environments including on the edges of roads and tracks.

Carnaby's Black-Cockatoo was recorded by Ecologia (2006) and was present during the April 2014 site inspection, with a flock of about 300 foraging on the verge of Mettler's Lake Road (near Lots 6857 and 6859 outside the project area; Figure 2) and two birds in a pine plantation on Lot 555 (formerly Lot 6832). There was evidence of the species foraging at many locations visited during the April site inspection, including in the pine plantations on Lot 555 (formerly Lot 6832) (Figures 3 and 4).

Carnaby's Black-Cockatoo is likely to be a regular non-breeding migrant to the region from late spring to early winter, with some non-breeding birds possibly remaining during the winter/spring period. Remnant native vegetation in the project area and nearby is likely to support foraging, as will pine plantations. It is possible that the flock of 300 birds seen in April 2014 was roosting in Tasmanian Blue Gum plantation on Lot 6857; these were some of the largest trees seen in the region. Breeding is likely to take place further north and west where the vegetation contains large trees that provide suitable hollows. There are no such trees in the project area but one area of woodland that included some large Marri was identified to the west, at around 626600mE, 6167350mN (Figure 5). This is the nearest possible breeding habitat to the project area.

The main purpose of the April 2014 site inspection was to assess the relative value for Carnaby's Black-Cockatoo of native vegetation in the project area compared with potential offset areas that could be purchased by the SDJV.

4 Significance of MNES in Project Area

Of the 19 bird and nine mammal species that are MNES and may at some time have occurred in the project area, only seven bird and one mammal species may still be present. The remainder are locally extinct due to factors such as clearing for agriculture, introduced predators and changed fire regimes. The species listed as locally extinct have all shown extreme range contractions across the entire South-West and there is limited habitat for them. For example, the native vegetation south of the mine area, along the route of the desalination pipelines, lacked plant species such as WA Peppermint *Agonis flexuosa*, favoured by the Western Ring-tailed Possum, and searching failed to locate the characteristic dreys of this species. There is little low heathland as favoured by the Western Ground Parrot, or dense riparian thickets as favoured by the Quokka.

The status of each MNES in the project area, based upon observations and interpretation of the environments present, is given in Table 1. The relationship between status and possible impacts of the proposed development is discussed below for those species that are or might be present. Possible impacts are briefly discussed in terms of key impacting processes as described by Gleeson and Gleeson (2012), such as habitat loss, habitat fragmentation and increase in mortality.

Malleefowl. A former resident that is now probably only a vagrant in the region. Occasional birds moving through the project area are unlikely to be affected by small areas of habitat loss associated with the mine and infrastructure, and the risk of an increase in mortality, such as from roadkill, would be

little changed due to current traffic volumes in the region. The species has not been seen during surveys in the area or reported by residents, and no mounds have been found.

Australasian Bittern. A species of densely-vegetated wetlands, this is a vagrant in the project area as there is little if any suitable habitat. No effect from the project expected.

Forest Red-tailed Black-Cockatoo. Expected only as a vagrant or irregular visitor and unlikely to be reliant upon native vegetation within the impact areas of the mine and associated infrastructure, as primary food plants are eucalypts and the Marri, with these absent or very poorly represented.

Carnaby's Black-Cockatoo. A regular migrant with some birds possibly resident. Foraging habitat is represented within impact areas but there is no breeding habitat. The possible roost in a Blue Gum plantation described above is outside areas of direct impact and lies within a possible offset area. The effect of impacts upon foraging habitat is discussed elsewhere in a Carnaby's Impact Assessment report.

Migratory waterbirds. Up to 10 species may occur in the project area as vagrants, including Eastern Great Egret, Red-necked Stint, Common Greenshank, Sharp-tailed Sandpiper and Wood Sandpiper. The White-bellied Sea-Eagle and Eastern Osprey may both occur along the nearby coastline where the desalination intake and outlets are located. All these species are best considered only as vagrants in the project area, as they would occur infrequently and only in small numbers due to lack of suitable habitat. As a consequence, no effect from the project is expected.

Fork-tailed Swift. This is a non-breeding migrant to Australia and tends to be nomadic, and is expected as an irregular visitor in the general region; it could occasionally occur in moderate numbers. The Fork-tailed Swift is largely aerial in Australia and thus independent of terrestrial environments, and therefore it is not expected to be affected by very localised impacts associated with this project.

Rainbow Bee-eater. This is a breeding migrant to southern Australia, with breeding occurring in late spring to summer. It is almost certainly present annually in the project area but breeds in disturbed environments and thus is unlikely to be impacted, although there is a chance of earthworks along roads directly affecting nests. This can be managed by either avoiding earthworks during the breeding season (November to mid-January) or identifying nests and avoiding works around actual nest sites.

Chuditch. A former resident that is now probably only an irregular visitor due to land clearing and predation by feral predators. However, there is extensive suitable habitat in native vegetation south of the highway, and the species could even be resident in this region. This is outside the main mine and infrastructure area, but the desalination pipelines pass through habitat where the species could occur at least irregularly. The footprint of the pipeline is narrow and largely avoids native vegetation, and therefore any impact in terms of habitat loss or fragmentation is expected to be negligible. The risk of an increase in mortality, such as from roadkill, would be little changed due to current traffic volumes in the region.

Of the above species, only Carnaby's Black-Cockatoo is considered likely to experience any possible adverse impacts from the proposed development, due to some loss of foraging habitat, and this risk is assessed in detail elsewhere.

Table 1. Species listed under the EPBC Act for the area and therefore Matters of National Environmental Significance, and that occur or may have occurred in the project area (mining and desalination pipeline). The predicted status of each species in the project area is given (as per Section 2).

Species		EPBC Listing	Status in Project area
BIRDS			
Malleefowl	*Leipoa ocellata*	Vul/Mig	Vagrant (formerly resident)
Australasian Bittern	*Botaurus poiciloptilus*	End	Vagrant (formerly resident)
Forest Red-tailed Black-Cockatoo	*Calyptorhynchus banksia naso*	Vul	Irregular visitor or Vagrant
Carnaby's Black-Cockatoo	*Calyptorhynchus latirostris*	Vul	Regular migrant
Western Ground Parrot	*Pezoporus flaviventris*	Cr End	Locally extinct (formerly resident)
Migratory waterbirds	Five to 10 species possible	Mig	Vagrants as little suitable habitat
Fork-tailed Swift	*Apus pacificus*	Mig	Irregular visitor
Rainbow Bee-eater	*Merops ornatus*	Mig	Regular migrant
Noisy Scrub-bird	*Atrichornis clamosus*	Vul	Locally extinct (formerly resident)
Western Whipbird	*Psophodes nigrogularis nigrogularis*	End	Locally extinct (formerly resident; possibly persists west of Cape Riche)
Western Bristlebird	*Dasyornis longirostris*	Vul	Locally extinct (formerly resident)
MAMMALS			
Dibbler	*Parantechinus apicalis*	End	Locally extinct (formerly resident)
Chuditch	*Dasyurus geoffroii*	Vul	Irregular visitor (formerly resident)
Numbat	*Myrmecobius fasciolatus*	Vul	Locally extinct (formerly resident)
Red-tailed Phascogale	*Phascogale calura*	Vul	Locally extinct (formerly resident)
Western Ring-tailed Possum	*Pseudocheirus occidentalis*	Vul	Locally extinct (formerly resident)
Woylie	*Bettongia penicillata*	End	Locally extinct (formerly resident)
Quokka	*Setonix brachyurus*	Vul	Locally extinct (formerly resident)
Gilbert's Potoroo	*Potorous gilberti*	Cr End	Locally extinct (formerly resident)
Dayang or Heath Rat	*Pseudomys shortridgei*	Vul	Locally extinct (formerly resident)

Vul = Vulnerable; End = Endangered; Cr End = Critically Endangered; Mig = Migratory.

Figure 1. A seasonal wetland on Lot 555 (formerly Lot 6832) consisting of a eucalypt open woodland over sedges on seasonally damp and occasionally flooded soil. Some other wetlands in the area have suffered weed invasion and canopy loss.

Figure 2. Part of a flock of 300 Carnaby's Black-Cockatoos foraging amongst banksias on the verge of Mettler's Lake Road and flying to perch in Tasmanian blue Gums on Lot 6857 which is outside the project site.

Figure 3. Cones of two banksia species chewed by Carnaby's Black-Cockatoo, Mettler's Lake Road near Lot 6857, 23rd April 2014. This is outside the project site.

Figure 4. Pine plantation with chewed cones discarded by Carnaby's Black-Cockatoo, Lot 555 (formerly Lot 6832), 24th April 2014.

Figure 5. Eucalypt woodland along South Coast Highway at 626600mE, 6167350mN. Some Marri potentially large enough for nesting by black-cockatoos are located in this area. This is outside the project site.

5 References

Ecologia Environment (2006). *Albany Iron Ore Project, Southdown Magnetite Proposal: Terrestrial Vertebrate Fauna Assessment,* prepared for Grange Resources Pty Ltd, November 2006.

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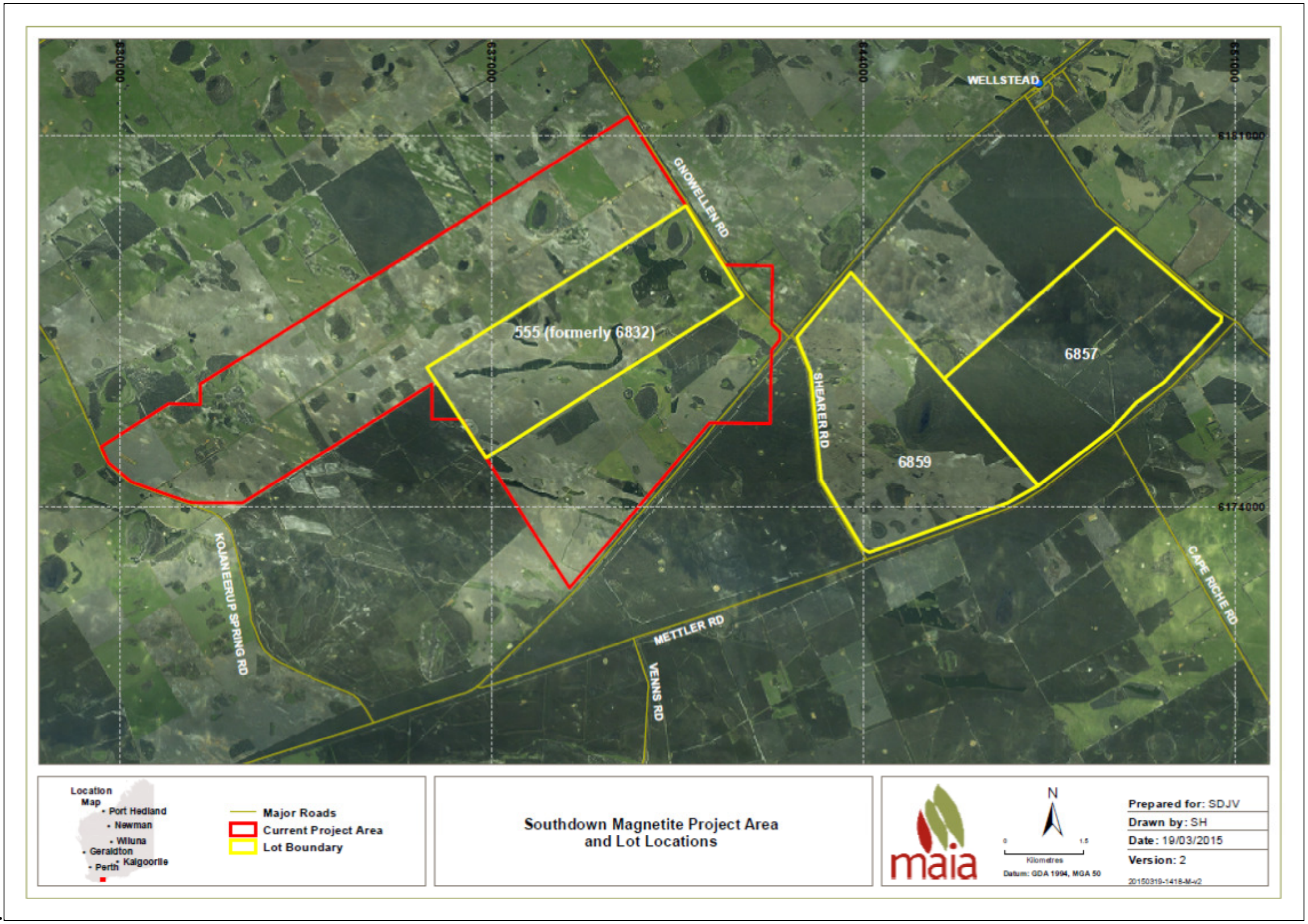

Appendix 1. The project area and adjacent locations mentioned in the text.

Appendix 5 – Groundwater Monitoring and Management Plan

Southdown Magnetite Project

Groundwater monitoring and management plan

Prepared for
Grange Resources Limited

November 2018

DOCUMENT TRACKING

Item	Detail
Project Name	Southdown Magnetite Project – Groundwater Monitoring and Management Plan
Project Number	10579
Project Manager	Lisa Adams
Prepared by	Corneli van der Merwe
Reviewed by	Lisa Adams
Approved by	Lisa Adams
Status	FINAL
Version Number	6
Last saved on	20 November 2018

This report should be cited as 'Eco Logical Australia (2018). *Southdown Magnetite Project – Groundwater monitoring and management plan*. Prepared for Grange Resources Limited'

ACKNOWLEDGEMENTS

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Contents

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1 Purpose and scope of Groundwater Monitoring and Management Plan

Grange Resources Limited (Grange Resources), on behalf of Southdown Joint Venture, proposes to develop a magnetite mine (Southdown Magnetite Project) as part of the Albany Iron Ore Project in the Wellstead area east of Albany. Development of the mine will involve dewatering to enable safe mining of the identified magnetite deposit, a portion of which is located below the regional watertable, and possible groundwater abstraction for water supply from separate aquifers to the north and south of the Project area.

This Groundwater Monitoring and Management Plan describes the adaptive management approach to groundwater abstraction for both dewatering and water supply to address any unexpected and adverse damage to the ecosystems of the region that might result from groundwater abstraction. This Plan has been prepared to support the assessment of impacts to Matters of National Environmental Significance under the *Environmental Protection and Biodiversity Conservation Act 1999.* This process would be based on monitoring groundwater responses to abstraction in the deeper aquifers and monitoring shallow groundwater levels to determine if there are any responses to the abstraction. If an unexpected groundwater level drawdown occurs, then vegetation health monitoring will be conducted to determine if there is a response in comparison to a control site. This information can then be used to inform adaptive management of the Project.

The purpose of the monitoring program is to assess aquifer response to expected modelled rates of drawdown and to trigger the implementation of contingencies where necessary. The monitoring plan will also validate, provide new information and improve the current understanding of the conceptual and numerical hydrogeological model.

2 Summary of predicted outcomes and residual risk

Groundwater abstraction will be undertaken for mine dewatering and for water supply as part of the Southdown Magnetite Project, creating spatially and temporally distinct areas of drawdown. There is no overlap between the areas of drawdown associated with the abstraction areas and the groundwater response to abstraction has been modelled separately for each activity.

Figure 1 shows the location of the proposed mine pit and the Palaeovalleys where the proposed water supply borefields may be located. The exact location of the borefields are unknown but will be within one or both of the Palaeovalleys shown within Figure 1.

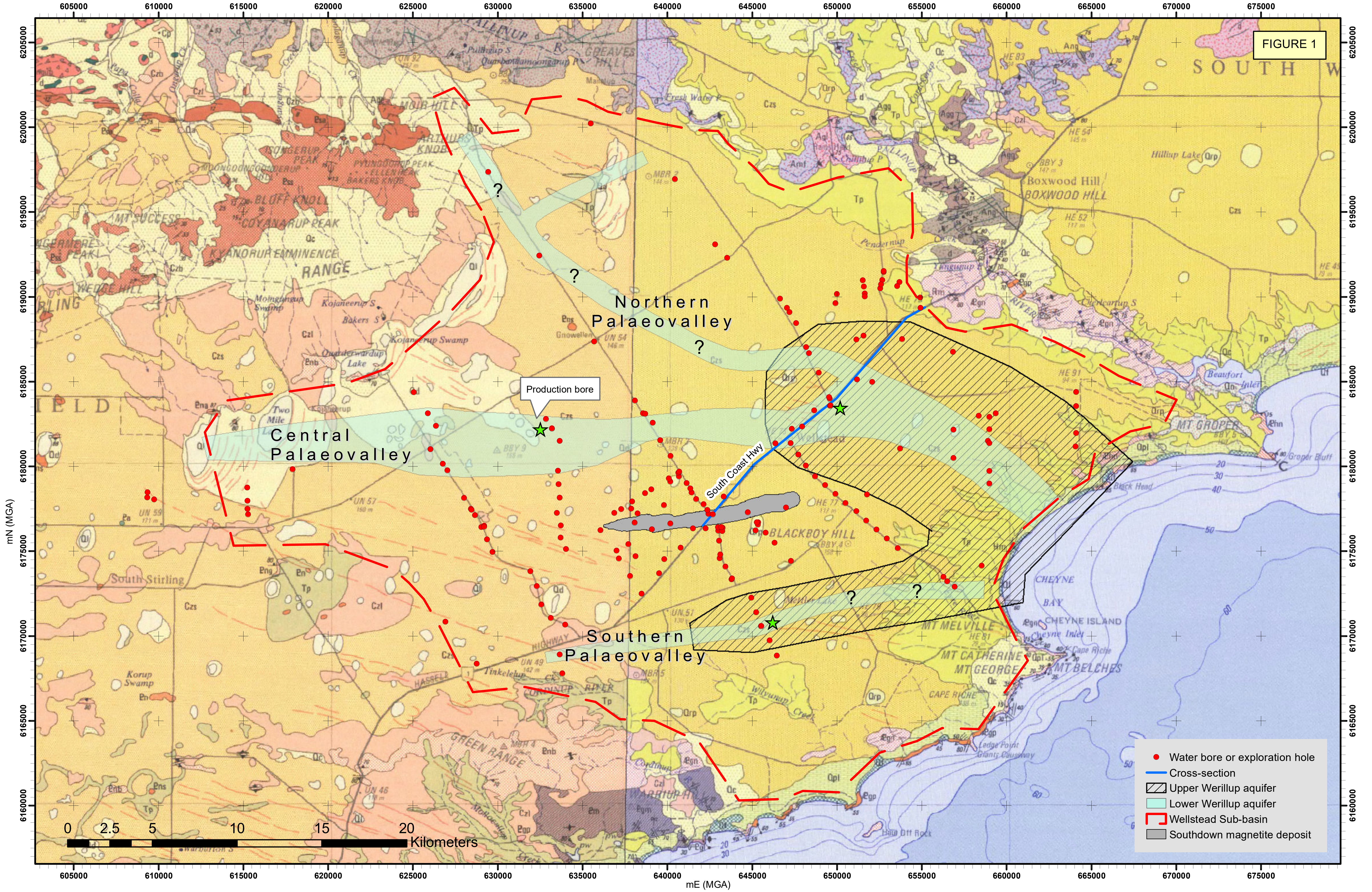
Groundwater abstraction from the proposed water supply borefield is expected to result in up to 25 m of drawdown in the potentiometric surface (i.e. pressure) in the lower Werillup aquifer. Groundwater investigations and the model developed by Rockwater (2017) indicate that no measurable drawdown will occur in the shallow Pallinup aquifer as a result of water supply abstraction from the Werillup aquifers as shown in the cross section in Figure 2. This is due to the confining layer between the shallow Pallinup aquifer and the deeper Werillup aquifers. However, as a precautionary measure, an adaptive

management process will be implemented to address any uncertainty regarding hydraulic connection between the aquifers and potential transfer of drawdown into the shallow aquifer.

The average depth to water in the Pallinup Formation is about 15 m with an annual variation of up to 1 m (based on review of quarterly monitoring dataset from March 2006 to June 2018 provided by Rockwater). Shallower depths to water occur beneath sump-like surface depressions, which, where not cleared for agriculture, form ephemeral wetlands such as Mettler Lake which is about 7.5 km south east of the proposed mine (Figure 3). Mettler Lake is one of the most significant wetlands in the vicinity of the project area and is protected within the Mettler Lake Reserve. The current depth to water in the Pallinup Formation beneath the deepest part of the Mettler Lake basin floor is estimated to be approximately 5 m (Figure 3). The depth to watertable below Springwell Lake is approximately 8 m. Any surface water in these lakes is derived from rainfall and perched watertables. Shallow groundwater levels are also associated with the coastal creek lines that discharge to the sea south of the proposed mine and water supply borefield. The most significant of these are Wilyun Creek and Eyre River which intersect the shallow groundwater table and have permanent groundwater inflows as illustrated in the cross-section in Figure 2.

The mine pit dewatering was modelled by Golder (2006) as part of a Public Environmental Review (PER) for the Southdown Project. The model was based on progressive mining of a 300 m deep pit in an easterly direction for a 20 year period. Modelled drawdowns for the end of mining, shown in Figure 4, are highest for the western margin of the pit, where they extend up to 1 km from the pit margin. Most of the cone of depression is predicted to lie under the waste dump and other components of the mine infrastructure. Therefore, potential impacts to the environment are considered unlikely. If more extensive groundwater drawdown did occur, the areas most at risk from drawdown would be the vegetation associated with surface depressions such as Springwell Lake (Figure 3) down gradient (south east) of the mine pit. Therefore, groundwater levels beneath Springwell Lake and near Mettler Lake will be monitored.

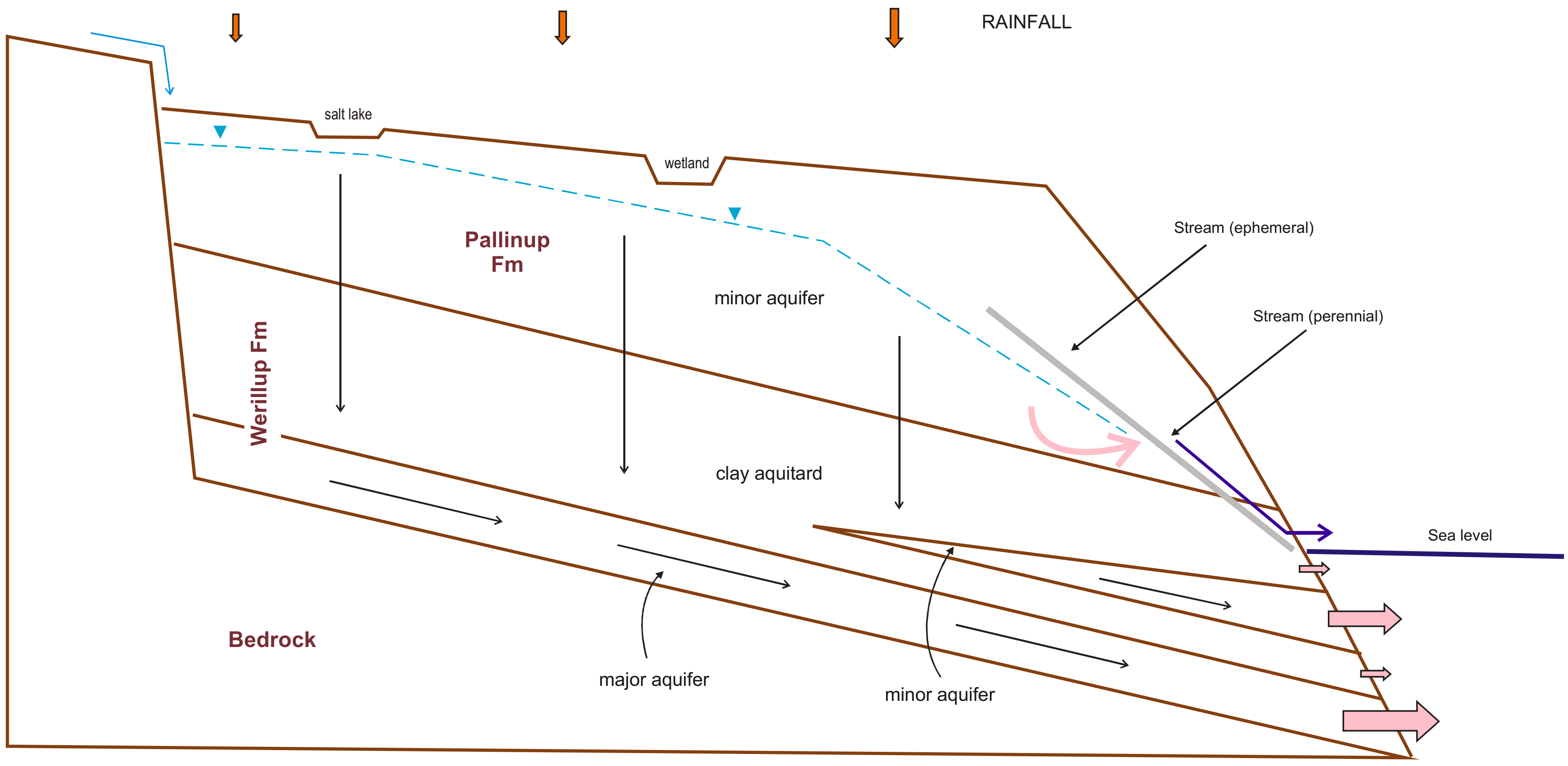
The water quality of the regional aquifer is brackish to saline and as such, is unlikely to provide a preferred water supply source to any vegetation, as the species present within the mine locality do not represent salt tolerant species (Ecologia 2007) and are unlikely to utilise groundwater, even in areas where depth to groundwater is shallow. Therefore, this adaptive management plan is conservative as it monitors groundwater levels adjacent to low lying areas (such as Springwell Lake) even though the risk of impact is considered low.



CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: July. 2018
Dwg No: 216.1.1/18/1-1

BORES, PALAEOVALLEYS AND WERILLUP AQUIEFRS

Rockwater Pty Ltd



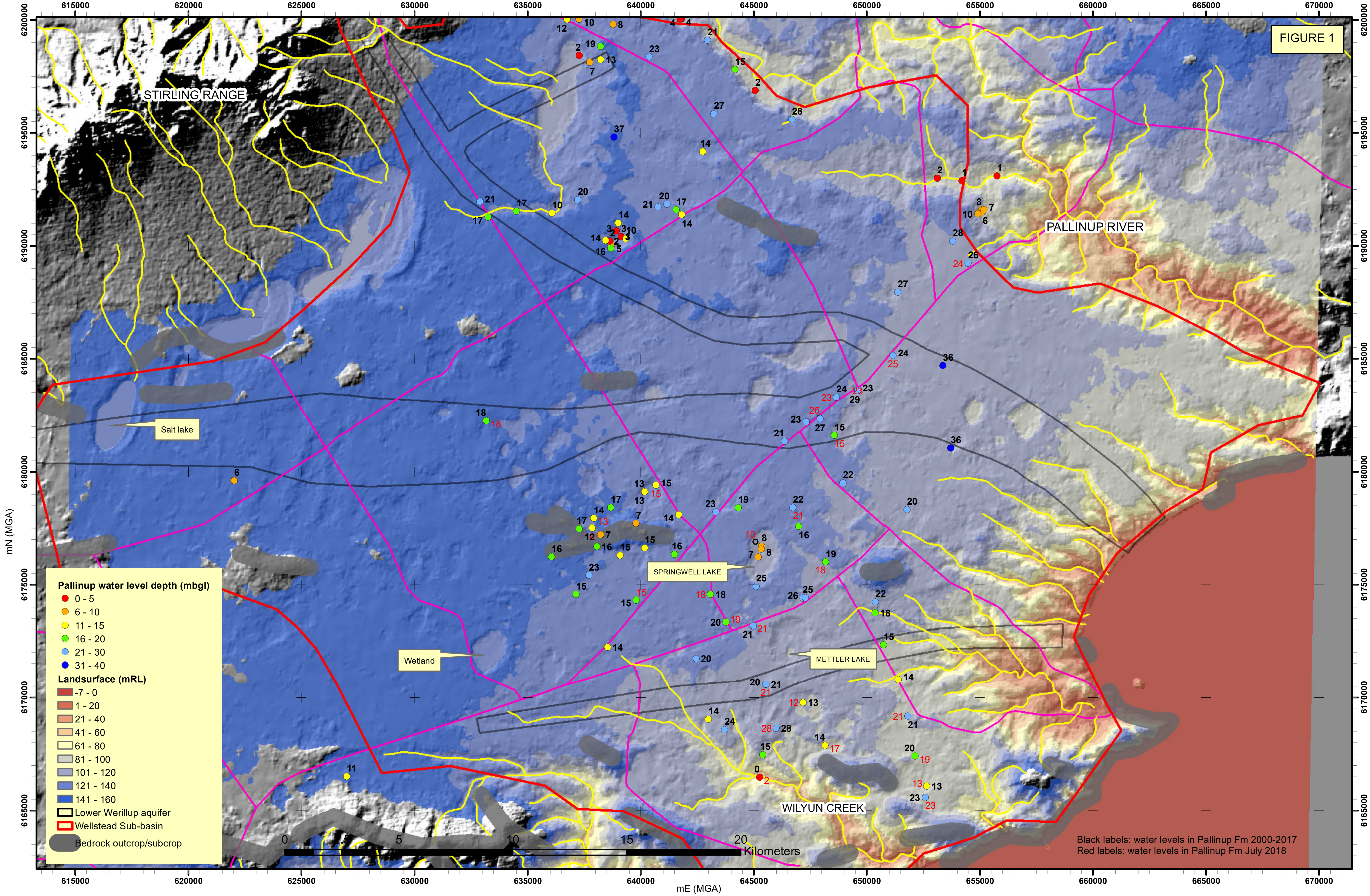
NOT TO SCALE

FIGURE 16

CONCEPTUAL GROUNDWATER FLOW SYSTEM

Client: Southdown Joint Venture
Project: Water Supply Investigation
Date: Sept. 2017
Dwg No: 216-1-1/17/2-16

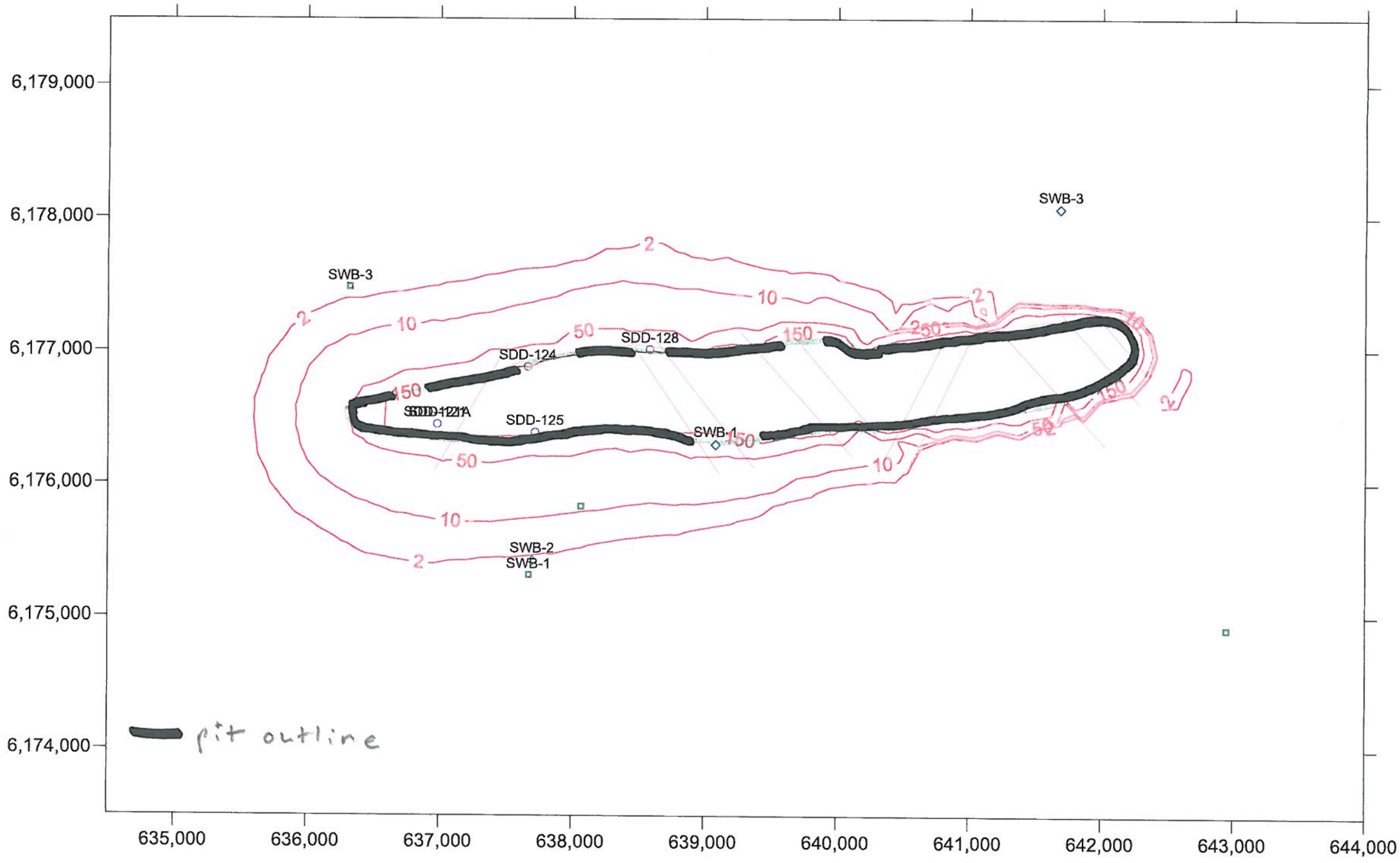
Rockwater Pty Ltd



CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: Ju;y 2018
Dwg No: 216.1.1/18/2-1

PALLINUP FORMATION WATER LEVEL DEPTH

Rockwater Pty Ltd



Refer to Groundwater Drawdown in Weathered Zone

CLIENT	Grange Resources			PROJECT	Dewatering		
DRAWN	JJV	DATE	November 2005	TITLE	MODELLED GROUNDWATER DRAWDOWN AFTER 20 YEARS (m)		
CHECKED	RF	DATE	July 2006				
SCALE	NOT TO SCALE		A3	PROJECT No	05641009-16	FIGURE No	10

Golder Associates

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3 Monitoring plan

The Southdown Magnetite Project will implement a monitoring program in the areas potentially affected by the proposed groundwater abstraction for dewatering and water supply. This monitoring program will also include control sites so that the effect of the project can be separated from other variables. These control sites will be chosen once the proposed abstraction regime has been finalised and the groundwater model updated to ensure they are appropriate controls and outside of the area of potential impact.

The monitoring program is outlined in Table 1 and Figure 5. Figure 5 indicates the existing network of nested monitoring bores and the areas within which new bores are proposed. At least eight new nested monitoring bores will be installed in the northern palaeovalley and at least eight new nested monitoring bores within and adjacent to the southern palaeovalley. The exact location of new monitoring bores is subject to landholder discussion and consent and therefore only general locations are shown in Figure 5.

3.1 Werillup Aquifer

The monitoring program for the Werillup Formation will be based on the following:

- Groundwater abstraction will occur from this formation. Drawdown levels in this aquifer will be monitored to validate the modelled aquifer response by Golder (2006) for mine dewatering and by Rockwater (2017) for water supply abstraction.

3.2 Pallinup Aquifer

The monitoring program for the Pallinup Formation will be based on the following:

- The shallow aquifer in the Pallinup Formation will be monitored for any pressure changes due to groundwater abstraction from the underlying Werillup Formation or from mine dewatering.
- Groundwater levels of this formation will be monitored in areas with shallow depth to groundwater to identify any impacts on the groundwater system that may potentially affect native vegetation.

3.3 Vegetation monitoring

The vegetation monitoring program will be based on the following:

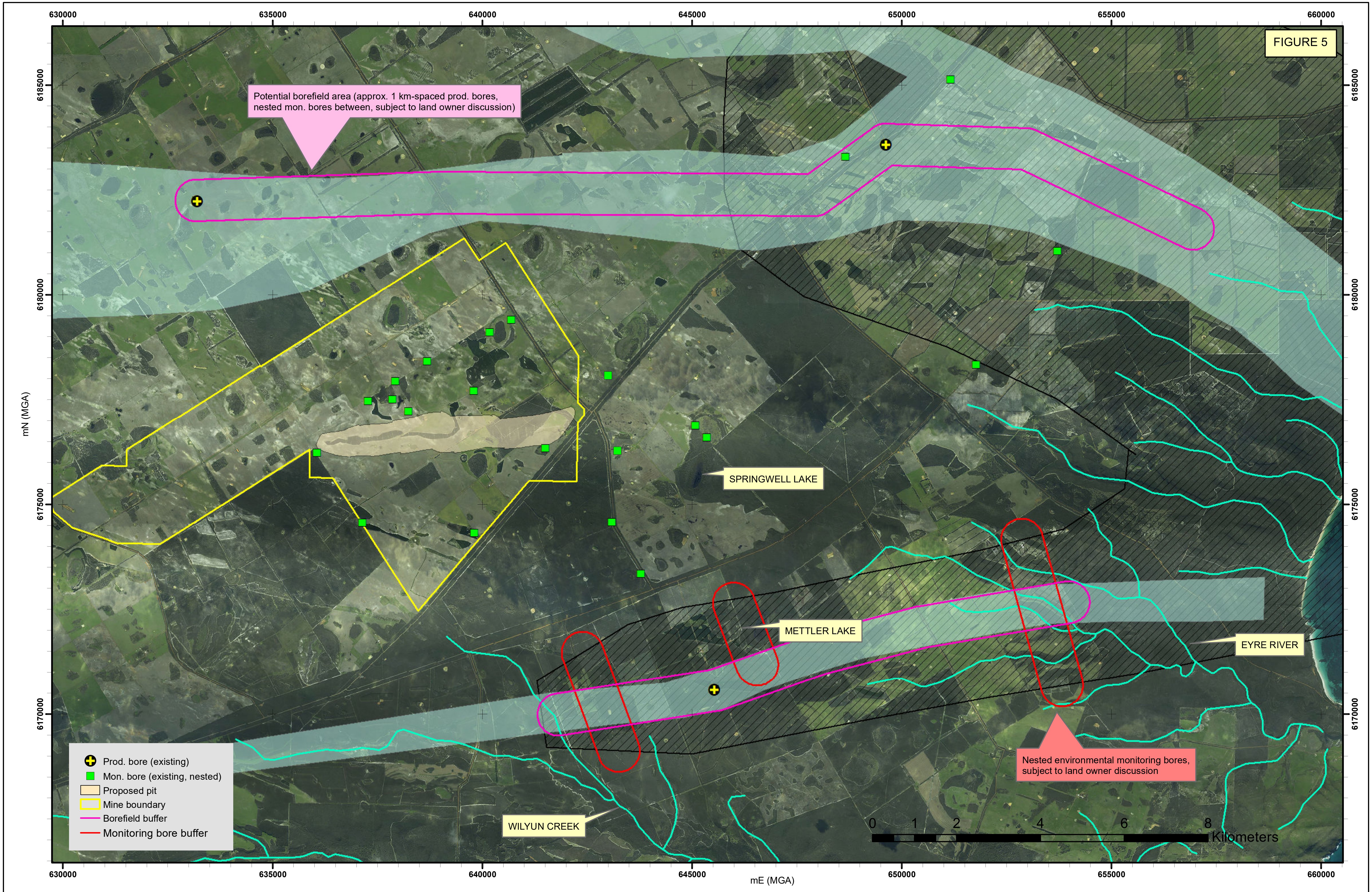
- Baseline vegetation monitoring in areas of interest and in control areas will be undertaken. Additional monitoring will be triggered in response to unexpected changes to shallow groundwater levels.

The monitoring plan outlined below will identify any impacts on vegetation due to groundwater abstraction from mine dewatering or water supply abstraction.

Monitoring results will be reviewed (annually) against baseline data and will be used to determine whether any changes need to be made to the management of the project.

Table 1: Proposed Monitoring Program

Parameter	What?	Purpose	Location	Frequency
Groundwater levels	Monitor groundwater levels in Pallinup and Werillup Formations. All monitoring sites will have nested monitoring bores to measure the level within each aquifer, where multiple aquifers occur	To determine whether the aquifer response is as predicted. To determine whether groundwater levels are likely to change in areas with a shallow depth to groundwater.	Adjacent to the borefield, around the mine site, in Springwell Lake, adjacent to Mettler Lake, headwaters of Wilyun Creek and Eyre River. Indicative locations are provided in Figure 5.	Monthly for the first three years of abstraction, then every three months. After five years, the monitoring will continue annually for the duration of the groundwater abstraction.
Groundwater quality	Monitor groundwater quality in Pallinup and Werillup Formations	To determine whether the hydrological response to abstraction is affecting groundwater quality.	Adjacent to the borefield, around the mine site, in Springwell Lake, adjacent to Mettler Lake, headwaters of Wilyun Creek and Eyre River. Indicative locations are provided in Figure 5.	Monthly for the first three years of abstraction, then every three months thereafter – Salinity, EC or TDS, pH and temperature. After five years, the monitoring will continue annually for the duration of the groundwater abstraction.
Vegetation health	Monitor vegetation health in permanent quadrats according to the Keighery condition rating system	To identify any change in vegetation health that may result from groundwater drawdown.	Springwell Lake, Mettler Lake, Wilyun Creek, at the mine site boundary and control sites.	Baseline vegetation health survey in early autumn (end of dry season) prior to the commencement of dewatering. Further monitoring only conducted if triggered by unexpected changes in the shallow groundwater levels.



CLIENT: Southdown Joint Venture
PROJECT: Water Supply Investigation
DATE: Nov. 2018
Dwg No: 216.1.1/18/2-

SOUTHDOWN DEWATERING AND WATER SUPPLY, EXISTING AND PROPOSED MONITORING BORES (SUBJECT TO LAND OWNER DISCUSSION AND CONSENT)

Rockwater Pty Ltd

4 Adaptive management

If monitoring indicates that unexpected and significant impacts are likely, Grange Resources will implement appropriate contingency actions within an adaptive management framework. The proposed approach to adaptive management will ensure that no unexpected impacts occur.

The key elements of the adaptive management approach that will be applied in the operation of the Southdown Magnetite Project are:

- Tiered monitoring approach will verify model predictions and ensure early warning of unexpected changes
- Clear decision-making framework
- Hydrological model, triggers and contingencies will be refined based on results of monitoring
- Monitoring results, triggers and contingencies will be regularly reviewed (annually) and where necessary, revised in agreement with the regulatory agencies.

4.1 Adaptive management process

The process for determining the need for triggering contingency actions is set out in Figure 6.

The groundwater modelling used to provide the basis for assessment of environmental impacts has predicted rates of groundwater level change in both the deep aquifer (Werillup Formation) and shallow aquifer (Pallinup). Comparison of the observed and modelled response will be evaluated in accordance with the processes in Figure 6 and set out in Table 2. The model will be updated prior to the commencement of dewatering to incorporate more recent hydrogeological information and groundwater abstraction plans. The model will then be periodically reviewed (nominally every five years or as project plans change or triggered by an unexpected monitoring response) during the life of the project.

The specific contingency action and triggering process for each of these potential risk areas is set out in Table 2, to be read in conjunction with Figure 6.

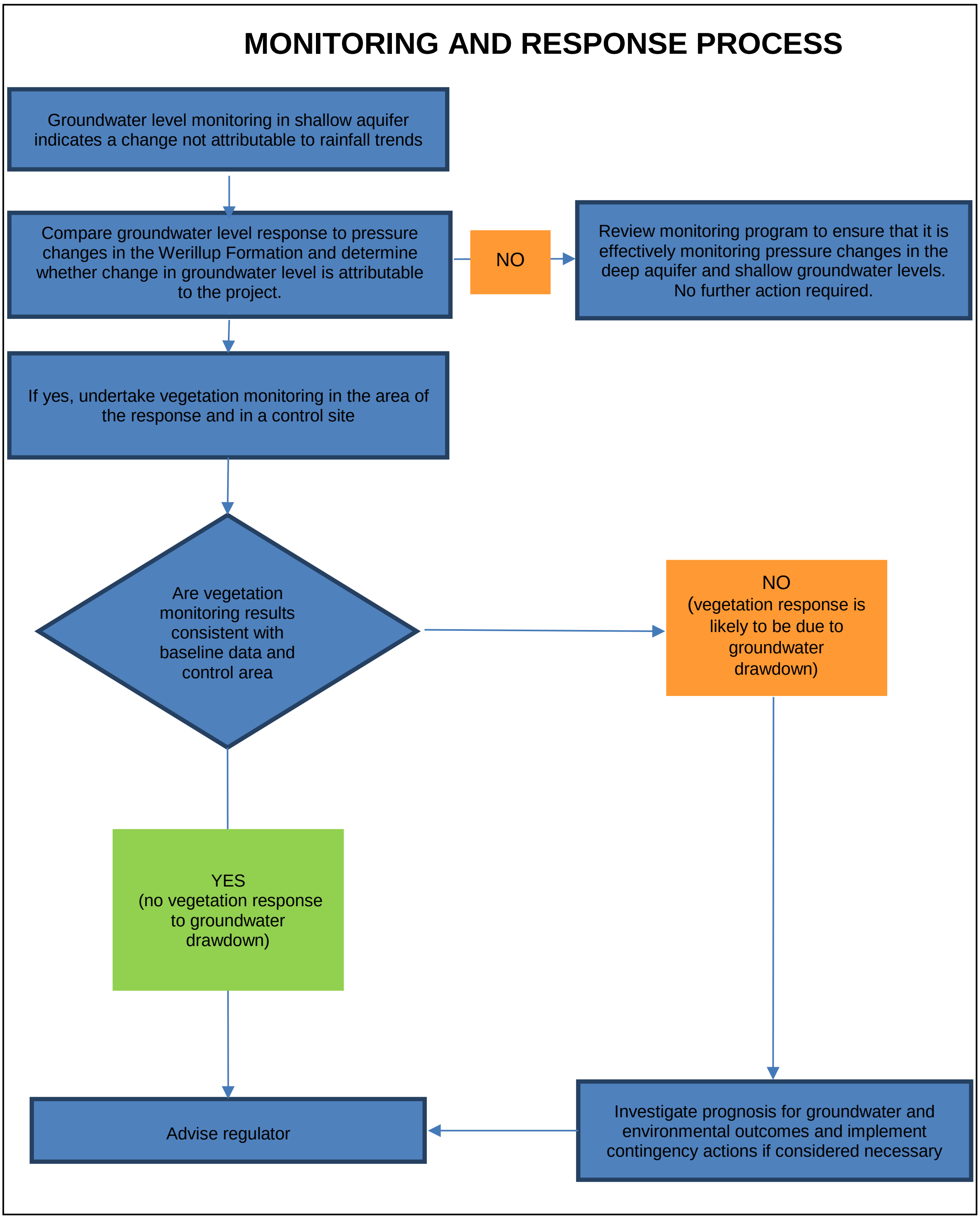


Figure 6: Flow chart showing process for responding to groundwater monitoring triggers

4.2 Triggers and contingencies

The following contingencies will be implemented, if required:

- Advise regulators of trigger event or unexpected hydrological responses within one month.
- Investigate reasons for the hydrological response
- Review numerical model with the new data and determine whether environmental impacts are like to occur as a result of dewatering
- Implement vegetation and surface water monitoring in risk areas, if needed
- Implement appropriate contingency actions as agreed with regulators.
- Amend the abstraction regime, if required and monitor response.

The triggers and contingencies are outlined in Table 2.

Table 2: Triggers and contingency actions

Feature	Response Trigger Level	Contingency action
Deep borehole monitoring (Werillup Formation)	Drawdown exceeds the modelled rate of decline by greater than 20%.	Investigate reasons for hydrological response by looking at drawdowns in surrounding bores. Review the model(s) with new information and determine whether environmental impacts are likely. Assess whether contingencies are required.
Shallow borehole monitoring (Pallinup Formation)	Groundwater level drawdown in the shallow Pallinup Formation indicate groundwater level change due to abstraction from Werillup Formation	Advise regulators of trigger event. Review modelling with new information and determine whether environmental impacts are likely. Implement vegetation monitoring program in areas of risk (i.e. if drawdown is near areas with groundwater levels <10 m). Implement surface water monitoring program in areas of risk (i.e. if drawdown is near/within 1 km of areas with perennial groundwater discharge such as Wilyun Creek or Eyre River).

Feature	Response Trigger Level	Contingency action
	Groundwater levels indicate unacceptable change in water table (>1 m drawdown in comparison to reference sites and/or expected water levels) at key monitoring sites that may potentially affect native vegetation or surface water discharge.	Investigate monitoring results from deeper aquifer, rainfall and control sites to determine whether response from shallow aquifer is due to dewatering or over-abstraction from deep aquifer. If a correlation between the aquifers is determined, advise regulators of exceedance and planned response. Implement appropriate contingency actions as agreed with regulators. Likely to include amending the abstraction regime.
Vegetation health	Monitoring of vegetation health outside the Development Envelope indicate water-stress related to change in groundwater levels	Advise regulators Reduce groundwater abstraction from deep aquifer and increase monitoring of vegetation health and observe response.

5 Review and revision

The monitoring plan will be reviewed annually for the first two years of abstraction to determine whether changes need to be made to the adaptive management of the project. The monitoring program should then be reviewed every five years and modifications made where necessary.

References

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Appendix 6 – Noisy Scrub-bird Records

Towns
Major Roads

Noisy Scrub-bird (*Atrichornis clamosus*) NatureMap records close to the project area

(Note: outlier records do not indicate that birds occur in the area between them and the core population)

maia

N

0 7.5
Kilometres

Datum: GDA 1994, MGA 50

Map: 1
Prepared for: SDJV
Drawn by: SH
Date: 08/02/2018
Version: 4

Appendix 7 – Copies of Submissions Received

From: Peter Mckenzie <pb.mac1@bigpond.com>
Sent: Tuesday, 28 November 2017 10:23 PM
To: SDNapprovals@grangeresources.com.au
Cc: peter.watson@mp.wa.gov.au; Rick.Wilson.MP@aph.gov.au; southwest.evers@mp.wa.gov.au; wa-government@dpc.wa.gov.au
Subject: public comment

Hello

I am a resident of Wellstead community providing feedback on the EPBC Act referral documentation and additional information related to the Southdown Magnetite Project. I dropped in at the Wellstead Community Resource Centre to look at the hard copy of the report and documentation left there for public viewing. It is a very large document and would require a few days to fully review.

I noticed the public were invited to make comment on the EPBC Act referral documentation between Friday 3rd November 2017 to Thursday 30th November 2017. Like nearly every resident of the Wellstead community I am involved with the commercial agricultural industry. Grange Resources would have been FULLY aware that November and December is the busiest time of the year in Wellstead District with many landholders engaged with grain harvesting or intensive stock management. We would like it noted that the lack of public comment input from Wellstead community residents is not because we have no comment to make or interest in the very large proposed Grange Magnetite mine proposed for our District. It is just that none of us have time to review the documentation during the very short time it has been released and made available for comment. It coincides with the busiest time of our agricultural year. We are appalled and insulted that this is considered an acceptable action by Grange Resources.

Yours sincerely
Peter McKenzie

Sylvia Leighton
554 Mettler's Lake Road
Mettler, WA 6328
mob: 0427 991085

Public comment on the EPBC Act referral documentation and additional information related to the Southdown Magnetite Project November 2017

Feedback on the proposed shallow groundwater extraction of Wellstead Aquifers.

Grange has stated that they intend to extract up to 5 Gigalitres per year of groundwater in the identified Wellstead aquifers (Figure 6-1) for water supply to the mine site. I argue we do not understand the vegetation community/hydrology relationship well enough in the southcoast region to allow 5 billion litres of our shallow groundwater supply in Wellstead aquifers to be made accessible annually to the Southdown Mine project.

Grange predicts that the 5 billion litres extraction will have no impact on Matters of National Environmental Significance (MNES) and have specifically referenced the one species – the Carnaby Cockatoo. The specific aquifers that Grange have identified in Figure 6-1 actually extend under areas where there are other species of national significance; the Vulnerable Forest Red-tailed Black-Cockatoo, Karrak (*Calyptorhynchus banksii naso*), Baudin's Cockatoo, (*Calyptorhynchus baudinii*), Malleefowl (*Leipoa ocellata)* and the Endangered Australasian Bittern (*Botaurus poiciloptilus*) (has been recorded in Mettlers Lake Nature Reserve in the past) are other faunal MNES that need to be considered.

There are also floral MNES that need to be considered. The proposed Southdown Mine site itself is actually located within a native vegetation community that was recently listed as a Threatened Ecological Community (TEC), the Proteaceae Dominated Kwongkan Shrublands of the south east coastal floristic province. Much of the proposed extraction aquifers sit in under naïve vegetation areas which fall in under this TEC classification. The aquifers also extend under a WA Priority Ecological Community (PEC) made up of Flat Topped Swamp Yate (*Eucalyptus occidentalis*). These trees are located in seasonally inundated clay basin and are adapted to be able to survive with their roots under water for over 18 months duration.

The Grange Summary Report for the Southdown Magnetite Project identifies that much of the Wellstead District water table is more than 9-10m below the surface, and as such, any vegetation present in these areas is understood to be a facultative groundwater user that would not be affected by changes in the regional water table level. There have been no studies in the southcoast region on the root zone depth and the water extraction characteristics of the vegetation community's specific to southcoast region and more specifically in the Wellstead District. Grange have relied on data extrapolated from just one study by Froend & Loomes (2006) who investigated ecological water requirements on the Southern Blackwood and Eastern Scott Coastal Plain. Froend & Loomes postulate that vegetation requirements for groundwater decrease with depth to the watertable, and that vegetation is more tolerant to water table decline due to the corresponding increase in alternative water sources.

I live in Wellstead District and have a particular interest in the native vegetation communities, landform, soils, soil moisture profiles and water tables. The annual rainfall can range from 430mm - 915mm. We do not have any idea as to what depth the root zone is for different vegetation species or vegetation communities. It has been observed that the recent 20 year bluegum plantations in the southern part of the District have definitely dried out the soil moisture profile. One excavation of the root zone of blue-gums detected them down to a 20 metre depth. The blue-gums have visually caused a detrimental effect on the native vegetation communities in the District that are dependent on occasional seasonally wet soils like the Swamp banksia (*Banksia littoralis*) woodlands, *Melaleuca cuticularis* and *Eucalytpus occidentalis* swamp areas.

Froend & Loomes (2006) effectively classify vegetation overlying watertables at a depth greater than 10 m as being facultative groundwater users. That is, the individual plants may use groundwater if it is available, but do not experience any adverse impacts in its absence. I am deeply concerned about the recent deaths to certain vegetation communities in our District that appear to be reliant on damp seasonal soils. A change in the natural hydrology whether it was just the soil profile or there was also reduced access to ground water has not been ascertained. I believe we do not understand the vegetation/hydrology relationship well enough in the southcoast region to allow 5 billion litres of our shallow groundwater supply in Wellstead aquifers to be made accessible to the Southdown Mine project on an annual basis.

The proposed aquifers that Grange has targeted are located under four catchments in Wellstead District; Cordinup Creek, Wilyun Creek, Eyre River (including Windy Windy Creek and the Pallinup River Catchment. All four of these catchments are poorly researched and it is not known how much drainage from the shallow groundwater table flows into these surface creeks and is important to their yearly surface flow. These creeks and rivers are home to freshwater turtles, freshwater crayfish and water rats (*Hydromys chrysogaster).* Once again - it would be a shame to cause a major change to the ecology of these creeks by reducing the water supply BEFORE we have properly researched the special qualities of these four catchments and then can record if there are any impacts occurring by the proposed water extraction by Grange.

The final feedback I wanted to provide was my disappointment with Grange in choosing a very inappropriate time of the year to ‘open’ the public comment time period for the EPBC Act referral documentation and additional information related to the Southdown Magnetite Project in November (Friday 3rd November 2017 to Thursday 30th November 2017). Most residents of the Wellstead community are involved with the commercial agricultural industry. Grange Resources would have been FULLY aware that November and December is the busiest time of the year in Wellstead District with many landholders engaged with grain harvesting and intensive stock management. The lack of public comment input from Wellstead community residents is not reflective that they have no interest on the impacts of the proposed Grange Magnetite mine on the Wellstead landscape.

Thankyou

Your sincerely
Sylvia Leighton
MSc NRM, BSc Botany, Grad. Dip. Ed., Grad. Dip App. Sc.
30/11/2017

Hon. Diane Evers MLC
Member for the South West Region

Glenda Stirling
Community Liaison Manager
Grange Resources
PO Box 5454 | Albany | WA

Thursday 30 November 2017

Dear Ms Stirling

I write to formally request an extension to the submission period for public comment on Grange Resources' proposed Southdown Magnetite Project beyond today's date, in recognition that Wellstead is a largely farming community and November and December is their busiest time of year.

I understand that the dates for the submission period (3 to 30 November 2017) were proposed by the Federal Department of Environment and Energy, however I suggest these dates may just be a minimum requirement under the legislation and with Grange's support, the Department would not object to an extension to these dates in the circumstances.

I believe that extending the period during which submission will be formally accepted to end of January 2018 would demonstrate Grange Resources' good will to the community and albeit at this late date, hope Grange will agree to do so.

Kind regards,

Yours sincerely,

Diane Evers MLC

Email southwest.evers@mp.wa.gov.au
Phone (08) 9486 8070
Address 7 Harvest Tce, West Perth
Postage PO Box 949, West Perth WA 6872

Deborah Fitzgerald
143 Laithwood Circuit
Marbelup
WA 6330

29 November 2017,

Public comment on the EPBC Act referral documentation and additional information related to the Southdown Magnetite Project November 2017

To whom it may concern,

Southdown Joint Venture: Environment Protection and Biodiversity Conservation Act 1999; Matters of National Environmental Significance – Threatened Flora and Ecological Communities.

It is my opinion that flora surveys conducted over the project area when the project was referred in 2011 require further examination under the referral process, due to the project area now occurring in a Threatened Ecological Community (TEC).

The proposed Southdown Mine site is located within a native vegetation community that was listed as the Proteaceae Dominated Kwongkan Shrublands of the south east coastal floristic province TEC, which was nationally listed in 2014. Based on this listing there are now floral MNES that need to be considered.

The fact that the MAIA report 2016 states that “No ecological community MNES occurred adjacent to or near to the Wellstead Aquifer Investigation Area when the project was referred in July 2011” should now be reconsidered given the implications of the proposed project area lying within the nationally listed TEC. In addition to the TEC there are several WA Priority Ecological Communities, requiring consideration, particularly the Flat Topped Swamp Yate (Eucalyptus occidentalis), which is of State significance.

Further, there is little evidence of the implications of mine and infrastructure development on habitat for other nationally listed threatened species including the Critically endangered Western ring tailed possum (*Pseudochierus occidentalis*) and the Vulnerable Noisy scrub bird (Atrichornis clamosus).

I am frustrated that Grange Resources have chosen an inappropriate time of the year to ‘open’ the public comment time period for the EPBC Act referral documentation and additional information related to this project. Most residents of the rural community are involved with commercial agricultural harvest during this time, and are unlikely to respond.

Thankyou,

Yours sincerely
Deborah Fitzgerald
BA Business, Masters Social Work (current)

From: Jonas Mitchell <jobasm@outlook.com>
Sent: Saturday, 2 December 2017 4:29 PM
To: SDNapprovals@grangeresources.com.au
Subject: Feedback on Grange
Attachments: Jonas's feedback on Grange Nov. 17.docx

Please accept my public comment.

Sent from Mail for Windows 10

Public comment on the EPBC Act referral documentation and additional information related to the Southdown Magnetite Project November 2017

I wanted to make comment about the proposed road diversion of Gnowellen Road as indicated in Figure 3-2 Southdown Magnetite Project - Mine Area and Indicative Infrastructure Layout. I was talking to a Reserves Officer at the City of Albany and they have identified the roadside bushland on Gnowellen Rd as a very significant floral corridor between the Stirling Range National Park and the Cape Riche coastal reserve. The road reserve bushland is in good health and one of the few bits of bush that has continuous connectivity through to the southern coastal reserve. It is extremely important that this vegetation corridor connectivity is maintained. Some of this bushland is also part of the native vegetation community that was recently listed as a Threatened Ecological Community (TEC), the Proteaceae Dominated Kwongkan Shrublands of the south east coastal floristic province. I would therefore expect that it has special protection restricting it’s removal.

Thankyou

Your sincerely

Jonas Mitchell
30/11/2017