Tasman Extension Project

Environmental Impact Statement

APPENDIX B

GROUNDWATER ASSESSMENT

Resource Strategies

DONALDSON COAL

Part of Gloucester Coal

RPS Aquaterra

TASMAN EXTENSION PROJECT
GROUNDWATER ASSESSMENT





TASMAN EXTENSION PROJECT
GROUNDWATER ASSESSMENT

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	Name	Position	Signature	Date
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EXECUTIVE SUMMARY

BACKGROUND

The existing Tasman Underground Mine is located within ML 1555 in the Newcastle Coalfield in New South Wales (NSW), approximately 20 kilometres (km) west of the Port of Newcastle. The Project will involve the extension of underground mining west and north into Exploration Lease (EL) 5337, EL 5498 and EL 5497.

The Project provides for the extension and continuation of operations at the existing Tasman Underground Mine and would extend the operational life of the mine by approximately 15 years (i.e. until approximately 2029). This includes continued underground mining of the Fassifern Seam and extending mine development to the West Borehole Seam using a combination of total and partial pillar extraction methods.

THE EXISTING ENVIRONMENT

The study area is located within the Newcastle Coalfield of the Sydney Basin. The Permian aged coal reserves within the Tasman Extension Project (the Project) area are mostly within the Shortland Formation of the Hexham Sub-Group within the Newcastle Coal Measures.

The topography of the Project area is dominated by the Sugarloaf Range trending north-south, with Mount Sugarloaf the highest topographic point at 412 metres Australian Height Datum (mAHD). The Project area is characterised by undulating to steep terrain of the prominent Sugarloaf Range ridgeline spur and several natural drainage gullies.

The majority of the Project area lies within the headwaters of the Wallis Creek catchment, which flows into the Hunter River near Maitland. The main drainage system within the Tasman Extension Project area is the ephemeral Surveyors Creek and its multiple 2nd and 3rd order tributaries, which drains north to Wallis Creek. Other portions of the Project area are located in the ephemeral headwaters of Blue Gum Creek that flows to Hexham Swamp approximately 8km east, and within the headwaters of the Cockle Creek catchment which flows into the northern end of Lake Macquarie.

Two distinct aquifer systems are known to occur within the Project area:

- A fractured rock aquifer system in the coal measures, with groundwater flow occurring mainly in the coal seams; and
- A surficial granular aquifer system in the unconsolidated sediments of the colluvium associated with incised channels of Surveyors Creek in elevated terrain and alluvium outside the immediate Project area associated with Wallis Creek and the lower reaches of Surveyors Creek north of George Both Drive.

Groundwater levels in the surficial aquifer system (alluvium and regolith) are closely related to topography, with flow patterns broadly similar to the surface flow patterns. Recharge occurs by rainfall infiltration, and flow down gradient towards the local surface drainages. In the most elevated areas, alluvium is absent, and the regolith is unsaturated. Occasional localised perched groundwater is found in the colluvium and weathered bedrock zone in lower-lying areas along creek lines.

Groundwater levels in the strata of the deeper Permian coal measures have a more regional pattern, and are controlled to the topographic elevations in areas where specific coal seams outcrop or subcrop and receive recharge, and the discharge zones to the east beneath the Hunter River estuary and Hexham Swamp. Groundwater flows down gradient from the recharge zones towards the discharge areas, with a generally south-easterly flow direction. There is very little or no vertical flow across the bedding from shallow to deeper strata under natural conditions; flow is predominantly parallel to the bedding, and occurs mostly within the more permeable coal seams.

Groundwater quality has been monitored at the Donaldson Open Cut Mine, Abel and Tasman Underground Mines, and elevated salinity is found within much of the Permian coal measures aquifer system, with groundwater salinity ranging from less than around 600 microSiemens per centimetre (µS/cm) electrical conductivity (EC) in the more permeable coal seams to more than 16,000µS/cm EC within some of the less permeable overburden/interburden units.

Within the existing Tasman Underground Mine area, samples taken from underground Fassifern Seam workings are generally less saline, with a minimum of 900µS/cm EC. This reflects the influence of proximity to relatively direct rainfall recharge in areas of sub-crop within the high terrain.

Water quality within the Project area is expected to be intermediate between the groundwater quality signatures observed at the existing Tasman and Abel Underground Mines. Accordingly, the groundwater is expected to be moderately saline, with near-neutral pH.

APPROACH TO IMPACT ASSESSMENT

In order to assess the impacts that the Project may have on the hydrogeological environment, the MODFLOW-SURFACT Donaldson Regional Groundwater Model was used. The mining and post-mining phases of the Project were simulated with the model. This model is the culmination of progressive improvements implemented during previous studies, and the model has been further updated and improved for this Project. In particular, the model contains an appropriate representation of the groundwater flow regime, and is able to model changes in hydraulic properties of the rock mass as mining progresses, which is especially important for underground mining to account for the impacts of subsidence fracturing on hydraulic properties and the flow regime. The updated model contains realistic representations of other mines in the area, including Tasman, Abel and West Wallsend Underground Mines, and the Bloomfield and Donaldson Open Cut Mines.

The model was first calibrated against quasi ‘steady state’ pre-mining conditions, and was then subject to a transient calibration to water levels, groundwater and drawdowns during the early stages of the Abel and Tasman Underground Mines. As coal mining has been undertaken in this area for over 170 years, it is not possible to represent true pre-mining conditions, so a quasi steady state condition was adopted which is believed to represent relatively stable conditions before the start of large scale mining at the Donaldson Open Cut Mine and Abel and Tasman Underground Mines since 2000.

The groundwater modelling included a number of specific approaches that were used to simulate potential impacts from the proposed mining activities, including:

- Simulation of groundwater dewatering caused by both open cut and underground mining; and
- Changes to the hydraulic properties of overburden material caused by the caving and subsidence above underground mine panels.

The groundwater model was used to predict the potential impacts of the Project on groundwater levels in the Permian strata and Regolith, as well as stream ‘baseflow’ impacts (the contribution of groundwater to surface water flows) in Surveyors Creek.

The groundwater model was also used to examine the post mining recovery of groundwater levels and stream baseflows. For the recovery run, it was assumed that all mining operations had ceased.

POTENTIAL IMPACTS FROM THE PROPOSED MINING

Groundwater Inflows

Inflows to the Project underground mining areas have been predicted using the groundwater model. Inflows are predicted to begin slowly within the first year of development, with approximately 0.2 megalitres per day (ML/d) inflows occurring at the end 2014, increasing to a peak of approximately 1.35ML/d in 2024. Thereafter, inflows decrease to less than 0.6ML/d by the end of mining.

Groundwater Level Impacts

Modelling shows that the West Borehole Seam and overburden within the Project area are predicted to be essentially de-watered during mining. Outside of the Project area, the main impact from the Project on water levels within the Permian strata occurs to the east and south of the mine, where drawdowns of 5m or more could occur up to 2km from the Project following completion of coal extraction. Net impacts to the east are limited due to the buffering effect of the old abandoned workings which occupies the West Borehole Seam immediately to the east. Impacts to the west are limited by the sub-crop of the strata.

The geometry of the Project with respect to the abandoned workings and proximity to West Borehole Seam sub-crop effectively compartmentalises the mine and its impacts within the region.

The shallow regolith is generally unsaturated (dry) at the start of mining, with groundwater only occurring in the colluvium on the lower slopes and valley colluvium associated with Surveyors Creek down gradient of the Project area. No alluvium is present within the Project area.

The groundwater model has also been used to determine the impacts of the Project in isolation, separating it from the cumulative impacts of other nearby mining projects. To enable this, the model was run without the Project mine plan included, and predicted drawdowns at the end of mining and end of recovery compared to the base case model with the Project included. By subtraction, the incremental impacts of the Project have been identified.

Groundwater levels in strata below the West Borehole Seam are unaffected by the Tasman Extension Project.

Predicted Impacts on Stream Baseflows

Overall, the Project is predicted to have very limited impact on baseflow to Surveyors Creek. A maximum reduction in baseflow of 0.0045ML/d is predicted to occur as a result of impacts from the Project. The Surveyors Creek drainage system is ephemeral, with irregular streamflow limited to larger rainfall events.

POTENTIAL IMPACTS FOLLOWING POST MINING RECOVERY

The groundwater model was used to predict potential residual impacts from the Project during 100 years of post-mining recovery.

During the post mining period, the groundwater within the mine workings and caved overburden will be highly connected. Post-recovery groundwater levels within the workings and caved overburden are predicted to reach a dynamic equilibrium, where inflows from the surface and other strata balance outflows from the mine area.

These changes in the Permian do not significantly affect the shallow regolith and therefore as there is negligible impact on Surveyors Creek during mining, no residual impact is anticipated.

Recovery occurs within the Project over the majority of the mine area following 100 years after cessation of mining activities except for a small area in the south where residual drawdown remains. Elsewhere recovery is relatively rapid occurring within a 25-30 year period within down dip areas. There can be little doubt that recovery is delayed to some degree by the low water levels which exist within the Stockrington Mine area.

POTENTIAL IMPACTS ON GROUNDWATER DEPENDENT ECOSYSTEMS AND OTHER GROUNDWATER USERS

Impacts on flows and groundwater levels within the colluvium associated with the Surveyors Creek catchment are predicted to be insignificant, both during mining and post-mining. Therefore it is very unlikely that Groundwater Dependent Ecosystems associated with Surveyors Creek would be impacted by the Project. However, a monitoring regime is recommended for the drainage lines in the area above the mine.

All registered groundwater bores are outside the predicted zone of influence of mining in either the coal measures stratigraphy or the shallow regolith. Therefore the Project will not impact on any registered groundwater bore.

MONITORING AND MANAGEMENT OF IMPACTS

A comprehensive monitoring program is already in place for the Tasman Underground Mine which will be expanded to encompass the Project. Recommendations for additional monitoring are also outlined in the report. It is recommended that the Project's existing Groundwater Management Plan, with appropriate adjustments, be used for determining appropriate management strategies and response measures for any unforeseen impacts.

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FIGURES (compiled at end of report)

APPENDICES

1. INTRODUCTION

1.1 Background

This report presents the results of a groundwater assessment for the proposed Tasman Extension Project (the Project) undertaken by RPS Aquaterra for Donaldson Coal Pty Ltd (Donaldson Coal).

The existing Tasman Underground Mine is located within Mining Lease (ML) 1555 in the Newcastle Coalfield in New South Wales (NSW), approximately 20 kilometres (km) west of the Port of Newcastle. The Project will involve the extension of underground mining west and north into Exploration Lease (EL) 5337, EL 5498 and EL 5497.

Donaldson Coal owns and operates two underground mining operations west of Newcastle at the Tasman Mine (south of George Booth Drive) and Abel Mine (between John Renshaw Drive and George Booth Drive), as well as the Donaldson Open Cut Mine (on the northern side of John Renshaw Drive).

The Tasman Operations, in the vicinity of Mt Sugarloaf, are located to the immediate west of the F3 Freeway, approximately 4km south of John Renshaw Drive (Figure 1.1), and 18km south of Maitland by road. The existing mine extracts coal from the Fassifern Coal Seam. The Project will continue underground mining of the Fassifern Seam, as well as extend operations into the West Borehole Seam. The West Borehole Seam will be accessed via a new mine entry adjacent to George Booth Drive.

The coal from all three existing operations is processed through the Bloomfield Coal Handling and Preparation Plant (CHPP), situated on the outskirts of Maitland to the north-west of the Donaldson Open Cut Mine.

A detailed description of the Project is provided in Section 2 in the Main Report of the Environmental Impact Statement (EIS).

1.2 Proposed Mine Development

The Project provides for the extension and continuation of operations at the existing Tasman Underground Mine and would extend the operational life of the mine by approximately 15 years.

The main activities associated with the development of the Project would include:

- Continued underground mining of the Fassifern Seam using a combination of total and partial pillar extraction methods within ML 1555;
- Underground Mining of the West Borehole Seam using a combination of total and partial pillar extraction methods;
- Production of run-of-mine (ROM) coal up to 1.5 million tonnes per annum (Mtpa);
- Development of a new pit top facility, associated ROM coal handling infrastructure and intersection with George Booth Drive;
- Development of ventilation surface infrastructure;
- Continued transport of Fassifern Seam ROM coal from the existing Tasman Underground Mine pit top to the Bloomfield CHPP via truck on public and private roads to approximately 2015 (inclusive);
- Transport Of West Borehole Seam ROM coal from the new pit top to the Bloomfield CHPP via truck on public and private roads;
- Progressive development of sumps, pumps, pipelines, water storages and other water management equipment and structures;
- Ongoing exploration activities;
- Ongoing Surface monitoring, rehabilitation and remediation of subsidence effects; and
- Other associated minor infrastructure, plant, equipment and activities.

1.3 Groundwater Assessment Scope

The overall objective of this report is to describe the state of the groundwater environment within the Project area and immediate surrounds, and to assess the potential impacts on groundwater levels and quality from the Project. This has been done to address any potential impacts on the groundwater and surface water resources, groundwater dependent ecosystems and existing groundwater users, to the satisfaction of the Minister for Planning.

The key tasks for this assessment are:

- Characterisation of the existing groundwater environment including identification of potential groundwater dependent ecosystems (GDEs) in consultation with other relevant specialists;
- Collation And review of baseline groundwater data including:
  - Existing groundwater monitoring program piezometer data;
  - Existing mine water management records; and
  - Additional data – e.g. NSW Office of Water (NOW) records.
- Development Of a conceptual groundwater model and refinement through analysis of data collated to develop and calibrate a numerical groundwater model to predict potential impacts of the proposal on the groundwater regime; and
- Preparation of a Groundwater Assessment report for inclusion in the EIS, that includes the following:
  - Qualitative and quantitative assessment of groundwater impacts of the proposal, cumulative impacts with other existing and approved mines in the area and assessment of post-mining groundwater impacts (recovery of groundwater levels and stream baseflows); and
  - Development of measures to avoid, mitigate and/or remediate potential impacts on groundwater resources and to provide recommendations on groundwater monitoring to measure potential impacts on groundwater resources and other users.

1.4 Structure of this Report

This report is structured as follows:

- Section 2 addresses the statutory requirements, policies and guidelines relevant to the Project;
- Section 3 contains a summary of groundwater investigations undertaken, including relevant details of previous groundwater investigations undertaken within the Project area;
- Section 4 reports on the existing State of the Environment within the proposed Project area, and includes available information on climate, topography and drainage, land use (including existing mining activities), and an evaluation of the current groundwater environment based on available groundwater levels and groundwater quality, and groundwater-surface water interactions;
- Section 5 outlines the conceptual model used to inform the numerical groundwater model;
- Section 6 outlines the mining proposal and provides a brief summary of implementation in the model;
- Section 7 details the groundwater modelling work undertaken to assess the potential impacts of the proposal;
- Section 8 contains details of the potential groundwater impacts of the Project on groundwater and surface water resources, stream baseflows, GDEs, and other groundwater users;
- Section 9 details groundwater accounting, licensing and water sharing plans;
- Section 10 details proposed monitoring, mitigation and management strategies in relation to potential impacts on the groundwater resources, as well as recommendations for contingency response plans to address any unforeseen adverse impacts on groundwater and/or surface water;
- Section 11 provides a summary and conclusions; and
- Section 12 provides a list of references.

2. STATUTORY REQUIREMENTS

2.1 Director General's Requirements

In accordance with the *Environmental Planning and Assessment Act 1979*, the Director-General (DG) of the Department of Planning has issued requirements for the preparation of an Environmental Assessment for the Project. Specific requirements have been provided by the DG and relevant consulted public authorities in relation to the Project. The requirements relating to groundwater have been addressed within this report as detailed in Table 2.1.

Table 2.1: Director General's Requirements

Director General's Requirements	Relevant section of this report
General Requirements	
A description of the existing environment, using sufficient baseline data.	Section 4
An assessment of the potential impacts of all stages of the development, including any cumulative impacts, taking into consideration relevant guidelines, policies, plans and statutes.	Sections 2 & 8
A description of the measures that would be implemented to avoid, minimise and if necessary, offset the potential impacts of the development, including proposal for adaptive management and/or contingency plans to manage any significant risks to the environment.	Section 10
Key Issues (water resources)	
Detailed assessment of potential impacts on the quality and quantity of existing surface and groundwater resources, including: - Detailed modelling of potential groundwater impacts - Impacts on affected licensed water users and basic landholder rights - Impacts on riparian, ecological, geo-morphological and hydrological values of watercourses, including environmental flows	Sections 7.8 & 8 and Tasman Geomorphology Assessment (2012) (Appendix D of the EIS)
Identification of any licensing requirements or other approvals under the *Water Act 1912* and/or *Water Management Act 2000.*	Section 2
Demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP).	Refer to Evans and Peck (2012) (Appendix C of the EIS)
A description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo.	Section 2.3 & 9.3
A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts.	Section 9 & 10 and Evans and Peck (2012) (Appendix C of the EIS)
Key Issues (biodiversity)	
A detailed assessment of potential impacts of the development on any: - groundwater dependent ecosystems	Sections 8.2 & 8.4
NSW Office of Water comments	
Groundwater impacts – it is essential that the following issues are included in the EIS:	
• Details of the existing groundwater users (both licensed and stock and domestic users) within the area of the proposal and any potential impacts on these users, including the environment (groundwater dependent ecosystems).	Sections 4.8, 8.3 & 8.4
• Details of the results of any models or predictive tools used, including inputs, limitations for models used and any sensitivity analyses conducted.	Section 7
• Details of any proposed groundwater extraction, including purpose, location and construction details of all proposed bores and expected annual extraction volumes.	Refer to Evans and Peck (2012) (Appendix C of the EIS)
• Details of any estimated groundwater make during the life of the mine and any proposed re-use.	Refer to Evans and Peck (2012) (Appendix C of the EIS)

Director General's Requirements	**Relevant section of this report**
• Description of different aquifer systems including the extent and inter-relationships (including inter-relationships with surface water bodies and dependent ecosystems).	Sections 4 & 5
• Description of the current and anticipated changes (if any) in flow directions and rates and the physical and chemical characteristics of the aquifers.	Sections 4.6, 4.7 & 8
• Details of groundwater quality and the potential for aquifer mixing (between Permian and alluvial systems) post-mining.	Section 4.7 & 8
• Details of current and anticipated changes (if any) in preferential pathways for water flow.	Sections 5.3 & 8
• Description of the potential for tensile cracks, goaf fracturing and natural jointing fracturing and potential areas for bedding plan separation.	Section 5.3
• Details of the predicted impacts of any final landform on the groundwater regime (that is, post-mining equilibrium or quasi-equilibrium).	Section 8
• Details of the potential changes in baseflow contribution (quantity and timing) due to impact on aquifer-fed surface flows and groundwater dependent ecosystems (GDE) for each longwall panel extending under identified watercourses and the cumulative impact of the total subsidence envelope.	Section 7.8.4, 8.2 & 8.4
• Details of a proposed groundwater monitoring program, with trigger levels for response actions and remedial measures.	Section 10
Comments from other Agencies	
NSW Office of Environment and Heritage	
• Describe existing surface and groundwater quality. An assessment needs to be undertaken for any water resource likely to be affected by the proposal. - Proponents of relatively large and/or high risk developments may be required to collect some ambient…groundwater data to enable a suitable level of impact assessment. - Issues to include in the description of the receiving waters could also include…an outline of baseline groundwater information, including, for example, depth to watertable, flow direction and gradient, groundwater quality, reliance on groundwater by surrounding users and by the environment; where groundwater may be impacted the assessment should identify appropriate groundwater environmental values.	Section 4
• Describe the nature and degree of impact that any proposed discharges will have on the receiving environment. - Modelling may be required to assess the potential impact of any discharge(s) on the receiving environment; may include assumptions used in the modelling, including identification and discussion of the limitations and assumptions to ensure full consideration of all factors, including uncertainty in predictions. - Assess impacts on groundwater and groundwater dependent ecosystems.	Sections 7.8 & 8
• Describe how predicted impacts will be monitored and assessed over time.	Section 10
NSW Department of Resources and Energy	
The EIS should state the interaction between the proposed mining activities and the existing environment and so include a comprehensive description of…water management.	Entire report and Evans & Peck (2012)
The EIS should identify if the predicted subsidence will result in fracture connectivity to the surface, and the environmental consequence to the ground surface, groundwater aquifers and groundwater dependent ecosystems of the predicted subsidence.	Sections 5.3 & 7.8 and DgS (2012).
Lake Macquarie City Council	
• Assessment of the impacts of the proposed mining on the affected creek beds including: - Potential for interaction between surface water and groundwater	Section 8.2
Cessnock City Council	
In terms of the environmental assessment of the project it is anticipated that the following potential impacts of the project (including any potential cumulative impacts that may arise from the combined operation of the project with Donaldson, the existing Tasman development and Abel and Bloomfield mines) and describe what measures would be implemented to mitigate, manage and monitor these impacts: - Soil and Water – include a detailed water balance and refer to the various State Groundwater Policy documents.	Sections 2, 10 & Evans and Peck (2012) (Appendix C of the EIS)

2.2 Relevant State Policies and Guidelines

There are a number of guidance documents for groundwater protection and assessment in NSW. The key policy document is the *NSW State Groundwater Policy Framework Document* released by the then Department of Land and Water Conservation (DLWC) (currently NOW) (DLWC, 1997). This document outlines the policy objectives relating to groundwater management and implementation strategies. The *NSW State Groundwater Policy Framework Document* refers to three component policies:

- The *NSW Groundwater Quality Protection Policy* (DLWC, 1998) outlines the beneficial use classification system applicable to all aquifer systems in NSW. The policy states that all groundwater systems should be managed to maintain the most sensitive identified beneficial use. The beneficial uses adopted in this policy include ecosystem protection, recreation and aesthetics, raw water for drinking water supplies, agricultural water and industrial water. For new developments, the policy also outlines the scale and scope of work required to demonstrate adequate groundwater protection which shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource;
- The *NSW State Groundwater Dependent Ecosystem Policy* (DLWC, 2002) provides guidance on how to protect and manage ecosystems that rely on groundwater for their survival for the benefit of present and future generations. Groundwater dependent ecosystems (GDEs) may include terrestrial vegetation supported by shallow groundwater such as red gum forests, wetlands, ecosystems in streams fed by groundwater discharge and aquifer and cave ecosystems; and
- The policy on Groundwater Quantity Management has not been released but the principles and objectives are outlined in the *NSW State Groundwater Quality Protection Policy* and include the efficient, equitable and sustainable use of the State's groundwater resources. Groundwater access must be managed such that it does not cause unacceptable local impacts.

The draft guideline *Management of Stream/Aquifer Systems in Coal Mining Developments (Hunter Region)* (DIPNR, 2005) was developed to address potential impact on groundwater and rivers in the Hunter region. The objectives of the draft guideline incorporate protection of river systems which includes channels, stream beds and banks, connected alluvial groundwater and perched groundwater.

This report has also been prepared with due consideration of additional relevant state policies and guidelines including:

- Murray-Darling Basin Groundwater Quality Sampling Guidelines. Technical Report No. 3 (MDBC, 1997);
- Groundwater Flow Modelling Guidelines (MDBC, 2001); and
- Management of Stream/Aquifer Systems in Coal Mining Developments (Hunter Region) (DIPNR, 2005).

2.3 Water Sharing Plans

Water sharing plans (WSPs) are being progressively developed for rivers and groundwater systems across NSW following the introduction of the *Water Management Act 2000* (WM Act 2000). The Project lies within an area designated under the *Hunter Unregulated and Alluvial Water Sources WSP* (HUAWSWSP). The WSP commenced on 1 August 2009 and includes "*the highly connected alluvial groundwater (which are above the tidal limit)*". Non-alluvial groundwater systems are not included within the Plan, and are still governed by the *Water Act 1912*.

These WSPs are designed to provide long-term environmental protection and sustainability of the groundwater resources as well as directing how water will be allocated and shared among the various water users. WSPs apply the goals and principles of the State Groundwater Policy at a local and regional level.

The WSPs identify the recharge component to each groundwater source or zone and direct how the recharge component will be allocated and shared among different water users. They also outline the management of local impacts, including groundwater interference, and list beneficial uses of the groundwater to be protected and occurrence of any GDEs within the groundwater source or zone.

The WSPs refer to the National Health and Medical Research Council (NHMRC) 1996 *Drinking Water Guidelines for drinking water beneficial use*. Other beneficial uses are defined by the

Australian and New Zealand Environment and Conservation Council (ANZECC) *2000 Water Quality Guidelines* (ANZECC, 2000).

Compliance with the requirements of the HUAWSWSP is addressed in Section 9.3.

2.4 Water Licensing

According to the *NSW Office of Water – Environmental Impact Assessment Requirements Tasman Coal Extension Proposal* dated 10 November 2011:

> *The proposal will require the following approvals under legislation administered by the NSW Office of Water:*

- An access licence under the Water Management Act 2000 (WMA) will be required for any incidental take of surface water from the Surveyors Creek catchment;
- A licence under Part 5 of the Water Act 1912 will be required for any proposed use or interception of porous rock groundwater (including mine water make); and
- An aquifer interference approval will be required with regard to the underground longwall mining operations under s 91(3) of the WMA.

Groundwater licences under Part 5 of the *Water Act 1912* will be required for any of the following activities relating to the Project within the porous rock groundwater, including:

- Extraction of water from open cut mining;
- Production bores; and
- Monitoring piezometers (for the purposes of water level and quality monitoring and test pumping).

It should be noted that Part 5 licences will be required for the extraction of groundwater from the porous rock.

The extraction of any groundwater from alluvium systems will be subject to conditions and management in accordance with rules set out the HUAWSWSP. In areas governed by a WSP, Water Access Licences (WALs) may be granted to access available water. These licences are held and traded independently from land and are issued separately to approvals.

Any discharge of surplus water volumes to the environment will be managed in accordance with the site's Environmental Protection Licence, under the *Protection of the Environment Operations Act 1997*.

2.4.1 Aquifer Interference Approvals

NOW has recently issued a Draft Aquifer Interference Policy that incorporates the regulation of activities such as mining in regards to groundwater. The purpose of the policy is to ensure that water taken by certain activities that may interfere with aquifers is properly licensed and accounted for in the water budget and water sharing arrangements.

According to the WM Act 2000, an aquifer interference activity is any of the following:

- The penetration of an aquifer;
- The interference with water in an aquifer;
- The obstruction of the flow of water in an aquifer;
- The taking of water from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations; or
- The disposal of water taken from an aquifer in the course of carrying out mining, or any other activity prescribed by the regulations.

As such, the proposed activity within the Project area would require an aquifer interference approval (Part 3, Division 1 (s19), WM Act 2000). However at the time of writing, the aquifer interference approval application process is yet to be implemented by the State.

3. GROUNDWATER INVESTIGATIONS

3.1 Previous Work

3.1.1 Donaldson Open Cut

Donaldson Open Cut Mine is located approximately 10km north-east of the Project. Development Consent for the Donaldson Open Cut Mine was granted in 1999. Coal is extracted from the Donaldson Seam and a number of thinner overlying seams by conventional truck and shovel haul back methods in an open cut operation. Soil, overburden and coal are removed, then the mine area is progressively backfilled with overburden and rehabilitated. Donaldson Open Cut Mine has consent to operate until 2012.

Separate groundwater investigations for the Donaldson Open Cut Mine were undertaken by PPK Environment and Infrastructure (1998) and Mackie Environmental Research (1998). A number of piezometers were drilled around the Project area as part of initial groundwater investigations. Monitoring of these bores (prefixed DPZ) continues on a regular basis as part of ongoing groundwater monitoring for the Abel Underground Mine and Donaldson Open Cut Mine sites.

Core samples from some of the piezometer bores were subjected to laboratory analysis of permeability.

3.1.2 Bloomfield Colliery

The Bloomfield Colliery operations are located approximately 10km north-northeast of the Project, and are one of the Hunter Valley's oldest continuously running mining operations. Coal has been mined on the site for approximately 170 years. Underground mining ceased at the site in 1992, and current operations consist of open cut mining.

The coal bearing seams mined at Bloomfield Colliery are located in the Tomago Coal Measures, situated below the Newcastle Coal Measures. The seams mined include the Rathluba, Big Ben, Donaldson, Elwells Creek, Whites Creek followed by the uncorrelated A, B, and C seams and the Buttai seams.

A groundwater investigation was undertaken to assess the potential impacts for the completion and rehabilitation of open cut mining (Aquaterra, 2008) as part of a Part 3A Environmental Assessment (EA) Project Application submitted in November 2008.

This investigation indicated that the groundwater levels in the Bloomfield Colliery mining area showed the accumulated effects of long-term mining activity in the area. Although there was no evidence to suggest what pre-mining groundwater levels might have been, the influence of mining on water levels was apparent by the marked differences in groundwater levels between shallow and deeper coal measures.

Groundwater in the vicinity of the Bloomfield Colliery was also found to be saline and of negligible value for beneficial users.

The groundwater investigation included development of the Bloomfield Colliery groundwater model. The results of a steady-state calibration and sensitivity analysis informed predictive scenario modelling and uncertainty assessment for mine dewatering operations and post-mining recovery. The steady-state model included simulation of the past and present dewatering activities of Bloomfield Colliery and Donaldson Open Cut Mine operations. The predictive modelling also incorporated the Abel Underground Mine.

A total of twenty-four piezometers were installed at eight sites around the Bloomfield Colliery area to enable separate sampling, testing and monitoring of the main coal seams involved in past or proposed mining, as well as the shallow alluvium and/or regolith zone. Hydraulic testing of the piezometers was conducted to determine formation hydraulic properties.

3.1.3 Tasman Underground Mine

The existing Tasman Underground Mine is located south of Maitland with entry to the site off George Booth Drive, 1.5km west of Seahampton. The mine was approved in 2004 for a maximum extraction of 960,000 tonnes per annum ROM coal. The underground lease area covers approximately 950 hectares bounded by George Booth Drive to the north and the F3 freeway to the east. The Project area underlies the Sugarloaf Range.

The Project is a bord and pillar operation, which uses continuous miners for first workings and secondary extraction of coal from the Fassifern Seam. Construction began in 2007 and the mine is still operating.

As part of the approvals process, hydrogeological studies were undertaken by Peter Dundon and Associates (PDA) in 2002 to characterise the existing surface water and groundwater environments, and evaluate the potential impacts of mining operations. These hydrogeological studies presented the following findings (PDA, 2002):

- The Fassifern coal seam is believed to be the most permeable unit in the Project area. The Fassifern Seam is only moderately permeable, and is not a significant aquifer. Minor zones of moderate to low permeability also occur in other coal seams, and within the sandstones and siltstones of the coal measures sequence.
- Groundwater is present in the Fassifern Seam, which is partly saturated. Groundwater levels are within the seam in some locations, or slightly above the top of the seam away from outcrop areas. Groundwater present at higher levels in other coal seams and permeable clastic sediments are believed to be perched aquifers.
- The groundwater is moderately saline, with salinity ranging up to about 3500 milligrams per litre (mg/L) total dissolved solids (TDS), and is slightly acidic, with pH generally between 6 and 7.5.
- As at 2002, there were no licensed groundwater bores in the vicinity of the Project area, and no known groundwater use, other than environmental.
- Several coal exploration holes were converted to piezometers, for monitoring groundwater levels and quality in both the Fassifern Seam, and the roof and floor sediments. Permeability tests were carried out on these piezometers.
- Groundwater recharge occurs by infiltration of rainfall around the outcrop line of the Fassifern Seam and other relatively more permeable horizons of the coal measures sequence. Natural discharge is believed to occur partly by downward percolation to deeper aquifers but mostly by spring or seepage flow where the aquifers outcrop around the hillsides.

3.1.4 Abel Underground Mine

Abel Underground Mine is located to the south of the high wall of Donaldson Open Cut Mine, approximately 8km to the north-east of the Project. In June 2007 the NSW Government granted approval for Abel Underground Mine to extract up to 4.5Mtpa. Abel Underground Mine extracts coal from the Donaldson coal seams. These seams dip downwards towards the south across the site at approximately five degrees. Access to the Abel Underground Mine is from a portal in the Donaldson Open Cut Mine on the northern side of John Renshaw Drive.

A groundwater investigation was carried out for the Abel Underground Mine (PDA, 2006) in which a series of piezometers were installed across the lease area, to enable testing and monitoring of the Donaldson coal seams, as well as the overburden and interburden sediments, both within the shallow northern part of the deposit, and downdip to the south. Some bores were also installed along strike to the east of the Abel Underground Mine. A number of shallow piezometers were also installed around the Pambalong Nature Reserve.

The groundwater investigations undertaken indicated that groundwater is present in most lithologies in the area, but significant permeability is generally only present in association with fracturing and cleat development in the principal coal seams in the Permian coal measures. Lesser permeability may be present locally in interburden siltstones, mudstones and sandstones, and in the surficial alluvium/colluvium.

Predictive groundwater modelling was undertaken as a component of the 2006 Abel Underground Mine Environmental Assessment. The model has similarities to the current model design, although domain size was smaller and stratigraphical delineation was not as detailed. However, the current model design evolved from the original Abel Underground Mine model.

3.1.5 Regional Groundwater Model

In 2010, Aquaterra developed the Donaldson Regional Groundwater Model (DRGM) following the conditional approval for the Abel Underground Mine which required further development of the regional and local groundwater model. The model was designed to incorporate deeper layers and a larger regional extent that would integrate the Bloomfield Colliery operations and areas of possible future mine development by Donaldson Coal.

Hence the DRGM was developed to provide Donaldson Coal with a ‘platform’ for all future numerical groundwater assessments across its existing mine and exploration leases. The DRGM was produced both as an operational / regulatory planning tool, and to satisfy the requirements of Schedule 4, Condition 12 of the planning approval for the Abel Underground Mine. It also satisfies the Statement of Commitments contained within that planning approval.

Overall it was considered that the DRGM was a suitable platform that could be used to carry out the numerical evaluation of groundwater impacts that might be associated with future mining development in the Donaldson area. It is soundly based on the conceptual hydrogeology for the region, has satisfactory calibration and consistency with previous models, and model run times that make it a practical tool for impact assessment and operational predictive analysis. As such, the DRGM provides the platform from which numerical groundwater modelling for the Project has been based.

3.1.6 Piezometer Monitoring Network

A broad network of groundwater monitoring piezometers has been installed through the above investigation programs. Pertinent construction details of the piezometers are summarized in Table 3.1. Many of the piezometers continue to form part of an ongoing baseline and impact assessment monitoring network.

Bore locations are shown on Figure 3.1 and available bore logs are presented in Appendix A.

Table 3.1: Groundwater Piezometers and Other Monitoring Bores

Piezometer	MGA Coordinates		Surface RL (mAHD)	Depth (m)	Screen/Vibrating Wire Piezometer (m MBL)	Initial Water Level			Aquifer Formation
	Easting	Northing				Date	m BGL	m AHD	
Donaldson Open Cut Mine Piezometers									
DPZ1	370827	6369903	23.1	30	16.5-26.9	11/07/01	10.8	12.2	Lower Donaldson and Big Ben Seams
DPZ2	371846	6370119	22.3	30	15.8-27.8	16/12/04	15.1	7.2	Beresfield Seam
DPZ3	368773	6368608	49.1	30	6.8-18.8	17/08/05	12.4	36.7	Undifferentiated coal measures below Lower Donaldson Seam
DPZ4A	370541	6368779	35.0	23	18.7-22.7	17/03/04	14.15	20.86	Beresfield Seam
DPZ4B	370541	6368779	35.0	49	24.9-49.2	26/02/04	41.92	-6.91	Upper and Lower Donaldson and Big Ben Seams
DPZ5	371366	6368779	12.8	24	6-18	17/08/05	6.83	5.97	Undifferentiated coal measures above Donaldson Seams
DPZ6			57.7	43	26.7-42.5	14/08/02	13.64	31.02	Upper and Lower Donaldson Seams
DPZ7A	368847	6367640	55.4	18	12.9-16.9	11/07/01	16.9	38.5	Overburden above Upper Donaldson
DPZ7B	368847	6367640	55.4	41	22.9-34.9	17/08/05	23.5	31.9	Lower Donaldson
DPZ8	369374	6368073	51.8	33	22.2-32.2	17/08/05	25.3	26.5	Lower Donaldson and Big Ben Seams
DPZ9	369847	6368016	36.4	40	12.5-36.5	17/08/05	32.1	4.2	Upper and Lower Donaldson and Big Ben Seams
DPZ10	371001	6368463	19.8	30	11.8-29.8	17/08/05	13.8	6.0	Beresfield Seam
DPZ12	369114	6366414	59.5	24	6-18	17/08/05	16.8	42.7	Overburden above Upper Donaldson
DPZ13	371249	6367557	21.5	30	18-30	17/08/05	7.3	14.2	Overburden above Upper Donaldson
DPZ20A	370541	6368439	20.1	51	11.5-17.5	23/05/06	11.1	9.0	Surficial aquifer – creek bed level
DPZ20B	370540	6368439	20.1	51	44	23/05/06	32.2	-12.0	Big Ben Seam
Tasman Underground Mine Piezometers									
TA23	360603	6357701	380.7	220		27/03/06		+238.8	Fassifern Overburden
TA24	364952	6359786	196.2	146.15	120				Fassifern Seam
TA28	364163	6361235	158.9	303.25	290	27/11/06		+13.6	Donaldson Seam
TA41A	361231	6354126	315.7	663.5	382	30/04/09		+56.0	Sandgate Seam

Piezometer	MGA Coordinates		Surface RL (mAHD)	Depth (m)	Screen/Vibrating Wire Piezometer (m MBL)	Initial Water Level			Aquifer Formation
	Easting	Northing				Date	m BGL	m AHD	
TA41B	361231	6354126	315.7	663.5	303	30/04/09		+32.9	Fassifern - West Borehole Interburden
TA41C	361231	6354126	315.7	663.5	240	30/04/09		+74.5	Fassifern - West Borehole Interburden
Abel Underground Mine Piezometers									
C062A	370144	6366249	31.0	157	124-118	27/03/06	11.4	24.6	Donaldson Seam
C062B	370144	6366249	31.0	157	87-81	27/03/06	4.2	31.8	Overburden
C063A	372109	6366193	19.4	255	197	27/03/06	27.0	-8.0	?Donaldson Seam
C063B	372109	6366193	19.4	255	130	27/03/06	24.9	-5.9	Overburden
C072	369915	6362569	63.5	318	264	27/03/06	44.3	18.7	Donaldson Seam
C072A	369915	6362569	63.5		168	23/03/06	41.3	21.7	Overburden
C072B	369915	6362569	63.5		45-42	27/03/06	13.0	50.0	Alluvium/weathered Permian
C078A	367188	6367077	73.5	101	99-96 and 90-87	26/04/06	48.6	28.4	Donaldson Seam
C078B	367188	6367077	73.5	24	24-18	28/03/06	9.5	67.5	Alluvium/weathered Permian
C080	368017	6365168	175.3	300	280	27/03/06	148.4	28.6	Donaldson Seam
C081A	370011	6364017	1.9	225	149.7	27/03/06	-23.9	26.0	Donaldson Seam
C081B	370011	6364017	1.9	20	20-14	27/03/06	0.3	2.0	Alluvium/weathered Permian
C082	370319	6364647	34.0	20	20-14	27/03/06	15.3	18.7	Alluvium/weathered Permian
C087	367419	6366587	85.9	18.3	18.3-12.3	26/04/06	10.5	63.5	Alluvium/weathered Permian
C123C	366288	6364703	56.1	267.4	162	28/04/08		+15.5	Sandgate - Donaldson Interburden
C123D	366288	6364703	56.1	267.4	148	28/04/08		+21.9	Sandgate - Donaldson Interburden
C123E	366288	6364703	56.1	267.4	78	26/05/08		+36.0	Sandgate Seam
C123F	366288	6364703	56.1	267.4	29	28/04/08		+47.4	Fassifern - West Borehole Interburden
C138A	364964	6367034	29.2						Sandgate - Donaldson Interburden
C138A	364964	6367034	29.2						Donaldson Seam
C138A	364964	6367034	29.2						Ashtonfield Seam
C138B	364964	6367034	29.2						Big Ben - Ashtonfield Interburden

Piezometer	MGA Coordinates		Surface RL (mAHD)	Depth (m)	Screen/Vibrating Wire Piezometer (m MBL)	Initial Water Level			Aquifer Formation
	Easting	Northing				Date	m BGL	m AHD	
C138C	364964	6367034	29.2						Big Ben Seam
C141A	363873	6364370	30.3	303	282	24/11/08		+9.9	Ashtonfield Seam
C141B	363873	6364370	30.3	303	267	29/10/08		+9.9	Big Ben Seam
C141C	363873	6364370	30.3	303	150	29/10/08		+13.5	Donaldson Seam
C141D	363873	6364370	30.3	303	100	29/10/08		+19.7	Sandgate - Donaldson Interburden
C141E	363873	6364370	30.3	303	30	29/10/08		+19.7	Sandgate Seam
C148A	362443	6364501	22.2	243.3	237	25/02/09		+18.5	Big Ben - Ashtonfield Interburden
C148B	362443	6364501	22.2	243.3	200	25/02/09		+19.1	Big Ben Seam
C148C	362443	6364501	22.2	243.3	125	25/02/09		+19.6	Sandgate - Donaldson Interburden
C148D	362443	6364501	22.2	243.3	50	25/02/09		+20.5	West Borehole Seam
C223B	365530	6364594	164.8	294.81	325	26/02/10		+8.1	Donaldson Seam
C223C	365530	6364594	164.8	394.81	242	26/02/10		+17.8	Sandgate - Donaldson Interburden
C223D	365530	6364594	164.8	394.81	160	26/02/10		+30.9	Sandgate Seam
C223E	365530	6364594	164.8	394.81	125	26/02/10		+40.6	West Borehole Seam
C257	370030	6366642	41.6		75	17/08/10	29.6		Sandgate - Donaldson Interburden
C257	370030	6366642	41.6		55	17/08/10	22.5		Sandgate - Donaldson Interburden
C257	370030	6366642	41.6		35	17/08/10	19.6		Donaldson Seam
C262A	370208	6367201	33.4		70	17/08/10	34.4		Donaldson Seam
C262B	370208	6367201	33.4		50	17/08/10	20.9		Sandgate - Donaldson Interburden
C262C	370208	6367201	33.4		30	17/08/10	9.3		Sandgate - Donaldson Interburden
Tasman Extension Project Piezometers									
B002AA	361942	6360971	51.3	383.5		30/04/09		+43.5	Donaldson Seam
B002AB	361942	6360971	51.3	383.5		30/04/09		+35.7	Sandgate Seam
B002AC	361942	6360971	51.3	383.5		30/05/09		+27.5	West Borehole Seam
B002AD	361942	6360971	51.3	383.5		30/04/09		+2.04	Fassifern - West Borehole Interburden

Piezometer	MGA Coordinates		Surface RL (mAHD)	Depth (m)	Screen/Vibrating Wire Piezometer (m MBL)	Initial Water Level			Aquifer Formation
	Easting	Northing				Date	m BGL	m AHD	
B004	363050	6362107	60.5	402.3		30/08/06		+17.2	West Borehole Seam
B005	363765	6361992	125.7	476.1		30/08/06		-31.8	West Borehole Seam
B017A	360800	6359938	58.6	315.3		30/01/08		+44.0	Sandgate Seam
B017B	360800	6359938	58.6	315.3		30/04/07		+52.7	West Borehole Seam
B29A	361362	6360639	47.0	326.22					Donaldson Seam
B29C	361362	6360639	47.0	326.22					Sandgate - Donaldson Interburden
B29D	361362	6360639	47.0	326.22					Sandgate Seam
B29E	361362	6360639	47.0	326.22					Fassifern - West Borehole Interburden
B30B	361400	6359400	60.7	360.8					Sandgate - Donaldson Interburden
B30C	361400	6359400	60.7	360.8					Sandgate Seam
B30D	361400	6359400	60.7	360.8					Fassifern - West Borehole Interburden
B30E	361400	6359400	60.7	360.8					Fassifern - West Borehole Interburden
B031B	360186	6358946	180.9	294.8		31/08/10		+59.2	Sandgate - Donaldson Interburden
B031C	360186	6358946	180.9	294.8		31/08/10		+82.1	West Borehole Seam
Bloomfield Colliery Piezometers									
VW1(35m)	363632	6370167	17.4	171	35	18/04/07	24.23	-7.23	Donaldson Seam
VW1(46m)	363632	6370167	17.4	171	46	18/04/07	24.12	-7.12	Big Ben Seam
VW5(62m)	366700	6368083	55.7	92	62	11/05/07	46.26	+9.44	White Creek Seam
VW5(71m)	366700	6368083	55.7	92	71	11/05/07	51.19	+4.51	Donaldson Seam
VW5(89.5m)	366700	6368083	55.7	92	89.5	11/05/07	54.39	+1.31	Big Ben Seam
VW6(96m)	365337	6368293	52.5	130	96	11/05/07	82.31	-29.81	White Creek Seam
VW6(114m)	365337	6368293	52.5	130	114	11/05/07	88.46	-35.96	Donaldson Seam
VW6(128m)	365337	6368293	52.5	130	128	11/05/07	95.11	-42.61	Big Ben Seam
VW7(70m)	364619	6368701	24.9	110	70	26/05/07	29.79	-4.89	White Creek Seam
VW7(95m)	364619	6368701	24.9	110	95	26/05/07	31.21	-6.31	Donaldson Seam

Piezometer	MGA Coordinates		Surface RL (mAHD)	Depth (m)	Screen/Vibrating Wire Piezometer (m MBL)	Initial Water Level			Aquifer Formation
	Easting	Northing				Date	m BGL	m AHD	
VW7(107m)	364619	6368701	24.9	110	107	26/05/07	31.11	-6.21	Big Ben Seam
VW8(83m)	363072	6369003	22.5	240	83	11/05/07	28.46	-5.96	Donaldson Seam
VW8(97m)	363072	6369003	22.5	240	97	11/05/07	28.37	-5.87	Big Ben Seam
SP2-1	365112	6371264	65.2	65	50 – 53, 62 – 65	25/02/08	54.2	+9.8	Donaldson Seam
SP2-2	365112	6371264	65.2	65	82 – 85	25/02/08	61.4	+3.3	Big Ben Seam
SP3-1	366732	6371893	38.8	14	11 – 14	25/02/08	5.7	+33.1	Alluvium/weathered Permian
SP4-2	367612	6370989	27.8	9.4	6.4 – 9.4	25/02/08	3.1	+24.7	Alluvium/weathered Permian
SP7-1	364619	6368701	24.9	11.2	9.2 – 12.2	25/02/08	Dry	Dry	Alluvium/weathered Permian
West Wallsend Piezometers									
WWA1	364299	6353855							Alluvium/colluvium
WWA2	364199	6353895							Alluvium/colluvium
WWA3	364299	6354055							Alluvium/colluvium
WWA4	364299	6353955							Alluvium/colluvium
WWA5	364199	6354255							Alluvium/colluvium
WWA6	364299	6354355							Alluvium/colluvium
WWA7	364370	6354420							Alluvium/colluvium

BGL = below ground level.

3.1.7 Hydraulic Testing

Previous studies and investigations have included hydraulic conductivity[1] testing results for the coal seams and interburden in the regional area. Table 3.2 provides a summary of the typical range of values recorded to date.

Table 3.2: Summary of Historical Hydraulic Testing in the Study Area

Strata Layer Tested	Type of Testing Involved	Recorded Hydraulic Conductivity Range (m/d)	Notes
Alluvium/Weathered Permian	Slug & CRT (4 Tests)	0.07 – 0.6	-
'Overburden' – Abel Underground Mine Area	CRT (1 Test)	0.01 – 0.06	General result for reasonably deep overburden
'Overburden' – Tasman Underground Mine Area	Slug Test	0.09	Just above roof of Fassifern Seam
Bloomfield Colliery Rehabilitated Areas	Slug Test (3 tests)	0.02 – 2.3	-
Mudstone Interburden	Lab K Tests (Kh) (3 Tests)	0.0003 – 0.0037	Generally shallow samples
	Lab K Tests (Kv) (3 Tests)	0.0001 – 0.0002	
Mixed Mudstone/Sandstone Interburden	Lab K Tests (Kh) (2 Tests)	0.0014 – 0.0015	Generally shallow samples
	Lab K Tests (Kv) (2 Tests)	0.0001 – 0.0005	
Sandstone	Lab K Tests (Kh) (2 Tests)	0.0015 – 1.3	Generally shallow samples (high value only for very coarse/weathered sample)
	Lab K Tests (Kv) (2 Tests)	0.0009 – 0.19	
Fassifern Seam	Slug Tests (3 Tests)	0.01 – 0.12	-
Donaldson/Big Ben Seams	Slug & CRT (9 Tests)	0.002 – 2	The high value was a single, isolated record in a disturbed area at sub-crop. The next highest was 0.17. All deeper samples were at the lower end of the range (0.002 – 0.07). No samples below 100m.
Ashtonfield Seam	Slug Tests (3 Tests)	0.009 – 0.04	No samples below 100m, deepest sample at the lower end of the range.

m/d – metres per day.

These results show a noticeable decrease in permeability with depth for the coal seams, with permeability decreasing from the Fassifern Seam (0.01 – 0.12m/d) through to the Ashtonfield Seam (0.009 – 0.04m/d). This exhibited decrease is probably due to greater cover depth and/or remoteness from outcrop, as well as the near-surface effects of weathering.

The results also show that laboratory tests for interburden materials demonstrate very low permeabilities in comparison to field slug tests, and vertical permeability is typically less than horizontal permeability. Discrepancies between laboratory tests and field scale tests are expected, as the laboratory scale tests do not contain fractures or fissures. Mackie (2009) identified three 'types' of bulk rock mass permeability in the Hunter Coalfields:

- Areas where there are very few fissures, or where fissures are so deeply compressed by hydrostatic loading that they are effectively shut, and bulk rock mass permeability is similar to laboratory values;

[1] In this report, the terms "hydraulic conductivity" and "permeability" are used synonymously.

- Areas where there are 'limited' active joints. The impact this has on permeability depends on the rock type, with hydraulic conductivity for coarse grained or weathered sandstones/conglomerates only increasing by a factor of 5, whereas mudstones could increase by up to 100 times the laboratory value; and
- Areas that are de-stressed and heavily jointed. Most rock types in this category have similar hydraulic properties, in the range 0.01 to 0.001m/d.

Differences between vertical and horizontal permeability are also well documented, with vertical permeabilities typically at least an order of magnitude or so less than horizontal permeability. This is because fractures and fissures tend to be oriented with bedding planes, and layers of mudrocks or other low permeability strata tend to cause coherent barriers to flow in the vertical direction.

The coal seams tend to be the most permeable parts of the coal measures, and the permeability of coal seam layers also varies, generally dependent on the degree of cleating within the coal (which dominates permeability) and the depth of cover (and hence compressive stress on the cleats) (Mackie, 2009). Both empirical analysis (Laubach *et al*., 1998) and modelling of cleat fracture permeability (Mackie, 2009) suggests that the permeability of coal seams tends to reduce by around an order of magnitude with each 200m of additional overburden.

3.2 Current Project Investigations

3.2.1 Drilling and Installation of Piezometers

To supplement the existing piezometer network, further vibrating wire piezometers have been installed in exploration holes across the model area both for the Project and for the possible future mining developments. Installation involved the grouting of the boreholes with the vibrating wire piezometer set at appropriate depths. This includes seven multi-level vibrating wire piezometers located within the Project area itself (B002A, B004, B005, B017, B29, B30, B31). Their locations, as well as all monitoring bores installed during previous investigations, are shown on Figure 3.1.

3.2.2 Laboratory Permeability Testing

A number of cored drill holes were sampled to gain representative lithologies from major interburden units. The core samples were laboratory tested to determine vertical and horizontal hydraulic conductivity. Testing for vertical permeability was taken perpendicular to the bedding planes, while horizontal permeability was taken parallel to the bedding planes.

A summary of the core test results is provided in Table 3.3. These results can be regarded as lower limits for use in model calibration, as cores do not capture the bulk fractured characteristics of a formation.

During the testing process one horizontal and four vertical samples failed under the test regime. Additional samples were also tested for total porosity.

Table 3.3: Summary of Groundwater Investigation Program Core Test Results

Model Layer	Formation	Core test				Packer test
		average Kh (m/d)	average Kv (m/d)	Kh range (m/d)	Kv range (m/d)	(m/d)
5	Above West Borehole Seam	6.53E-07	5.60E-07	5.11E-07 to 7.95E-07	5.41E-07 to 5.8E-07	2.07E-05
7	West Borehole Seam	1.59E-05	2.04E-06	1.59E-05	2.04E-06	
8	West Borehole - Sandgate Interburden					
9	Sandgate Seam	1.69E-03	5.96E-07	4.57E-07 to 6.75E-03	1.35E-07 to 1.69E-06	1.21E-05

Model Layer	Formation	Core test				Packer test
		average Kh (m/d)	average Kv (m/d)	Kh range (m/d)	Kv range (m/d)	(m/d)
10	Sandgate - Donaldson Interburden	3.09E-05	3.72E-07	4.27E-07 to 8.03E-05	2.68E-07 to 5.74E-07	8.12E-06
12	Above Donaldson Seam	3.58E-06	4.18E-07	1.35E-07 to 1.10E-05	8.39E-08 to 1.23E-06	
13	Upper and Lower Donaldson Seams	2.85E-03	2.15E-07	1.08E-07 to 8.55E-03	1.27E-07 to 3.79E-07	1.30E-04
14	Thornton Claystone	3.10E-06	3.61E-05	1.73E-07 to 7.51E-06	1.73E-07 to 1.78E-04	
15	Big Ben Seam	1.71E-06	4.56E-07	7.36E-07 to 3.35E-06	2.67E-07 to 8.64E-07	1.30E-04
16	Just below Big Ben Seam	1.85E-06	5.13E-07	1.85E-06	5.13E-07	
17	Ashtonfield Seam	1.95E-06	6.78E-07	6.94E-08 to 6.03E-06	8.88E-08 to 1.55E-06	

In addition to hydraulic conductivity tests of drill core, packer tests were also conducted at drill hole C242 down to the Big Ben Seam. Nine tests were conducted throughout the borehole. Seven tests straddled a 6.5m interval and two tests spanned a 4.5m interval. The highest flow was recorded within the Donaldson and Big Ben Seams at 1.3 x 10^{-4}m/d (1.5 x 10^{-9}m/s). The lowest recorded flow was effectively zero equating to a hydraulic conductivity of 8.0 x 10^{-7}m/d (1.0 x 10^{-11}m/s) or less.

3.2.3 Groundwater Level Monitoring

Hydrographs and hydrostatic head profiles for standpipes and multi-level vibrating wire piezometers are provided in Appendix B.

The hydrostatic head profile is used to gauge the quality of data sets and to explore the vertical head gradients which may be apparent. Generally, under pre-mining conditions, and assuming no perching of groundwater, pressures can be expected to plot close to the 45° "hydrostatic line", while a slight shift away from the line reveals that there is a vertical head gradient. Deviations from the 45° line may occur in areas already affected by mining stresses, or where perched aquifers are present.

Including the previous investigations associated with mining development, there are over 40 monitoring boreholes in the regional study area. These cover the majority of the model domain, as shown in Figure 3.1, and monitor most of the coal seams and interburden layers described above.

4. HYDROGEOLOGICAL SETTING

4.1 Rainfall and Evaporation

The climate of the region is temperate with hot summers and cool winters. The average daily maximum temperature ranges from 30.7º Celsius (C) in January to 16.6ºC in July.

Table 4.1 summarises rainfall data from the East Maitland Bowling Club (open 1902 – 1994) and the Maitland Visitor Centre (open 1997 – current) meteorological stations, both situated approximately 10km to the north of the Project. Rainfall data from the Cessnock (Nulkaba) meteorological station (open 1966 – current), situated approximately 12km west of the Project has also been included in Table 4.1.

Table 4.1: Rainfall Data for East Maitland Bowling Club Station 61034, Maitland Visitor Centre Station 61388 and Cessnock (Nulkaba) Station 61242.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Station 61034 Mean Rainfall (mm)	89.0	94.1	96.5	87.4	70.3	84.2	58.1	52.2	54.8	65.5	61.6	81.3	895.0
Station 61034 Mean Rain days	7.8	7.6	7.6	7.7	7.0	7.7	6.8	6.3	6.2	7.4	6.6	6.4	85.1
Station 61388 Mean Rainfall (mm)	46.5	111.9	90.5	84.0	67.3	86.6	48.7	33.5	54.4	65.1	86.3	61.1	835.9
Station 61388 Mean Rain days	10.7	11.5	11.6	11.9	10.9	12.4	10.6	8.9	8.9	9.8	12.4	10.4	130.0
Station 61242 Mean Rainfall (mm)	87.9	105.1	85.3	58.2	54.2	60.2	32.6	37.1	43.8	59.3	72.7	70.7	767.1
Station 61242 Mean Rain days	10.7	10.6	10.6	8.7	8.8	9.0	7.7	7.7	7.6	9.6	10.8	9.7	111.5

mm = millimetres.

Rainfall at the East Maitland and Cessnock sites exhibits a moderate seasonal pattern, with the highest mean rainfall generally occurring during the December to June period and the lowest rainfall observed between July and November.

Regionally rainfall is the primary source of groundwater recharge. Therefore, fluctuations in the groundwater table under natural conditions typically display a close relationship to variations in rainfall. Periods of above average rainfall generally lead to rising groundwater levels, and below average rainfalls lead to declining groundwater levels. Typically, under natural conditions, changes in the groundwater elevation reflect the deviation between the long-term monthly (or yearly) average rainfall, and the actual rainfall, usually described as the Residual Mass Curve (RMC).

The groundwater levels recorded during periods of rising RMC are expected to rise in proximity to recharge areas while those recorded during periods of declining RMC are expected to decline. A plot of the RMC at Cessnock since 1991 is shown in Figure 4.1. Below average rainfall has occurred from 2002 to 2007 and again in 2010. Above average rainfall is observed to occur in 2008, 2009 and again in 2011.

No evaporation data is available from the Maitland meteorological stations. Average class A pan evaporation data for Cessnock (Station 61242) and Paterson (Station 61250), located approximately 20km to the north of the Project, is provided in Table 4.2.

Table 4.2: Pan Evaporation Data for Cessnock (Nulkaba) Station 61242 (opened 1966) and Paterson (Tocal AWS) Station 61250.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Station 61242 Mean Evaporation (mm)	177	140	121	84	59	45	53	78	105	136	153	177	1328
Station 61250 Mean Evaporation (mm)	192	148	130	99	74	63	74	105	132	161	174	208	1560

Although actual evapotranspiration is generally only around 85% of the pan data, Tables 4.1 and 4.2 show that there is a clear annual rainfall deficit, as potential evaporation generally exceeds rainfall for most months of the year (except during the April to July period).

4.2 Topography and Drainage

An overview map of the regional topography is shown in Figure 4.2. The topography of the Project area is dominated by the Sugarloaf Range trending north-south, with Mount Sugarloaf the highest topographic point at 412m Australian Height Datum (AHD). The Project area is characterised by undulating to steep terrain comprising the prominent Sugarloaf Range ridgeline spur and several natural drainage gullies.

The majority of the Project area lies within the headwaters of the Wallis Creek catchment, which flows into the Hunter River near Maitland. This includes Surveyors Creek, an ephemeral water course which acts as the main drainage system to the immediate north of the Project area. Minor portions of the Project area are located in the ephemeral headwaters of Blue Gum Creek that flows to Hexham Swamp approximately 8km east, and within the headwaters of the Cockle Creek catchment which flows into the northern end of Lake Macquarie in the south-east.

The model area for the Project (Figure 4.2) runs from Wallis Creek on the western boundary through to the low-lying Hexham Swamp, saline parts of the Hunter River and Lake Macquarie on the eastern side of the model. The Sugarloaf Range dominates the south-eastern part of the model area, and rises to a height of over 450mAHD (outside the Project area). The Sugarloaf Range is drained by a number of ephemeral creeks that run to either Wallis Creek on the western side, or Hexham Swamp and Lake Macquarie on the eastern side of the range. The northern part of the model area is dominated by low lying (up to 150mAHD) hills that are bounded by Wallis Creek to the west and north, and low lying land associated with Hexham Swamp to the east.

4.3 Land Use

The majority of the Project area comprises forested land reserved as the Sugarloaf State Conservation Area and Heaton State Forest. This vegetation forms part of a corridor of contiguous vegetation that links Sugarloaf Range to the Watagan Mountains in the south. Private land holdings occur within the western and northern portions of the Project area.

Existing development immediately surrounding the Project area includes:

- Transmission lines;
- Communication infrastructure (including towers on Mount Sugarloaf and buried fibre optic cables);
- Sydney Newcastle (F3) Freeway, George Booth Drive, Mount Sugarloaf Road and other minor roads;
- Orica Limited’s technical and research facility off George Booth Drive; and
- Locality of O’Donneltown and township of West Wallsend.

The operational mines in the vicinity of the Project area include:

- The existing Tasman Underground Mine;
- West Wallsend Colliery, approximately 5km south-east;

- Westside Colliery, approximately 6km south-east;
- Abel Underground Mine, approximately 8km north-east;
- Donaldson Open Cut Mine, approximately 10km north-east; and
- Bloomfield Colliery, approximately 10km north-northeast.

Construction has commenced on the Hunter Expressway to the north-east of the Project area. The four-lane expressway is scheduled to be open to traffic by the end of 2013.

4.4 Stratigraphy and Lithology

A surface geological map of the model area for the Project is shown in Figure 4.3 (Hawley and Brunton, 1995).

The majority of the Project area is underlain by the Permian Tomago and Newcastle Coal Measures. These include a number of coal seams, described further below. Figure 4.4 shows a schematic stratigraphic column of the Permian coal measures, with depths to the main coal seams indicated based on exploration drill hole C233. Sediments above and below the coal seams comprise predominantly interbedded claystone, siltstone, sandstone and tuff.

The Mulbring Siltstone is the oldest sub-cropping formation, and occurs in the far western part of the assessment area, sub-cropping around and below the Wallis Creek Alluvium. The higher parts of the Sugarloaf Range are topped by Triassic sandstones of the Narrabeen Group.

The Tomago and Newcastle Coal Measures contain a number of named, significant coal seams that occur within the Model Area. These are (from youngest to oldest):

- Great Northern Seam;
- Fassifern Seam;
- West Borehole Seam;
- Sandgate Seam;
- Donaldson Seam: Upper, Lower*;
- Big Ben Seam*; and
- Ashtonfield Seam.

**N.B: There is some splitting of these seams, and Big Ben is currently only mined within the Bloomfield Colliery. The Upper and Lower Donaldson tend to split downdip to the south of the model area.*

Minor seams are present between the West Borehole and Donaldson seams. To the north the Beresfield Seam is regularly encountered. Other, generally undifferentiated, seams have been encountered within this horizon. It is understood that these seams are not significant enough to be mined.

It should be noted that some nomenclature at the adjacent Bloomfield operation differs from that used elsewhere in the region. At Bloomfield Colliery, the Donaldson Seam is called the ‘Whites Creek’ Seam; the Big Ben Seam is known as the ‘Donaldson’ Seam, and the Ashtonfield Seam is known as the ‘Big Ben’ Seam.

Through most of the area, fresh rock is overlain by regolith materials that are formed by *in situ* weathering of the Permian strata. Some Quaternary alluvial deposits are present, and are generally associated with the floodplains of Wallis Creek, the lower parts of the Hexham Swamp tributaries and the permanent river reaches of Cockle Creek. Minor alluvial development associated with Hexham Swamp/Pambalong Nature Reserve extends upstream from Pambalong for some distance along the lower reaches of Blue Gum Creek and Long Gully.

A regional view of the structural geology is provided in Figure 4.3.

4.5 Structural Geology

Structurally, the area is dominated by the Maitland Syncline, which plunges to the south, as shown on Figure 4.3. There is a steep monocline on the western side of the Maitland Syncline, which causes sequential outcropping of Permian strata within the higher terrain associated with the Sugarloaf Range. The eastern flank of the syncline is bounded by either a shallow anticline or monocline structure.

There are a few faults within the area, which run sub-parallel to the syncline, as shown on Figure 4.3. These occur in the southern part of the model area, near Lake Macquarie and Cockle Creek. The major structures shown in Figure 4.3 were sourced from Geoscience Australia. Additional structures shown in Figure 4.3 were provided by Donaldson Coal and include fault structures and dykes mapped within the area. These include shallow reverse fault structures in the Donaldson Open Cut Mine and Abel Underground Mine areas. Of these, a number of smaller faults do not extend to the Donaldson Seam.

The Krecji Fault however, is a significant reverse fault which has displaced and disconnected strata through to the Donaldson Seams, preventing mine development east of this structure. It is evident that the Krecji Fault in particular does have enhanced hydraulic conductivity associated with the disturbed fault zone, as elevated mine inflows are experienced during coal excavation in near proximity at the Abel Underground Mine. The effect of the Krecji Fault on water levels and hydraulic conductivity is discussed further in Sections 4.6.3 and 5.2, respectively.

A number of igneous dykes are also known to occur, which also tend to run sub-parallel to the axis of the syncline. They tend to have a basic (taschenite) petrology, and are thought to be of Cretaceous age (Hawley and Brunton, 1995).

Contours of the base of the West Borehole and the Upper Donaldson coal seams are shown in Figures 4.5 and 4.6, respectively. Structural contours for the Donaldson Seam clearly show the plunging synclinal structure within the Project area and the steep, monoclinal structure on the western flank of the basin. These regional structures are less obvious higher in the stratigraphic sequence.

As noted above, the main synclinal structure is not particularly evident in the upper Permian and Triassic strata of the Sugarloaf Range. The Fassifern and Great Northern Seams are shallow dipping with a relatively uniform slope. The Great Northern Seam is isolated and only occurs in the higher parts of the range. The Fassifern Seam outcrops around the hillsides of the Sugarloaf Range, and dips gently towards the centre of the range, at around three to four degrees in the Project area. It forms a shallow basinal structure, with a gentle plunge to the south. The coal deposit currently being mined is almost an outlier, with only a narrow neck about 1km wide connecting the deposit to the rest of the Sugarloaf Range, south-west of the existing Tasman Underground Mine. The approximate sub-crop line of the Fassifern Seam is shown on Figure 4.3. The Fassifern Seam ranges from 5m to 30m in total thickness, including interburden sediments, but the economic mining section is generally only 1.8m to 2.6m thick.

All of the seams below the Fassifern Seam follow the main synclinal structure. This results in progressive sub-cropping to the north and west for each seam, and maximum seam depths occur in the central southern parts of the model area. The inferred sub-crops and geometry of the West Borehole and Donaldson Seams are also shown in Figure 4.3. These are based on the resource models provided by Ellemby Resources, modified on the western boundary to enable the formation sub-crop to be shown on the geological map. There is a slight discrepancy between the Geoscience Australia-sourced geological map and the resource model sub-crop lines which can be seen towards the west in Figure 4.3.

The West Borehole, Sandgate, Donaldson, Big Ben and Ashtonfield Seams all vary in thickness and the thickness of the interburden also varies according to the location on the synclinal structure. Details of seam and interburden thicknesses are given as part of the model description contained in Section 7.5. In general there is around 200m of interburden between the West Borehole and Donaldson seams. The Ashtonfield Seam is generally 30m to 60m below the Upper Donaldson Seam, except close to sub-crop.

4.6 Hydrogeology

4.6.1 Hydrogeological Units

The main hydrogeological units relevant to the coal mining operations and proposed developments in the area are as follows:

- Alluvium;
- Colluvium/weathered bedrock;
- Triassic Narrabeen Group;
- Coal measures overburden/interburden, comprising mudstones, siltstones, sandstones, with occasional minor coal seams;
- Main coal seams of interest to mining, including in stratigraphic order:
- Great Northern Seam;
- Fassifern Seam;
- West Borehole Seam;
- Sandgate Seam;
- Buttai Seam: Upper and Lower;
- Beresfield;
- Donaldson Seam: Upper and Lower;
- Big Ben; and
- Ashtonfield.
- Basal units which included coal measures and interburden of the Tomago Seam, as well as underlying Wallis Creek Formation.

4.6.2 Groundwater Level Contours

Groundwater levels in the alluvium, regolith and near surface zones in the hard rock units tend to closely reflect local topographic elevation, as they are recharged and discharge locally. Groundwater levels at depth within the hard rock Permian sequence tend to be more regional in character, and are controlled by the surface elevations in the areas of outcrop, which may be many kilometres up dip. Therefore groundwater contour patterns are distinctly different in the near surface and deeper zones.

Groundwater level contours for the West Borehole Seam specifically within the Project area dip to the north-east and east, influenced by the geometry of the West Borehole Seam and the residual low groundwater levels within the former Stockrington workings. Although there is limited information on water levels within the old workings, the water table is assumed to be relatively flat within the abandoned workings to the east of the Project, and the West Borehole Seam is believed to be unsaturated to the north (updip) of the proposed mine entry point.

Groundwater level contours for the Donaldson Seam exhibit a gradient to the south in the north of the model area where high groundwater levels occur and to the east further south, influenced by the central ridge prominent in the Project area. The contours also indicate the influence of dewatering north of John Renshaw Drive, associated with Donaldson Open Cut Mine and Bloomfield Colliery and to the south of John Renshaw Drive, associated with underground mining activities at Abel Underground Mine.

Shallow groundwater levels in the near surface material, which includes alluvium, colluvium and weathered bedrock, show a much closer relationship to the local topography.

Groundwater contours generated during groundwater model calibration for the alluvium/regolith, Fassifern Seam, West Borehole Seam and Donaldson Seam are described further in Section 7.6.4 and provided in Figures 7.5, 7.6, 7.7 and 7.8 respectively.

Recharge to the coal measures occurs in the high groundwater levels that occur in the north of the model area, and flows down dip to the south and east, except in areas around the Bloomfield Colliery, where local hydraulic gradients are affected by ongoing, long-term mining activities.

4.6.3 Groundwater Level Hydrographs

The locations of all monitoring bores are shown in Figure 3.1 and detailed as follows:

- The DPZ monitoring bores are predominantly standpipes installed as part of the Donaldson open cut mine and generally monitor groundwater levels in the Donaldson Seam and overburden.
- The C series bores were installed during investigations for the Abel underground mine.

TA bores are those installed for the Tasman Underground Mine.

The B series bores were installed as part of the ongoing baseline monitoring program for the needs of future mining within the Donaldson lease areas, initially the West Borehole Seam extraction proposed in the Project.

SP and BL series bores are those monitoring the neighbouring Bloomfield Colliery. WWA series bores are located at the West Wallsend Colliery south of the Project.

Hydrographs and hydrostatic head profiles for the key standpipes and multi-level vibrating wire piezometers are provide in Appendix B. The groundwater level hydrographs show changes in levels with time, in response to both mining effects and seasonal recharge effects.

Donaldson Open Cut Mine Area

Figure 4.7 shows hydrographs for all the DPZ bores used to calibrate the groundwater model. Many of these are no longer functioning as they were located within the Project area and have been progressively mined out.

Monitoring of water levels was maintained regularly through until early 2010. A number of piezometers show drawdown effects of mining from the Donaldson Open Cut Mine, especially DPZ8 and DPZ9 (all screened in the Donaldson and Big Ben Seams) (Figure 4.7). Bores DPZ4, DPZ15, DPZ16 and DPZ17 have all been mined out.

Abel Underground Mine Area

Figure 4.8 shows hydrographs for C063 which is located to the east of the Abel Underground Mine adjacent to the F3 freeway. Bore C063 has two vibrating wire piezometers, placed in the Lower Donaldson Seam (C063A) and within sandstone interburden below the Buttai Seam (C063B) at respective depths of 280m and 129m. No response to mining at the Abel Underground Mine is observed in C063A within the Donaldson Seam. The Krecji Fault is a significant structure identified between Abel Underground Mine and C063A which has caused disruption of the geologic strata. The lack of drawdown response in the Donaldson Seam east of this fault indicates that the fault is preventing the eastward migration of groundwater depressurisation. The water level decline observed in C063B suggests a very slow recession following installation in 2005, considered to be an indication of extremely low permeability, and not as a result of mining stresses. Accordingly, bore C063B was not used in the model calibration.

Bore C081A monitoring the Donaldson Seam (Figure 4.8) shows a strong drawdown response to mining at the Abel Underground Mine from August 2008, correlating to development of the North South and East West Mains in Area 1. Shallow bore C081B, screened in alluvium/regolith, shows no drawdown response to mining (Figure 4.8).

The large drawdown in the Donaldson Seam observed at C081, has led to a reversal of the previous upward hydraulic gradient between the Permian coal measures and the overlying alluvium/regolith (Figure 4.8). This bore is located at a low-lying site on the western margin of the Pambalong Nature Reserve in the lower-lying eastern parts of the model area, south of the Abel Underground Mine. Prior to mining, the groundwater pressure in the Donaldson Seam was 24m higher than groundwater level in the shallow alluvium/regolith (and 22m above ground level), however the Donaldson Seam pressure is now well below the surficial groundwater level, and well below ground level. The lack of drawdown in the surficial groundwater confirms the lack of hydraulic connection between the surface and the Donaldson Seam.

The groundwater level observations in C080 and C081 provide key pressure response trends to mining at the Abel Underground Mine, which have been relied upon for model calibration.

Bore C080 is a single standpipe piezometer to the Donaldson Seam. The hydrograph (Figure 4.9) shows drawdown due to mining at Donaldson prior to 2007, and then shows further drawdown believed to be in response to the Abel Underground Mine starting in 2009.

Bore C072 site has three piezometers, one of which (C072A) was damaged and lost shortly after construction. Hydrographs for the remaining piezometers in the Donaldson Seam and weathered overburden (Figure 4.9) show no significant response to mining. Bore C078A (Donaldson Seam) and C078B (weathered overburden) likewise show no response to mining at the Abel Underground Mine, but may have been influenced by mining at the open cut prior to 2006 (Figure 4.10).

The data from these monitoring bores support the assessment that there is low vertical hydraulic connectivity between the surficial groundwater and the deeper Permian groundwater. The historic (pre-mining influence) groundwater levels within the deeper Permian are generally more indicative of the elevation of the sub-crop zones where they are recharged. The groundwater in the alluvium and regolith is much more closely related to local topography, and tends to form localised, shallow groundwater flow systems, which are dominated by local recharge and discharge.

Bores C082 and C087 (Figure 4.10) are shallow standpipe piezometers in the regolith. Both show no response to mining.

Standpipe piezometer C082, located just northern of Pambalong Nature Reserve, monitors groundwater levels within shallow weathered Permian overburden and is screened from 14 to 20m below surface. Groundwater levels are relatively stable as shown in Figure 4.10, with a subdued response to rainfall, by comparison with the residual mass rainfall curve also presented on Figure 4.10. The hydrograph for C072 (Figure 4.9), monitoring the Donaldson Seam - Sandgate Seam interburden at a depth of 42 to 45m, also shows a subdued response to rainfall.

C123 and C223 are multi-level vibrating wire piezometers located between the Abel Underground Mine and Tasman Underground Mine operation areas (Figure 3.1).

Figure B14 in Appendix B provides hydrographs and a hydrostatic head profile for C123. Water levels in the Lower Donaldson became erratic from early 2010, suggesting a failure of the piezometer, and this record was not used as a model calibration target.

The hydrostatic head profile for C223 (Figure B18 in Appendix B) shows a linear trend with groundwater pressures generally along the 45° hydrostatic line, but with the deeper strata (Buttai and Donaldson Seams) being slightly depressurised, possibly due to long-term mining at Donaldson Open Cut Mine and Bloomfield Colliery. Hydrographs indicate relatively stable groundwater levels, however a slight decrease in water pressures in the Lower Donaldson Seam from early 2011 indicates a potential response to the Abel Underground Mine operations.

Both C123 and C223 indicate that pressures within the deeper strata are lower than pressures in stratigraphically higher lithologies around the Tasman Underground Mine further south under the Mt Sugarloaf range (see piezometers B002, B029, C141 and C148 in Figures B1, B3, B9 and B10 respectively in Appendix B).

North of the Project area, bores C133 and C138 are located west of the Abel Underground Mine and south-southwest from the Bloomfield Colliery (Figure 3.1).

A total of five piezometers in C133 show water levels in all piezometers below sea level, in the range 0 to - 20mAHD. They are also believed to be responding to mine dewatering at Bloomfield Colliery.

Figure B15 of Appendix B illustrates the hydrographs and hydrostatic head profile for C138. At the time of installation in 2008, groundwater pressures were well below sea level in the Donaldson Seam and deeper strata, at approximately -10mAHD to -13mAHD. Groundwater levels have subsequently shown a continued downward trend, to between -21mAHD and -26mAHD by mid 2011. These are assessed to be responding to mining operations at Bloomfield Colliery. In contrast, the piezometer placed 25m above the Lower Donaldson Seam shows little drawdown, and suggests that the overburden is largely insulated from the Bloomfield dewatering, and also highlights the low vertical hydraulic conductivity characteristic of interburden units.

Piezometers C140, C141, C143 and C148 are shown are located to the west of the Abel Underground Mine and south of Bloomfield Colliery (Figure 3.1). All show generally lower groundwater levels, albeit not as low as in C133 and C138. These bores all also showing the influence of mine dewatering at Bloomfield. Piezometers set in strata above the Donaldson Seam in C141 show only limited drawdown effects.

Bores C242 and C252 are located to the south of the current active mining at the Abel Underground Mine (Figure 3.1). C242 shows groundwater pressures in the range 3mAHD to 26mAHD, but with a declining head in the Sandgate Seam which cannot be readily explained. The deep piezometer (Donaldson Seam) at this site failed during installation. It is possible that other piezometer readings at this site are also questionable. The C252 piezometer data are spurious, and suggest that the cement grouting at this site was incomplete.

Bore C284 is located south of the Abel Underground Mine, and has three piezometers, all of which are giving spurious data, suggesting that the cement grouting of the hole was incomplete.

Tasman Underground Mine Area

Hydrographs for TA23 and TA24 are also shown on Figure 4.11. TA23 was cemented up in 2009.

The multi-seam monitoring data provided in Appendix B clearly show that the regional flow patterns are dominated by the high surface elevations associated with the Sugarloaf Range and perched groundwater tables that exist in the elevated terrain. For example, TA23 located south of the Project at an elevation of 379mAHD, has monitored water levels at approximately 237mAHD from 2006 to 2009 before being cemented (Figure 4.11). This indicated water level is more than 100m higher than measured elsewhere in the range. The higher groundwater levels are due to the high elevation of the sub-crop area where this stratum is recharged. Otherwise, regional flow tends to be towards the discharge/subcrop areas associated with Lake Macquarie and the tidal sections of the Hunter River to the east and south-east. Regional flow patterns at depth are also influenced by low water levels that are known to occur within the abandoned workings of the West Borehole Seam associated with former mining.

Regional monitoring bores in the vicinity of the existing Tasman Underground Mine show a very strong downward hydraulic gradient beneath the Sugarloaf Range, with a water level difference of over 40m between the Fassifern Seam and the underlying West Borehole Seam. This downward gradient was present prior to commencement of mining at Tasman, and indicates that the Fassifern Seam and higher groundwater is perched above the deeper groundwater. This confirms that vertical permeability is very low, and that the main flow paths within the Permian strata are along the coal seams and parallel to bedding in the interburden layers.

Within the Fassifern Seam in the vicinity of the existing Tasman Underground Mine, TA24 (Figure 4.11) shows progressive depressurisation in response to mining from 2006, and by mid 2011 the piezometer has almost been dewatered. TA24 is located close to the area where mining commenced at Tasman Underground Mine (Figure 3.1). Bore TA28 shows dewatering drawdown commencing in early 2010, when mining advanced closer to this site. The higher piezometers at TA32 both showed only limited pressurisation (around 2m) at the time of installation, and both have been dry since 2008. Only the deepest piezometer remains saturated, and shows no significant dewatering effect.

Tasman Extension Underground Mine Area

Within the West Borehole Seam, a steep hydraulic gradient exists between subcrop on the western margins at elevated levels, and historic workings where water levels are believed to be at -67.5mAHD, based on measurement in a water disposal borehole in the Tasman Underground Mine. Figure 4.12 shows water levels within the West Borehole Seam which illustrate the gradient observed within that coal seam.

Bores B004 and B005 are single vibrating wire installations in the vicinity of the historical mining areas of the abandoned Stockrington Colliery. Water levels are relatively stable, with some variability possibly indicating a subdued recharge response. The West Borehole Seam outcrops in the floor of the Black Hill Quarry, providing a possible enhanced recharge opportunity.

Observations from additional bores located within the Project area include the following:

- B002A is a multi-level vibrating wire installation which has four piezometers placed between the West Borehole Seam overburden and the Big Ben Seam (Figure B20). Pressures within the Big Ben are lower than normal hydrostatic trend and this is also reflected in the lower groundwater levels within the hydrograph. This is probably due to mining at Bloomfield Colliery, and all data was used for transient model calibration;
- B029 is a multi-level vibrating wire installation which has five transducers placed between the West Borehole Seam and the Lower Donaldson Seam. Figure B23 shows the hydrostatic head profile and hydrographs for each instrument. Data from the Upper and Lower Donaldson Seams both show drawdown effects, presumably from the Abel Underground Mine, with drawdown greatest in the Upper Donaldson seam;
- B030 (Figure B24) contains five transducers placed between the West Borehole Seam overburden and the Donaldson – Big Ben Interburden (B030A). There is good hydrostatic correlation between the upper 4 piezometers; however overall B030A shows a marked departure from the expected hydrostatic profile. It suggests a groundwater head of -10mAHD, which is inconsistent with heads in the Donaldson Seam floor at locations closer to the Abel Underground Mine workings. It is considered that the piezometer may not have been completely sealed in the cement grouting, and B30A was not considered for calibration purposes; and
- B031 (Figure B25) contains four piezometers placed between the West Borehole Seam (B031D) overburden and near the Upper Donaldson Seam (B031A). The hydrostatic profile is erratic with no correlations between instruments. There is some doubt about placement depths as for B031A which has missed the major coal zone. Both B031C (within the West Borehole Seam) and B031D (West Borehole Seam overburden) have low pore pressures and indicate that these strata are close to dry by the end of the available monitoring record. The site is close to the West Borehole Seam subcrop. The very low pressure in B031D indicates that the groundwater within the West Borehole overburden is probably perched. B031A and B031D were not used as potential calibration targets.

4.7 Groundwater Quality

Assessments of groundwater and surface water quality can be useful in understanding conceptual hydrogeology, particularly in relation to EC and Piper diagram plots. Different strata horizons can demonstrate differing amounts of salinity, which tend to be low in areas of high recharge or connectivity with surface waters. Piper plots provide an assessment of the recharge-discharge processes, and also allow a comparison of water samples derived from different environments within the hydrological cycle. Recently-recharged water tends to plot closer to the left-hand apex of the diamond field in the Piper diagram, and waters further from the source of recharge closer to the right-hand side.

No groundwater sampling has been undertaken for the West Borehole Seam as part of the Project as all installed monitoring bores are multi-level vibrating wire piezometers. The following previous investigations were reviewed to provide an understanding of the existing conditions across the region:

- In 2002, groundwater quality in the vicinity of the Tasman Underground Mine was characterised by the collection of samples from monitoring piezometers installed in seven exploration drillholes within and around the mine site as part of the groundwater impact assessment studies for the Tasman Underground Mine (PDA, 2002). Three sampling rounds were conducted between September and December 2001;
- In 2007, groundwater samples were collected in winter and summer (May and December) from the Bloomfield Colliery standpipe piezometers, and submitted to accredited laboratory ALS Environmental for detailed chemical analysis (Aquaterra, 2008). EC and pH were measured in the field and at the time of sampling; and
- In 2006, groundwater quality in the vicinity of the Abel Underground Mine was characterised by the collection of samples from monitoring piezometers installed within and around the mine site as part of the impact assessment studies for the Abel Underground Mine (PDA, 2006).

4.7.1 Salinity

The salinity of groundwater within the Project area is variable (PDA, 2002; PDA, 2006; Aquaterra, 2008), with TDS ranging from less than 500mg/L to 16,000mg/L. The highest salinities are recorded from the surficial groundwater, i.e. the colluvium and weathered Permian, with some high salinity recorded in the Permian overburden layers. The groundwater appears to be more saline in the aquifers above the Fassifern Seam (2770-5280 microSiemens per centimetre [µS/cm]), and to a lesser degree in the aquifers below the Fassifern Seam (2100µS/cm), than in the Fassifern Seam itself (900 – 1260µS/cm).

Elevated salinity is found within much of the Permian coal measures aquifer system, ranging from less than around 600µS/cm EC in the more permeable coal seams to more than 16,000µS/cm EC within some of the less permeable overburden/interburden units.

Salinity in the creeks was found to be highly variable as salinity is often found to be elevated in the colluvium. During periods of high runoff, salinity can be very low (<300mg/L TDS). However, during dry periods, shallow groundwater seepages (often from temporary, perched regolith aquifers) can increase creek salinities, with values of between 1,000 and 15,000mg/L TDS being recorded in Four Mile Creek. Therefore, salinity is not considered to be a good indicator of the degree of connectivity between surface water systems and deeper regional groundwaters in this area due to the high variability in surface water flow rates and quality, as well as the presence of high salinity in the shallow colluvium.

4.7.2 pH

The pH of the groundwater in the model area for the Project is found to be generally close to neutral, or slightly acidic, with pH values ranging from 6.2 to 7.4 (PDA, 2002; PDA, 2006; and Aquaterra , 2008). However, three samples collected from a bore completed in the Fassifern Seam were found to be moderately acidic, with pH around 4.7. These samples all contained very high concentrations of dissolved iron, ranging from 272 to 1245mg/L. This bore was located very close to outcrop, where the Fassifern Seam is likely to be readily exposed to the atmosphere.

4.7.3 Dissolved Metals

In addition to the previously mentioned bore in the Fassifern Seam, some other samples also contained high concentrations of dissolved iron, ranging up to 85mg/L. The high dissolved iron suggests the likely presence of pyrite in the coal, and in conjunction with the mostly acidic pH, suggests that the mine waters could have moderate acid generating potential.

Sampling of dissolved metals within the Model Area for the Project (Aquaterra, 2008) produced the following observations (Aquaterra, 2008):

- Generally low concentrations relative to ANZECC (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, with the exception of copper and zinc. The concentrations of copper exceeded the ANZECC guideline value of 0.0014mg/L in all samples. The zinc guideline value of 0.008mg/L was exceeded in all but 2 samples;
- Exceedance of the cadmium guideline value of 0.0002mg/L was reported from the two samples from SP4-2. Both samples from SP3-1 reported elevated manganese concentrations above the ANZECC guideline. The nickel guideline value was also exceeded in several samples. Finally, one exceedance for aluminium was reported (the December sample from SP3-1) (ANZECC, 2000); and
- Dissolved iron concentrations were also found to be relatively high in some samples, although no ANZECC guideline value is set.

4.7.4 Nutrients

Limited sampling for nutrients has only been undertaken at the Bloomfield Colliery in 2007. The sampling revealed concentrations of all parameters tested (ammonia, nitrite, nitrate and total Kjeldahl Nitrogen; and total phosphorous and reactive phosphorous) to be generally within the ANZECC guidelines, with a very slight exceedance for ammonia only in on sample from SP2-1 (ANZECC, 2000).

4.7.5 Major Ion Chemistry

The chemistry of groundwater samples can be evaluated with the aid of a Piper Trilinear Diagram. The major ion concentrations are plotted on the Piper Diagram as percentage milli-equivalents, with one triangular field for the major cations (calcium, sodium and magnesium) and another for the major anions (chloride, sulphate and bicarbonate). The plotted positions for each sample are then projected into the central diamond field and the intersection located, thus defining a unique plotted point for each sample, allowing a generalised classing of groundwaters and evaluation of groundwater evolution and mixing processes.

Figure 4.13 presents a composite Piper plot of the groundwater samples from within the Model Area for the Project. The plot shows the groundwater sample from bore C062A (which is located at a coal seam sub-crop) plotting near the centre of the Piper diamond, whereas the remaining groundwater samples are grouped close to the right hand side of the diagram. The Piper Plot shows that the groundwater is of a sodium chloride type, indicating little evidence of direct recharge. However, as with salinity, there is no clear distinction between hard rock and colluvial groundwater types, so few further significant conclusions can be drawn about conceptual hydrogeology from these results.

4.8 Existing Groundwater Use

Groundwater occurs generally in the area, but there are no significant exploitable aquifers underlying or close to the Project area.

The use of groundwater, other than environmental use and mine dewatering/inflow, in the vicinity of the Project is negligible. The majority of the area within 2 to 3km around the lease is steep forested land which includes the Heaton State Forest and Sugarloaf State Conservation Area.

A search of the NOW database of registered groundwater bores in the vicinity of the Project identified only 9 registered bores within 5km of the Project area (shown in Figure 4.14). A summary of the registered bore details for these 9 bores is provided in Table 4.3, with additional details provided in Appendix C.

Table 4.3: Registered Bore Locations within 5km of the Tasman Extension Project

Borehole No.	Easting	Northing	Depth (m)	Intended Use	Salinity (ppm)
GW053411	361215	6366699	20	Irrigation	0-500
GW053412	361240	6366730	7.9	Irrigation	0-500
GW051353	365986	6365810	49.7	Domestic/stock	3001-7000
GW078600	357366	6359467	4.2	Domestic	Not recorded
GW078814	363579	6359884	256.5	Test bore	Not recorded
GW078815	364460	6359652	131.1	Test bore	Not recorded
GW078816	363348	6359269	310.5	Test bore	Not recorded
GW078578	363861	6358055	99	Monitoring bore	Not recorded
GW080369	357796	6354334	10	Domestic/stock	Not recorded

Aside from the bores located within the existing Tasman Underground Mine (GW078814, GW078815, GW078816 andGW078578) which are monitoring potential impacts from mining activities, none of the bores listed in Table 4.3 are located within aquifers that are potentially hydraulically connected to the Project.

Of the bores not associated with Tasman Underground Mine, two bores (GW078600 and GW080369) are located west of the Newcastle Coal Measures sub-crop adjacent to Wallis Creek, GW053411 and GW053412 are located within the down gradient section of Surveyors Creek near the confluence with Wallis Creek north of George Booth Drive. This location is stratigraphically higher and up-dip of the Tasman Extension Project and outside the sub-crop of the West Borehole Seam. GW051353 is associated with the Abel Underground Mine.

4.9 Groundwater Dependent Ecosystems

Within the Project area, there are a number of habitats which could be considered GDEs (Hunter Eco, 2012.). These include:

- Alluvial Tall Moist Forest – located along drainage lines;
- Warm Temperate Rain Forest – located along drainage lines; and
- Sugarloaf Uplands Paperbark Thicket – located on a plateau on Sugarloaf Range with a shallow soil profile overlying bedrock (status as a GDE still under consideration).

Further details on these habitats are provided in the Hunter Eco (2012) report (Appendix F of the EIS).

In addition to the above habitats, there are some areas of springs/seeps that have been observed in the field by a number of specialists along the cliff/steep slope/rock outcropping areas. One of these locations also includes a small remnant dam built by historical loggers/State Forests for fire fighting purposes.

It has also been noted that shallow groundwater in the alluvium/colluvium is utilised by trees and shrubs along the banks of Surveyors Creek north (downstream) of the Project.

5. CONCEPTUAL MODEL

The conceptual model is a simplified representation of the real groundwater system, identifying the most important geological units and hydrogeological processes, while acknowledging that the real system is inherently more complex. The conceptual model forms the basis for the numerical groundwater flow model. A conceptual model for the Project groundwater system has been provided in Figure 5.1.

Based on the above, and consistent with the *Hunter Unregulated and Alluvial Water Sources* WSP, the data supports two generalised groundwater systems within the Project area:

- Porous Rock groundwater system - including the Tomago and Newcastle coal measures; and
- Alluvial groundwater system – associated with the low-lying areas associated with Wallis Creek to the west, and Hexham Swamp/Hunter River to the east.

Recharge to the groundwater systems occurs via rainfall and runoff infiltration, lateral groundwater flow and minor leakage from surface water sources (e.g. Wallis Creek). Although groundwater levels are sustained by rainfall infiltration, they are controlled by topography, geology and surface water levels in local drainage systems. Local groundwater systems tends to mound beneath hills, with ultimate discharge to local drainage and loss by evapotranspiration through geological outcrops and vegetation where the water table is near the ground surface (generally within 2 to 3m below ground level).

Evapotranspiration will vary across the Project area due to variability in ground coverage, topography and depth to water. Water levels are close to surface in lower-lying areas to the east of the Project area, and some areas close to Wallis Creek to the west.

During mining, the water levels in the porous rock groundwater system will be reduced in the vicinity of each mine in the area.

5.1 Hydrogeological Units

The local geology has been represented by a 20 layer model. These layers are largely defined by the main coal seams noted in Section 4.4 and the associated interburden intervals. The top layer (Layer 1) represents alluvium where present, and elsewhere the weathered regolith. Model layering is described in greater detail in Section 7.5.

It should be noted, that some ‘perched’ groundwater does also occur within the upper weathered mantle of the Permian coal measures and in elevated terrain occupied by Triassic sandstones of the Narrabeen Group. These perched groundwater systems have not been incorporated into the numerical groundwater model, as they are local in nature and of limited utility for other users and the environment.

5.2 Hydraulic Properties

The permeability of the coal measures is generally low, with rock mass hydraulic conductivities more than two orders of magnitude lower than the unconsolidated alluvium. It has also been observed that hydraulic conductivity decreases significantly with increasing depth of cover.

Within the coal measures themselves, the most permeable horizons are the coal seams, which commonly exhibit hydraulic conductivities one to two orders of magnitude higher than the siltstones, claystones, shale and sandstone units. Within the Project area, testing of the laminated mudstones/claystones has typically shown hydraulic conductivities lower than 1 x 10^{-6}m/d.

The coal seams are generally more brittle, and therefore more densely fractured, than the overburden and interburden strata, which cause the higher permeability. Within the coal seams the groundwater flows predominantly through cleat fractures, with very little evidence of structure-related fracturing. Due to the laminar nature of the coal measures, groundwater flow generally occurs within, or along the boundaries between, stratigraphic layers. This means that effective rock mass vertical permeability is significantly lower than horizontal permeability (typically two or more orders of magnitude).

The results of core permeability testing did not show a noticeable decrease in permeability with depth for the coal seams; however this is probably the result of testing in near surface areas where mining operations occur. Despite this, decreasing permeability with depth is expected with greater cover depth and/or remoteness from outcrop and near-surface effects of weathering.

Based on the results of the field testing, and the analysis provided above in Section 3.1.7, an estimate of the likely characteristics for the coal measures strata within the Model Area for the Project was postulated, summarised in Table 5.1.

Table 5.1: Probable Ranges of Hydraulic Conductivity within the Model Area for the Project

Hydrogeologic Unit	**Estimated Hydraulic Conductivity – Shallow (<150m) strata**		**Estimated Rock Mass Hydraulic Conductivity – Deeper Strata**	
	Kh (m/d)	**Kv (m/d)**	**Kh (m/d)**	**Kv (m/d)**
Weathered Permian/Regolith	0.1 – 0.5	0.01 – 0.05	N/a	N/a
Coal Measures Interburden	0.001 - 0.01	0.0001 - 0.005	0.0001 - 0.005	0.00001 - 0.0005
Fassifern Seam	0.01 – 0.2	0.001 – 0.02	N/a	N/a
West Borehole Seam	0.005 – 0.2	0.0005 – 0.02	0.0005 - 0.02	0.00005 – 0.002
Donaldson Seam	0.005 – 0.2	0.0005 – 0.02	0.0005 - 0.02	0.00005 – 0.002
Ashtonfield Seam	0.005 – 0.1	0.0005 – 0.01	0.0005 – 0.02	0.00005 – 0.002

Intermediate seams such as the Sandgate have not been tested, but given the nature of the coal, are likely to have similar hydraulic properties to the Donaldson Seam.

Direct testing data are not generally available for specific storage (Ss- also referred to as elastic storage) of coal seams or interburden. However, good estimates can be made based on Young's Modulus and porosity. For coal, Ss generally lies in the range 5×10^{-6} to $5\times10^{-5}m^{-1}$, and interburden is generally slightly higher than this, due to the greater porosity (Mackie, 2009).

Faults and dykes in the area are not thought to be transmissive and are likely to represent a minor barrier to groundwater flow in most cases. The 'basic' igneous nature of the dykes means that they will tend to weather to impermeable clays, and the faults are relatively small, normal features that include a number of sealing clay layers. Larger, continuous dykes and faults are only present within the southern and eastern parts of the model area for the Project, which are located away from the environmental receptors and proposed mine development areas.

The Krecji Fault, previously mentioned in Section 4.6.3, is a mapped fault structure within shallow stratigraphy which has disturbed the Donaldson Coal Seams and overlying strata to the east of the Abel Underground Mine. Coal excavation near this zone has indicated that the structure does transmit groundwater and this has resulted in higher than expected groundwater inflows into the Abel Underground Mine during late 2011 and early 2012. Although elevated inflows are anticipated to be short term due to the limited storage available within the fault zone structures, absolute inflows to the Abel Underground Mine were not used as a calibration measure. No hydraulic testing of the fault zone area has been undertaken however observed inflows suggest that higher hydraulic conductivity than host parameter values are evident.

However, as well as possibly being a local source of higher groundwater inflows, the lack of drawdown response east of the Krecji Fault from early mining at the Abel Underground Mine suggests that the fault is also acting as a regional barrier to groundwater flow, possibly preventing groundwater impacts from extending east of the fault to areas beneath the Hexham Swamp/Hunter River wetland areas. As a conservative measure, the fault was not represented in the model as a barrier boundary structure, but hydraulic continuity was assumed across the fault to the east.

5.3 Subsidence Fracturing

There are a number of physical hydrogeological effects that are expected to occur during the Project. These effects, including the changes to the hydraulic nature of overburden material caused by the caving and subsidence above panels, need to be represented using specific modelling approaches.

The impact of mining on the permeability of caved overburden has been based on in-field monitoring and groundwater modelling experience, combined with research available for subsidence impacts on hydraulic properties. The *Aquifer Inflow Prediction above Longwall Panels* report to the Australian Coal Association Research Programme (ACARP) (SCT Operations Pty Ltd, 2008) contains assessments of the impact of longwall mining on overlying rock mass permeability, based on the depth of overburden above the mined seam and the degree of subsidence associated with the longwall panel. This report includes more generalised assessments based on worldwide empirical experience.

5.3.1 Subsidence-Induced Permeability Changes

The modelling contained within the ACARP report, as well as the transient calibration for this study, indicate that four 'zones' of subsidence permeability change may develop above the mined coal seam:

- A high permeability, caved zone where there is direct connectivity with the mined goaf, and vertical permeability has been assumed in this report to have increased to 10m/d;
- Above this, a zone of 'tortuous cracking'. Within this zone enhanced permeability occurs due to discrete vertical fractures that connect with horizontal layer separation features, allowing water to travel between and along layer boundaries. The tortuous flow paths that are created along bed layers and down fractures result in a zone where the overall permeability is lower than the caved zone below;
- Possibly, if the cover depth is great enough, there may be a 'barrier zone' above this, with no significant change to the in-situ permeability; and
- A near-surface zone, where surface fracturing extends for a limited distance downwards and with shallow enhanced vertical hydraulic conductivity.

5.3.2 Subsidence Control Zones

The panels will typically have final mined widths of approximately 203m to 366m, with cover depths ranging between 50m and 240m. Where appropriate, the Project will employ Subsidence Control Zones (SCZs) to control height of fracturing in sensitive areas to manage subsidence effects in the vicinity of sensitive surface features (Figure 5.2). Within the SCZ, pillars will be 'stripped' or reduced in width along four sides on retreat, leaving square remnant pillars. The SCZ may involve either partial pillar extraction, or limiting extraction to first workings (i.e. no secondary extraction) in some areas. A similar approach has been undertaken successfully to date for the current Tasman Underground Mine in the Fassifern Seam.

Five SCZs have been applied to the proposed mine workings layout to meet the proposed performance measures (DGS, 2012). These have been simplified for groundwater modelling purposes as follows:

- Level 1 - No constraints on development;
- Level 2 - Partial Pillar Extraction with mine subsidence from second workings limited to less than 300mm; and
- Level 3 - First Workings only with mine subsidence from workings limited to less than 20mm.

5.3.3 Fracture Zone Implementation in the Model

The layer definition within the model has allowed most mined coal seams to be represented individually. In underground mining areas, this allows the overburden to be subdivided into multiple layers and therefore allows subsidence caving and fracturing effects to be simulated to various heights above each seam that is mined, so that the impact of progressive caving and fracturing associated with the mining is adequately represented.

The fractured zone was simulated with horizontal hydraulic conductivity enhanced by a factor of two, and with vertical hydraulic conductivity enhanced according to a log-linear monotonic (ramp) function. The function varied the vertical hydraulic conductivity field within the deformation zone overlying coal extraction areas and "weighted" the permeability changes based on layer thickness. Limits for the variability were governed by predicted fracture height and predetermined upper and lower bounds of hydraulic conductivity.

Implementation of the SCZs was constrained using a maximum of 80m height of fracturing within Level 1 areas where there was no restriction on subsidence. A limit of 40m maximum height of fracturing was applied to Level 2 areas where partial extraction is planned. And no fracturing was applied above Level 3 areas designated as first workings only.

A ramp function was employed to designate increased vertical hydraulic conductivities. Separate ramp functions were also found necessary in areas of variable cover depth.

Permeability of the model layer directly beneath underground mined areas was also increased, with a uniform increase in vertical hydraulic conductivity to three times the *in situ* parameters being applied.

5.4 Existing Mine Workings

Figure 5.3 presents the existing and abandoned mining areas that occur within the Model Area for the Project. Extensive abandoned mine workings are known to occur within the West Borehole Seam adjacent to the Project (former Stockrington mine).

Additionally, active mining is occurring within the West Borehole Seam at the West Wallsend colliery in the southern part of the model area. The degree of connectivity between the active West Wallsend Colliery and the older mine workings is currently unknown. However, the available evidence indicates that there is extensive depressurisation of the West Borehole Seam due to past mining. Evidence from a single bore at the existing Tasman Underground Mine which intersects the West Borehole Seam indicates that the water level within the Stockrington workings close to the Project area is -67.5mAHD. This directly underlies current extraction in the Fassifern Seam at the existing Tasman Underground Mine.

The low groundwater levels measured reflect the relatively low groundwater levels encountered in B005 within the Project area, which show much lower water levels in the West Borehole Seam compared with the overlying Fassifern Seam (more than 40m difference). The model calibration process also indicated that the size of this head differential could not be entirely explained by the low vertical connectivity between the seams, and must partly result from mining-related depressurisation of the West Borehole Seam. It has been assumed that there is a high level of connectivity within the individual remnants of old workings leading to a relatively flat water table within the existing voids.

A water level of -67.5mAHD indicates that hydrogeologically, the dewatered voids associated with the abandoned Stockrington mine provide a significant groundwater sink in a regional context. While this level can only be considered as pseudo-steady state, the workings have been abandoned for some time and this level is significantly lower than the western (Wallis Creek) and eastern (Hunter River) boundary conditions which have been evoked in the model. The Old Stockrington Colliery consists of first workings bord and pillar extraction panels. Mining was completed in the early 1980s, though the workings directly below the Tasman Underground Mine lease are probably much older than this.

Existing mine workings in the Fassifern Seam (at the Tasman Underground Mine), the Donaldson Seams (at the Abel Underground Mine and Donaldson Open Cut Mine) and shallower seams (at the Donaldson Open Cut Mine and Bloomfield Colliery) have all been included in the model using the most recent reported proposed mine schedules. The limited former mining of the Great Northern Seam above the existing Tasman Underground Mine has not been included in the model.

5.5 Receptors and Potential Impact Assessment Targets

In order to ensure that this model can be used for robust groundwater impact assessments, all potentially significant surface water receptors were considered as part of this study, along with the potential mechanisms for surface/groundwater interaction. All permanent water bodies and ephemeral streams of third order or greater magnitude are shown on Figure 4.14.

5.5.1 Permanent Water Bodies

In terms of licensing and potential environmental impacts, permanent water bodies generally form the most sensitive environmental receptors to any changes in the groundwater regime. A summary of the nature and hydrogeological significance of each of the permanent water bodies in the study area is provided in Table 5.2.

Table 5.2: Summary of Permanent Water Bodies in the Study Area

Name of Water Body	Description and Nature of Surface/Groundwater Interaction
Hexham Swamp & Pambalong Nature Reserve	Both of these water bodies are primarily surface water fed, although they both sit within alluvial layers. Hexham Swamp exists due to the low lying nature of the terrain and the presence of the barrage near the Hunter River, which causes water to back up and fill ditches, etc. within the swamp (it was tidal before the introduction of the barrage). Pambalong Nature Reserve exists within a naturally low lying area to the west of Hexham Swamp, and water levels appear to have been increased by the presence of a high invert level in the drainage culvert beneath the F3. This causes water flowing down from Blue Gum Creek to back up and support the large pools within the nature reserve area. The close correlation between groundwater levels in the alluvium around the wetlands of Pambalong Nature Reserve and the swamp water levels indicate that the alluvium and the swamp are in good hydraulic connection. There is believed to be relatively free interchange of water between the alluvium and the surface water bodies, with some discharge from the alluvium to the surface during drier periods, and flows from the swamps to the alluvium during wetter periods (PDA, 2006).
Wallis Creek	This creek is associated with reasonably significant alluvial deposits, and these shallow alluvial aquifers are likely to be in hydraulic continuity with the creek.
Lake Macquarie	This is a saline environment that is directly connected to the Tasman Sea. Levels in the lake are not significantly affected by groundwater.
Cockle Creek	This is directly connected to Lake Macquarie, and as such will be tidally dominated in its lower reaches. Significant alluvium is present in the middle reaches, and it is likely there is some baseflow connection between the creek and its alluvium.
Hunter River	The Hunter River is tidal and saline dominated within the Model Area. Although groundwater and alluvium may influence water quality to a certain extent, levels outside of flood periods are essentially dominated by the sea and tidal ranges.

6. MINING PROPOSAL

6.1 Mining Schedule

The proposed mining schedule for development and the extraction of the panels within the West Borehole Seam is shown in Figure 6.1, in addition to the most recently reported mining schedules within the existing Abel and Tasman Underground Mines and West Wallsend Colliery. Bloomfield Colliery has been historically operating for some time, commencing well before the calibration period undertaken during the modelling study. The mine was incorporated into the steady state condition, with limited dynamic mine schedule changes evoked during predictive modelling.

The panels would be extracted initially at the same time as continuing operations at the Tasman Underground Mine within the Fassifern Seam, which will be completed by the end of 2014. A summary of the schedule that has been used for the Project, the existing Tasman Underground Mine, Abel Underground Mine and the West Wallsend Colliery within the numerical groundwater model (see Section 7) is provided in Table 6.1.

In order to investigate the incremental effects of mining as proposed in the Project, operational mining impacts and residual impacts following post mining recovery have been assessed.

6.2 Model Implementation

The underground mining and dewatering activity is defined in the model using drain cells within the mined coal seams, with modelled drain elevations set to 0.1m above the base of the West Borehole Seam (Layer 7). These drain cells were applied wherever workings occur, and were progressed through annual increments in a transient model set-up.

The model set-up involved changing the parameters with time in the goaf and overlying fractured zones directly after mining of each panel, whilst simultaneously activating drain cells along all development headings. Drain cells in the development headings were activated in advance of the panel extraction and subsequent subsidence. Although the coal seam void should be dominated by the drain mechanism, the horizontal and vertical permeabilities were raised to 10m/d to simulate the highly disturbed nature within the caved zone.

Table 6.1: Underground Mine Schedules Used for the Impact Assessment

Period	Stress Period	Length (days)	From	To	Tasman Extension West Borehole Underground		Tasman Underground		Abel Underground		West Wallsend Underground	
					Panels / Development Heading	Drain (model reach number)	Panels / Development Heading	Drain (model reach number)	Panels / Development Heading	Drain	Longwall Panels (model reach number)	Drain (model reach number)
CALIBRATION	SS	-	-	31/12/2005							<14	60
	1	180	1/01/2006	30/06/2006							14-34	62
	2	183	1/07/2006	31/12/2006								
	3	180	1/01/2007	30/06/2007			Mains Development	50			34-36	63
	4	183	1/07/2007	31/12/2007			Mains Development	50				
	5	181	1/01/2008	30/06/2008			Panel 1	50	N – S Mains Development	133	35-37	65
	6	183	1/07/2008	31/12/2008			Panel 2 & 3	50	N – S Mains Development	157		
	7	180	1/01/2009	30/06/2009			Panel 4 & 5	50	N – S Mains Development	134	37-38	67
	8	183	1/07/2009	31/12/2009			Panel 6 & 7	50	E – W Mains Development	158		
	9	180	1/01/2010	30/06/2010			Panel 8 & 9	50	Panel 1	135	38, 70	69
	10	183	1/07/2010	31/12/2010			Panel 10, 11 & 12	50	Panel 2 & 3	159		
PREDICTIVE MODELLING	11	365	1/01/2011	31/12/2011			Panel 13 & 14	50	Panel 4, 5 & 6	136	39-40	71
	12	366	1/01/2012	31/12/2012			Panel 15 & 16	50	Panel 7 & 8	160		
	13	365	1/01/2013	31/12/2013	N- S Mains Development	89	Panel 18	50	Panel 9	137,140	40, 72	73
	14	365	1/01/2014	31/12/2014		90	Retreat	50		141	41-42	74
	15	365	1/01/2015	31/12/2015		91				145	42-43	76

Period	Stress Period	Length (days)	From	To	Tasman Extension West Borehole Underground		Tasman Underground		Abel Underground		West Wallsend Underground	
					Panels / Development Heading	Drain (model reach number)	Panels / Development Heading	Drain (model reach number)	Panels / Development Heading	Drain	Longwall Panels (model reach number)	Drain (model reach number)
	16	366	1/01/2016	31/12/2016		92				144	43-45	78
	17	365	1/01/2017	31/12/2017		93				138	44-46	80
	18	365	1/01/2018	31/12/2018		94				139,142	46-47	82
	19	365	1/01/2019	31/12/2019		95				143,147	47-48	84
	20	366	1/01/2020	31/12/2020		96				146	48-50, 87	86
	21	365	1/01/2021	31/12/2021		97				148	49-50	88
	22	365	1/01/2022	31/12/2022		98						
	23	365	1/01/2023	31/12/2023		99				151		
	24	366	1/01/2024	31/12/2024		100				149		
	25	365	1/01/2025	31/12/2025		101				152		
	26	365	1/01/2026	31/12/2026		102				150		
	27	365	1/01/2027	31/12/2027		103				153,154		
	28	366	1/01/2028	31/12/2028		104				155		
	29	365	1/01/2029	31/12/2029						156		
	30	365	1/01/2030	31/12/2030								
	31	365	1/01/2031	31/12/2031								

7. GROUNDWATER SIMULATION MODELLING

7.1 Objective

The overall objective of the modelling was to develop and calibrate a numerical groundwater model to predict potential impacts of underground mining and mine development on the groundwater system and potential environmental receptors. To enable this, a regional model has been constructed that can examine synergistic impacts from open cut and underground operations across the area. The model was subjected to transient calibration against the observed impacts of recent mining in the model area. It was also designed to address the issues highlighted by the independent reviewer (Kalf & Associates, 2006) engaged by the NSW Department of Planning at the time of submission of the Abel Underground Mine EA. In summary these were:

- The vertical hydraulic conductivity of the alluvium (Layer 1) was excessively low. This had been implemented for valid modelling reasons; caused by model simplicity and the minimal number of layers involved;
- There were concerns over the use of arbitrary General Head Boundaries relatively close to the eastern-most extent of the mining area; and
- There was no transient calibration of the model.

As well as these regulatory requirements, the model has been constructed with the capability to carry out mining simulation to enable the reliable prediction of groundwater inflow rates to the mine. These inflow rates inform the water balances involved in potential mine development scenarios across multiple seams and multiple areas.

7.2 Model Selection

The MODFLOW numerical groundwater flow modelling package has been used for this study with the SURFACT Version 3 module (HydroGeoLogic, Inc., 2006), operating under the Groundwater Vistas Version 5 graphic interface software package (Environmental Simulations, Inc., 2005).

The MODFLOW package has industry-leading modules for simulating surface water and groundwater interaction which enable assessment of impacts on creeks and rivers. The SURFACT module enables simulation of both saturated and unsaturated flow conditions and provides for more stable drying and re-wetting of cells in thin model layers (especially the as coal seams).

The hydrogeological investigations (including modelling) were undertaken with reference to the *Guidelines for Management of Stream/Aquifer Systems in Coal Mining Developments – Hunter Region* (DIPNR, 2005); with the model developed in accordance with the best practice guideline on groundwater flow modelling (MDBC, 2001). The degree of model complexity required to accomplish the study objectives is a medium complexity model (MDBC, 2001).

7.3 Summary of Previous Models

The current groundwater model encompasses a much greater extent than has previously been considered for any of Donaldson Coal's individual projects, including the Donaldson Regional Groundwater Model. As discussed in Section 3.1, a number of models have been constructed within this region during the course of earlier hydrogeological studies. Much of the data used to inform the development of the Project model is based on these previous models. A summary of the extent and use of these earlier models is provided below.

7.3.1 Tasman Underground Mine Model

The model for the existing Tasman Underground Mine was developed to enable a simple, two layer assessment of the impacts of mining from the Fassifern Seam, carried out as part of the mine's water management study (PDA, 2002). Data on structure and seam hydrogeology for the Fassifern Seam in the upper parts of the Sugarloaf Range were obtained from the report and modelling assessment, and are reflected where appropriate within this assessment.

7.3.2 Abel Underground Mine and Bloomfield Colliery Models

Two previous models have been produced for the northern part of the model assessment area; the Abel Underground Mine model and the Bloomfield Colliery model.

The Abel Underground Mine model (PDA, 2006) was produced as part of the 2006 assessment for the Abel Underground Mine EA. The model domain was included within the boundaries of the current modelling assessment, but only included coal seams down to the lower Donaldson. It therefore used the northern sub-crop of the Donaldson Seam as a model boundary. The southern extent was also limited to approximately 2km south of the Abel Underground Mine workings. The overburden coal measures were significantly simplified in that there were only three layers between the Donaldson Seam and the weathered overburden, and there was no basal layer beneath the Donaldson Seam.

The model that was produced for the Bloomfield Colliery (Aquaterra, 2008) extended to the lower seams (including the Ashtonfield Seam and a basal layer), and included the associated areas to the north of the Abel Underground Mine model (i.e. north of the Donaldson Seam outcrop). As the modelling was carried out for an assessment of an open cut mine, it contained a considerable simplification of the overburden above the Donaldson Seam, effectively grouping it into just three layers.

Both of these models were used to inform the Donaldson Regional Groundwater Model as part of a regional modelling project. They provided some of the seam geometry for the key coal seams (although generally only related to thickness, as updated resource models were made available for this Project). The hydraulic testing, and associated data on hydraulic properties contained within those models were used as the basis for the hydraulic properties within the Donaldson Regional Groundwater Model.

The Project model can be considered the next evolutionary step in the development of groundwater models in the region, being informed by the models and studies preceding it. The model extent is slightly larger than that of the Donaldson Regional Groundwater Model (the most recent groundwater model undertaken in the region). The model's geological layering and hydrogeological processes are derived from the regional model, with some modification within the Project area incorporating recently obtained geological data.

7.4 Model Domain, Boundaries and Grid

The current Project model domain and boundaries were selected to satisfy the regulatory and operational constraints discussed in Section 1.2. An overview of the model domain and model boundaries is provided in Figure 7.1. The extents of previous models are also shown for comparison.

The model contains in excess of 1,400,000 active cells over 20 layers. The surface area of Layer 1 extends over 550km^2. A cross-section of the model is provided in Figure 7.2, while the recharge zonation enacted within the model is provided in Figure 7.3. The zones of recharge were defined using the regional geology map. The lateral extent of the different geologies at surface within the model domain was used in conjunction with their published recharge values to assign recharge zones.

A cell size of 100m by 100m was used globally across most of the model domain. Grid spacing was further refined in the immediate Project area to a cell size of 50 by 50m. While the potential impacts from the mining activities relate to regional scale effects, and experience has shown that discretisation of mine plans beyond the global scale discretisation has no significant impact on predicted mine inflows or impacts for mines, the grid refinement allowed for improved detailing of the mine plan scheduling.

The following boundaries were set for the model domain:

- A no-flow boundary was chosen for the northern side of the model as all active layers sub-crop on the northern side of the model domain;
- The southern model boundary is some distance from any potential mining and is parallel to the believed main direction of groundwater flow, so it was also represented as a no flow boundary;

- The western boundary of the model is Wallis Creek. It is a permanent water course, and as such provides a suitable boundary on the western side of the model. It has been represented using river cells; and
- Careful consideration was given to the representation of the eastern boundary, which was set as a General Head Boundary (GHB) at Easting 379000 globally, while a Constant Head Boundary was set along the alignment of the Hunter River in Layer 1. Although the selected boundary is relatively close to the north-eastern extent of the Abel Underground Mine workings, and some concerns were raised by Kalf and Associates (2006) in relation to this during the review for the Abel Underground Mine development consent, it was considered that a GHB boundary was still the best option for the eastern boundary. Justification for the use of a GHB includes the following:
  - There is no information on strata geometry beyond this point. The geological map (Hawley and Brunton, 1995) shows that this area is entirely overlain by alluvium and there is therefore no information about sub-crops of the Permian strata. This, combined with the fact that there is a syncline marked to the immediate east of the model boundary, means that there is considerable uncertainty over the geometry of the strata layers in that area. Attempting to represent this through the use of an extended model domain, with associated recharge and no-flow boundaries would introduce greater levels of uncertainty into the model. If this boundary condition set up was implemented, then the volume of water entering the model would largely depend on assumptions about sub-cropping of strata layers beneath the alluvium. Extending the model would therefore not improve the certainty of predictions, and would make it more difficult to quantify model uncertainty in this area;
  - The model produced for the Abel Underground Mine EA (PDA, 2006) indicated that the Abel Underground Mine will only cause groundwater levels near this boundary to reduce to around 0mAHD. It was therefore anticipated that there would be very little inflow or outflow across the boundary as a result of mining stresses, and this has been confirmed by the impact assessment runs described in Section 7.8. As transient conditions do not result in large head gradients near the boundary, the GHB will provide a good representation of the outflow (initially) and inflow (following mining development) that will occur in the regional flow patterns – provided conductance values that are suitably representative of the rock mass transmissivity are calculated and used. The GHB boundary was therefore only really significant during steady state model calibration, as it effectively controlled the steady state groundwater levels at this boundary. However the likely sub-cropping of the Permian layers beneath the Hunter River mean that the nearest Permian recharge boundary is effectively set at just over 0mAHD, so the presence of the GHB and the head elevation used should be a good representation of long-term dynamic reality in this area;
  - The model domain incorporates all of the potentially sensitive receptors, including Pambalong Reserve and Hexham Swamp. All significant, non-tidal creeks and rivers that may be affected by mining activities were fully contained within the model domain. As shown in Figure 4.14, the majority of the registered bores within the region lie to the north and east, outside of the model boundary. A number of these on the eastern side are buffered by the Hunter River, and therefore outside the zone of influence from mining activities; and
  - The eastern GHB was set with a head level of 2m, and the conductance value (C) was calculated based on the equation C=KA/L, where K = hydraulic conductivity, A = face area of the cell, and L = horizontal distance between cell centres. This equation ensured that the amount of water entering the cell at the boundary was the same as the amount of water that would pass through the cell, given Darcian flow (Q=AKi) between cells in an extended model. This resulted in a conductance of 0.25m^2/d for most layers. The Basal layer (Layer 18) was given a higher conductance due to its much greater thickness, with values of between 2 and 6m^2/d.

7.5 Model Layers and Geometry

Based on the conceptual hydrogeology described in Section 5, the following model layers were defined for the Project model:

- Layer 1: Alluvium and Regolith. Across the model domain, the alluvium and regolith was uniformly set at 20m;
- Layer 2: Overburden and coal seams above Fassifern Seam. This layer extends from the base of the Layer 1 regolith down to the Fassifern Seam in areas inside of the Fassifern outcrop. Elsewhere it was set as a 'dummy layer' (see below). The representation of this layer was probably the greatest simplification in the model, as Layer 2 actually covers bands of Narrabeen Group sandstones, as well as Coal Measures siltstones, coal and claystones. This was considered to be a justifiable simplification, as the geological strata being represented by Layer 2 only occurs high up on the Sugarloaf Range. There are no environmental receptors within this area, and the only influence on mine inflows is for the Tasman Underground Mine in the Fassifern Seam. However, it meant that the calibration targets for Layer 2 had to be treated with caution;
- Layer 3: Fassifern Seam. Geometry was calculated based on the sub-crop pattern with a slightly basinal structure. Layer thickness was set at a constant 6m;
- Layers 4-6: Fassifern – West Borehole interburden. The interburden between these seams was split into three layers in order to allow for modelling of potential changes to hydraulic properties if high subsidence impact mining (e.g. secondary extraction or longwall mining) is carried out within the West Borehole Seam;
- Layer 7: West Borehole Seam. The seam geometry was based on the updated resource model provided by Ellemby Resources. Some extension to the southern model boundary was required, and the edges of the geometry had to be modified to ensure that they reconciled with known sub-crop geometry. The seam thickness was taken from the previous Abel Underground Mine model;
- Layer 8: West Borehole – Sandgate interburden. This includes minor coal seams, as described previously. As there is only 50m between the Sandgate and West Borehole seams, the interburden was represented as a single layer in the model;
- Layer 9: Sandgate Seam. The geometry of this seam is not currently as well defined as the other coal seams, so based on investigation borehole records, it was set at a constant level of approximately 50m below the West Borehole Seam (except near sub-crop, where it was limited to one-third the distance between the West Borehole and Donaldson seams). Layer thickness was estimated at 7m, based on borehole records;
- Layer 10-12: Sandgate – Donaldson interburden. This interburden was split into three layers, for the same reasons as described for Layers 4 to 6 above;
- Layer 13: Upper Donaldson Seam. As with the West Borehole Seam, this was defined using the updated resource model. Definition near the western sub-crop was also relatively uncertain, so the geometry was modified according to the known, published sub-crops. Seam thickness was based on the Abel Underground Mine model;
- Layer 14: Upper Donaldson - Lower Donaldson interburden. Thickness of this layer was defined from the resource model details for the Upper and Lower Donaldson Seams. The interburden thickness increases to the south;
- Layer 15: Lower Donaldson Seam. As with the Upper Donaldson Seam, this was defined using the updated resource model. It has the same definition uncertainty near the western subcrop line;
- Layer 16: Donaldson – Big Ben interburden. This interburden unit is relatively thin, but does correspond to the Thornton claystone, so represents a very low permeability unit;
- Layer 17: Big Ben Seam. This is fairly consistent at approximately 5m below the base of the Donaldson Seams, with a 7m thickness;

- Layer 18: Big Ben – Ashtonfield interburden. Given the limited thickness of this layer, it is unlikely that this will need to be separated into additional layers to allow for the impacts of mining from the Ashtonfield Seam, so it was represented as a single layer;
- Layer 19: Ashtonfield Seam. The general geometry and seam thickness for this layer was taken from the Bloomfield Colliery model, extended to the south as a constant depth beneath the Donaldson Seam; and
- Layer 20: Basal Layer. This was set with a minimum thickness of 200m at the base of the model.

An example cross-section of the model layers within the MODFLOW-SURFACT model is shown in Figure 7.2.

It should be noted that all layers are present across the entire active model area, and each layer (apart from Layer 1) represents a single hydrogeological unit. Where a hydrogeological unit is absent, then to maintain continuity in the model, the layer representing that unit in the model has been extended across the remaining model domain as a 0.5m thick 'dummy' layer, which has the same properties as the highest underlying 'active' layer that exists in that area. For example, in the north of the model, north of their subcrop lines, all of the layers except the basement (Layer 18) are absent. The model therefore contains an 'actual' Layer 1 Regolith, underlain by a 0.5m 'dummy' layer for each of Layers 2 to 17, with Basal Layer hydraulic properties assigned to ensure that in the model they behave as if they were part of the basement.

The use of dummy layers has allowed the impacts predicted by the model to be examined separately for each hydrogeological unit across the full model area.

7.6 Model Calibration

7.6.1 Calibration Approach

Model calibration involves comparing predicted (modelled) and observed data and making modifications to model input parameters where required (within reasonable limits defined by available data and sound hydrogeological judgment) to achieve the best possible match.

Model calibration performance is demonstrated in both quantitative (value matching) and qualitative (pattern-matching) terms, by:

- Contour plans of modelled head, with posted spot heights of measured head;
- Hydrographs of modelled versus observed bore water levels;
- Baseflow comparisons;
- Water balance comparisons; and
- Scatter plots of modelled versus measured head, and the associated statistical measure of the scaled root mean square (SRMS) value.

The SRMS value is the Root Mean Square (RMS) error term divided by the range of heads across the site and it forms a quantitative performance indicator. Given uncertainties in the overall water balance volumes (e.g. it is difficult to directly measure evaporation and baseflow into the creeks), it is considered that a 10% SRMS value is an appropriate target for this study, with an ideal target for long-term model refinement recommended as 5% or lower. This approach is consistent with the Australian best practice groundwater modelling guidelines (MDBC, 2001).

Calibration can be carried out as either steady state (i.e. calibration to assumed long-term equilibrium conditions) or transient (i.e. calibration to the impacts of time-dependent stresses such as pumping/dewatering and/or climatic variation).

Initial calibration was undertaken for steady state conditions, whereby the model was used to compare assumed long-term average groundwater levels with model-predicted groundwater levels prior to the transient calibration period (2006 – 2010).

Steady state calibration was followed by transient or "history match" calibration using the steady state calibration to set initial conditions. The transient calibration period included open cut and underground mining at Donaldson Open Cut Mine, Abel and Tasman Underground Mines and Bloomfield Colliery.

Transient calibration was to a degree restricted by the number of monitoring locations within the Permian units. Attention was focussed on achieving a level of inter-connection between underground mining areas to match the assessed drawdown response seen. Variable fracture zone parameters using a "ramp function" as described in Section 5.3.3 were applied to Permian interburden/overburden to achieve this response.

7.6.2 Calibration Targets

In order to judge how well the model fits the actual groundwater system, calibration targets are used. For example, groundwater flow models calculate the groundwater level at many locations. When the groundwater level is measured in a monitoring bore at some or all of these locations, then a comparison can be made. A calibration target is a point in the aquifer where a measurement of water level has been made. Calibration targets may be either steady-state or transient. In this case, transient calibration targets have been used. The model compares target values (i.e. observed water levels over time) against model results, and interpolates results in both space and time to compute an error or residual. Calibration targets can also be developed for inflow of groundwater to underground workings.

A total of 45 groundwater monitoring locations, including standpipes and multilevel vibrating wire piezometers with 84 monitored horizons (Appendix D), provided a total of 2,932 transient water level targets which were included in the calibration.

The calibration targets are distributed throughout the model layers. Transient groundwater levels were taken from all records at each borehole where data was available. A full list of the calibration targets, including the layers monitored and, is included in Appendix D. The drain cell set up used for the transient calibration is shown in Appendix E. A comparison of actual versus modelled groundwater levels is included in Appendix F.

Groundwater inflows to active mining areas provide a valuable calibration measure and are critical for achieving a robust calibration. Data for mine inflows is recorded at Abel Underground Mine; however this is not reliable for calibration due to the occurrence of short term elevated inflows as a result of localised high conductive zones intercepted on the eastern boundary of the Abel Underground Mine. Calibration refinement utilising mine inflow data will be necessary during subsequent modelling stages to ensure robust predictive results in future modelling tasks.

7.6.3 Steady State Calibration

Steady state (or baseline 'long-term') calibration was carried out as the first stage of the calibration process. The primary purpose of initial steady state calibration was to allow for the generation of an initial head distribution for all model layers and to check assumptions for the conceptual hydrogeological processes.

The steady state model has been calibrated to groundwater levels recorded as close as possible to the beginning of 2006, with the assumption that these represent long-term average groundwater levels. Estimated pre-mining water levels were included in the calibration data set for a number of bores installed after 2003. However, the pre-mining water levels in all bores have, to some extent, been influenced by the surrounding mining operations including both active and abandoned projects. With this in mind, the steady state model was principally used to provide a reasonable set of starting conditions for the transient calibration model.

Calibration was carried out against 71 targets, using a combination of auto-sensitivity analysis and manual modification of model zones and parameters. Steady state calibration results for the SRMS was good, at 5.4%.

7.6.4 Transient Calibration

Transient calibration against groundwater levels was carried out for the period 2006 to 2010 inclusive. The water level outputs in the targets from the steady state model in 2005 were used as the initial water level heads in the targets for the transient model. The transient model period (2006 to 2012), included the Donaldson and Bloomfield open cut mines, as well as the initial two and four years of development at Abel Underground Mine and Tasman Underground Mine respectively. All mines were represented using a conventional drain cell representation approach. The drain cell set up used for the transient calibration is shown in Appendix E. SRMS value for the six year calibration period is 4.7%.

Calibrated Hydraulic Properties

Table 7.1 summarises the calibrated hydraulic properties for the Project model. The hydraulic conductivity zonation set up used for the transient calibration is shown in Appendix G.

Table 7.1: Calibrated Hydraulic Properties

Layer	Zone	Formation and Area Represented	Kh (m/d)	Kv (m/d)	S (Sy)	Notes
1	1	Regolith	1.00E-01	1.00E-02	5.00E-02	
	2	Wallis Creek, Cockle Creek, Hexham Swamp (and Pambalong) Alluvium	5.00E+00	1.00E-02	1.00E-01	Kh consistent with Abel EA report, Kv increased as per comments detailed in Kalf Associates, 2006.
	20	other creeks	2.00E-01	1.00E-02	5.00E-02	
2	33	Overburden and coal seams above Fassifern Seam	1.00E-03	1.00E-03	2.00E-05	Deeper cover depth
	4		1.00E-03	1.00E-03	5.00E-05	Shallower cover depth
3	3	Fassifern Seam	1.00E-02	5.00E-03	1.00E-02	Deeper cover depth
	22		2.00E-02	5.00E-05	1.00E-02	Shallower cover depth
4	6	Fassifern - West Borehole interburden	1.70E-04	2.00E-05	2.00E-03	
5	6		1.70E-04	2.00E-05	2.00E-03	
6	8		1.00E-03	1.00E-04	5.00E-05	
7	16	West Borehole Seam	2.00E-02	1.00E-03	1.00E-03	Deeper cover depth
	23		1.00E-02	1.00E-03	1.00E-03	Shallower cover depth
	21	Old West Borehole mining area	1.00E+01	1.00E-03	1.00E-01	Older workings (predominantly bord and pillar)
	26		2.00E+00	1.00E-01	1.00E-01	More recent workings (old panels)
	27		2.00E+00	1.00E-05	1.00E-01	
8	5	West Borehole - Sandgate interburden	7.00E-03	5.00E-03	2.00E-03	Deeper cover depth
	24		1.00E-02	1.00E-03	2.00E-03	Shallower cover depth
9	32	Sandgate Seam	2.00E-03	5.00E-04	5.00E-03	Deeper cover depth
	9		1.00E-02	1.00E-03	5.00E-03	Shallower cover depth
10	10	Sandgate - Donaldson interburden	1.00E-04	1.00E-05	2.00E-03	Main area
11	11		3.00E-05	5.00E-07	2.00E-03	
12	40		3.00E-06	6.00E-07	2.00E-03	
	25		2.50E-04	1.00E-05	2.00E-03	Subcrop area only - based on higher recharge and Bloomfield model
13	7	Upper Donaldson Seam	2.00E-04	2.00E-05	1.00E-06	Deeper cover depth
	18		6.000E-02	6.00E-05	1.00E-06	Shallower cover depth

Layer	Zone	Formation and Area Represented	Kh (m/d)	Kv (m/d)	S (Sy)	Notes
14	7	Donaldson Seams interburden	2.00E-04	2.00E-05	1.00E-06	Deeper cover depth
	20		2.00E-01	1.00E-02	1.00E-06	Shallower cover depth
15	14	Lower Donaldson Seam	5.00E-02	5.00E-03	1.00E-06	Deeper cover depth
	20		2.00E-01	1.00E-02	1.00E-06	Shallower cover depth
16	29	Donaldson – Big Ben interburden	5.00E-05	1.00E-06	1.00E-06	Deeper cover depth
	14		2.00E-04	2.00E-05	1.00E-06	Shallower cover depth
17	28	Big Ben Seam	5.00E-04	3.00E-05	1.00E-06	Deeper cover depth
	12		5.00E-02	5.00E-03	1.00E-06	Shallower cover depth
18	28	Big Ben - Ashtonfield interburden	5.00E-05	1.00E-06	2.00E-05	Deeper cover depth
	12		5.00E-04	2.00E-04	2.00E-05	Shallower cover depth
19	36	Ashtonfield Seam	1.00E-04	6.00E-04	5.00E-05	Deeper cover depth
	17		5.00E-02	8.00E-03	5.00E-05	Shallower cover depth
20	13	Basement layer	1.00E-04	5.00E-05	2.00E-05	Deeper cover depth
	15		1.00E-04	5.00E-05	2.00E-05	Shallower cover depth

Calibration Statistics

The scatter diagram of measured versus modelled groundwater level targets is plotted in Figure 7.4, and it can be seen that the model is reasonably well balanced against the measured targets (i.e. there is no systematic under or over prediction). Scatter plots of modelled versus measured water levels for 84 monitored piezometers show reasonable agreement between observed and computed water levels across shallow and deep model layers, with an SRMS error of 4.7% (within the target range of 10%), and coefficient of determination of 1.03. The SRMS value (Table 7.2) is the RMS value divided by the range of heads across the site, and forms the main quantitative performance indicator. This result is consistent with the relevant groundwater modelling guideline (MDBC, 2001).

Table 7.2: Calibration Statistics

Calibration Statistic	Value
Number of Data Points	2906
RMS	13.1 m
Scaled RMS (SRMS)	4.7 %
Coefficient of Determination (CD)	1.03

Water Balance

There are multiple opportunities for groundwater to discharge from, and recharge to, the groundwater system/model. Those implemented in the model include:

- Baseflow to major streams (represented by the river cells in MODFLOW);
- Baseflow to minor streams (represented by the drain cells in MODFLOW);
- Outflow/inflow to the western margin boundary (represented by GHB in MODFLOW); and
- Mine inflows to active mining areas including Tasman and Abel Underground Mines.

The average water balance across the calibration period for the transient calibration model across the entire model area is summarised in Table 7.3. The total predicted inflow (recharge) to the aquifer system, in the modelled area, is approximately 18.6ML/d, comprising river leakage from Wallis Creek (approximately 44%), rainfall recharge (approximately 36%) and inflow from the head-dependent boundaries on the eastern margins (approximately 16%). The remainder is predominantly accounted for with changes in storage.

It is assumed that any water carried by ephemeral streams would have a negligible contribution to groundwater recharge through leakage.

Table 7.3: Simulated Water Balance at End of Transient Calibration

Water Source	Inflow (ML/d)	Outflow (ML/d)
Storage	0.75	0.02
Constant Head	2.98	0.34
Wells	0.00	0.00
Drains (Baseflow)	0.00	3.48
Recharge (Direct Rainfall)	6.69	0.00
Seepage Face	0.00	0.35
Et (Evapotranspiration)	0.00	12.32
River (Leakage/Baseflow)	8.19	2.11
Head Dependent Boundary (GHB)	0.01	0.02
Total	18.62	18.64
% Discrepancy	-0.09%	

Evapotranspiration and baseflows represent the major outflows to the model. Evapotranspiration accounts for about 66% of the water balance outflow. Baseflow to creeks, streams and rivers accounts for about 30% of the total discharge under transient conditions, with high elevation ground seepage, changes in storage and head dependent boundaries accounting for the remainder. The water balance residual of -0.09% is -9.0 x 10^{-3}ML/d. This is considered an adequate discrepancy, as the MDBC groundwater modelling guideline suggests a 1% limit or up to 2% for complex models.

Calibrated Water Levels Prior to the Project

Model-predicted groundwater levels prior to the proposed Tasman Extension Project are shown in Figures 7.5 to Figure 7.8. These figures show groundwater levels in the alluvium/regolith (Layer 1), the Fassifern Seam (Layer 3), the West Borehole Seam (Layer 7) and the Lower Donaldson Seam (Layer 15) at the end of the calibration period (2011). The presence of ‘dry cells’, particularly prevalent in Layer 1 where the relevant layers of strata are or becomes de-watered, is consistent with drilling which showed generally no or negligible groundwater in the surficial material in upland areas.

The regolith in Layer 1 is generally dry in elevated areas covering a large proportion of the model domain (Figure 7.5). Layer 1 is saturated in lower elevations, with groundwater occurring in the alluvium and adjacent colluvium on the slopes adjacent to Wallis Creek, the Hunter River and Hexham Swamp. Within the proposed mine site area the potentiometric groundwater levels dip to the north, underlying the Surveyors Creek catchment.

Within the Fassifern Seam Layers, mining activities from 2008 to present result in drawdown of up to 70m as shown in Figure 7.6 with drawdown focused on Panels 1 to 7 and development headings further west.

Water levels within the West Borehole Seam Layer 7 are shown on Figure 7.7 which illustrates that the potentiometric groundwater surface dips to the north-east and east, influenced by the low groundwater levels which exist within the Stockrington area as indicated within monitoring data presented in Section 4.6. The water table is seen to be flat within the abandoned workings to the east of the Project, and the West Borehole Seam becomes unsaturated near the Project entry. Drawdown within the West Borehole Seam on the southern boundary of the model is also shown, which is associated with mining at West Wallsend Colliery. The sub-crop of the Permian Coal measures to the west of the proposed Project and the abandoned workings of the former Stockrington Mine effectively compartmentalise the Project within the West Borehole Seam.

Water levels within the Lower Donaldson Seam (Layer 15) are shown in Figure 7.8 with potentiometric groundwater levels predominantly dipping to the east in the Project area. Drawdown is evident in the vicinity of the Bloomfield Colliery and Donaldson Open Cut Mine. Drawdown surrounding the Donaldson Open Cut Mine is overprinted with mining-related depressurisation from the Abel Underground Mine in Area 1 which has occurred since 2008

Match to Measured Groundwater Levels

Transient calibration hydrographs were produced for 84 piezometers, which includes groundwater levels in multiple seams from the alluvium right through to the Ashtonfield Seam. The calibration hydrographs are presented in Appendix F. Results were generally acceptable, particularly given the stresses placed on the model by the various mining activities, and the water level differential that occurred within the different model layers at the start of the transient modelling period.

Hydrographs listed below, and displayed in Appendix F, showed levels or responses that were not well reproduced in the model:

- Bore C078B is screened in shallow weathered Permian, and the modelled heads are levels approximately 18m lower than measured values. The bore is located near the north-west corner of Abel Underground Mine (Figure 3.1), just south of John Renshaw Drive;
- Bore C087 is located south of C078 (Figure 3.1), and is screened within the Sandgate-Donaldson Interburden. The measured water levels indicate a receding trend from mid-2006, potentially due to depressurisation as the bore is located within the Abel Underground Mine. The water level recession was not reproduced by the model;
- Bore B030D is located within the middle of the Project (Figure 3.1) and is screened within the Fassifern-West Borehole interburden. The modelled water levels are 15m higher than the measured levels and are not matching the observed downward trend;
- Within the upper layers (Fassifern-West Borehole interburden) of bore TA41, the modelled groundwater is exhibiting generally higher levels, as well as steeper recession gradients. The bore is located south of the Project, to the west of West Wallsend Colliery (Figure 3.1);
- Within the coal seams (Sandgate and Donaldson Seams) at bore B29, the modelled groundwater levels are not showing the recessive downward trend observed, potentially due to depressurisation of the neighbouring Tasman Underground Mine (Figure 3.1);
- Bore TA28 is screened within the Upper Donaldson Seam, with observed water levels of approximately 15m AHD prior to 2010. Early in 2010, groundwater levels lower sharply, receding to 10m AHD by the start of 2011. This drawdown is likely a response to mining at the Abel Underground Mine, but this impact is not predicted by the groundwater model;
- Deeper piezometers C223A, C223B and B002AA below the Sandgate Seam are showing declines not matched by the model predictions;
- Bore C063B, which is located to the east of the Abel Underground Mine adjacent to the F3 Freeway, does not respond to depressurisation stresses resulting from mining of Area 1 at the Abel Underground Mine (Figure 3.1). It has one vibrating wire piezometers placed in the Lower Donaldson Seam (C063A) and another in the Donaldson-Sandgate interburden. The lack of response suggests that the Krecji Fault may be acting as a major flow barrier, preventing depressurisation effects extending east of the fault; and
- Bore C138D, located south of the Bloomfield Colliery and assessed to be influenced by mining activities at Bloomfield Colliery, is not responding in the model as monitoring data would suggest. This is probably due to poor representation of the Bloomfield Colliery scheduling within the model. The bore was installed in late 2008. As indicated in Section 4.6.3, groundwater levels were initially recorded at approximately -10m to -15mAHD and have been falling steadily since. The groundwater model over-predicts groundwater levels in all layers monitored below the Donaldson Seam and is not able to reproduce the recession which has been observed. Future model development will aim to achieve better calibration to the dynamic mining stresses at Bloomfield Colliery by more accurate representation of the past and future Bloomfield Colliery mining progression.

Pressure Head Profiles

Steady state pressure head cross-sections have been completed, the locations of which are provided in Figure 7.9.

Figure 7.10 presents a north-south steady state cross-section at Easting 364850 (Column 133). Depressurisation within the West Borehole Seam is observed to occur, associated with the abandoned Stockrington workings and West Wallsend Colliery in the south of the Model Area.

Figure 7.11 presents an east-west steady state cross-section at Northing 6359025 (Row 192). Depressurisation within the West Borehole Seam is observed to occur, associated with the abandoned Stockrington workings in the south of the Model Area.

Baseflows

Model-predicted baseflow within Surveyors Creek and other watercourses within the Model Area are provided in Figure 7.12. This figure includes modelled baseflow from the calibration model run (up to the end of 2010), summarized in Table 7.4. Locations of the river and creeks listed in Table 7.4 are shown on Figure 4.14. Surveyors Creek reaches are shown on Figure 5.2.

Table 7.4: Average Modelled Baseflow during Calibration (2006 - 2010)

Surface Water Body	Modelled Baseflow (ML/day)[1]
Hunter River	5.5
Lower Wallis Creek	0.75
Blue Gum Creek, Four Mile Creek, Buttai Creek, Slatey Creek, Upper Wallis Creek, Cockle Creek, Minmi Creek, Viney Creek, Weakleys Flat Creek, Lower Surveyors Creek, Bangalow Creek.	0.0
Surveyors Creek	
S2(2) to S2(3); S2(1) to S2(2); upstream of S2C and upstream of S2D	0.0
Upstream of S2B	0.0044
S2(3) to S2B, S2C and S2D	0.0002
S2G	0.0004
S2(1) Cumulative	0.005

[1] Positive modelled baseflow represents flow from the surface water body to the groundwater.

Table 7.4 indicates that the Hunter River and Lower Wallis Creek are currently contributing leakage to the underlying alluvial groundwater system (as indicated in the water balance provided in Table 7.3). The remaining creeks within the Model Area are generally shown not to provide flow to the groundwater, nor do they appear to be obtaining significant baseflows from the groundwater system.

Within the footprint of the Project area, the upper sections of Surveyors Creek control the majority of drainage. The model indicates minimal baseflow within this system south of George Booth Drive.

Seepage face options were made active within the river cells which enabled water rejected from model layers at sub-crop areas to be captured within the river cell boundary conditions. A small proportion (2%) of outflow exited the model through this seepage. It has been assessed that the majority of this component would be assigned to evapotranspiration.

7.7 Sensitivity Analysis

Auto sensitivity analysis was carried out in order to examine the sensitivity of the overall model calibration to variations in Kh, Kv and recharge in each of the model zones. Summary graphs of the auto-sensitivity results for the final steady state model are provided in Figures 7.13 to 7.15.

The model was found to be most sensitive to the following parameters:

- Recharge to the exposed sub-crops in the elevated terrain;
- Horizontal hydraulic conductivity in the regolith, West Borehole Seam and West Borehole – Fassifern interburden; and
- Vertical hydraulic conductivity in the West Borehole – Fassifern interburden.

The sensitivity analysis for the steady state model showed that results are most significantly affected by assumptions made over recharge to the Triassic Narrabeen Group along elevated ridgeline areas (Zone 9) and elevated Permian sub-crop areas east of the main ridgeline (Zone 4).

In addition, horizontal hydraulic conductivity parameters for the *in situ* rock mass were found to be sensitive within the regolith (Zone 1) and historical Bloomfield Colliery workings (Zone 34) as the magnitude of the multiplier increased. To a lesser extent, horizontal hydraulic conductivity was also sensitive within the West Borehole Seam (Zone 23) and Donaldson Seam overburden in sub-crop areas north of the Donaldson Mine (Zone 8).

Overall, vertical hydraulic conductivity does not appear to be as sensitive as horizontal hydraulic conductivity. The main exception to this is the West Borehole – Fassifern interburden (Zone 6); which actually exhibits greater sensitivity than horizontal hydraulic conductivity, particularly as the magnitude of the multiplier increases.

The impact of changes to these parameters on the model predictions were subsequently examined by uncertainty analysis modelling, described in Section 7.9.

7.8 Prediction Modelling

7.8.1 Prediction Simulations

In order to assess the impacts that the Project could have on the hydrogeological environment, the calibrated MODFLOW-SURFACT groundwater model was used to simulate the operational and post mining recovery stages of the Project.

The assessment considers the impacts attributable to the Project on its own, as well as the potential cumulative impacts of the Project and the existing mining operations in the area, taking into consideration the known historical abandoned mining areas. To enable this, a Base Case modelling run was undertaken with the Project included (the 'with Tasman Extension Project' case) which represents potential cumulative impacts. The model was then run without again the Project (the 'without Tasman Extension' case), the results of which were subtracted from the impacts of the 'with Tasman Extension Project' case, to determine the incremental impact of the Project in isolation.

As described above for the calibration modelling, mining was simulated by means of drain cells in active mining areas in each mined coal seam, and hydraulic properties for subsidence affected zones above extraction panels altered accordingly.

The model simulation runs included a post-mining recovery period of 100 years.

7.8.2 Mine Inflows

Model predictions of total mine inflows to the Project underground workings during the course of the operational mining are shown in Figure 7.16.

This figure indicates that inflows begin within the first year of development with approximately 0.2ML/d inflow occurring at the end of 2014, which increases to a peak in 2024 at approximately 1.35ML/d. Inflows drop to less than 0.8ML/d from 2026 as mining of the final up-dip panels and retreat excavation of the East-West Mains occurs at the end of the mining schedule.

Predicted mine inflows to the existing Tasman Underground Mine are also provided in Figure 7.16. It shows that inflow rates between 0.1ML/d and 0.2ML/d are predicted to occur throughout the life of the Project and this is consistent with monitored rates at the mine.

7.8.3 Predicted Water Levels during Mining and Post-Mining Recovery

Model-predicted groundwater levels before and during mining operations are shown in Figures 7.17 to 7.26. They demonstrate the impact of the Project in isolation. All of these figures show groundwater levels in the relevant layer with the presence of the Project (after mining has commenced in 2013), as well as the presence of 'dry cells' where the relevant layers of strata have become de-watered. These figures provide the following details:

- Figures 7.17 and 7.18 respectively show water levels and drawdown due to the Project in isolation in the alluvium and regolith (Layer 1), at the start of underground mining (2013) and at the end of mining (2029);
- Figures 7.19 and 7.20 respectively show water levels and drawdown due to the Project in isolation present in the Fassifern Seam (Layer 3) in the same periods as above;
- Figures 7.21 and 7.22 respectively show water levels and drawdown due to the Project in isolation, in the West Borehole Seam overburden (Layer 4) above direct fracturing in the same periods as above;
- Figures 7.23 and 7.24 respectively show water levels and drawdown due to the Project in isolation in the West Borehole Seam overburden (Layer 5) in the same periods as above; and
- Figures 7.25 and 7.26 respectively show water levels and drawdown due to the Project in isolation in the West Borehole Seam (Layer 7) in the same periods as above.

A large proportion of the alluvium and regolith is unsaturated (dry), generally corresponding to areas of elevated terrain around the southern and eastern boundaries of the Project mine plan (Figure 7.17). Within the northern section of the Project area, the groundwater flows to the north-west, underlying the Surveyors Creek catchment. Post-mining drawdown of up to approximately 15m is observed in the northern section of the Project area (Figure 7.18), with drawdown receding to 5m within 1km of the Project.

Within the Fassifern Seam Layer 3, predicted groundwater levels (Figure 7.19) show high groundwater heads associated with areas of elevated terrain. In the area to the north-east of the Project area, groundwater levels are shown to rise between 2012 and 2028 due to completion of the Tasman Underground Mine in the Fassifern Seam in 2014.

Differences in groundwater levels before and after the Project can also be observed in the southern and eastern margins of the Project area. Figure 7.20 shows drawdown in the Model Area in the Fassifern Seam. Residual drawdowns east of the Project can be observed, and are associated with the existing Tasman Underground Mine. Drawdown of up to 20m occurs to the south of the Project area, as well as mid way down the North-South Mains.

Within the upper parts of the West Borehole Seam Overburden, which are above the height of expected subsidence fracturing, the highest groundwater levels occur to the south of the Project area both before and after the Project (Figure 7.21), again reflecting the elevated terrain. In general, groundwater flows outwards from this point in northerly and easterly directions. Under the existing Tasman Underground Mine, the groundwater gradient is smoother in 2028, sloping gently to the north-east.

Drawdown in the West Borehole Seam overburden above the predicted height of fracturing (Layer 4) is shown in Figure 7.22 which indicates that a maximum drawdown of 35m is predicted within the south-eastern quadrant. The area is limited in comparison to the underlying fractured overburden layer (refer to Figure 7.24). The SCZs restrict drawdown to 20m along the alignment of Surveyors Creek. Similar to above, residual drawdown results from the Project within southern and eastern parts of the model area, underlying cliff line areas.

Within the fractured overburden in Layer 5, the groundwater levels are again generally highest in the south. Figure 7.23 indicates that they exhibit a predominantly east-northeasterly gradient. Drawdown of up to 80m occurs in the south-eastern quadrant of the Project (Figure 7.24), with drawdown somewhat limited by the SCZs (although a drawdown of up to 40m is still seen in these areas). Within 2km to the north, east and south of the Project area, drawdown reduces to 5m.

Within the West Borehole Seam (Layer 7), Figure 7.25 indicates that groundwater levels are highest in the south. Prior to the Project, the groundwater gradient is quite smooth, heading in a north-east and then easterly direction across the area. Figure 7.26 shows that approximately 120m drawdown occurs in the south-eastern quadrant of the Project area, centred on the East-West Mains. The drawdown cone is relatively steep to the east, buffered to a degree by the abandoned workings to the east. A 5m drawdown contour extends approximately 2km to the north and south of the Project following completion of mining.

Further illustrations of drawdown impacts are provided in Figures 7.27 to 7.29 which show pressure head profiles along two north-south and one east-west cross-sections at locations shown on Figure 7.9.

Figure 7.27 presents a pressure cross-section for the start and end of mining at Easting 364850 (Column 133). Depressurisation within the West Borehole Seam is observed to occur, associated with the abandoned Stockrington workings and West Wallsend Colliery in the south of the Model Area. At the end of mining at the Project, pressures remain relatively static within the Stockrington area with some recovery observed in the West Wallsend area as mining operations there end in 2021.

Figure 7.28 presents a pressure cross section for the start and end of mining at Easting 362175 (Column 88), which crosses both West Wallsend Colliery and the Project. Similar to above, some recovery is observed at West Wallsend Colliery. At the Project, depressurisation occurs as water levels are drawn down to West Borehole Seam elevations during mining. Groundwater levels are maintained under higher cover depth below higher terrain, while pressures over Surveyors Creek are maintained nearer to sub-crop in the SCZ.

Figure 7.29 presents a pressure cross-section for the start and end of mining at Northing 6359025, which indicates that the impact of mining-related drawdown within the Project area is limited in extent to the west by sub-crop areas and elevated terrain, as well as pressures in shallow layers in areas occupied by the higher ridgelines. Contouring also suggests maintenance of shallow water levels within Surveyors Creek upstream of S2D (Figure 5.2).

7.8.4 Predicted Baseflow Changes

Model-predicted baseflow within Surveyors Creek and other watercourses within the Model Area are provided in Figure 7.12. This figure includes modelled baseflow from the prediction model runs (2012 to 2028), summarised in Table 7.5. The Surveyors Creek catchment is broken into sub-catchment areas within the Project area. Monitoring locations on Surveyors Creek are shown on Figure 5.2. Locations of other creeks are shown on Figure 4.14.

Table 7.5: Average Modelled Baseflow during Mine Life (2012 - 2028)

Surface water body	Modelled Baseflow at 2012 (ML/day)[1]	Modelled Baseflow at 2028 (ML/day)[1]
Hunter River	5.5	5.5
Lower Wallis Creek	0.75	0.75
Blue Gum Creek, Four Mile Creek, Buttai Creek, Slatey Creek, Upper Wallis Creek, Cockle Creek, Minmi Creek, Viney/Weakleys Flat Creeks, Lower Surveyors Creek, Bangalow Creek	0.0	0.0
Surveyors Creek		
S2(2) to S2(3); S2(1) to S2(2); upstream of S2C and upstream of S2D	0.0	0.0
Upstream of S2B	- 0.0043	0.0
S2(3) to S2B, S2C and S2D	- 0.00002	0.0
S2G	- 0.00004	0.0
S2(1) Cumulative	- 0.0049	0.0

[1] Positive modelled baseflow represents flow from the river/creek to the groundwater.

Figure 7.12 shows that baseflow into the entire Surveyors Creek catchment is negligible with the only apparent baseflow change during mining occurring upstream of S2(1) (Figure 5.2), predicted to reduce over the life of the mine from about 0.0049ML/day at present to approximately zero at the end of mining.

Figure 7.12 shows baseflows for all major watercourses within the model domain, which indicates that only Lower Wallis Creek and the Hunter River have any significant fluxes in terms of river stream leakage or aquifer discharge. All other drainages are essentially ephemeral and only flow under periods of sustained rainfall. There is no observed change in baseflow for any of these watercourses over the scheduled life of the mine.

7.9 Uncertainty Analysis

Uncertainty analysis is the process by which the impacts of variations in critical parameters (identified as being "sensitive" during the sensitivity analysis) on model predictions and model reliability is assessed.

The sensitivity analysis for the steady state model was presented in Section 7.7. In order to assess the impact from uncertainty of these parameters and to what extent these could impact on mine inflows, drawdown and baseflow, the model was run multiple times focussing on those parameters that were shown by sensitivity modelling to be the most sensitive parameters. The uncertainty model runs included (Figures 7.30 to 7.32):

- Uncertainty model runs 1 and 2, in which recharge to the elevated ridgeline area above the underground mine (Zone 9) was increased by a factor of 2 and 10 respectively;
- Uncertainty model runs 3 and 4, in which the vertical hydraulic conductivity of the West Borehole Seam overburden within the Project area (Zones 6 and 23) was increased by a factor of 2 and 10 respectively; and
- Uncertainty model runs 5 and 6, in which horizontal hydraulic conductivity of the West Borehole Seam within the Project area (Zones 23 and 6) was increased by a factor of 2 and 10 respectively.

Recharge has the most significant impact on Surveyors Creek baseflow and to combined baseflow to all creek systems. Parameter variation that caused the largest changes to simulated mine inflows and baseflow are provided in Figures 7.30 to 7.32, which show that:

- Predicted mine inflow rates are largely unaffected by the increase in recharge, and peak inflow rate increases by only around 0.1ML/d at the end of mining;
- An increase in horizontal permeability in the West Borehole Seam results in higher inflows occurring early in the mine life. However the peak inflow rate is only slightly higher than the base case at approximately 0.75ML/d, and elevated inflows at the end of mine life of approximately 0.6ML/d; and
- An increase in vertical hydraulic conductivity in Zone 6 within the West Borehole – Fassifern Interburden (Layer 4) results in the highest peak inflows at almost 1.5ML/d.

Results of the uncertainty analysis show that there is little predicted impact on mine inflows from uncertainty in the most sensitive model parameters.

It should be noted that there have been no uncertainty runs carried out on the hydraulic properties of the mine during the recovery phase, as the impacts during the mining phase were quite limited. In all cases, the horizontal and vertical conductivity values in the order of 10m/d for the caved material result in a very high degree of connectivity within the abandoned mine. This results in a relatively flat potentiometric groundwater surface within the mine workings and caved overburden. Increasing the permeability of the caved overburden would therefore have limited affect on the recovery.

8. POTENTIAL IMPACTS OF TASMAN EXTENSION PROJECT

This section contains a summary of the impacts on the hydrogeological environment from the Project, including a subsequent 100 year period of post-mining recovery.

The main effect of the underground mining upon the groundwater regime occurs due to changes in bulk rock mass permeability in the area immediately above the mine, caused by the fracturing associated with subsidence, and the subsequent pumping out of groundwater that enters the mine as a consequence. Details of these mechanisms, and the quantification of the effects on rock mass permeability, were provided in Section 5.3. This caving, and associated extraction of groundwater (mine dewatering), has a number of effects on the hydrogeological system during mine operations that have been evaluated as part of the impact assessment. These are summarised as follows:

- Inflow of water to the underground mine and the management of that mine water;
- Impacts on groundwater levels within the Permian hard rock strata during mine operation;
- Impacts on baseflow to Surveyors Creek during and after completion of mining;
- Impacts on existing users; and
- Impacts on GDEs.

Water accounting and licensing arrangements are discussed in Section 9.

8.1 Groundwater Level Impacts

Water level contours for the regolith, West Borehole Seam overburden and the West Borehole Seam during the Project have already been described in Section 7.8, and are shown graphically in Figures 7.17 to 7.26.

In general, the duration of mining and the degree of caving associated with extraction means that most of the strata above and including the West Borehole Seam within the Project area will become de-watered during mining. This will create a cone of depression down to -120mAHD in Permian Strata, however the low permeability of the in situ rock mass means that the cone will exhibit a steep gradient towards the workings, and the effects will diminish rapidly away from the area of mining.

8.1.1 Mining Phase

After separating out the impacts from other current and past mining in the vicinity, the predicted drawdown impacts due to the Project are generally quite localised, and in the Permian strata are limited to the West Borehole Seam, the Fassifern Seam and their overburden sediments. Drawdowns at the end of mining attributable to the Project are shown on Figure 7.18 (regolith – Layer 1), Figure 7.20 (Fassifern Seam – Layer 3), Figures 7.22 and 7.24 (West Borehole Seam overburden – Layers 4 and 5 respectively), and Figure 7.26 (West Borehole Seam – Layer 7). No drawdown is predicted to occur below the West Borehole Seam due to the Project.

The regolith layer is largely dry above the Project area at present prior to commencement of the Project, and the area of dry regolith is predicted to increase slightly through the Project. Figure 7.18 shows that there will be drawdowns of up to more than 5m in the areas that remain partially saturated, and up to 15m along the hillslope to the north-west of the mine.

The Fassifern Seam has been extensively dewatered prior to start of the Project, due to mining in the existing Tasman Underground Mine. Additional drawdown due to the Project is predicted, with drawdowns of up to 20m or more over areas immediately south and east of the Project are, as shown on Figure 7.20. This drawdown impact will be due to the effects of subsidence fracturing above the Project panels that will extend upwards into the Fassifern Seam.

More substantial drawdowns are predicted to occur from the Project in the West Borehole Seam overburden (Model layers 4 and 5 – see Figures 7.22 and 7.24), as a result of the subsidence fracturing above the extraction panels. The lower parts of the overburden are predicted to be fully dewatered above the Project area (Figure 7.24) whereas partial recovery of saturation will have occurred in the higher overburden over the eastern part of the Project area (Figure 7.22).

The West Borehole Seam will be fully dewatered over the entire Project area but the completion of mining, and depressurisation of at least 5m is predicted to extend for about 2km to the south and less than 1km to the east (Figure 7.26).

The dewatering and depressurisation effects of the Project, as well as other mining operations in the vicinity (Tasman Underground Mine and West Wallsend Colliery) and the residual effects of the former Stockrington mine, are shown on pressure head cross-sections on Figure 7.27 to 7.29. By the end of the Project, the West Wallsend Colliery will have finished and partial recovery of water levels in that part of the area is predicted to have occurred.

8.1.2 Post-Mining Recovery

Post-mining recovery is illustrated in Figures 8.1 to 8.4 for the Fassifern Seam, West Borehole Seam overburden and interburden, and more extensively in Appendix H.

Figure 8.1 shows groundwater levels and residual drawdown 100 years after completion of mining in the Fassifern seam (Layer 3) which indicates up to 1.5m residual drawdown to the immediate south of the Project area.

Figures 8.2 and 8.3 show groundwater levels and recovered drawdown in the Fassifern-West Borehole interburden (upper section – Layer 4; lower section – Layer 5). It is seen that around 5m residual drawdown will remain in the lower interburden (Figure 8.3) over the southern part of the Project area and extending south for 1-2km.

Figure 8.4 shows groundwater levels and residual drawdown in the West Borehole Seam (Layer 7), and indicates that 100 years after completion of mining, groundwater levels will have virtually fully recovered in that seam.

The extent of long-term recovery in groundwater levels/pressures is further demonstrated by the pressure head cross-sections provided in Figures 8.5 to 8.7 (locations of cross-sections are shown on Figure 7.9). These figure indicate that depressurisation within the West Borehole Seam, previously associated with the Project, abandoned Stockrington workings and West Wallsend Colliery, is no longer observed,

The timing of recovery across the Project area is demonstrated in simulated recovery hydrographs for key bores monitoring the West Borehole Seam within the Project area. Figure 8.8 shows recovery hydrograph for B004 and B005 located in the northern area of the Project (Figure 3.1). B005 recovers rapidly as it is heavily affected by the impact of low groundwater levels within the Stockrington workings prior to proposed development in the Project. B004, located further up dip in the vicinity of the North-South Mains, also recovers within 25 years of cessation of mining. Water levels following 100 years recovery are significantly higher than prior to the start of proposed mining activities, due to the impact of historical mining in the Stockrington mine.

Figure 8.9 shows simulated recovery hydrographs for B017A and B030C and indicated that recovery to near pre-mining levels occurs within approximately 40 years.

Figure 8.10 shows simulated recovery hydrographs for B031C and this show that pseudo-steady state conditions are attained following 50 years recovery, with water levels lower than pre-mining conditions by approximately 30m. This correlates with the area in the southern sector of the Project area where a residual drawdown has been modelled following recovery and is assessed to be the product of high connectivity resulting from mining and the gradient that exists within the coal measure strata.

8.2 Potential Baseflow Impacts

The majority of the area above the Project drains towards Surveyors Creek, an ephemeral headwaters tributary of the Wallis Creek catchment, which in turn flows into the Hunter River near Maitland. Other portions of the Project area are located in the ephemeral headwaters of Blue Gum Creek that flows into Hexham Swamp approximately 8km to the east, or within the headwaters of Cockle Creek which flows into the northern end of Lake Macquarie.

Modelled impacts on baseflows during the mining period were described in Section 7.8.4 and shown on Figure 7.12 and Table 7.5. Only Wallis Creek and the Hunter River have any significant fluxes in terms of river stream leakage or aquifer discharge (baseflow). All other drainages are essentially ephemeral and only flow following periods of sustained rainfall.

Baseflow into the Surveyors Creek catchment is negligible, with the only apparent baseflow change during mining occurring in the upper reaches of the Surveyors Creek tributaries. This incorporates the baseflow into the creek segment upstream of S2(1) (Figure 5.2), predicted to reduce over the life of the mine from about 4.5m^3/d (0.0045ML/day) at present to approximately zero by the end of mining. The model indicates that baseflows into the other headwaters tributaries are less than 0.5m^3/d.

Changes to baseflows due to the Project in isolation are shown on Figure 8.11, which shows that overall the Project is predicted to have very limited impact on baseflow to Surveyors Creek, with the only impact being a very small deduction in baseflow within its upper reaches (approximately 4.5m^3/d, or 0.0045ML/day). This is due to the fact that the Surveyors Creek drainage system is ephemeral, with irregular flow mechanics relating primarily to rainfall events.

Figure 8.11 shows that Slatey Creek, which flows into the Cockle Creek catchment, will undergo a minor reduction in baseflow due to the Project (approximately 0.5m^3/d, or 0.0005ML/day). Bangalow Creek (a tributary of Wallis Creek) and Upper Wallis Creek both also indicate an insignificant reduction in baseflow of less than 0.03m^3/d (less than 0.00003ML/day.

8.3 Existing Groundwater Users

As indicated in Section 4.8, there are five registered bores within 5km of the Project which are not associated with Donaldson Coal projects. These are generally screened within shallow alluvium either associated with Wallis Creek or in Surveyors Creek near the confluence of Wallis Creek. The locations of the registered bores are shown on Figure 4.14. All registered bores are outside the predicted zone of influence of drawdown in the alluvium, as depicted on Figure 7.18.

It is therefore predicted that the Project will not impact on any registered groundwater bore or well, or other groundwater users.

8.4 Groundwater Dependent Ecosystems

Impacts on flows and groundwater levels within the colluvium and weathered bedrock within the Wallis Creek and Surveyors Creek catchments are predicted to be insignificant, both during mining and post-mining. Therefore, it is considered very unlikely that there would be any impact on GDEs associated with either Wallis Creek or Surveyors Creek.

However, it is recognised that within the incised drainage channels in higher terrain associated with Surveyors Creek, there is colluvium which supports important biota and is recharged by rainfall infiltration that may form small localised perched aquifers. This localised perched groundwater is not represented in the groundwater model, but as it is not regionally continuous, it is expected to be unaffected by mining. Monitoring of potential impacts of the Project on GDEs in the Project area would be conducted as part of the Biodiversity Management Plan for the Project (Section 4.8.3 of the EIS).

8.5 Climate Change and Groundwater

Climate change is expected to have varying impacts on groundwater across the world however few modeling studies on the impacts of climate change to groundwater levels have taken place so far. Modelling of climate change takes into account surface water and groundwater interactions, and inter-annual temporal variations.

The NSW Climate Impact Profile - The Impacts of Climate Change on the Biophysical Environment of New South Wales (DECCW, 2010) projects the following changes to the climate of the Project region by 2050:

- Increased maximum and minimum temperatures in all seasons;
- An increase in summer rainfall, with no decrease during winter. These projected changes are within the historical variation in rainfall;
- Increased evaporation due to increased projected temperatures. The projected increases in

evaporation are likely to counteract the expected increases in summer rainfall across the state; and

- Increased rainfall intensity for flood producing rainfall, particularly for short duration storms.

Annual rainfall is expected to change by -10% to +5% by 2030 (Pittock, 2003) in parts of south-eastern Australia. In addition, annual temperatures are projected to increase by 0.4 to 2.0ºC (relative to 1990) at that time.

The approach taken for this assessment involved conducting steady state simulations at the completion of mining (Year 30) for three scenarios:

- Rainfall infiltration reduced by 20%;
- Rainfall infiltration increased by 20%; and
- Rainfall infiltration was increased by 20% and evapotranspiration was increased by 10%.

Results for each scenario are detailed in Table 8.1 and illustrated in Figures 8.12, 8.13 and 8.14. The Base Case (calibrated rainfall) includes only the proposed mining for this Project and the historical workings in the Project area. All external mines are excluded. Hence, the Base Case baseflows at key water bodies presented in the following table are higher than those for full model extend mining and transient simulation shown in Table 8.1.

In Table 8.1 the modelled baseflows corresponding to each surface water body are shown in ML/day on the left of the table. The changes in volumes (in m^3) following the completion of each of the three scenarios described above are shown on the right hand side of the table. It is important to note that these quantities are a change in the volume of baseflow, and not a total baseflow volume.

The results show that the results from each of the simulated scenarios have a very low impact on baseflows. Three of the surface water bodies are not impacted (Four Mile Creek, Lower Surveyors Creek and Minmi Creek).The largest impact to baseflow is seen in Slatey Creek (Figure 8.13). Here, following simulation of increased recharge by 20% in 2012, the baseflow changes by 1.248m^3/day.

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Table 8.1: Change in Average Modelled Baseflow during Mine Life (2012 – 2028) taking into account impacts due to climate change

	Base Case	Base Case	Infiltration reduced by 20%	Infiltration reduced by 20%	Infiltration increased by 20%	Infiltration increased by 20%	Infiltration increased by 20% ET increased by 10%	Infiltration increased by 20% ET increased by 10%
Surface water body	**Modelled Baseflow at 2012 (ML/day)1**	**Modelled Baseflow at 2028 (ML/day)1**	**Change in Modelled Baseflow at 2012 (m3/day)1**	**Change in Modelled Baseflow at 2028 (m3/day)1**	**Change in Modelled Baseflow at 2012 (m3/day)1**	**Change in Modelled Baseflow at 2028 (m3/day)1**	**Change in Modelled Baseflow at 2012 (m3/day)1**	**Change in Modelled Baseflow at 2028 (m3/day)1**
Hunter River	5.500	5.500	-0.466	-0.122	0.464	0.109	0.110	0.103
Lower Wallis Creek	0.750	0.750	-0.106	-0.025	0.105	0.023	-0.006	0.016
Blue Gum Creek	0.000	0.000	-0.048	0.004	0.049	0.055	0.0418	0.018
Four Mile, Creek, Lower Surveyors Creek, Minmi Creek,	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Slatey Creek	0.000	0.000	-1.228	-0.135	1.248	0.271	1.189	0.060
Upper Wallis Creek	0.000	0.000	-0.152	-0.144	0.150	0.099	0.024	0.078
Cockle Creek	0.000	0.000	-0.008	-0.003	0.008	0.003	0.002	0.002
Viney/Weakleys Flat Creeks	0.000	0.000	-0.008	-0.003	0.008	0.003	0.003	0.002
Bangalow Creek	0.000	0.000		-0.371	1.250	0.348	1.247	0.301
Surveyors Creek								
S2(2) to S2(3); S2(1) to S2(2); upstream of S2C and upstream of S2D	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Upstream of S2B	- 0.0043	0.000	-0.186	0.197	0.236	-0.057	0.235	-0.053
S2(3) to S2B, S2c and S2D	- 0.00002	0.000	-0.002	0.000	0.002	-0.057	0.002	0.000
S2G	- 0.00004	0.000	-0.029	0.000	0.148	0.000	0.144	0.000
S2(1) Cumulative	- 0.0049	0.000	-0.218	0.197	0.387	-0.057	0.381	-0.053

9. GROUNDWATER ACCOUNTING AND WATER SHARING PLAN

9.1 Licensing

A water licence is required under either the *Water Act 1912* or the *Water Management Act 2000* (unless an exemption applies) where any aquifer interference activity causes:

- The removal of water from a water source;
- The movement of water from one part of an aquifer to another part of an aquifer; and
- The movement of water from one water source to another water source.

9.1.1 Licensing Under the *Water Act 1912*

In water sources where WSPs do not yet apply, a water licence is required under the *Water Act 1912*. Within the Project area, the fractured rock aquifer system in the coal measures is such a water source.

This water licence would authorise both the taking of a volume of water from the aquifer and the work or activity that causes this water to be taken. Conditions relating to the management of aquifer interference activities would therefore be placed on the water licence itself.

As the aquifer interference activity is taking groundwater (through the occurrence of mine inflows), a water licence is required under Part 5 of this Act. In Section 7.8.2, it was determined that the predicted maximum rate of mine inflows will be 1.35ML/day, occurring in 2024. Donaldson Coal would therefore require a 493ML/yr volume water licence to account for these inflows.

9.1.2 Licensing Under the Water Management Act 2000

Aquifer interference activities occurring in those water sources where WSPs have commenced under the WM Act 2000 require a water access licence, except where exempt under other legislation or through an Aquifer Interference Regulation.

Where aquifer interference activities induce (take) flow from connected surface water sources, separate access licences are required to account for the take from all individual water sources. In Section 8.2, it was determined that the predicted maximum loss of baseflows in specific creeks were as follows:

- Surveyors Creek (Wallis Creek Water Source) – 0.0045ML/day;
- Bangalow Creek (Wallis Creek Water Source) – less than /L 0.0003ML/day;
- Upper Wallis Creek (Wallis Creek Water Source) – less than /L 0.0003ML/day; and
- Slatey Creek (North Lake Macquarie Water Source) – 0.0042ML/day.

As such, total losses from baseflow are predicted to be negligible, and on this basis, it is not anticipated that these potential impacts on local streams would require licensing under the WM Act 2000. This is consistent with recent NSW Government draft policy documentation and press releases that indicate that activities that involve extraction of more than 3 ML of water per year will require licences.

If licensing under the WM Act 2000 is required, Donaldson Coal would therefore require unregulated river access licences totalling 1.9ML/yr and 1.6ML/yr within the Wallis Creek and North Lake Macquarie Water Sources, respectively. If licensed entitlements already held are insufficient, these excess entitlements would have to be purchased on the water market.

9.2 Approvals

Under the WM Act 2000, an aquifer interference activity requires:

- The necessary volumetric water access licences; and
- A separate aquifer interference approval.

An aquifer interference approval confers a right on its holder to carry out specified aquifer interference activities at a specified location or area.

Aquifer Interference approvals are being rolled out across the State under the WM Act 2000, with the draft *Aquifer Interference Policy* currently out on public exhibition. The first stage of the roll out will require aquifer interference activities in groundwater that is covered by the WM Act 2000 and underlies Biophysical Strategic Agricultural Land to hold an aquifer interference approval, unless the activity is exempt.

Biophysical Strategic Agricultural Land is defined by Strategic Regional Land Use Plans. Currently the draft *Upper Hunter Strategic Regional Plan* has been prepared and is currently out on public exhibition, with all submissions submitted up until 3 May 2012 being considered prior to finalisation. Review of the draft Plan suggests that the Project area lies just outside its extent; however confirmation of this would be required upon finalisation of the Strategic Regional Land Use Plans.

The second stage of the roll out will address the aquifer interference approval requirements for activities in groundwater that does not underlie Biophysical Strategic Agricultural Land.

9.3 Compliance with the Water Sharing Plan

As stated earlier, the Project lies within the Wallis Creek Water Source of the Hunter Extraction Management Unit under the HUAWSWSP. The Project is also predicted to cause small impacts on baseflows within Slatey Creek, which lies within the North Lake Macquarie Water Source of the Lake Macquarie Extraction Management Unit under the HUAWSWSP.

The WM Act 2000 provides for a system of assessment and licensing and approvals relating to the equitable take of water from water sources, in addition to works and activities occurring within or affecting these water sources. The HUAWSWSP sets out Water Sharing Rules that operate under these water management principles. The Water Sharing Rules that pertain to the Wallis Creek and Lake Macquarie Water Sources are provided in Table 9.1.

Table 9.1: Water Sharing Rules

Subject	Wallis Creek Water Source	North Lake Macquarie Water Source
Total surface water entitlement	492ML/yr	1,216ML/yr
Total groundwater entitlement	0 unit shares/yr	0 unit shares/yr
Access Rules		
Cease to Pump	Existing licence conditions remain for the first five years. From year six of the plan, cease to pump is when there is either no visible inflow to, or outflow from, the pumping pool.	For Cockle Creek the cease to pump is when there is no visible flow at The Weir Road, Barnsley.
Reference Point	Riffles upstream and downstream of the pump.	Reference point for Cockle Creek is causeway on The Weir Road, Barnsley.
Trading Rules		
Trading INTO the water source	Permitted, subject to assessment, if the trade will not increase the total licensed entitlement for the water source (no net gain*).	
Trading WITHIN the water source	Permitted, subject to assessment.	
Conversion to High Flow Access Licence	Not permitted.	
Conversion to Aquifer Access Licence	Not permitted.	

* 'No net gain' trades means that a trade cannot increase entitlement in a water source to a level above that at the start of the Plan.

These rules apply to all surface waters in these water sources, as well as the alluvial groundwater that is highly connected to the surface waters. The Project will take these rules into consideration prior to, and during operations, including 'cease to pump' controls during periods of low flow.

The HUAWSWSP also sets out management rules for the operation of aquifer interception activities. The management rules that pertain to the Wallis Creek and North Lake Macquarie Water Sources are provided in Table 9.2.

Table 9.2: Management Rules for Aquifer Interception Activities

	Rule	Applicable Water Source
To minimise interference between neighbouring bores	New activities are not to be located within 400m from an access licence bore.	Both
	New activities are not to be located within 200m from a Basic Landholder Right bore.	
	New activities are not to be located within 50m from the boundary (unless negotiated with neighbour).	
	New activities are not to be located within 500m from a local or major water utility bore (or as otherwise assessed).	
	New activities are not to be located within 400m from departmental monitoring bore (unless negotiated with the department).	
Granting of bores near groundwater dependent ecosystems	Rules relating to high priority GDEs.	Not applicable, as none found in the Water Sources of interest
	Activities are not to be located within 500m of karsts.	Both
	Activities are not to be located within the bed of the river, unless assessment indicates that work will have minimal harm on the river environment or stability.	
	These specified distances may be amended, or high priority GDEs identified within the Plan may be added or removed, based on further studies of groundwater ecosystem dependency undertaken by the Minister.	

There are no specific sensitive environmental areas classified under Part 9 Section 41(1) of the HUAWSWSP associated with the relevant Water Sources, and no other licensed users within 200m of the proposed panels (as prescribed under Part 9 Section 39(1)). The Project will take the additional rules into consideration prior to and during operations, being incorporated into the Groundwater Management Plan (GWMP) for the Project.

Accordingly, it is considered that the Project is consistent with the provisions of the HUAWSWSP.

10. MONITORING AND MANAGEMENT

10.1 Impacts of Groundwater Extraction / Dewatering

The groundwater system in the vicinity of all Donaldson Projects is already being closely monitored as part of the ongoing underground and open cut mining activities, as detailed in the site GWMP for each operation. It is recommended that the current GWMP for the existing Tasman Underground Mine is amended to incorporate the Project.

In addition, the monitoring network at the Project should be maintained and expanded to include:

- Monitoring of inflow rates and inflow water quality to the mine once groundwater is encountered;
- Regular measurement of groundwater levels/pressures within all vibrating wire piezometers and standpipes;
- Installation of two additional multilevel vibrating wire piezometers at the Project, with instrumentation placed within, above and below the West Borehole Seam, including:
  - Within the barrier between North-South Mains and abandoned workings near E362860, N6360000; and
  - Within the southern end of North-South Mains near E362860, N6358300.

10.2 Subsidence Impact Monitoring

A comprehensive monitoring program is recommended to investigate the subsidence impacts as they develop above initial extraction panels. This monitoring will provide definitive information on the behaviour of the rock strata from subsidence, and will provide more reliable data on which to base the changes to hydraulic conductivities resulting from subsidence fracturing. This will enable the groundwater model to be recalibrated and used to improve the certainty of forward inflow predictions and resulting impacts, before inflows lead to potentially significant water excess, which is currently expected to be from approximately Mine Year 2.

Some multi-level vibrating wire piezometers are already in place to enable ongoing monitoring. Additional multi-level vibrating wire piezometers are recommended to be installed. Monitoring of these facilities will be conducted in conjunction with the subsidence monitoring recommended by DGS (2012).

10.3 Review and Reporting

The existing Tasman Underground Mine GWMP should be updated to reflect the above monitoring recommendations, as well as the management rules outlined in the HUAWSWSP. As detailed within the existing GWMP, collated monitoring data should be subjected to an annual review by an approved, experienced hydrogeologist in order to assess the impacts of the Project on the groundwater environment, and to compare any observed impacts with those predicted from groundwater modelling.

It is also recommended that, in accordance with industry best practice (MDBC, 2001) a modelling post-audit should be carried out following the excavation of the North-South Mains and Panel 1. Following this review, if necessary, the Project model should be re-calibrated and confirmatory forward impact predictions made in relation to the Project.

Further post-audits should be carried out at five-yearly intervals throughout the remainder of the Project, and at any other time should inflows or impacts vary significantly from predictions.

Should any review or post-audit indicate a significant variance from the model predictions with respect to water quality or groundwater levels, then the implications of such variance should be assessed, and appropriate response actions implemented in accordance with the protocols described in the GWMP.

10.4 Recommendation for Development of Response Plans

Trigger Action Response Plans (TARPs) have already been developed as part of the existing Tasman Underground Mine GWMP. These should be reviewed to include the issues specified above relating to the Project.

Notwithstanding that secondary extraction is not proposed directly beneath creek lines, it is recommended that, in addition to these environmental TARPs, specific operational responses to any connective cracking through the colluvium above the Project within channels of Surveyors Creek should be implemented to minimise the risk of water entering the underground workings following periods of sustained rainfall.

If monitoring indicates that connective cracking has occurred, then the triggers discussed within the design section of this EIS should be followed.

11. CONCLUSIONS

This groundwater impact assessment contains a review of the potential hydrogeological impacts of the proposed Project. The proposed extension includes continued mining of the Fassifern Seam and mining of the West Borehole Seam.

The groundwater impact assessment detailed in this report examined the effect of mining on the groundwater system and the recovery of groundwater levels following mining. The assessment considers the impacts attributable to the Project in isolation, as well as cumulative impacts incorporating other mining operations in the area, and known historical abandoned mining areas.

The main conclusions from the study are summarised below.

Existing Environment

The climate of the region is temperate with average rainfall in the order of 900mm/a.

The topography of the Project area is defined by the Sugarloaf Range trending north-south, with Mount Sugarloaf the highest topographic point at 412mAHD. The Project area is characterised by undulating to steep terrain comprising the prominent Sugarloaf Range ridge and several natural drainage gullies.

The proposed mining area lies within the Newcastle Coal Measures on the western side of the Maitland Syncline.

Groundwater levels in the surficial aquifer system (alluvium and regolith) are closely related to topography, with flow patterns broadly similar to the surface flow patterns. Recharge occurs by rainfall infiltration, and flow down gradient towards the local surface drainages. In the most elevated areas, alluvium is absent, and the regolith is unsaturated. Occasional localised perched groundwater is found in the colluvium and weathered bedrock zone in lower-lying areas along creek lines.

Groundwater levels in the deeper Permian coal measures strata have a more regional pattern, and are controlled to the topographic elevations in areas where specific coal seams outcrop or subcrop (their recharge zones), and the elevations in discharge zones to the east beneath the Hunter River estuary and Hexham Swamp. Groundwater flows down gradient from the recharge zones towards the discharge areas, with generally a south-easterly flow direction. There is very little or no flow across the bedding from shallow to deeper strata under natural conditions; flow is predominantly parallel to the bedding, and occurs mostly within the relatively more permeable coal seams.

Groundwater quality has been monitored at the Donaldson Open Cut Mine, Abel and Tasman Underground Mines, and elevated salinity is found within much of the Permian coal measures aquifer system.

Within the existing Tasman Underground Mine area, samples taken from underground Fassifern Seam workings are much less saline, with a minimum of 900µS/cm EC. This reflects the influence of proximity to relatively direct rainfall recharge in areas of sub-crop within the high terrain.

Water quality within the Project is expected to be intermediate between the groundwater quality signatures observed at the existing Tasman and Abel Underground Mines. Accordingly, the groundwater is expected to be moderately saline, with near-neutral pH.

Groundwater Modelling to Assess Impacts

The MODFLOW-SURFACT groundwater model used for assessment of impacts from the Project was first calibrated against interpreted ‘steady state’ conditions. It was subsequently subjected to transient calibration against groundwater levels and drawdowns during the mining of Abel and Tasman Underground Mines. Overall good calibration results were obtained. Details relating to other current and past mining at Bloomfield and West Wallsend Collieries, and the former Stockrington Colliery, are not known in sufficient detail to be represented other than generally in the model simulations, so some parts of the model are less well calibrated than the main areas of interest.

The groundwater modelling included a number of specific approaches that were used to simulate potential impacts from the proposed mining activities:

- Simulation of groundwater dewatering caused by both open cut and underground mining; and
- Changes to the hydraulic properties of overburden material caused by the caving and subsidence above underground mine panels.

The groundwater model was used to predict the potential impacts of the Project on groundwater levels in the Permian strata and Regolith, as well as stream 'baseflow' impacts (the rate of groundwater flow to) in Surveyors Creek.

The groundwater model was also used to examine the post mining recovery of groundwater levels and stream baseflows. For the recovery run, it was assumed that the all mining operations had ceased.

Predicted Groundwater Inflows

Inflows to the proposed Tasman Extension mine have been predicted using the groundwater model. Inflows are predicted to begin slowly within the first year of development, with approximately 0.2ML/d inflows occurring at the end 2014, increasing to a peak of approximately 1.35ML/d in 2024. Thereafter, inflows decrease to less than 0.6ML/d by the end of mining.

Predicted Impacts on Groundwater Levels/Pressures

Modelling shows that the West Borehole Seam and overburden within the Project area are predicted to be essentially de-watered during mining. Outside of the Project area, the main impact from the Project on water levels within the Permian strata occurs to the east and south of the mine, where drawdowns of 5m or more could occur up to 2km from the mine following completion of coal extraction. Net impacts to the east are limited due to the buffering effect of the old abandoned workings which occupies the West Borehole Seam immediately to the east. Impacts to the west are limited by the sub-crop of the strata.

The geometry of the Project with respect to the abandoned workings and proximity to West Borehole Seam sub-crop effectively compartmentalises the mine and its impacts within the region.

The shallow regolith is generally unsaturated at the start of mining, with groundwater only occurring in the colluvium on the lower slopes and valley colluvium associated with Surveyors Creek down gradient of the Project area. No alluvium is present within the Project area.

The groundwater model has also been used to determine the impacts of the Project in isolation, separating it from the cumulative impacts of other nearby mining projects. To enable this, the model was run without the Project mine plan included, and predicted drawdowns at the end of mining and end of recovery compared to the base case model with the Project included. By subtraction, the incremental impacts of the Project have been identified.

Groundwater levels in strata below the West Borehole Seam are unaffected by the Project.

Predicted Impacts on Stream Baseflows

Overall, the Project is predicted to have very limited impact on baseflow to Surveyors Creek. A maximum reduction in baseflow of 0.0045ML/d is predicted to occur as a result of impacts from the Project. The Surveyors Creek drainage system is ephemeral, with irregular streamflow limited to larger rainfall events.

Post-Mining Recovery

During the post mining period, the groundwater within the mine workings and caved overburden will be highly connected. Post-recovery groundwater levels within the workings and caved overburden are predicted to reach a dynamic equilibrium, where inflows from the surface and other strata balance outflows from the mine area.

These changes in the Permian do not significantly affect the shallow regolith and therefore as there is negligible impact on Surveyors Creek during mining, no residual impact is anticipated.

Recovery occurs within the Project over the majority of the mine footprint following 100 years after cessation of mining activities except for a small area in the south where residual drawdown remains. Elsewhere recovery is relatively rapid occurring within a 25-30 year period within down dip areas. There can be little doubt that recovery is delayed to some degree by the low water levels which exist within the Stockrington Mine area.

Potential Impacts on Existing Groundwater Users

There are only five registered bores within 5km of the Project, other than monitoring bores around the Donaldson Coal operations. None are predicted to be affected by the Project.

Potential Impacts on GDEs

Investigations carried out by Hunter Eco (2012) suggest that Alluvial Tall Moist Forest (located along drainage lines), Warm Temperate Rain Forest (located along drainage lines) and Sugarloaf Uplands Paperbark Thicket (located on a plateau on Sugarloaf Range with shallow soil profile overlying bedrock) could be considered GDEs (Appendix F of the EIS).

Impacts on flows and groundwater levels within the colluvium associated with the Surveyors Creek catchment are predicted to be insignificant, both during mining and post-mining. Therefore it is very unlikely that impact GDEs associated with Surveyors Creek would be impacted by the Project.

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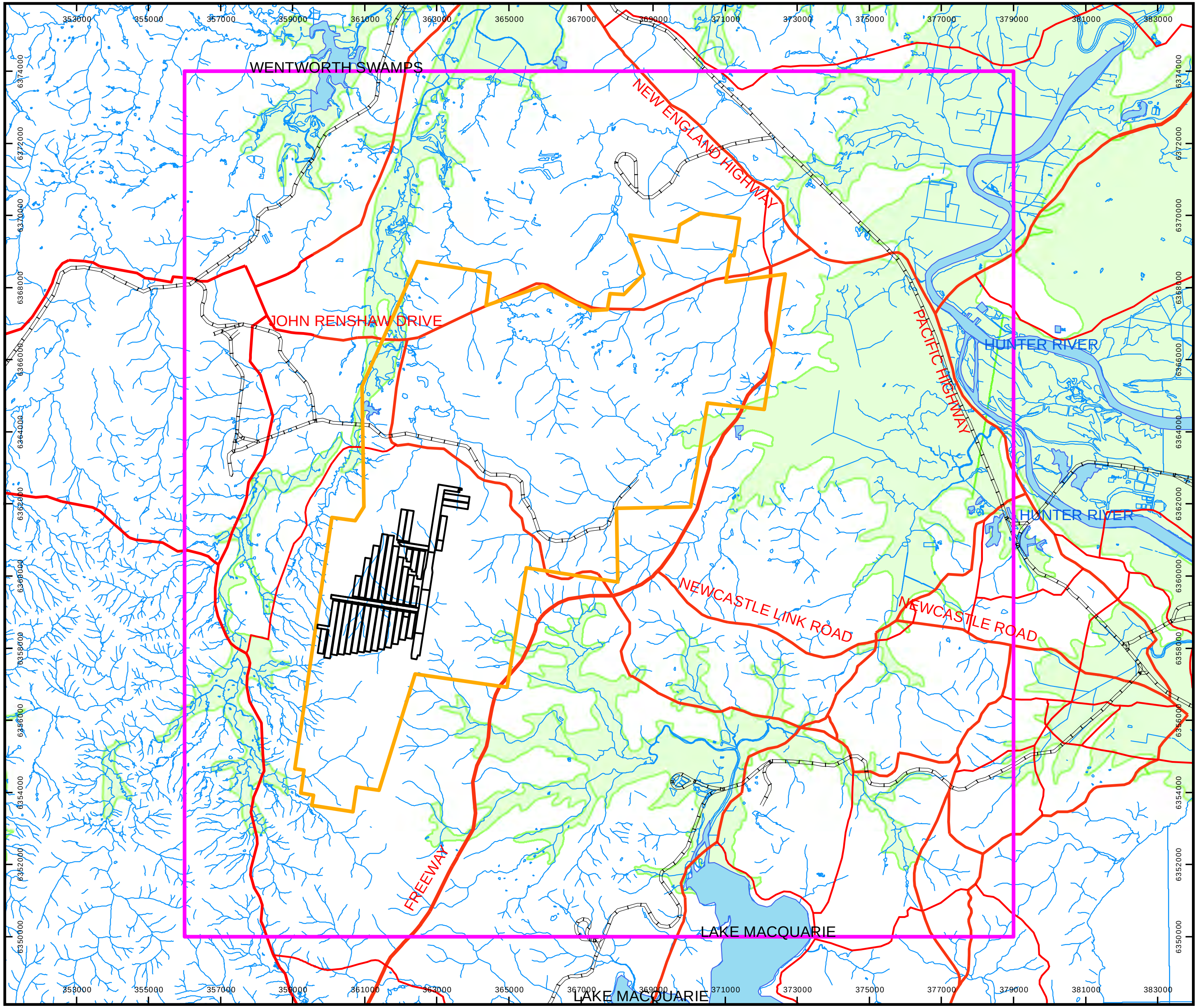
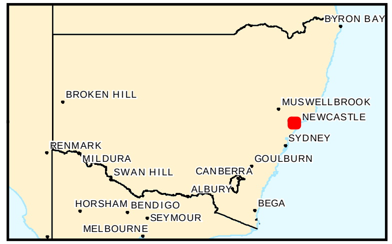
FIGURES





LEGEND

- Tasman Extension Mine Plan
- Donaldson Coal Tenement Boundary
- Model Area
- Railway
- Freeway
- Principal Road
- Secondary Road
- Lake or River
- River or Creek
- Alluvium

N

2,000 0 2,000 4,000

Metres

APPROX SCALE 1:150,000 @ A4

GDA 1994 MGA Zone 56

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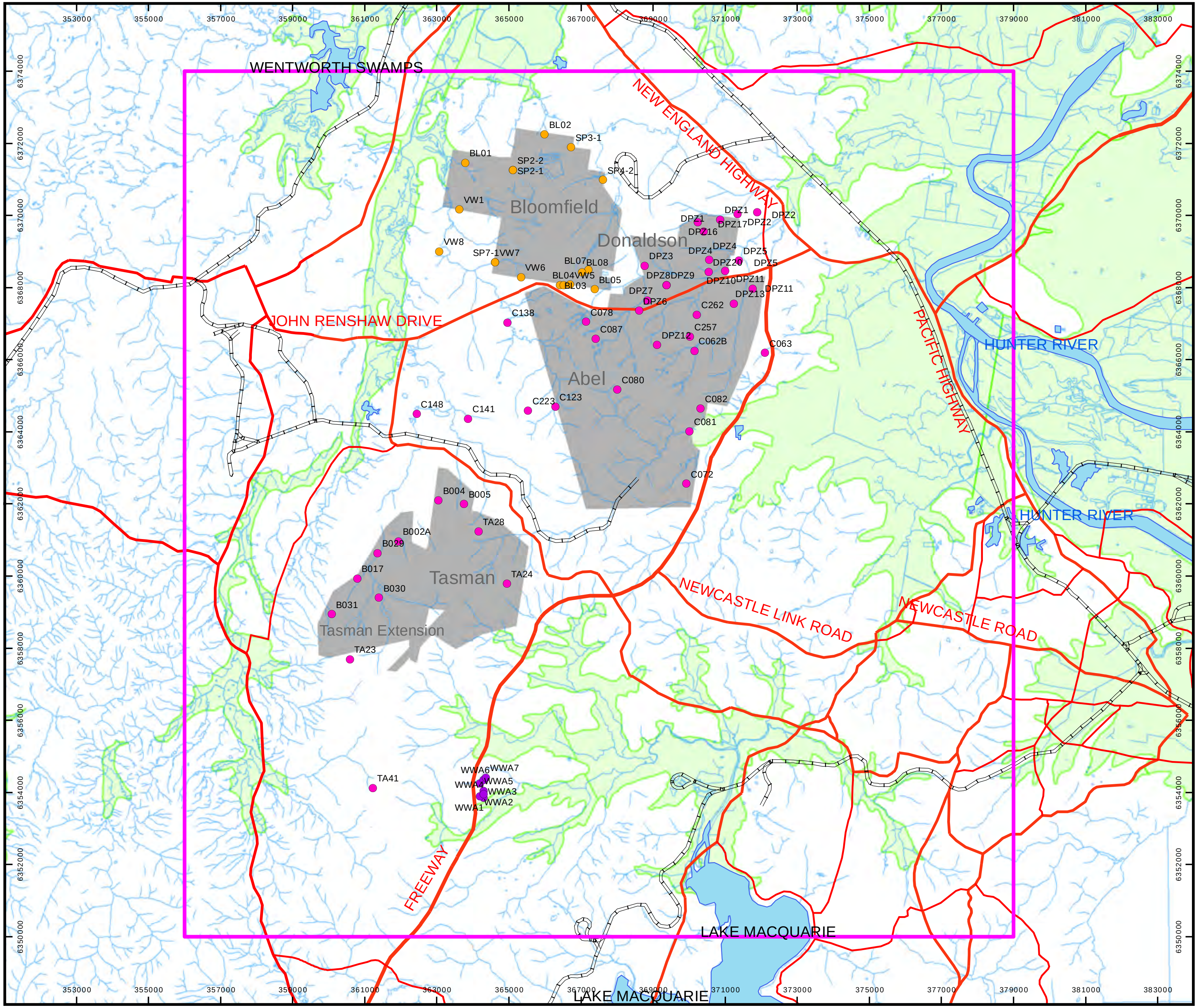
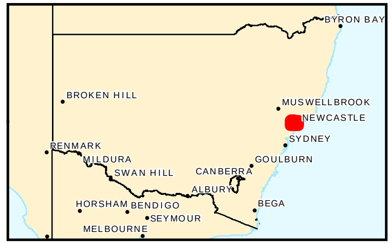
FIGURE 1.1

General Location

S35_005a Rev: A Produced: HZ Reviewed: AF Date: 10/04/2012





LEGEND

- Bloomfield Bore
- Donaldson Coal Bore
- West Wallsend Bore
- Model Area
- Railway
- Freeway
- Principal Road
- Secondary Road
- Lake or River
- River or Creek
- Mine Lease
- Alluvium

2,000 0 2,000 4,000
Metres

APPROX SCALE 1:150,000 @ A4

GDA 1994 MGA Zone 56

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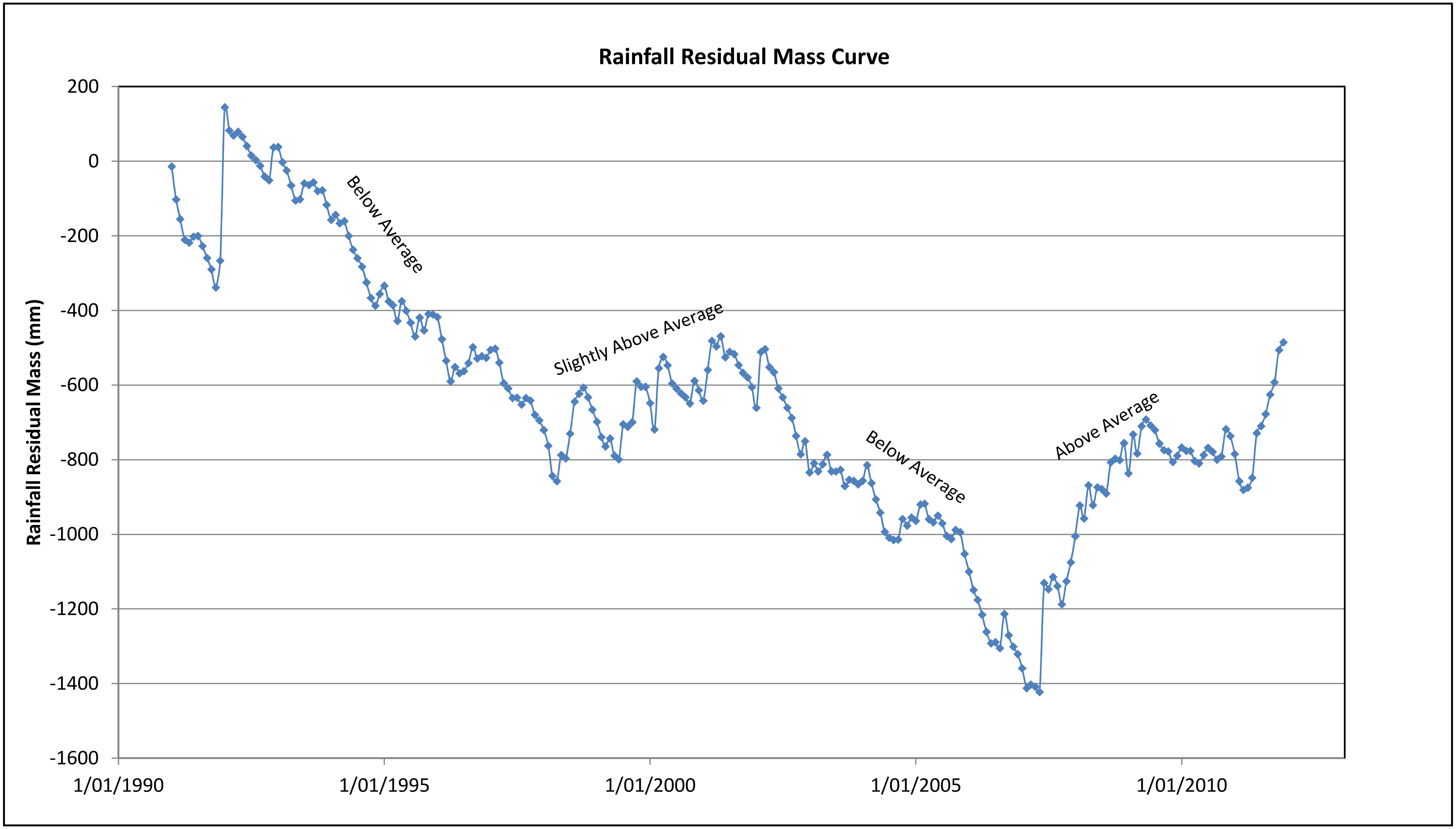
FIGURE 3.1

Groundwater Monitoring Bore Locations

S35_004b Rev: B Produced: HZ Reviewed: PD Date: 14/05/2012



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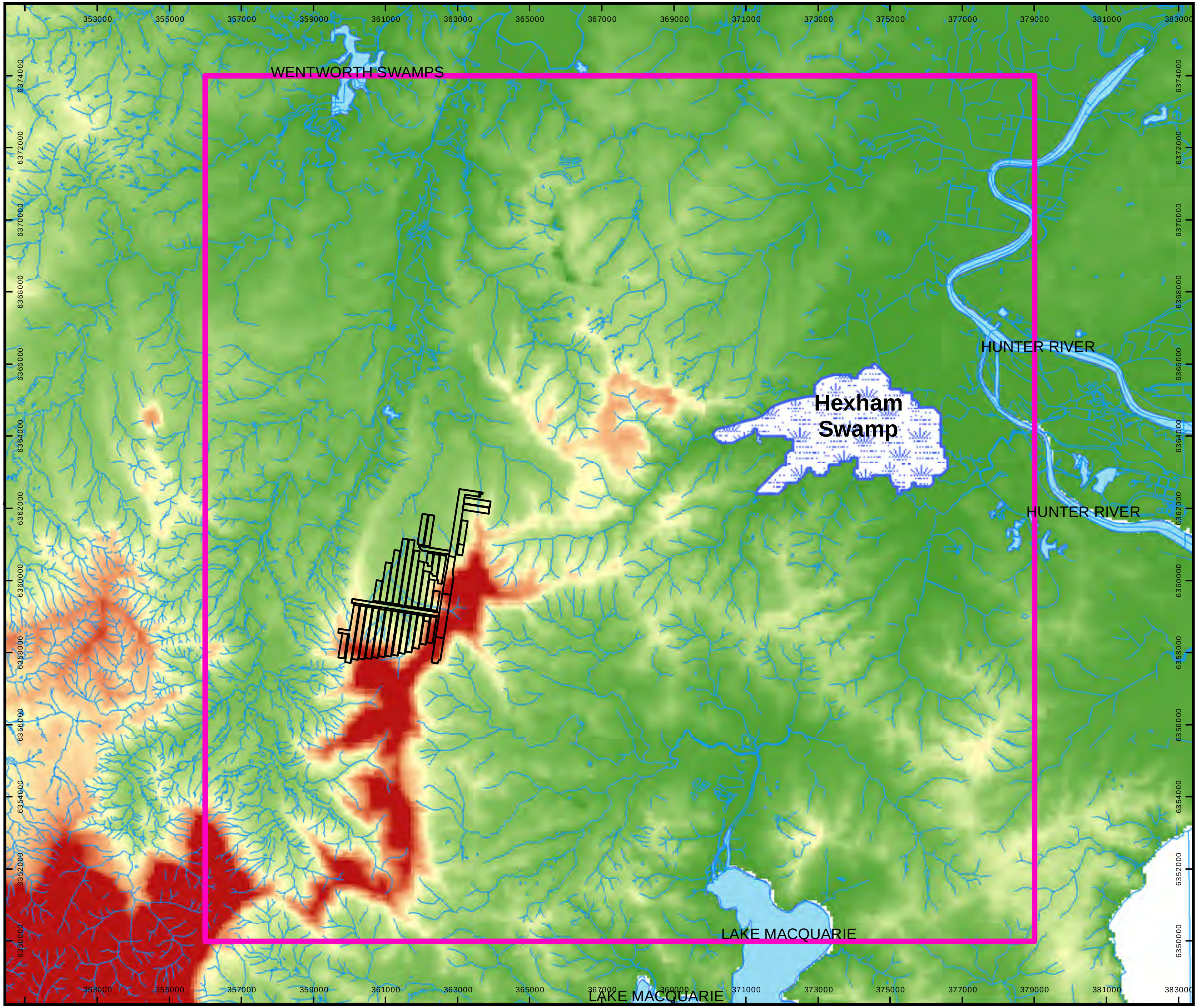
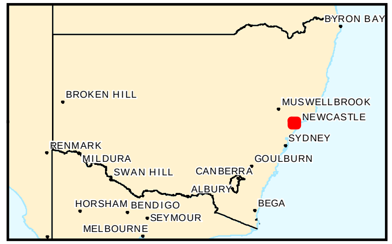
Rainfall Residual Mass Curve - Cessnock FIGURE 4.1

F:\Jobs\S35\300 Technical\380_Background Data\[Rainfall Residual Mass CurveCessnock v2.xlsx]F4.1





LEGEND

Tasman Extension Mine Plan

Model Area

Hexham Swamp

River or Creek

Regional Topography

High : 640

Low : -20

2,000 0 2,000 4,000

Metres

APPROX SCALE 1:150,000 @ A4

GDA 1994 MGA Zone 54

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Please verify the accuracy of all information prior to use.

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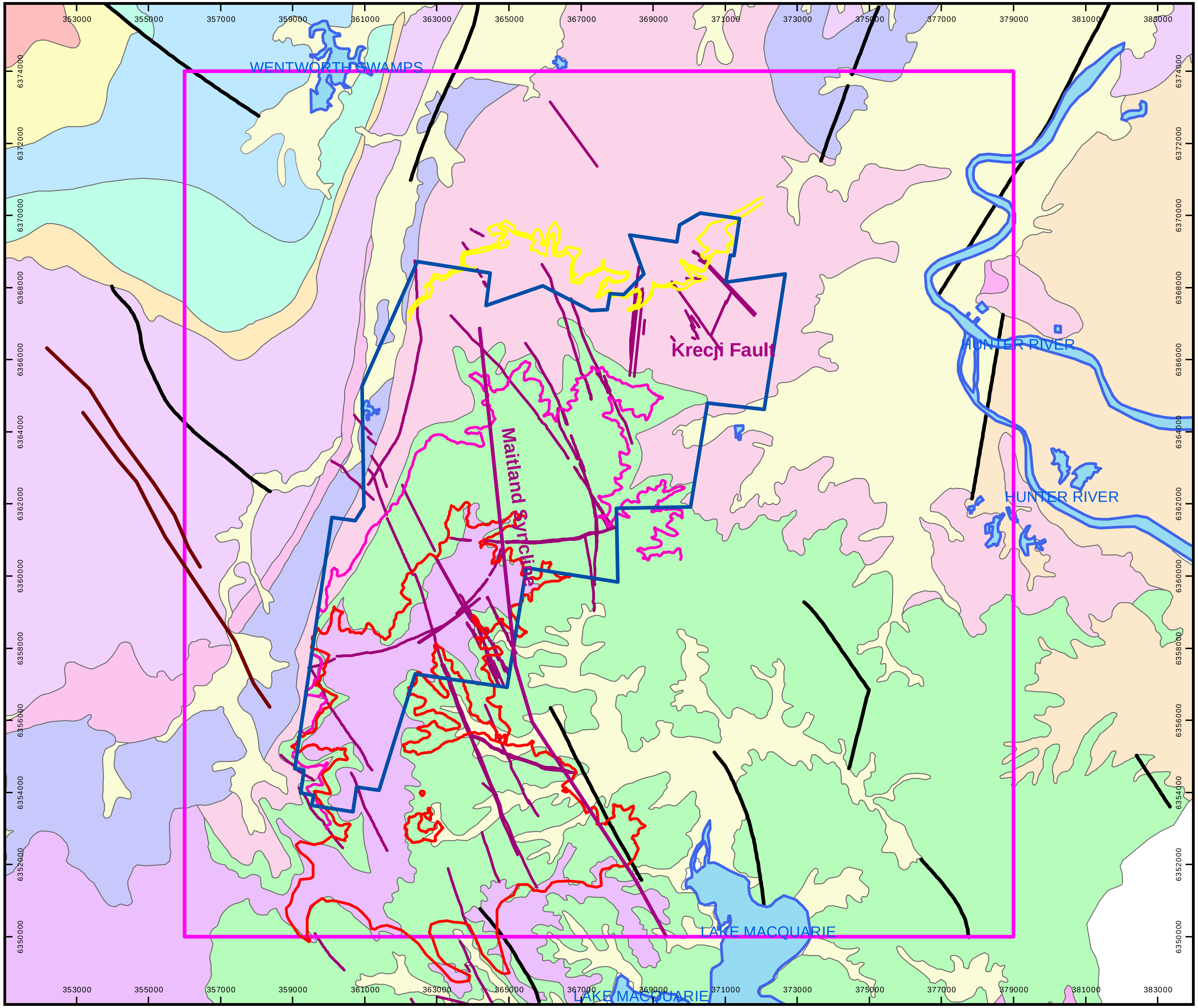
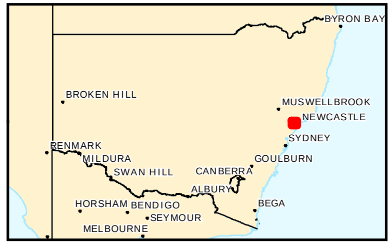
FIGURE 4.2

Regional Topography

S35_006a Rev: A Produced: HZ Reviewed: AF Date: 10/04/2012





LEGEND

- Donaldson Seam Outcrop (Upper & Lower)
- West Borehole Seam Outcrop
- Fassifern Seam Outcrop
- Donaldson Coal Tenement Boundary
- Model Area
- Lake or River
- Fault
- Allandale Formation
- Branxton Formation
- Farley Formation
- Greta Coal Measures
- Lochinvar Formation
- Mulbring Siltstone
- Muree Sandstone
- Narrabeen Group
- Newcastle Coal Measures
- Rutherford Formation
- Tomago Coal Measures
- Alluvium
- Coastal Dunes
- Dunes

N
2,000 0 2,000 4,000
Metres

APPROX SCALE 1:150,000 @ A4

GDA 1994 MGA Zone 56

DATA SOURCES
Geoscience Australia (Geology Map)
Donaldson Coal Pty Ltd (Outcrop Lines)

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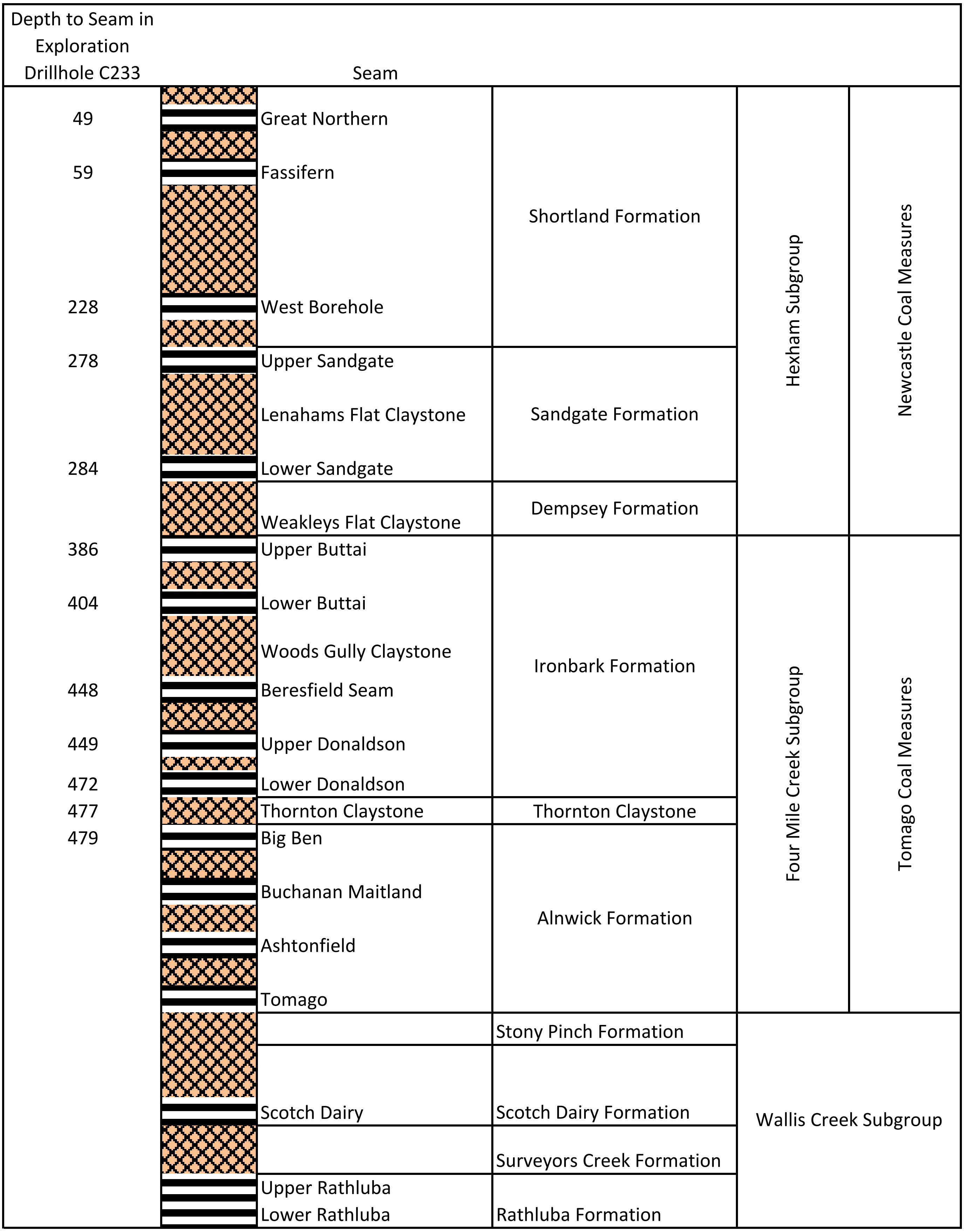
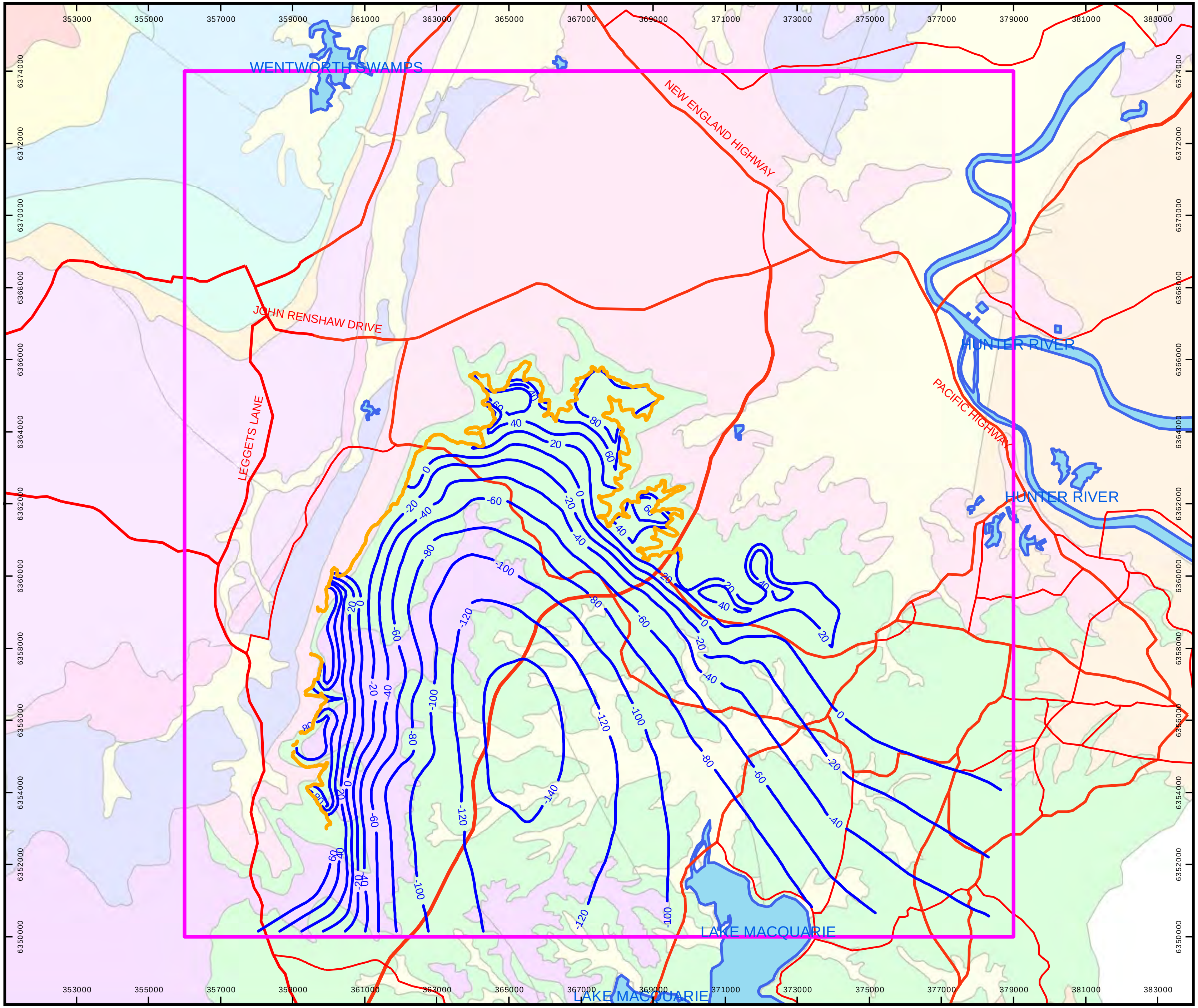
FIGURE 4.3

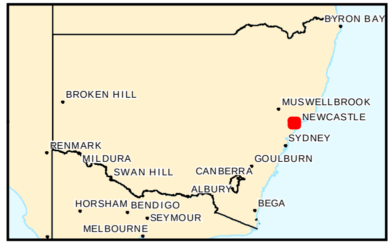
Regional Geology

S35_007b Rev: B Produced: HZ Reviewed: PD Date: 14/05/2012



(after Brown and Preston, 1985)





LEGEND

- West Borehole Seam Outcrop
- Bottom of West Borehole Seam (mAHD)
- Model Area
- Freeway
- Principal Road
- Secondary Road
- Lake or River
- Allandale Formation
- Branxton Formation
- Farley Formation
- Greta Coal Measures
- Lochinvar Formation
- Mulbring Siltstone
- Muree Sandstone
- Narrabeen Group
- Newcastle Coal Measures
- Rutherford Formation
- Tomago Coal Measures
- Alluvium
- Coastal Dunes
- Dunes

N

2,000 0 2,000 4,000
Metres

APPROX SCALE 1:150,000 @ A4

GDA 1994 MGA Zone 56

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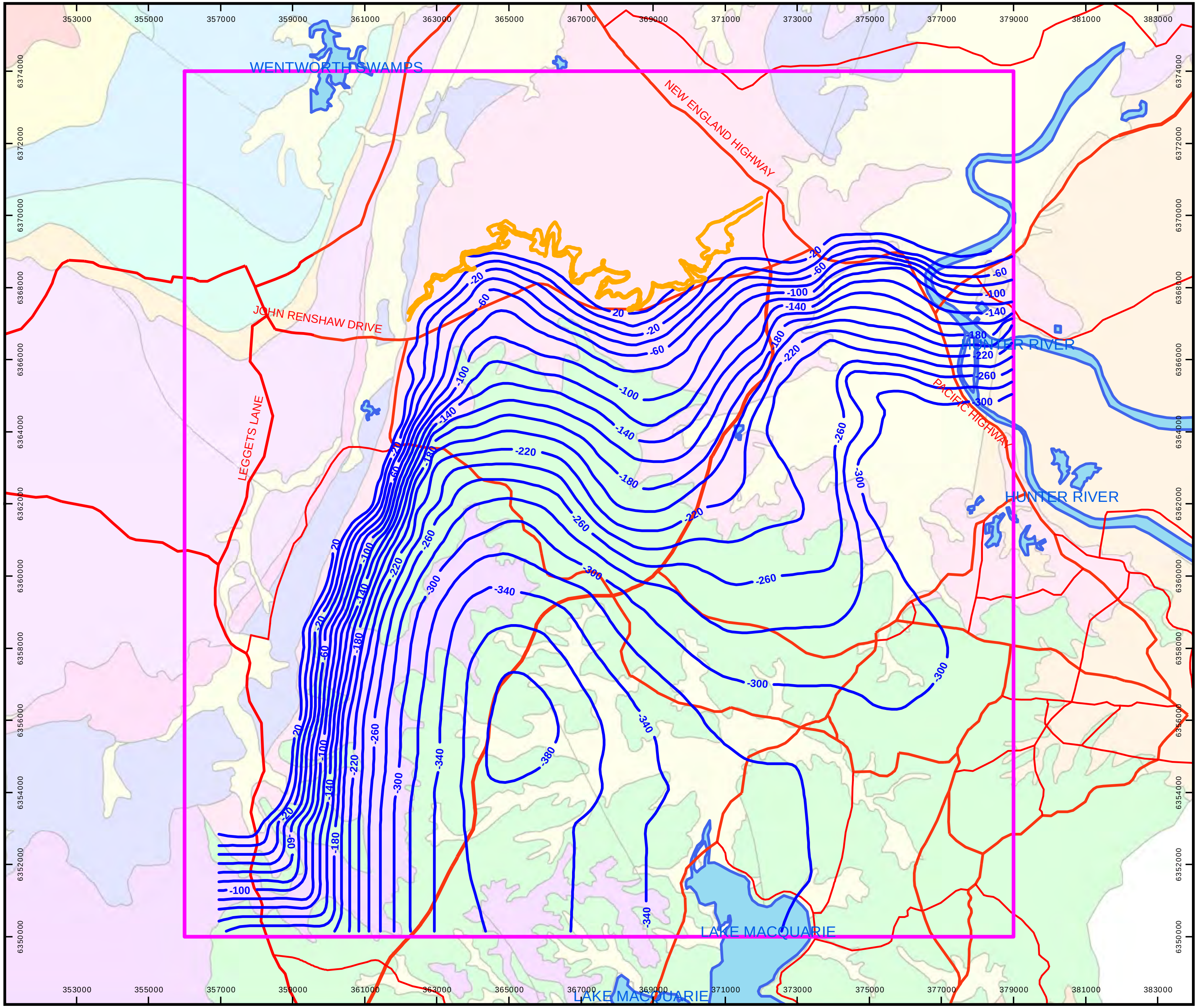
FIGURE 4.5

West Borehole Seam **Floor** Structural Contours

S35_011a Rev: A Produced: HZ Reviewed: PD Date: 14/05/2012

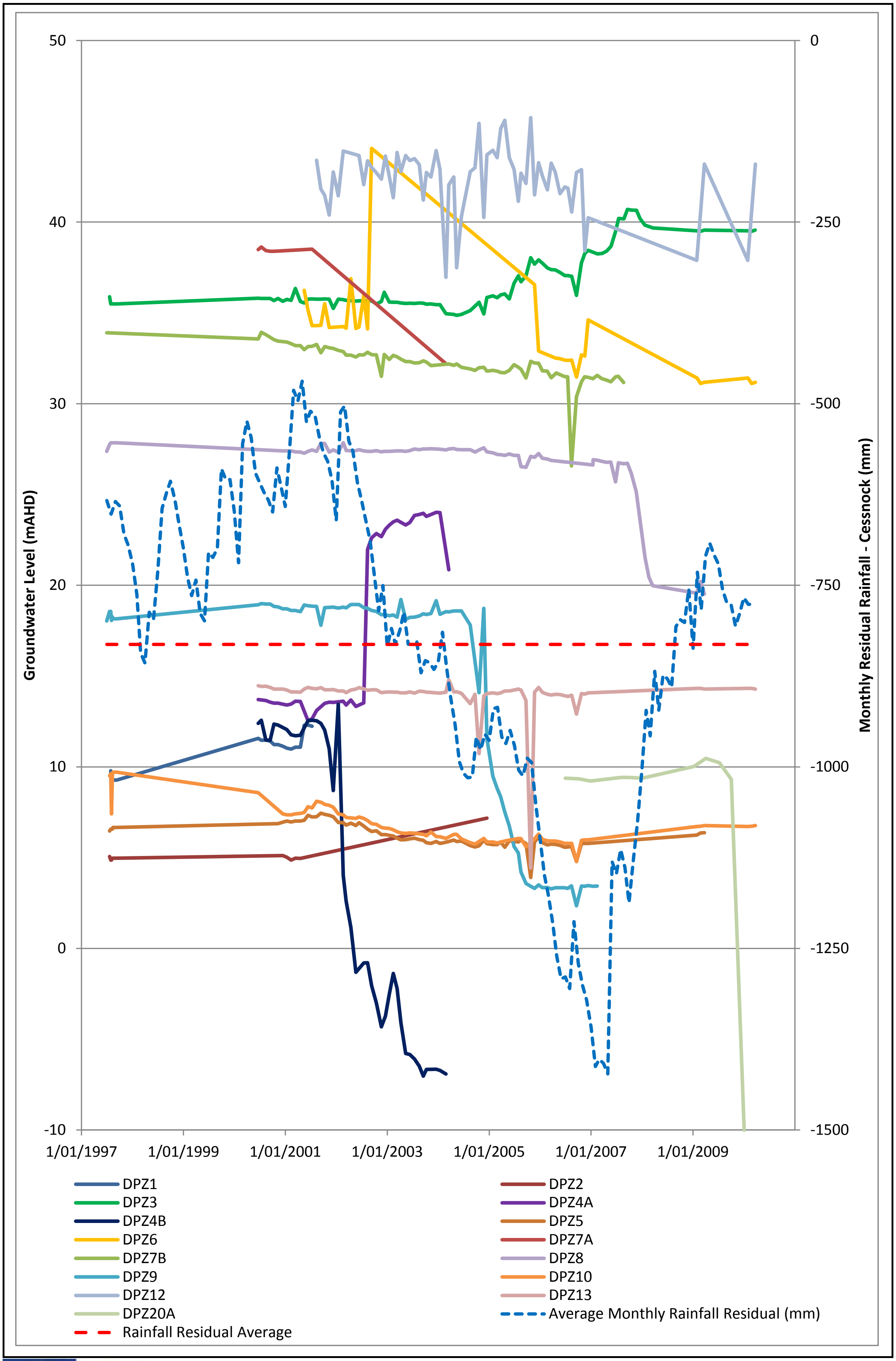


Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Please verify the accuracy of all information prior to use.

FIGURE 4.6

Upper Donaldson Seam
Floor Structural Contours

S35_008a Rev: A Produced: HZ Reviewed: PD Date: 14/05/2012



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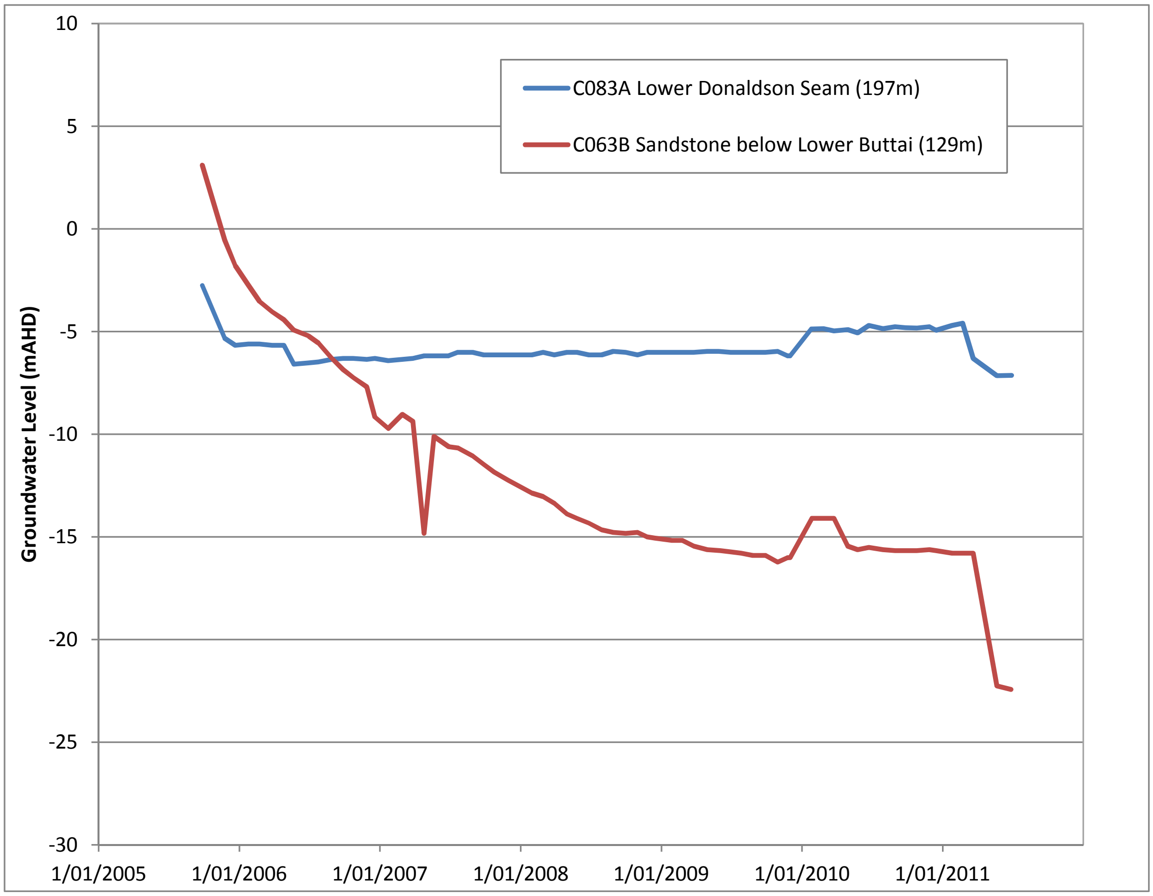
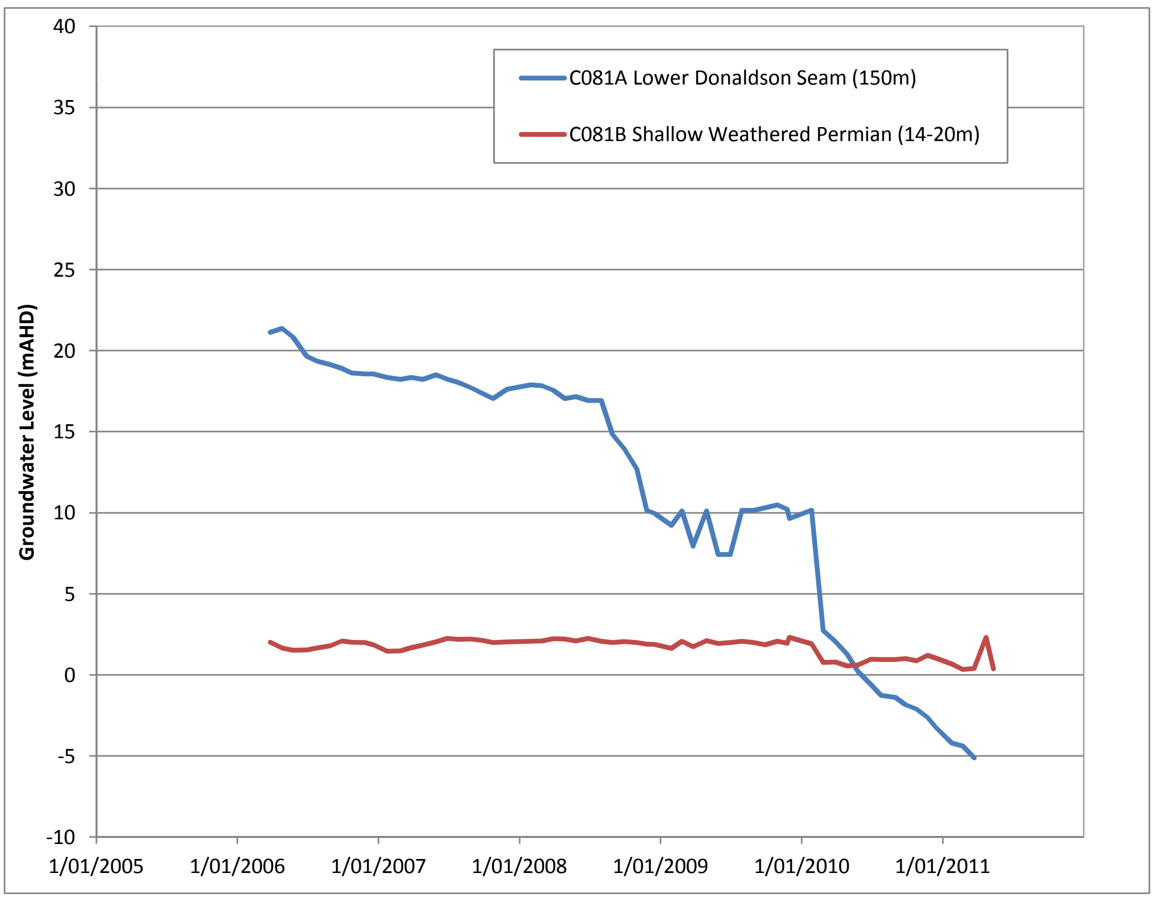
Donaldson Groundwater Monitoring Hydrographs FIGURE 4.7

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[DPZ_bores.xlsx]Fig_4.7





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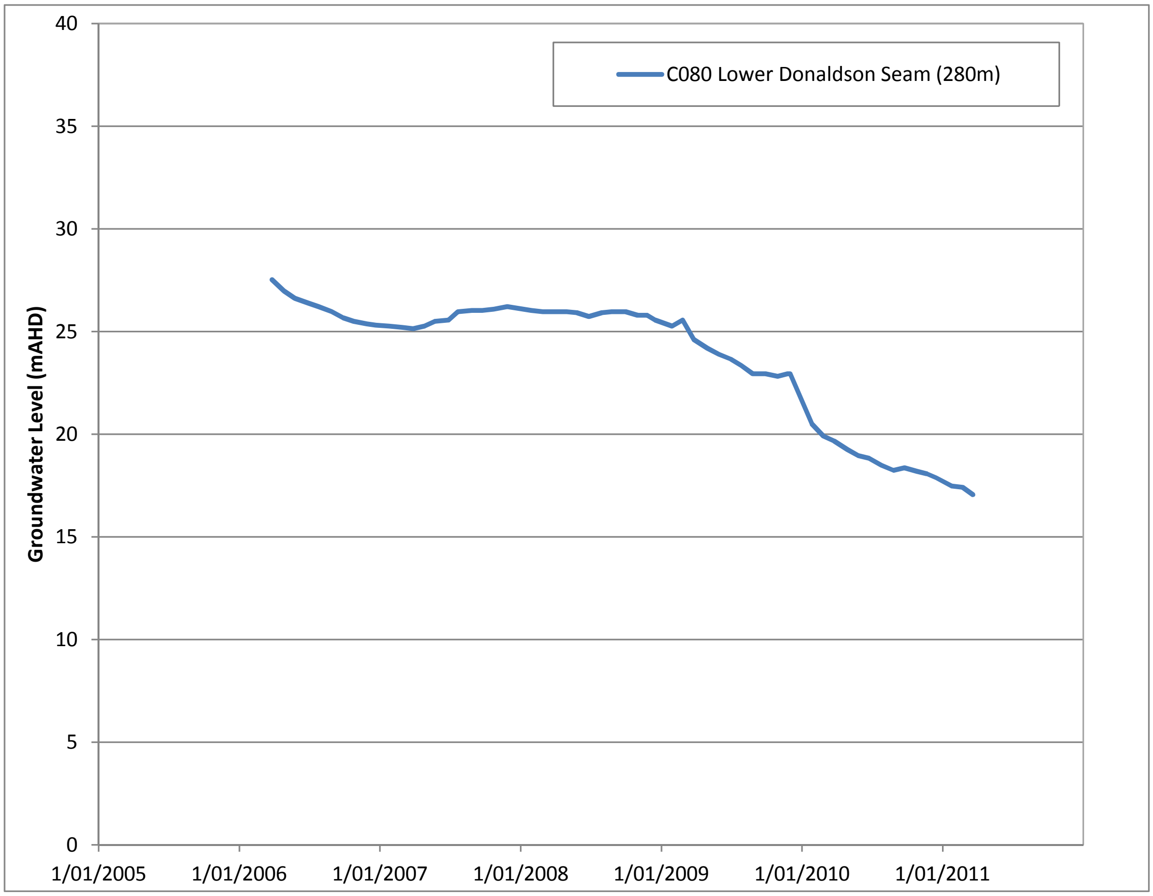
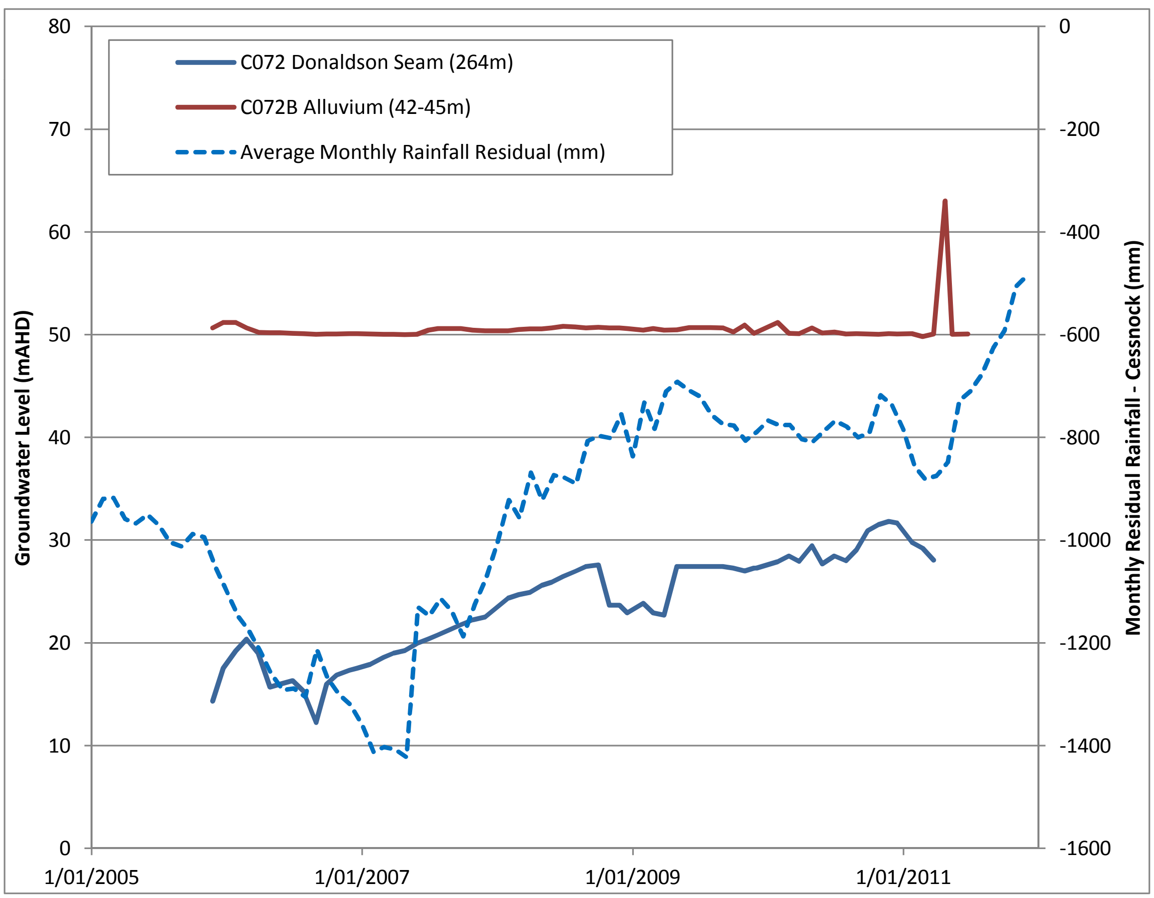
C063A, C063B, C081A and C081B Hydrographs FIGURE 4.8

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[Select_Abel_bores.xlsx]Fig_4.8

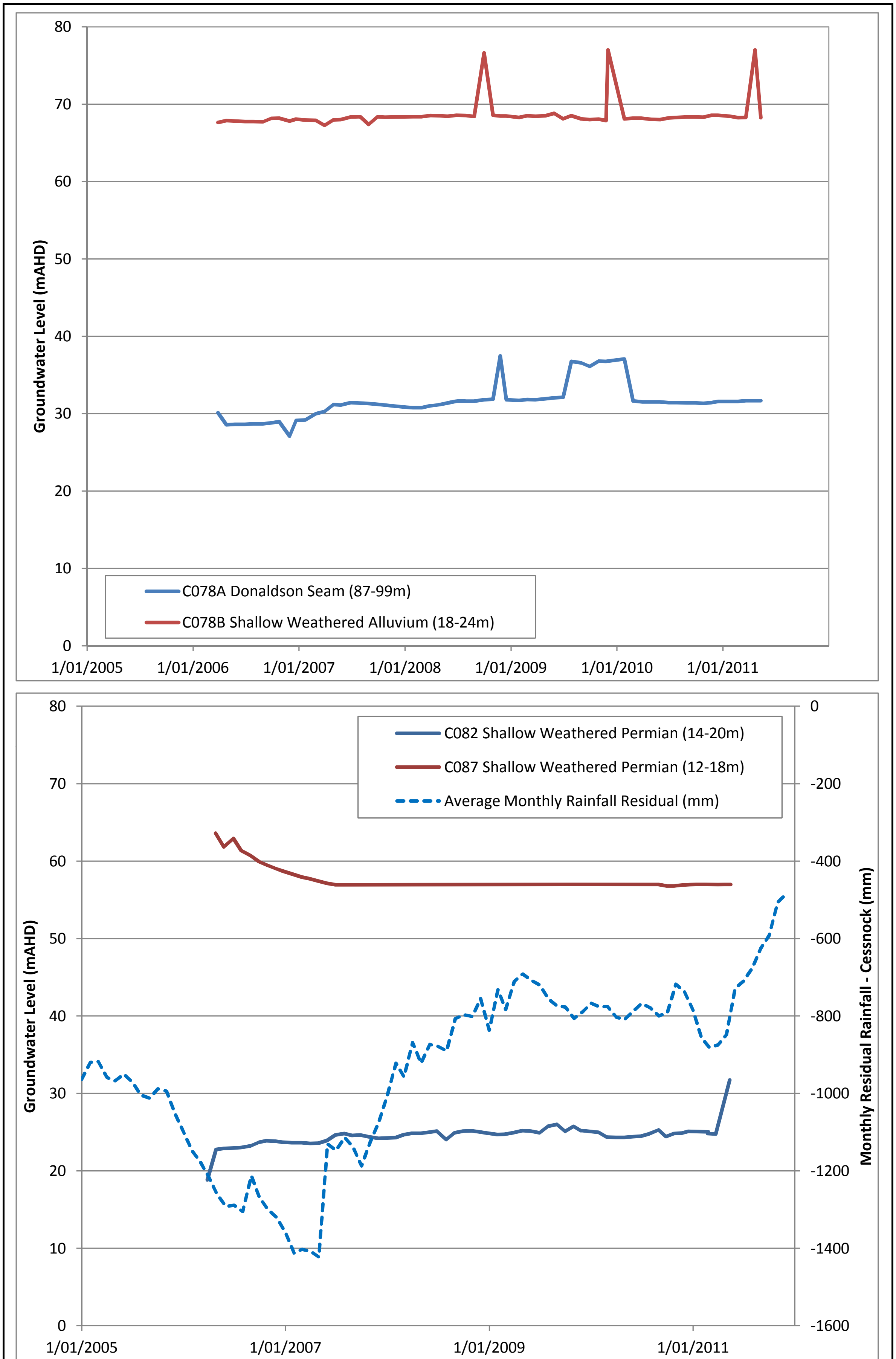




RPS Aquaterra

C080, C072 and C072B Hydrographs FIGURE 4.9

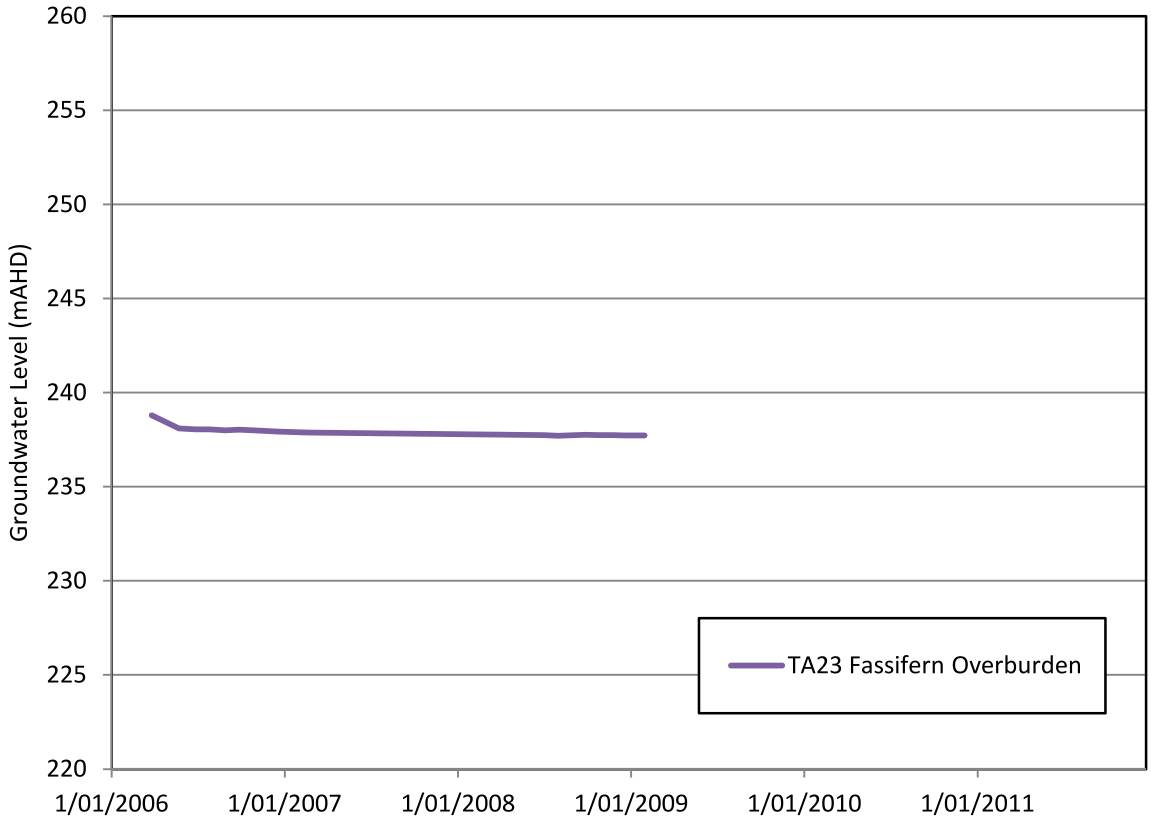
F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[Select_Abel_bores.xlsx]Fig_4.9

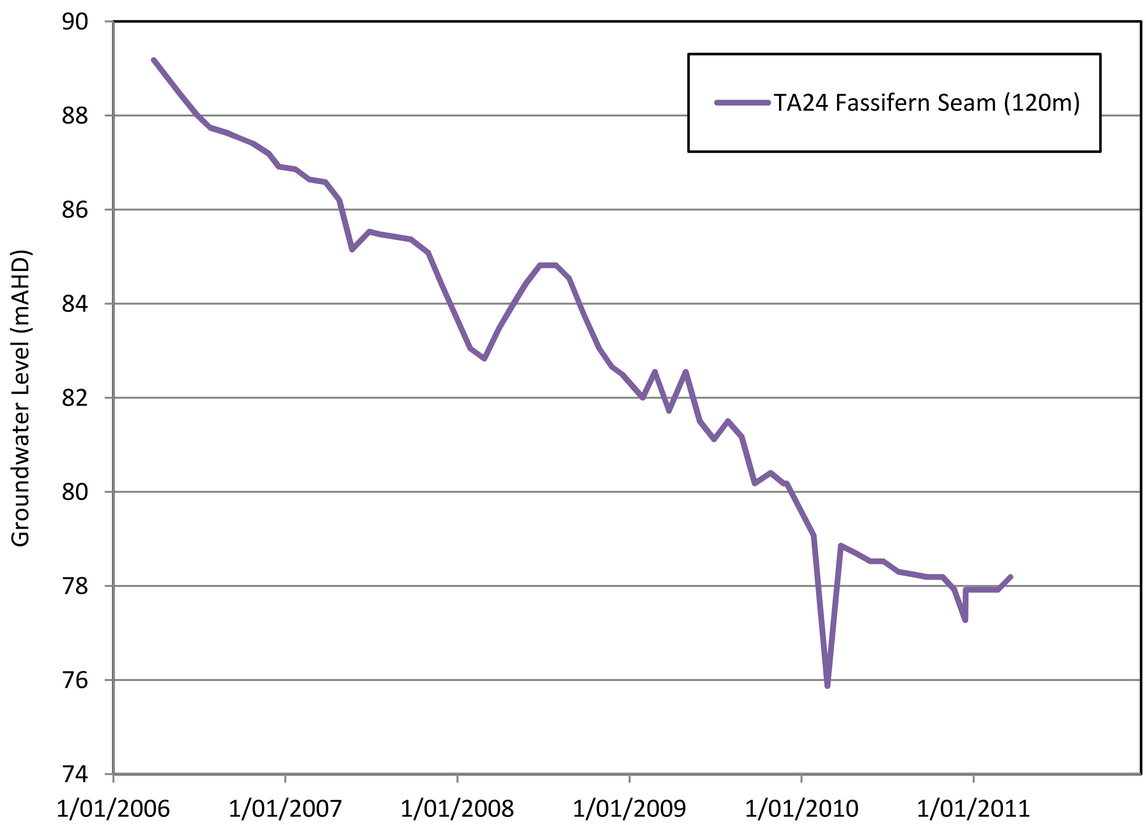


RPS Aquaterra

C078A, C078B, C082 and C087 Hydrographs FIGURE 4.10

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[Select_Abel_bores.xlsx]Fig_4.10





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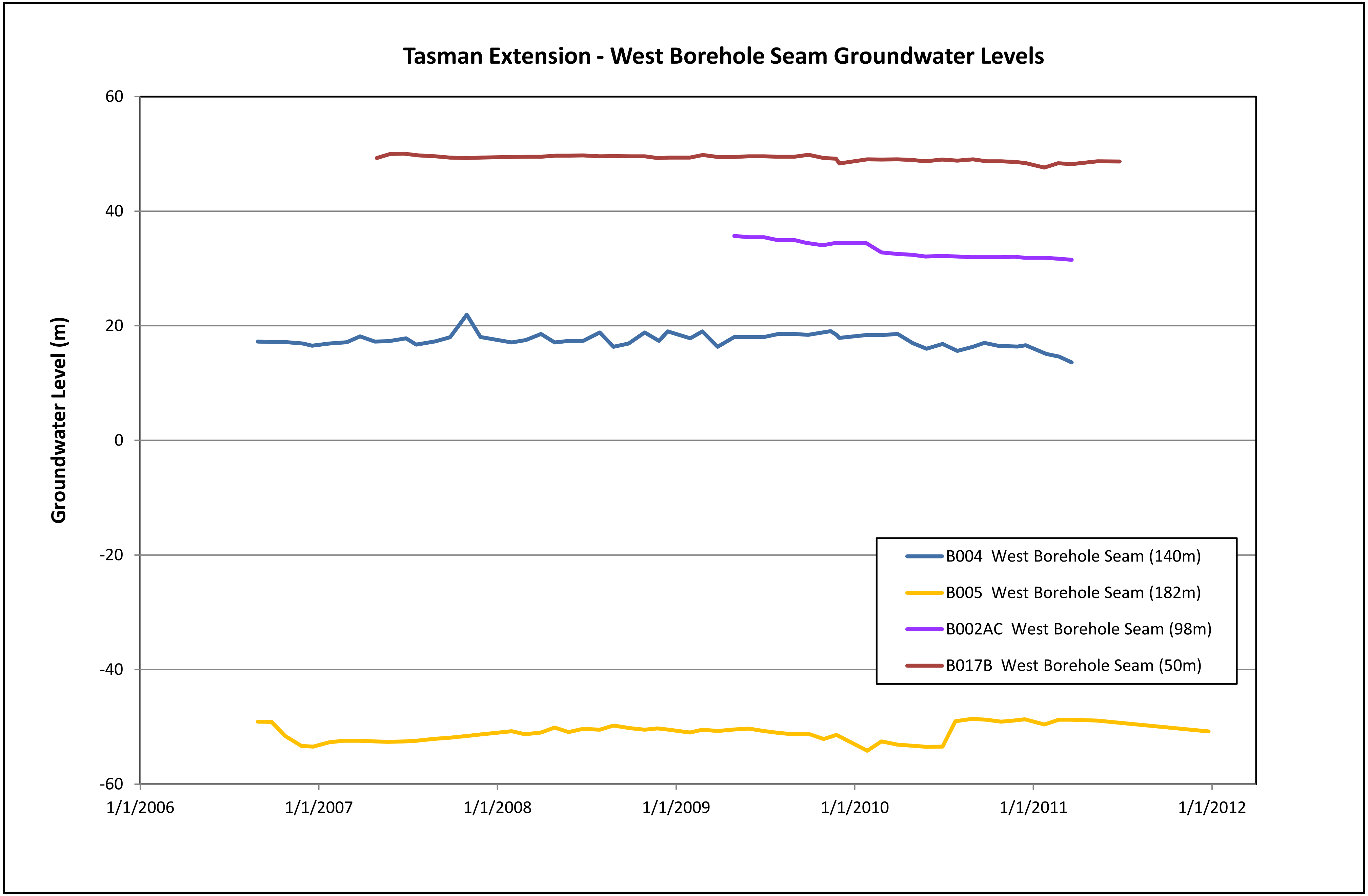
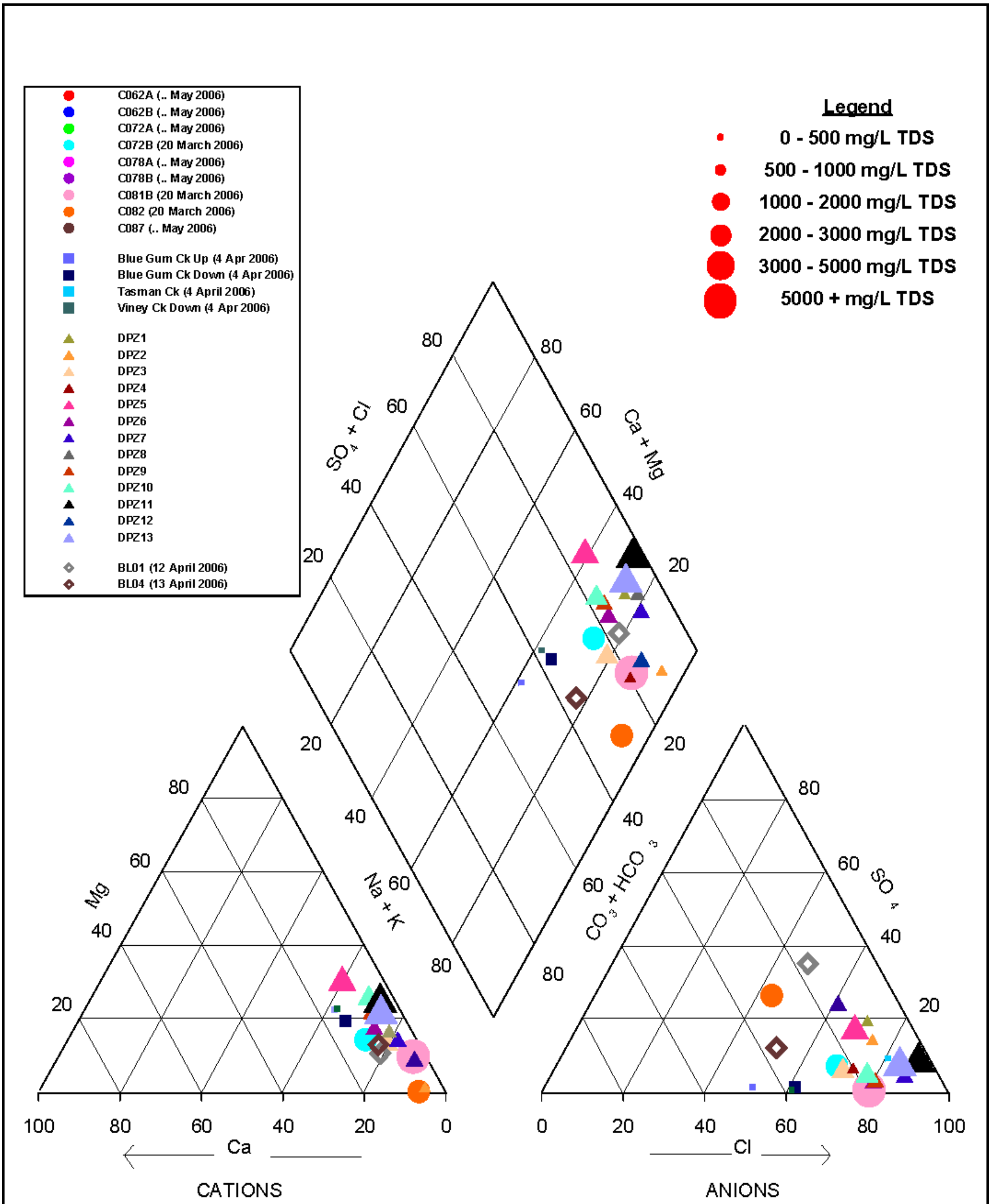
TA23 & TA24 Hydrographs FIGURE 4.11

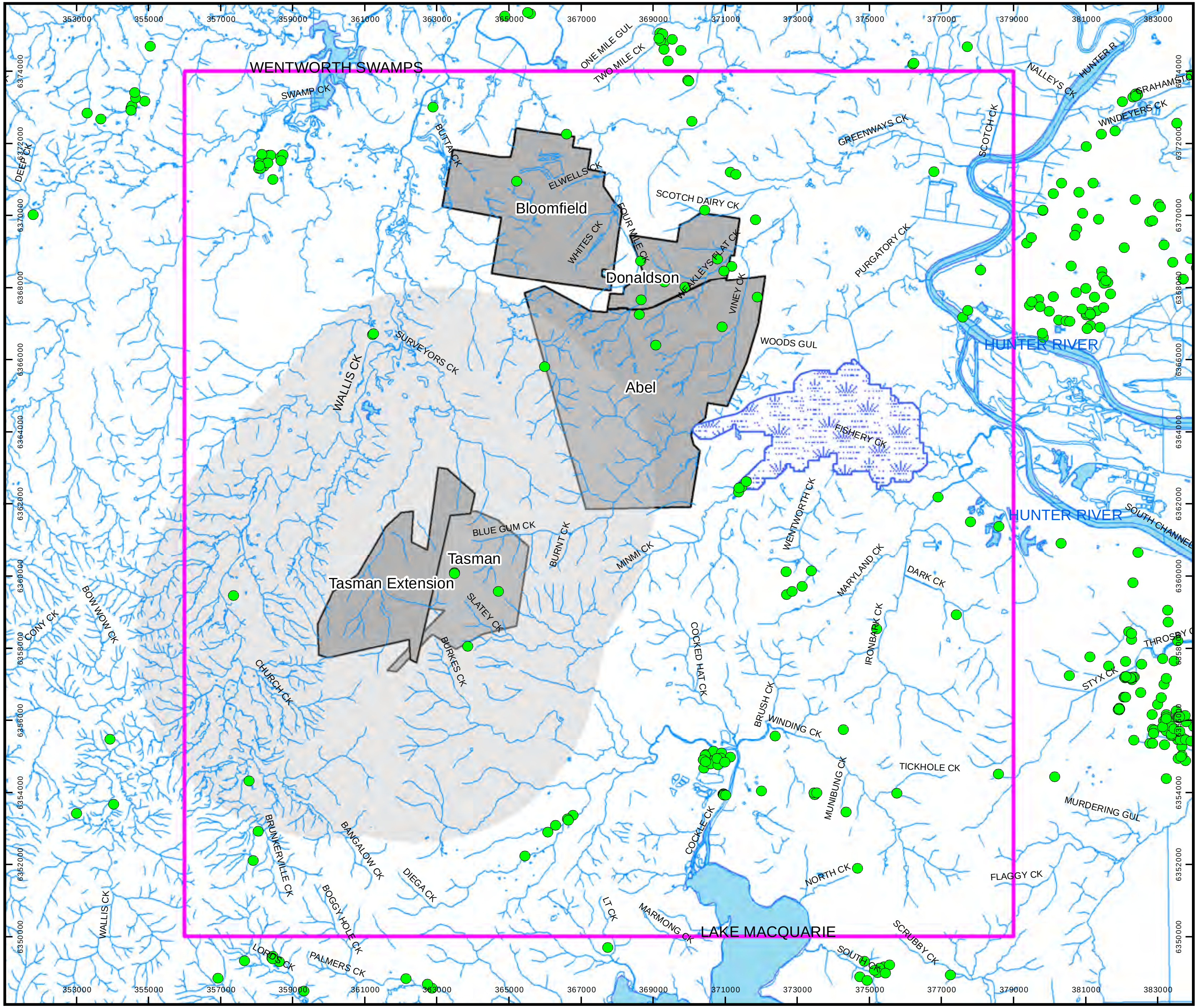
F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v2.xlsx]4.11

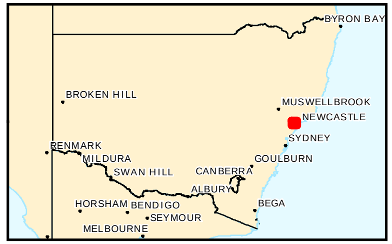


Tasman Extension - West Borehole Seam Groundwater Levels
Groundwater Level (m)
60
40
20
0
-20
-40
-60
1/1/2006
1/1/2007
1/1/2008
1/1/2009
1/1/2010
1/1/2011
1/1/2012
B004 West Borehole Seam (140m)
B005 West Borehole Seam (182m)
B002AC West Borehole Seam (98m)
B017B West Borehole Seam (50m)



C062A (.. May 2006)
C062B (.. May 2006)
C072A (.. May 2006)
C072B (20 March 2006)
C078A (.. May 2006)
C078B (.. May 2006)
C081B (20 March 2006)
C082 (20 March 2006)
C087 (.. May 2006)
Blue Gum Ck Up (4 Apr 2006)
Blue Gum Ck Down (4 Apr 2006)
Tasman Ck (4 April 2006)
Viney Ck Down (4 Apr 2006)
DPZ1
DPZ2
DPZ3
DPZ4
DPZ5
DPZ6
DPZ7
DPZ8
DPZ9
DPZ10
DPZ11
DPZ12
DPZ13
BL01 (12 April 2006)
BL04 (13 April 2006)
Legend
0 - 500 mg/L TDS
500 - 1000 mg/L TDS
1000 - 2000 mg/L TDS
2000 - 3000 mg/L TDS
3000 - 5000 mg/L TDS
5000 + mg/L TDS
SO4 + Cl
Ca + Mg
Mg
Na + K
CO3 + HCO3
SO4
Ca
Cl
CATIONS
ANIONS





LEGEND

- Registered Bores
- Hexham Swamp
- Model Area
- Rivers or Creeks
- 5 km Radius from Tasman Extension
- Mine Lease

2,000 0 2,000 4,000

Metres

APPROX SCALE 1:150,000 @ A4

GDA 1994 MGA Zone 56

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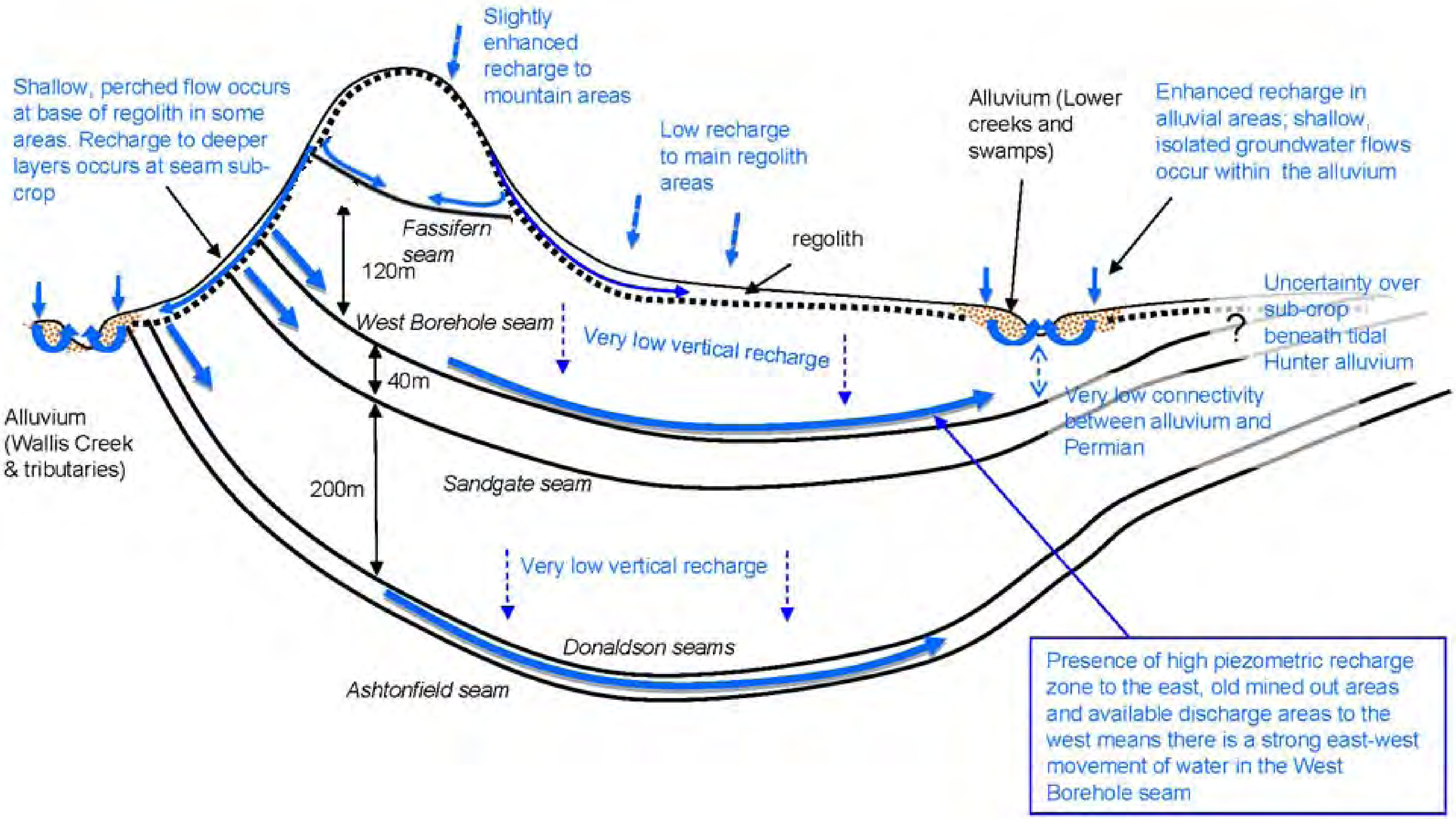
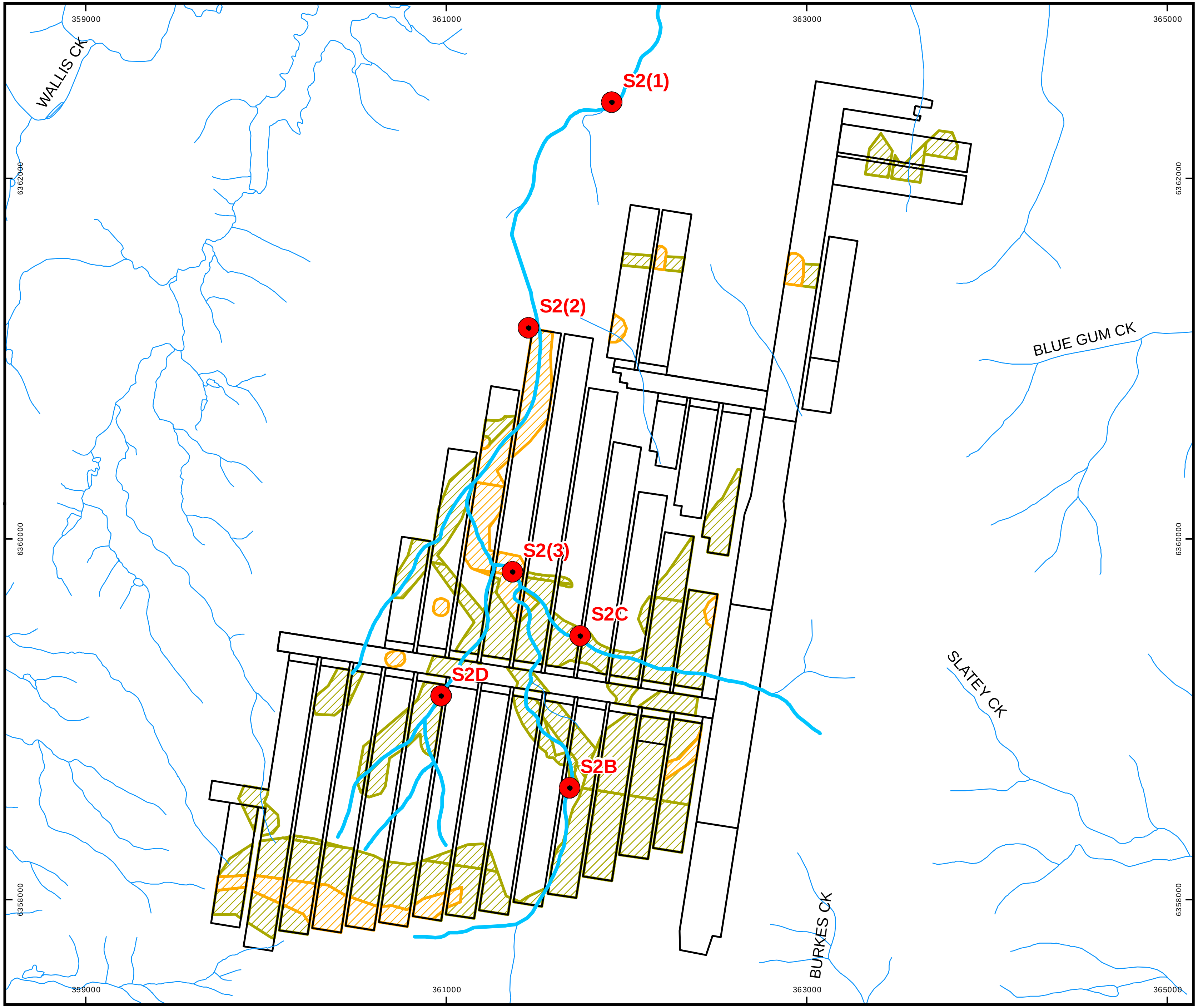
FIGURE 4.14

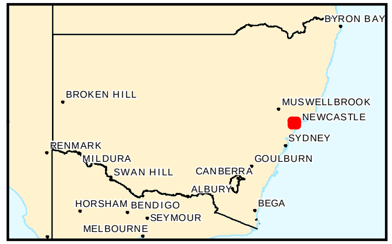
Water Bodies and Registered Bores

S35_009a Rev: A Produced: HZ Reviewed: AF Date: 10/04/2012



Date	09/03/2012	Scale	As Shown	**Donaldson Coal Pty Ltd**
Initials	HZ	Project	S35	**Conceptual Model Cross Section**
Drawing Number	S35-017	Revision	A	
RPS Aquaterra				**Figure 5.1**





LEGEND

- Surface Water Modelling Location
- Surveyors Creek
- River or Creek
- Tasman Extension Mine Plan
- First Workings Only
- Partial Pillar Extraction

N

400 0 400 800

Metres

APPROX SCALE 1:30,000 @ A4

GDA 1994 MGA Zone 56

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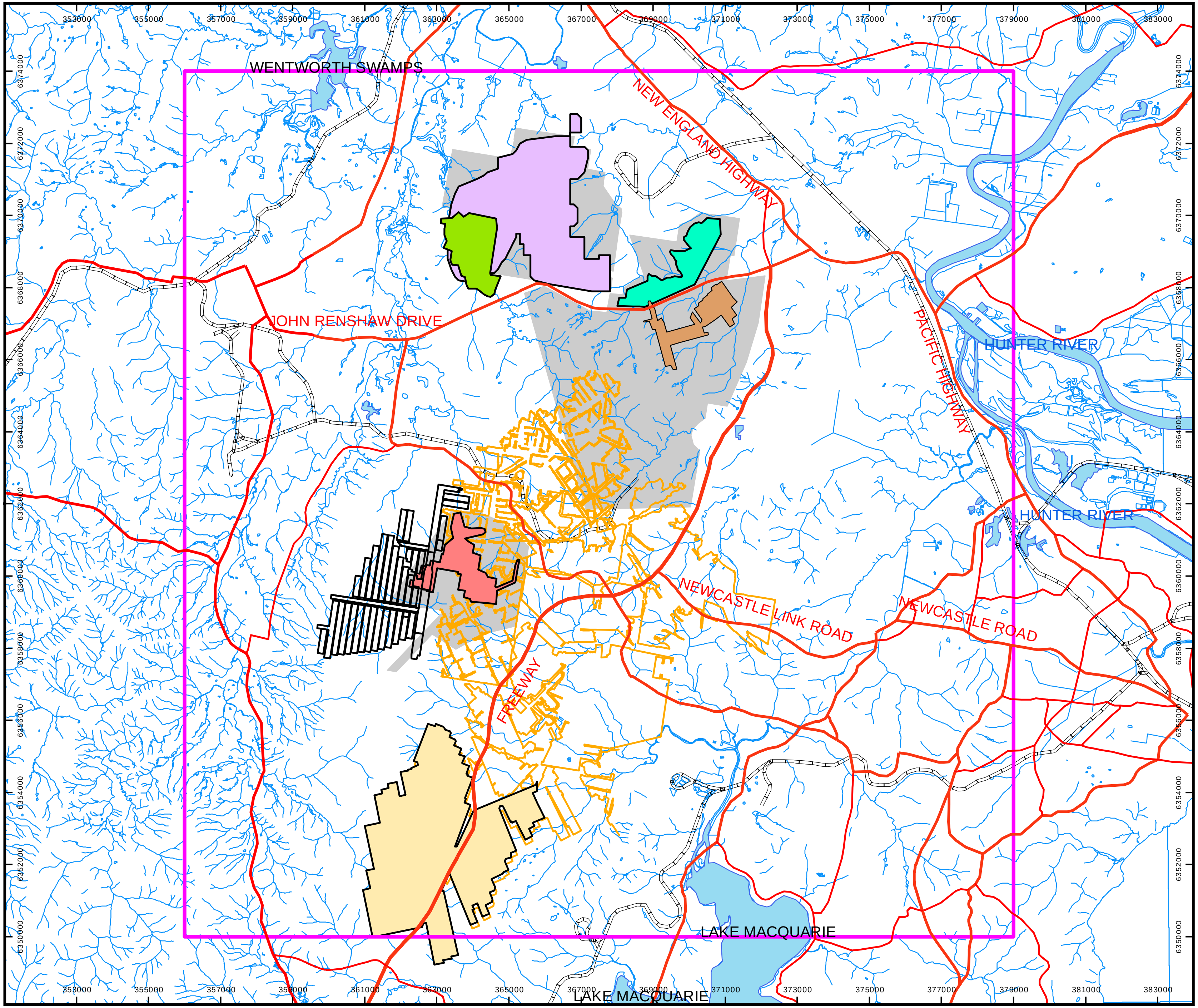
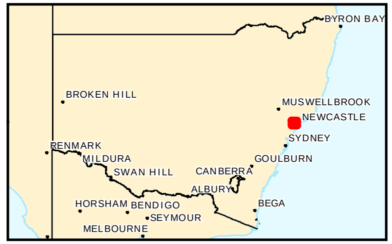
FIGURE 5.2

Surveyors Creek **Drainage and** Subsidence Control Zones

S35_013a Rev: A Produced: HZ Reviewed: PD Date: 14/05/2012





LEGEND

- Model Area
- Tasman Extension Mine Plan
- West Wallsend Underground Mine
- Current Abel Underground Mine
- Current Donaldson Open Cut Mine
- Current Bloomfield Open Cut Mine
- Historical Bloomfield Mine Workings
- Current Tasman Underground Mine
- Historical West Borehole Workings
- Railway
- River or Creek
- Mine Lease

N

2,000 0 2,000 4,000

Metres

APPROX SCALE 1:150,000 @ A4

GDA 1994 MGA Zone 56

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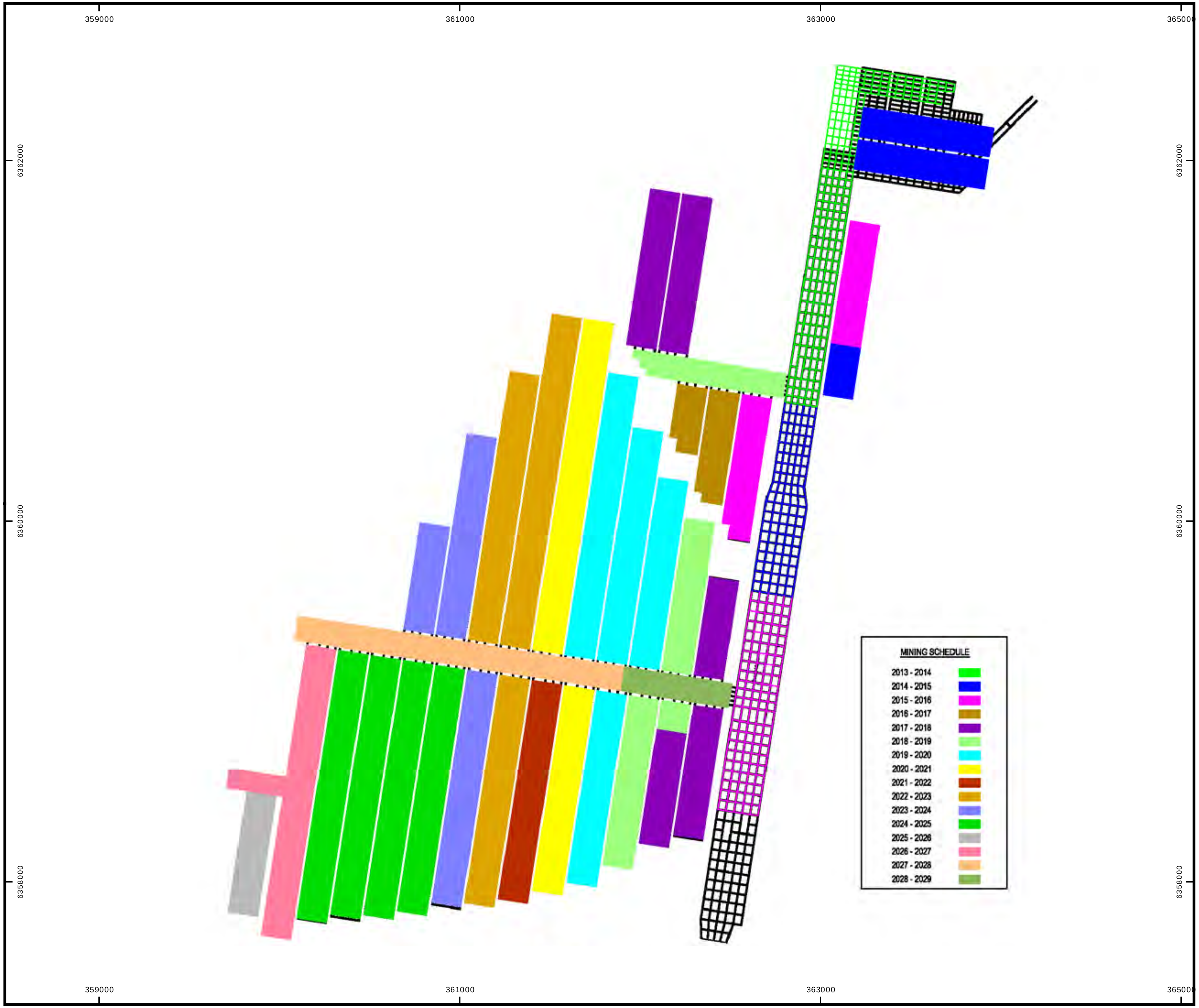
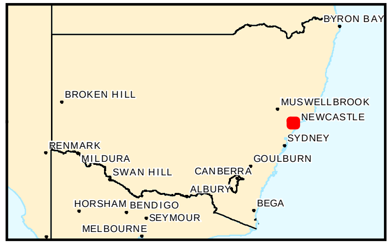
FIGURE 5.3

Historical And Active Mine Areas

S35_010a Rev: A Produced: HZ Reviewed: AF Date: 10/04/2012





N

400 0 400 800

Metres

APPROX SCALE 1:30,000 @ A4

GDA 1994 MGA Zone 56

Disclaimer: While all reasonable care has been taken to ensure the information contained on this map is up to date and accurate, no guarantee is given that the information portrayed is free from error or omission. Please verify the accuracy of all information prior to use.

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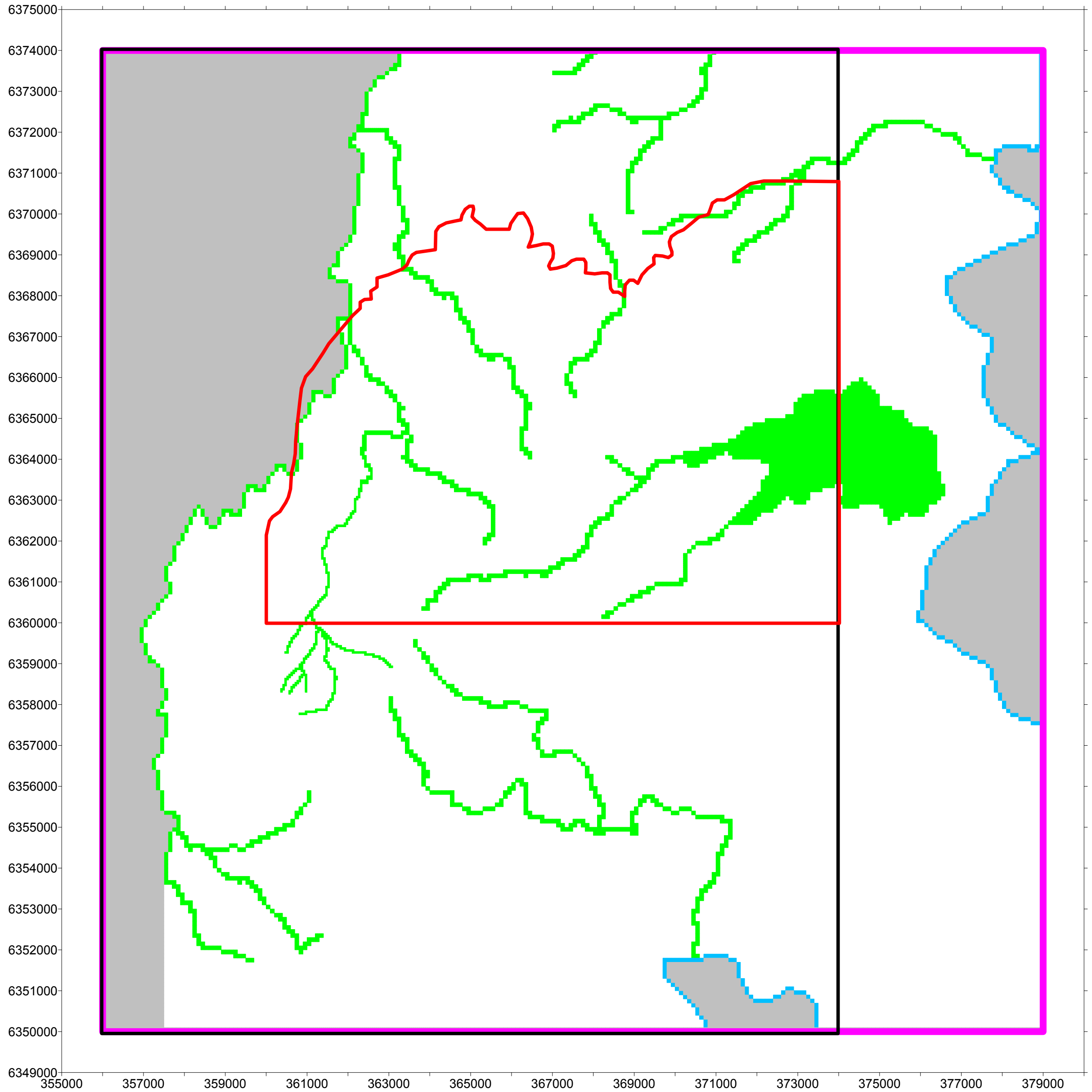
FIGURE 6.1

Tasman Extension Mining Schedule

S35_012a Rev: A Produced: HZ Reviewed: AF Date: 10/04/2012



Rivers or Creeks

No Flow

General Head Boundary

Current Model Boundary

Abel Bloomfield Model Boundary

Donaldson Regional Model Boundary

Date	**22/03/2012**	Scale	**As Shown**
Initials	**HZ**	Project	**S35**
Drawing Number	**S35-015**	Revision	**A**

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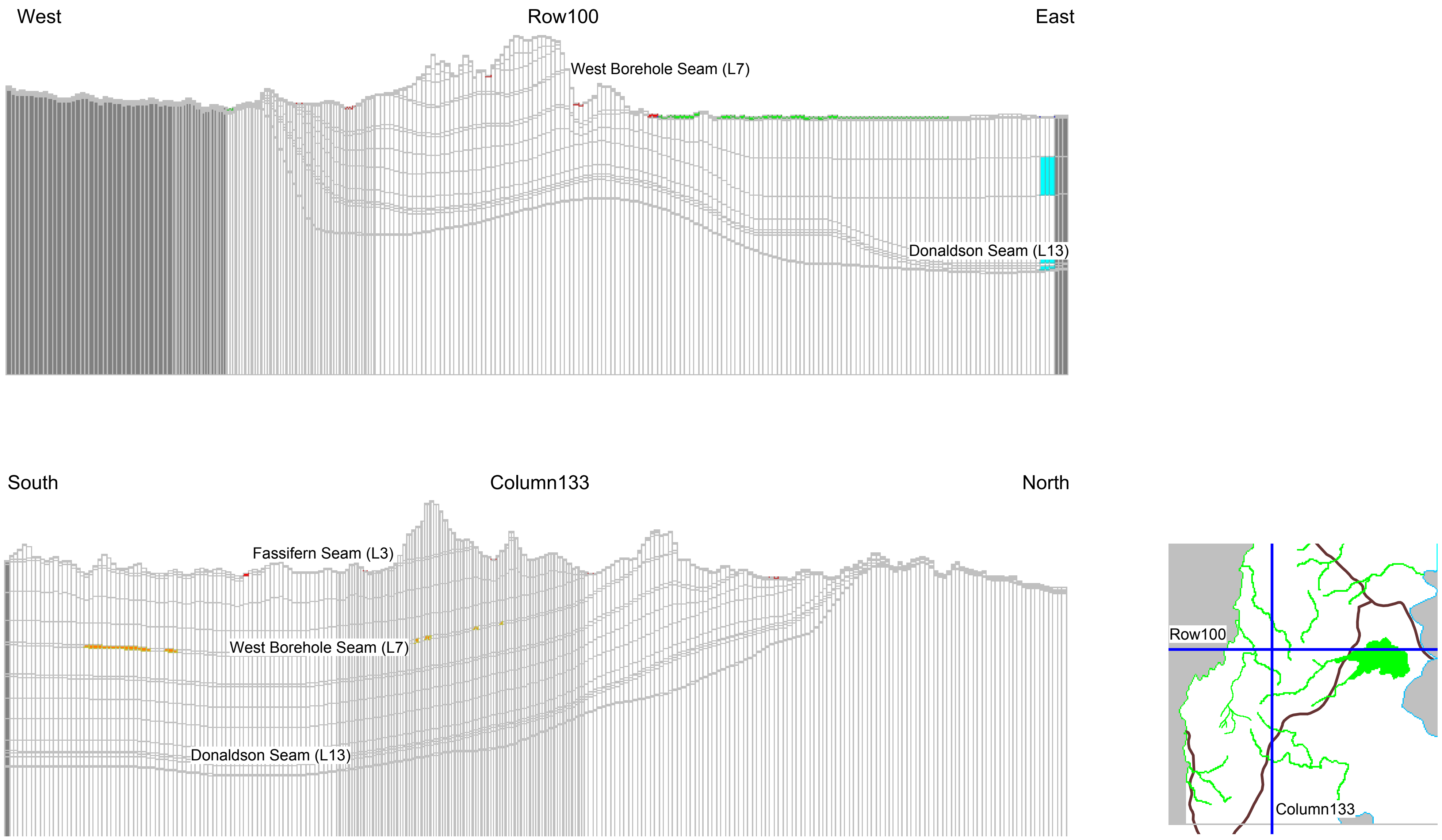
Donaldson Coal Pty Ltd

Model Domain
Model Boundaries

Figure 7.1



- Drains
- Rivers or Creeks
- No Flow
- General Head Boundary
- Main Road

Date	09/03/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-016	Revision	A

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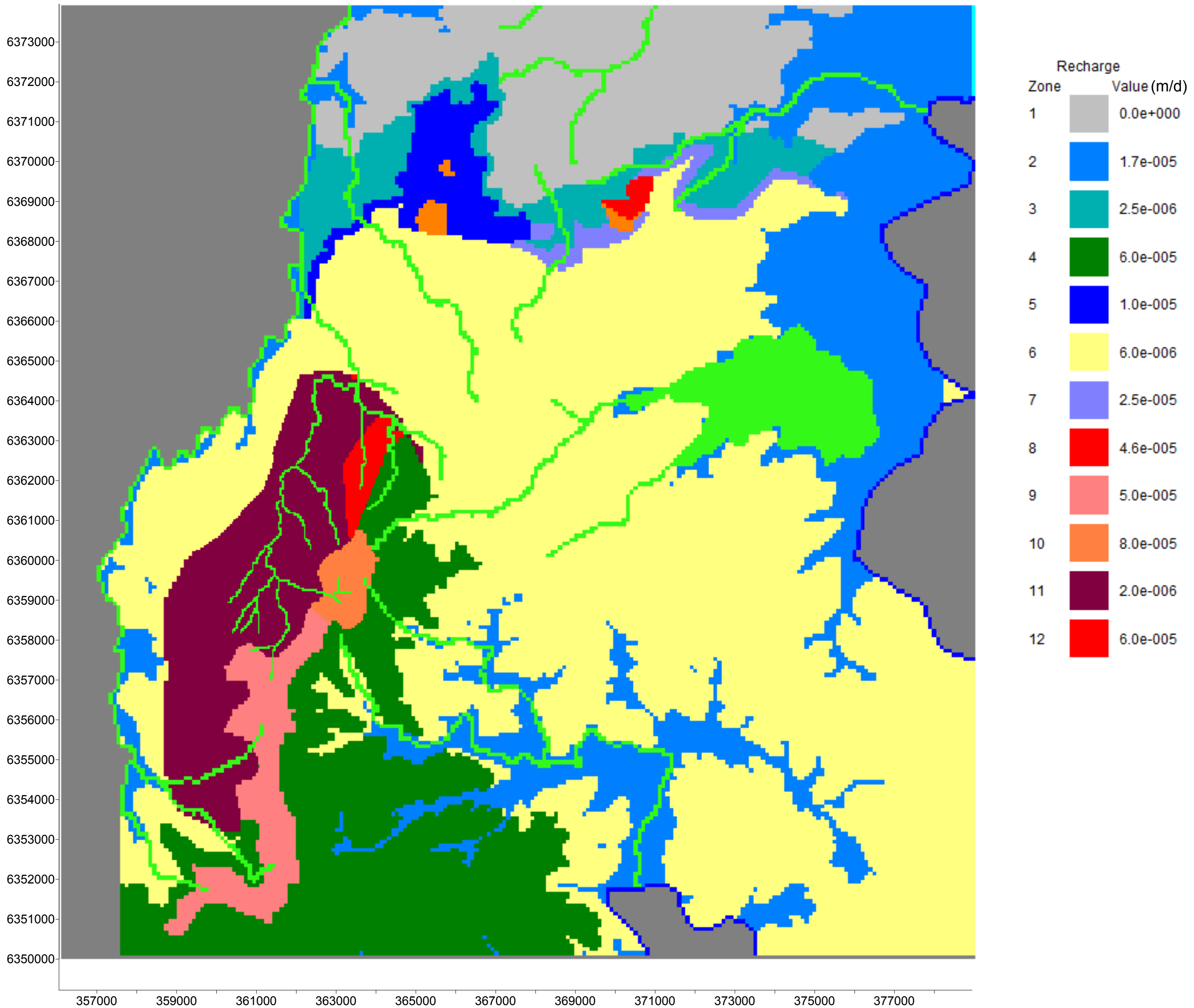
Donaldson Coal Pty Ltd

Model Cross Sections

Figure 7.2



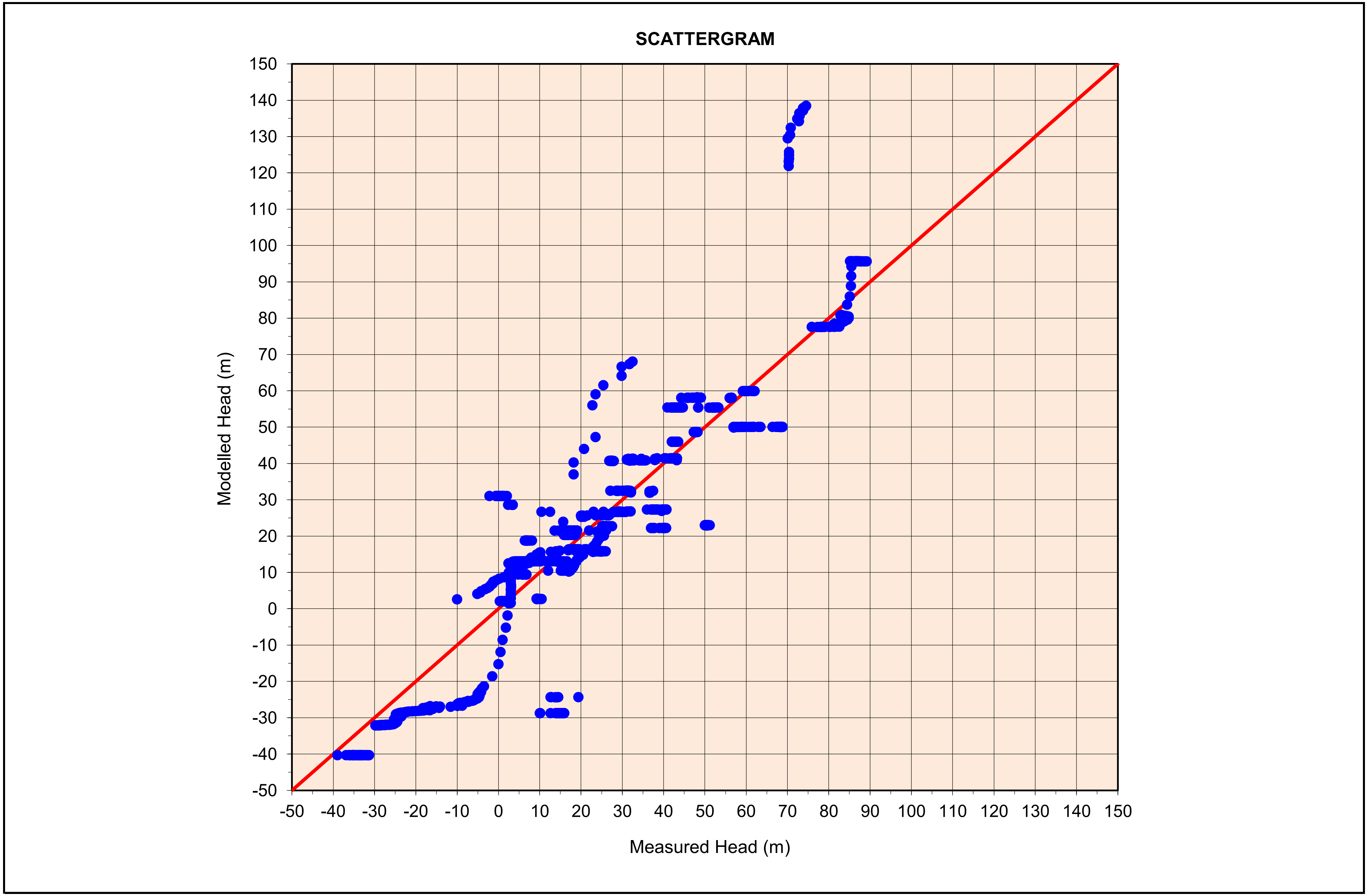
Date	12/03/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-026	Revision	A

RPS Aquaterra

Donaldson Coal Pty Ltd

Model Recharge Zones

Figure 7.3



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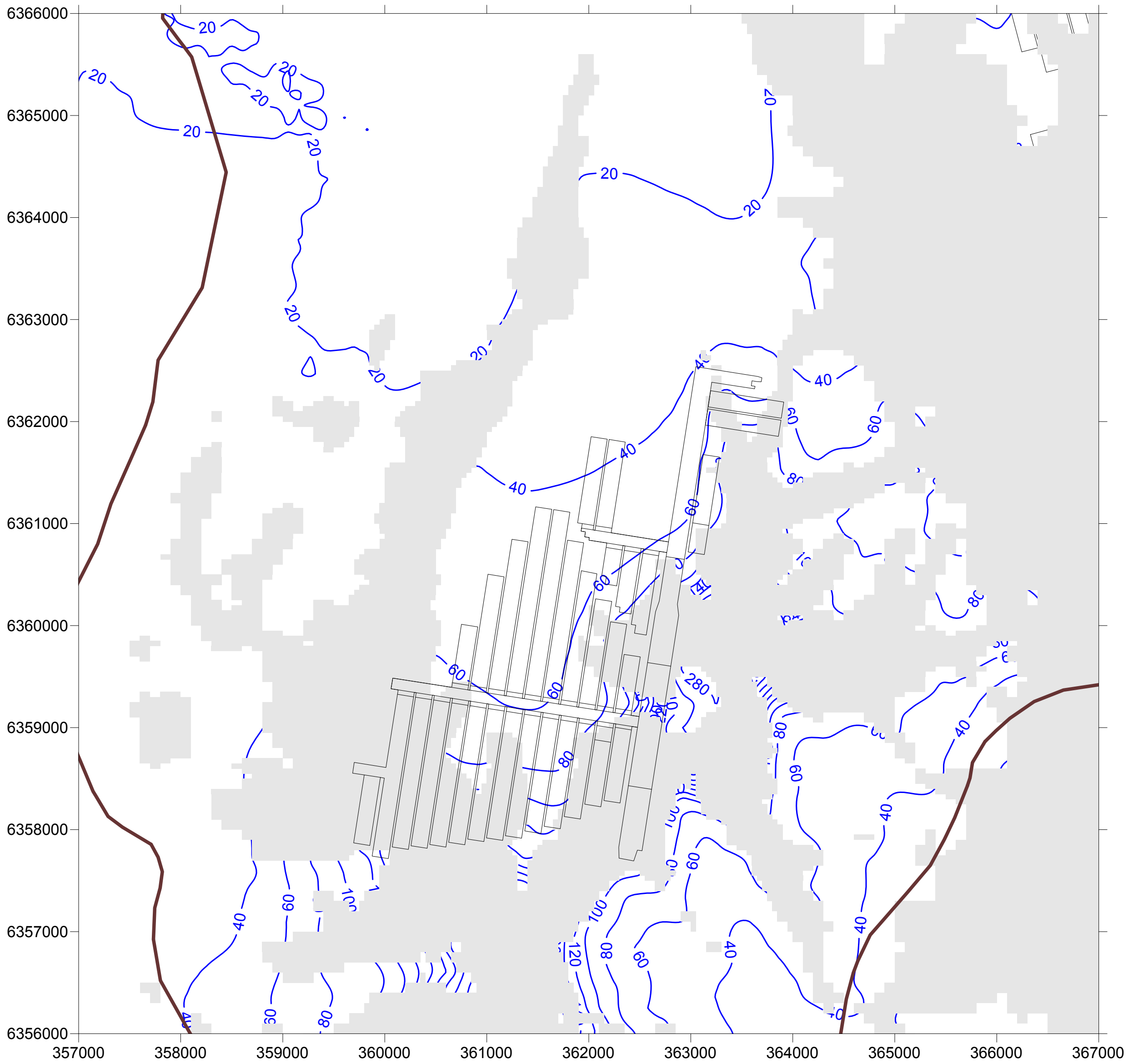
Scatter Diagram of Measured Versus Modelled Potentiometric Head FIGURE 7.4

F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[scatter_diagram.xlsx]F7.4



Mine Plan

Main Road

Dry Cells

Predicted Groundwater Levels (mAHD)

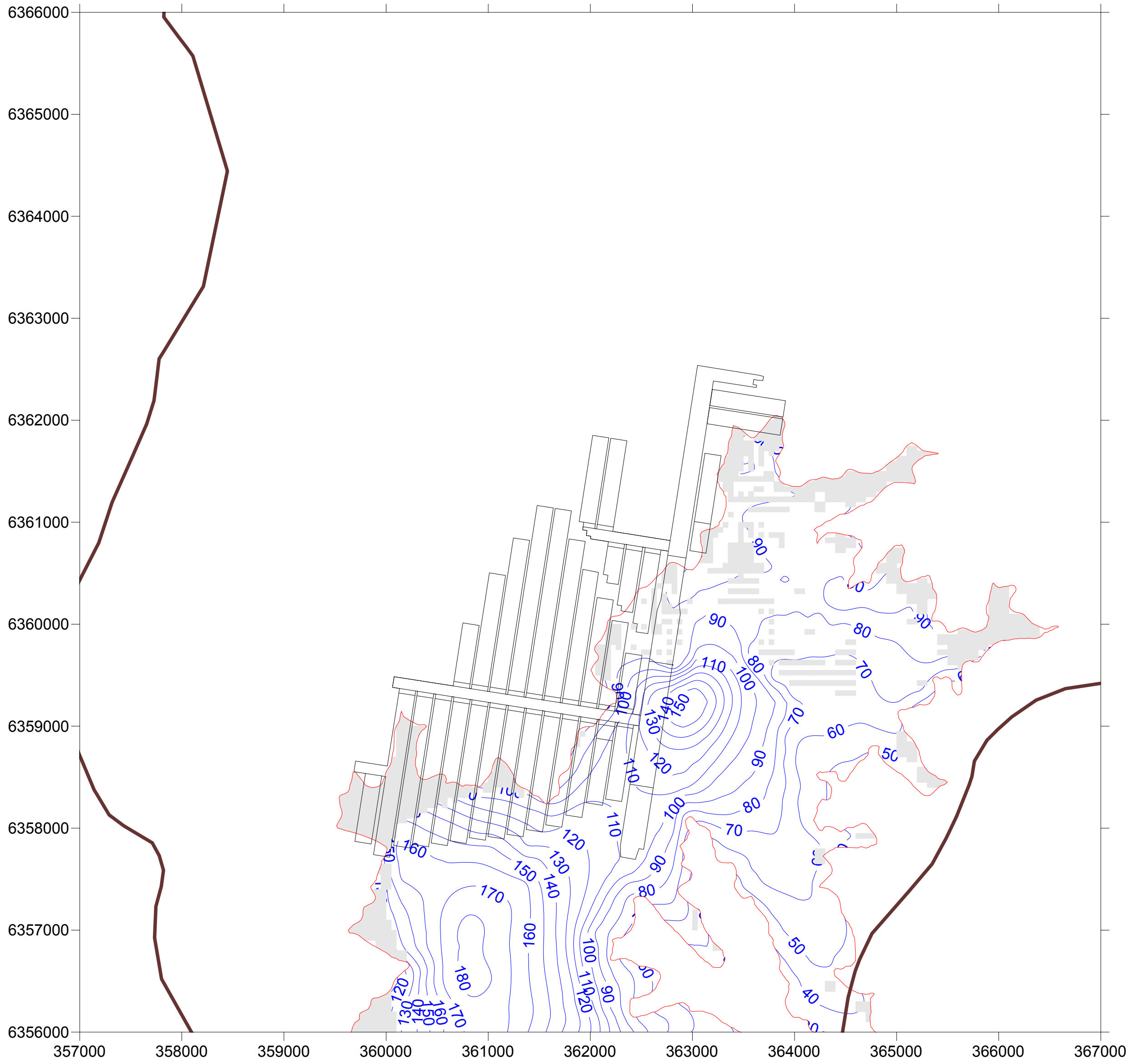
Date	13/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-018a	Revision	A

RPS Aquaterra

Donaldson Coal Pty Ltd

Calibrated Heads in Alluvium / Colluvium/Regolith (Layer 1) Prior to Tasman Extension Mining

Figure 7.5



Mine Plan

Main Road

Dry Cells

Predicted Groundwater Levels (mAHD)

Boundary of Fassifern Seam

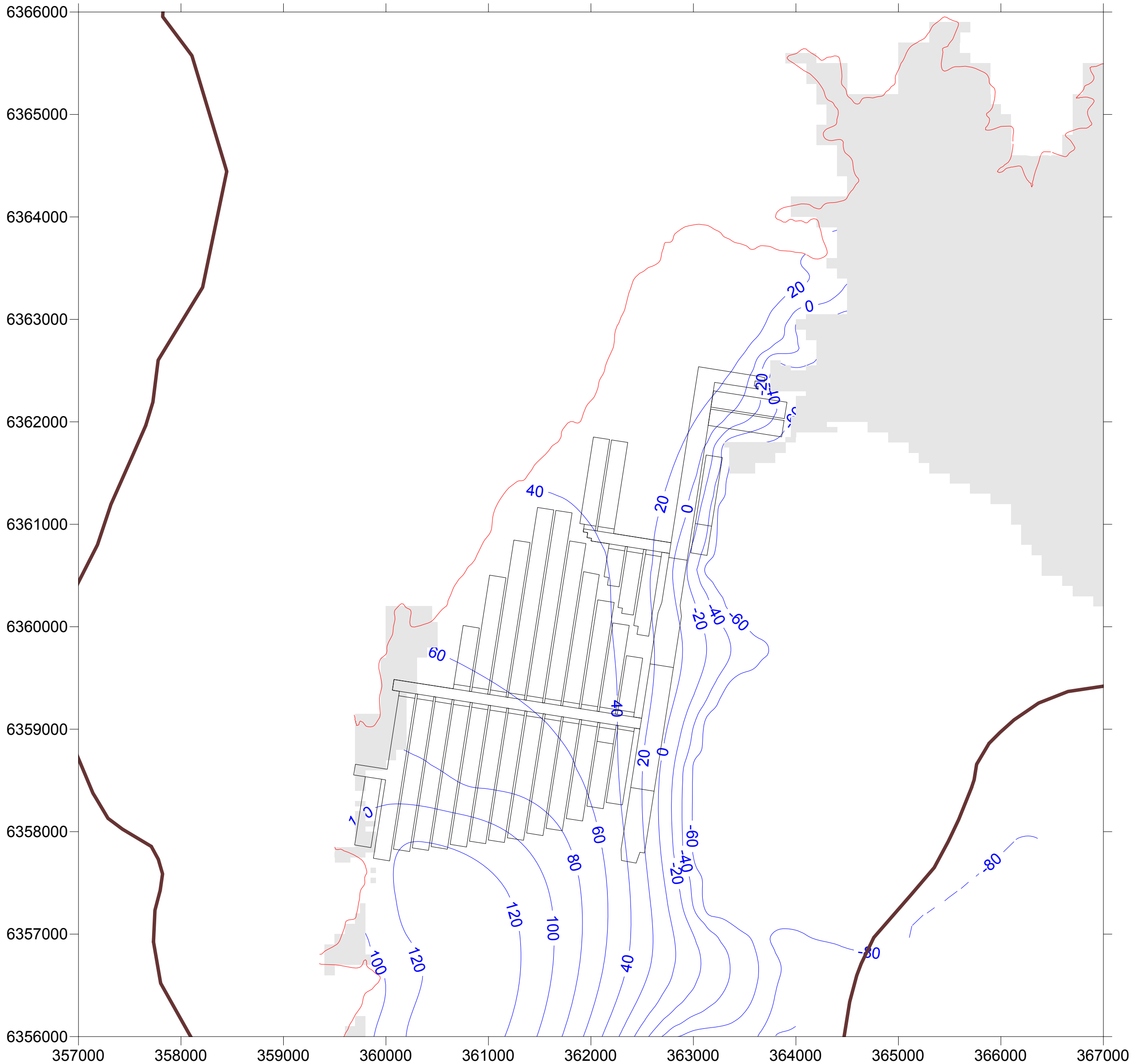
Date	23/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-019a	Revision	A

RPS Aquaterra

Donaldson Coal Pty Ltd

Calibrated Heads in Fassifern Seam (Layer 3) Prior to Tasman Extension Mining

Figure 7.6



Date	23/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-020a	Revision	A

Mine Plan

Main Road

Dry Cells

50 Predicted Groundwater Levels (mAHD)

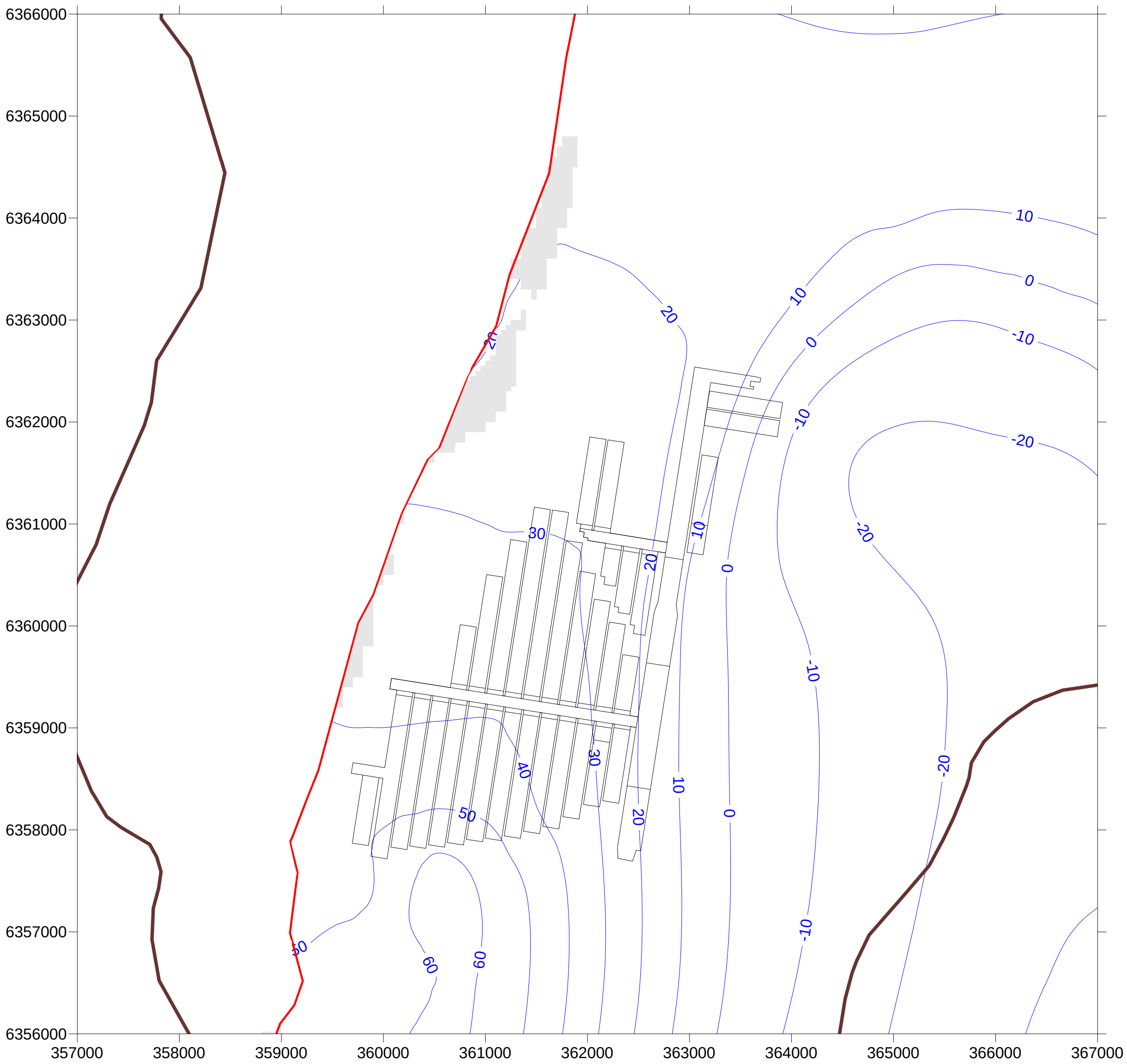
Boundary of West Borehole Seam

RPS Aquaterra

Donaldson Coal Pty Ltd

Calibrated Heads in West Borehole Seam (Layer 7)
Prior to Tasman Extension Mining

Figure 7.7



Mine Plan	Boundary of Donaldson Seam
Main Road	
Dry Cells	
Predicted Groundwater Levels (mAHD)	

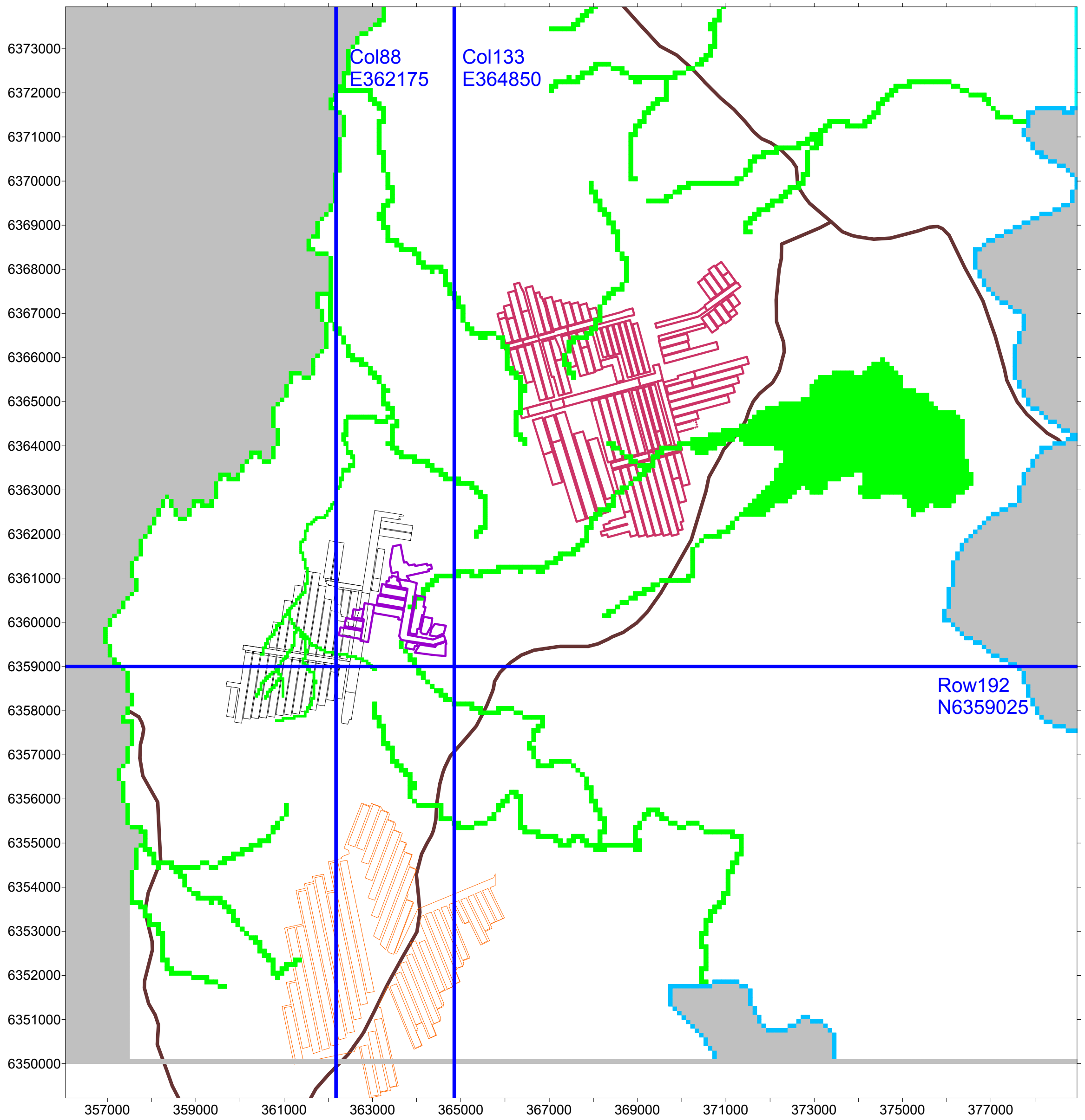
Date	**23/04/2012**	Scale	**As Shown**
Initials	**HZ**	Project	**S35**
Drawing Number	**S35-021a**	Revision	**A**

RPS Aquaterra

Donaldson Coal Pty Ltd

Calibrated Heads in Lower Donaldson Seam (Layer 15)
Prior to Tasman Extension Mining

Figure 7.8



Rivers or Creeks	Tasman Extension Mine Plan		
No Flow	Current Tasman Mine		
General Head Boundary	Donaldson / Abel Mine Plan		
Main Road	West Wallsend Mine Plan		

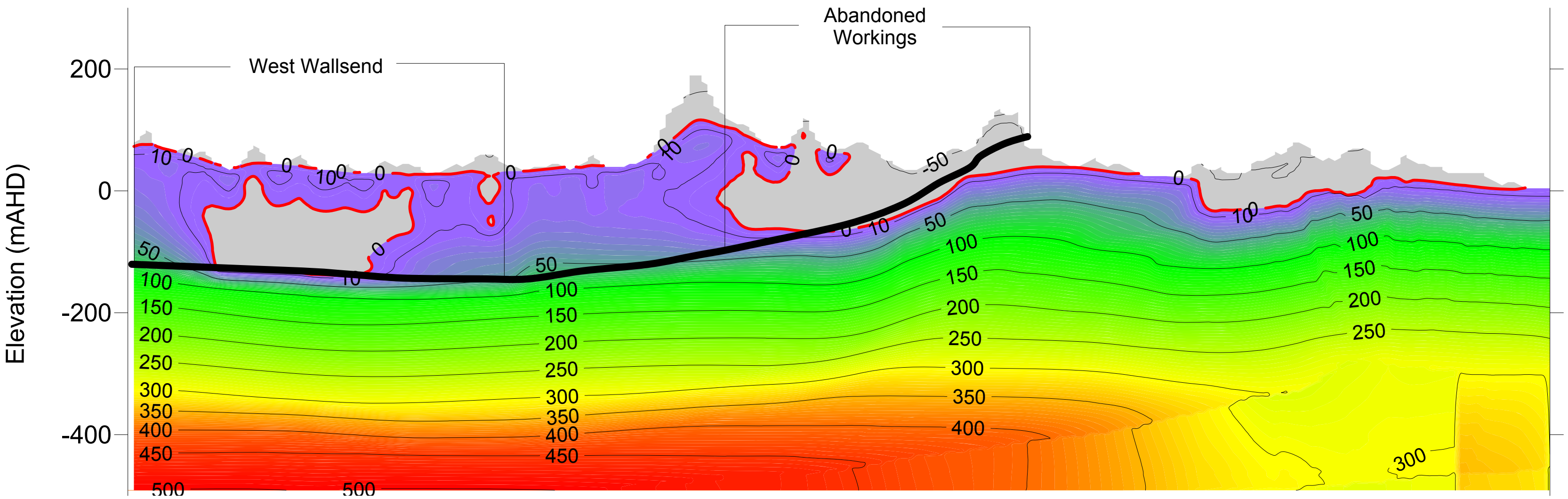
Date	**14/05/2012**	Scale	**As Shown**
Initials	**HZ**	Project	**S35**
Drawing Number	**S35-007**	Revision	**A**

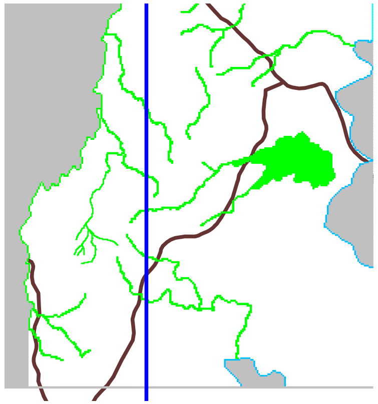
RPS Aquaterra

Donaldson Coal Pty Ltd

Groundwater Model Area
Showing Location of
Pressure Head Cross-Sections

Figure 7.9





West Borehole Seam
Rivers or Creeks
No Flow
General Head Boundary
Main Road

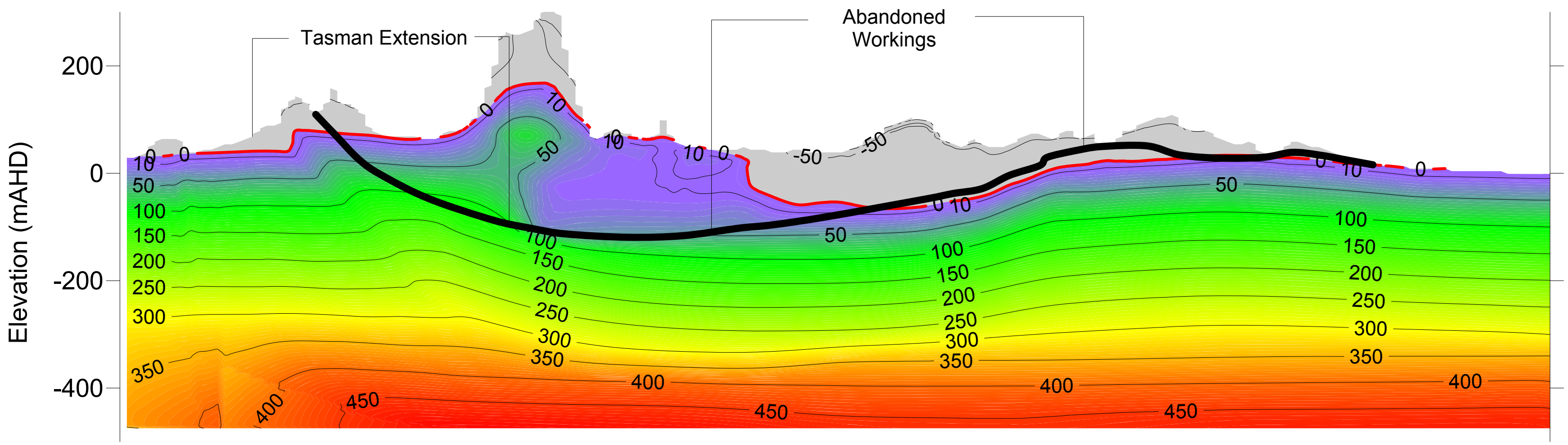
Date	14/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-024a	Revision	A

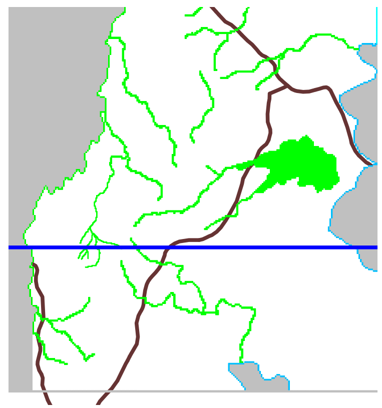
RPS Aquaterra

Donaldson Coal Pty Ltd

Steady State Water Pressure Heads
Along Easting 364850 (Column 133)

Figure 7.10





- West Borehole Seam
- Rivers or Creeks
- No Flow
- General Head Boundary
- Main Road

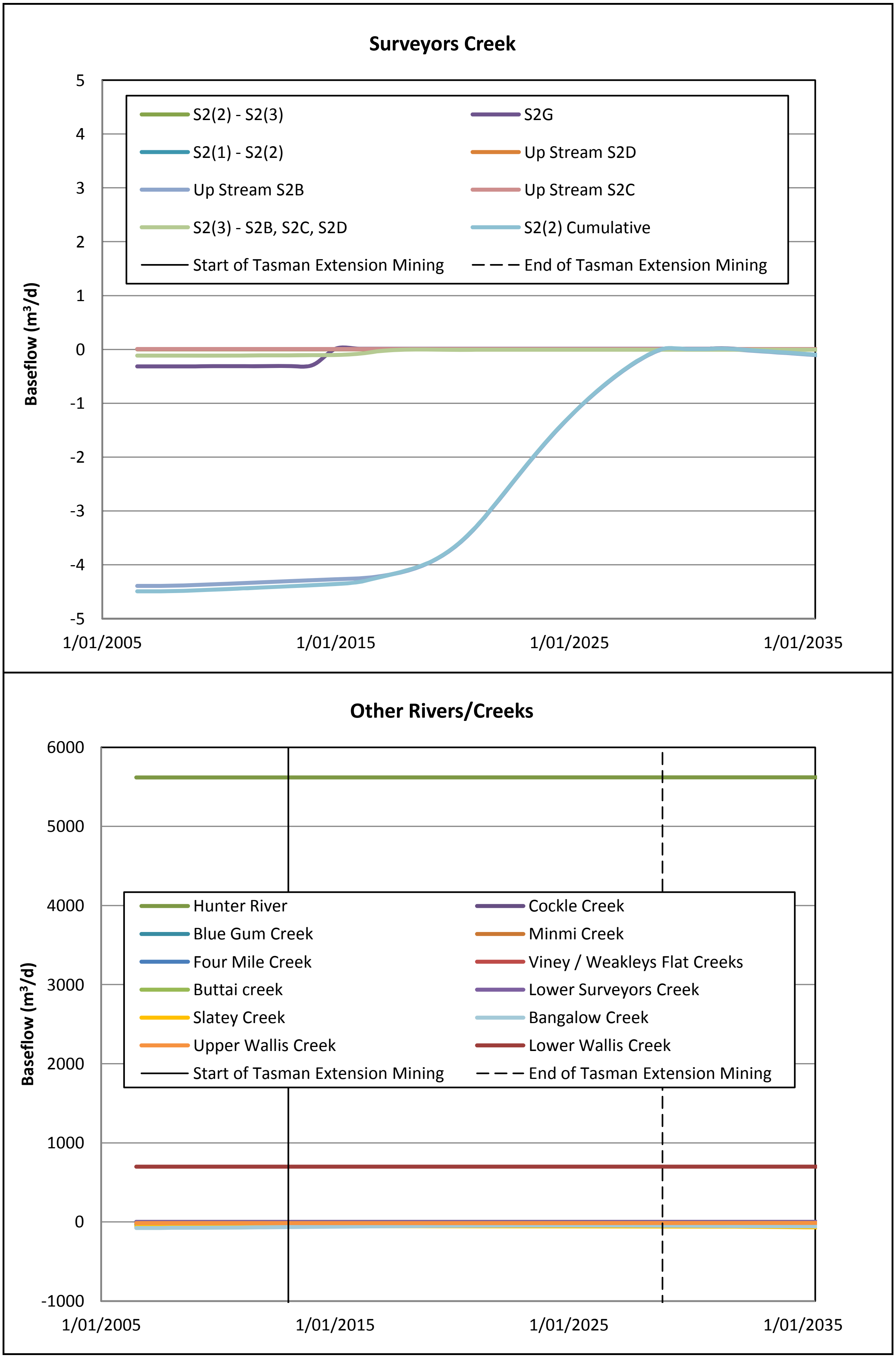
Date	14/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-025a	Revision	A

RPS Aquaterra

Donaldson Coal Pty Ltd

Steady State Water Pressure Heads Along Northing 6359025 (Row 192)

Figure 7.11



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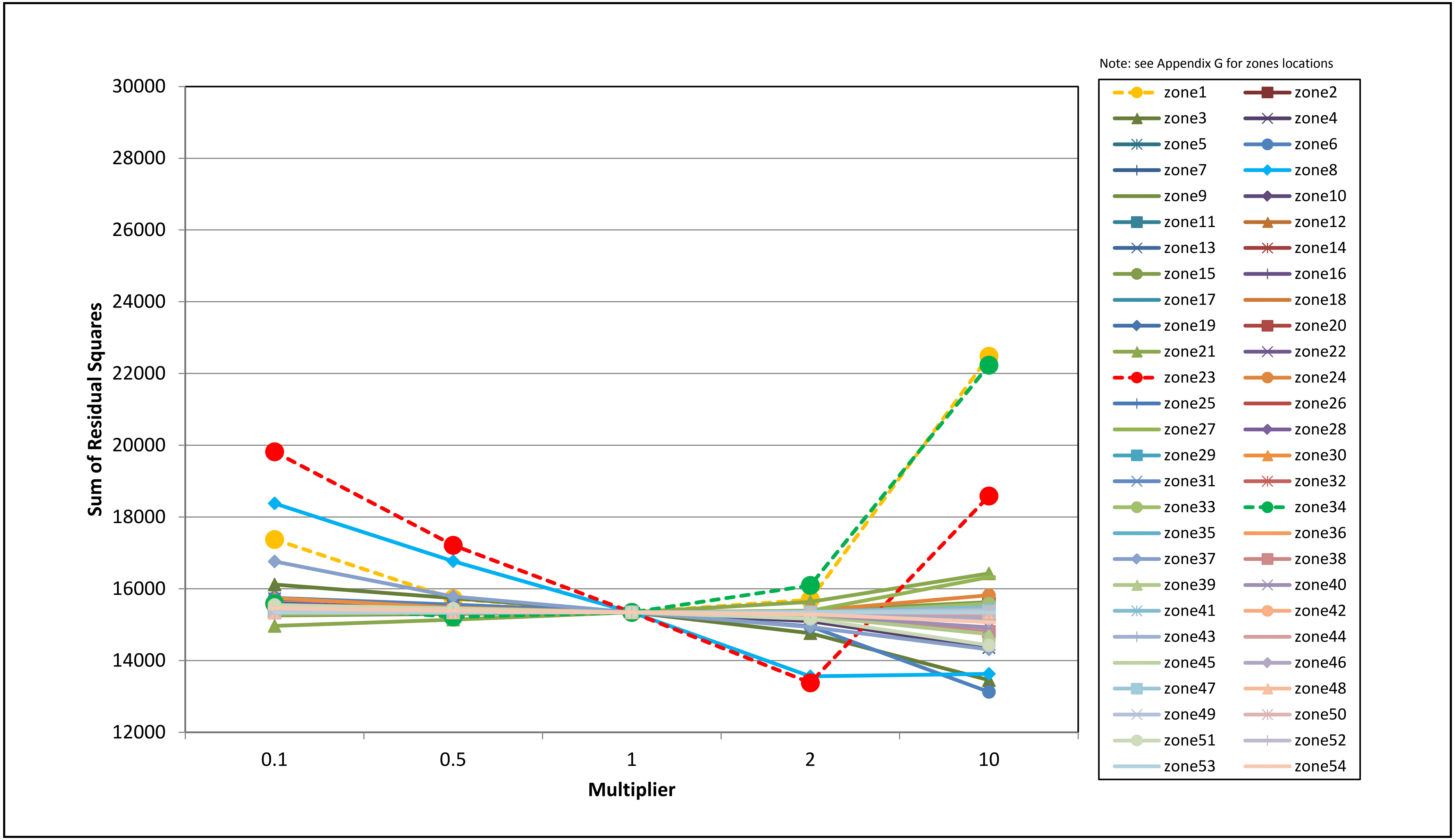
Predicted Modelled Baseflows (to aquifer) FIGURE 7.12

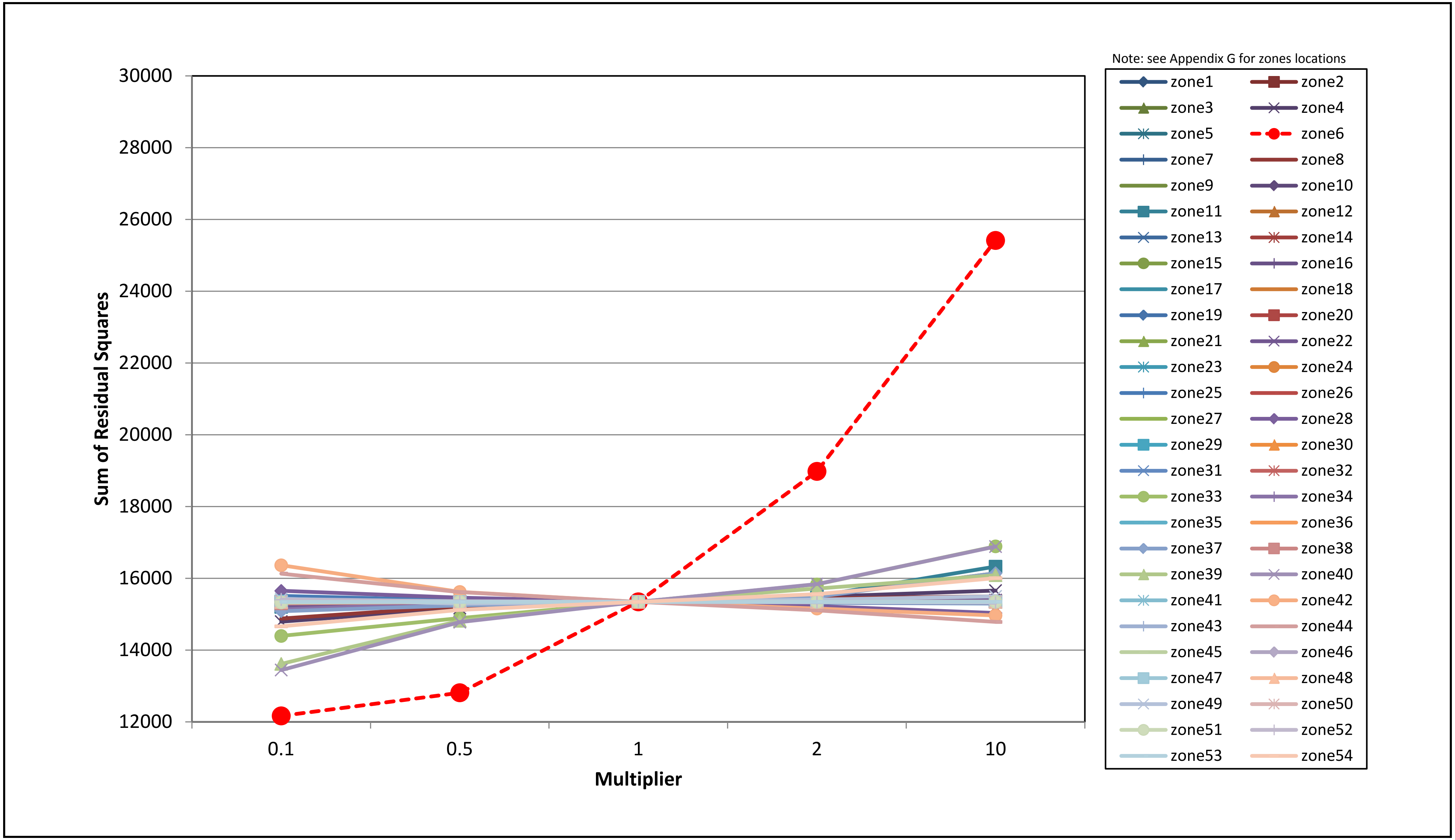
F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v3.xlsx]7.12



RPS Aquaterra

Auto Sensitivity Results for Horizontal Hydraulic Conductivity FIGURE 7.13

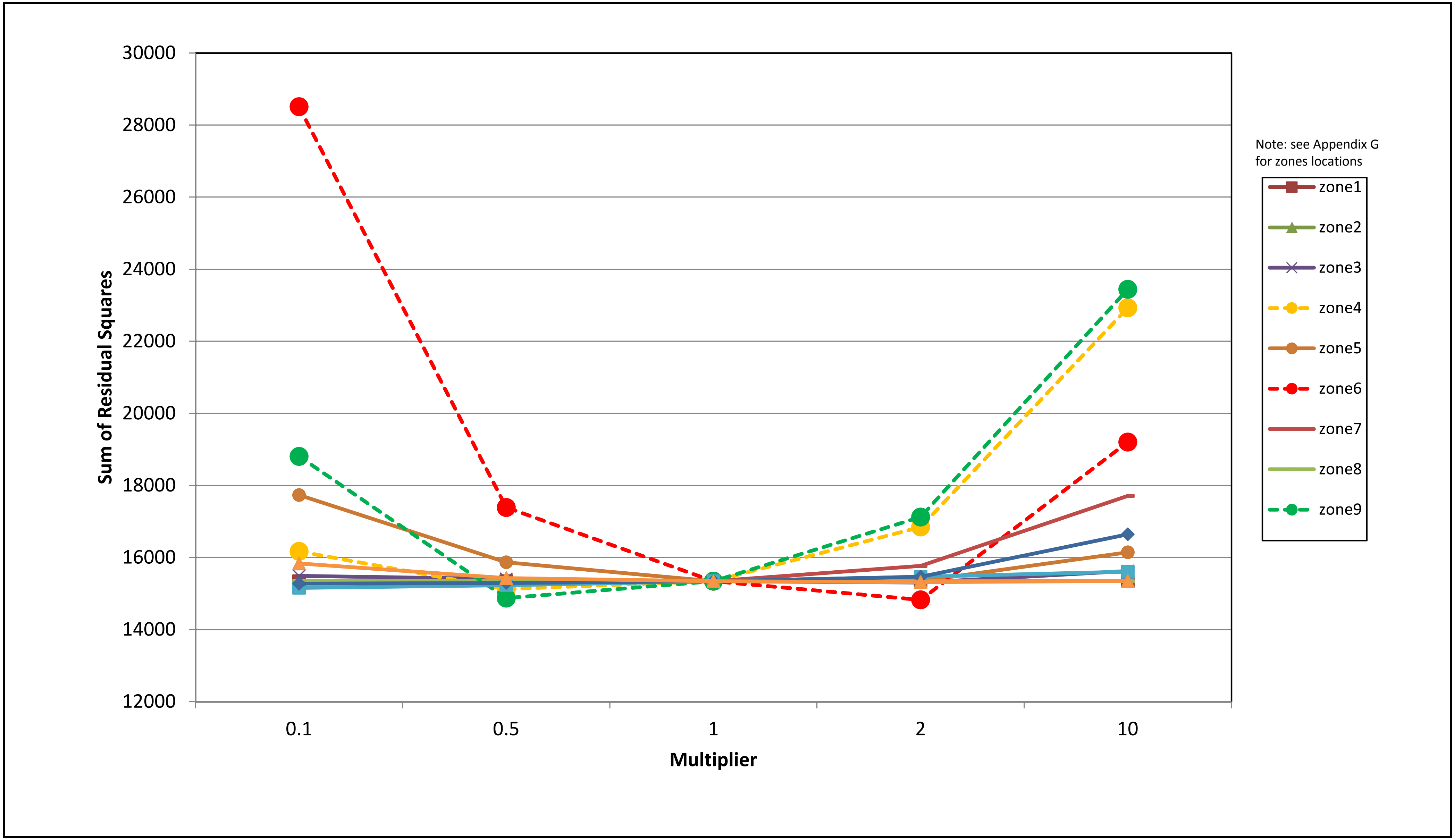
F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\323_Sensitivity\[D9_autosens.xlsx]Kx



RPS Aquaterra

Auto Sensitivity Results for Vertical Hydraulic Conductivity FIGURE 7.14

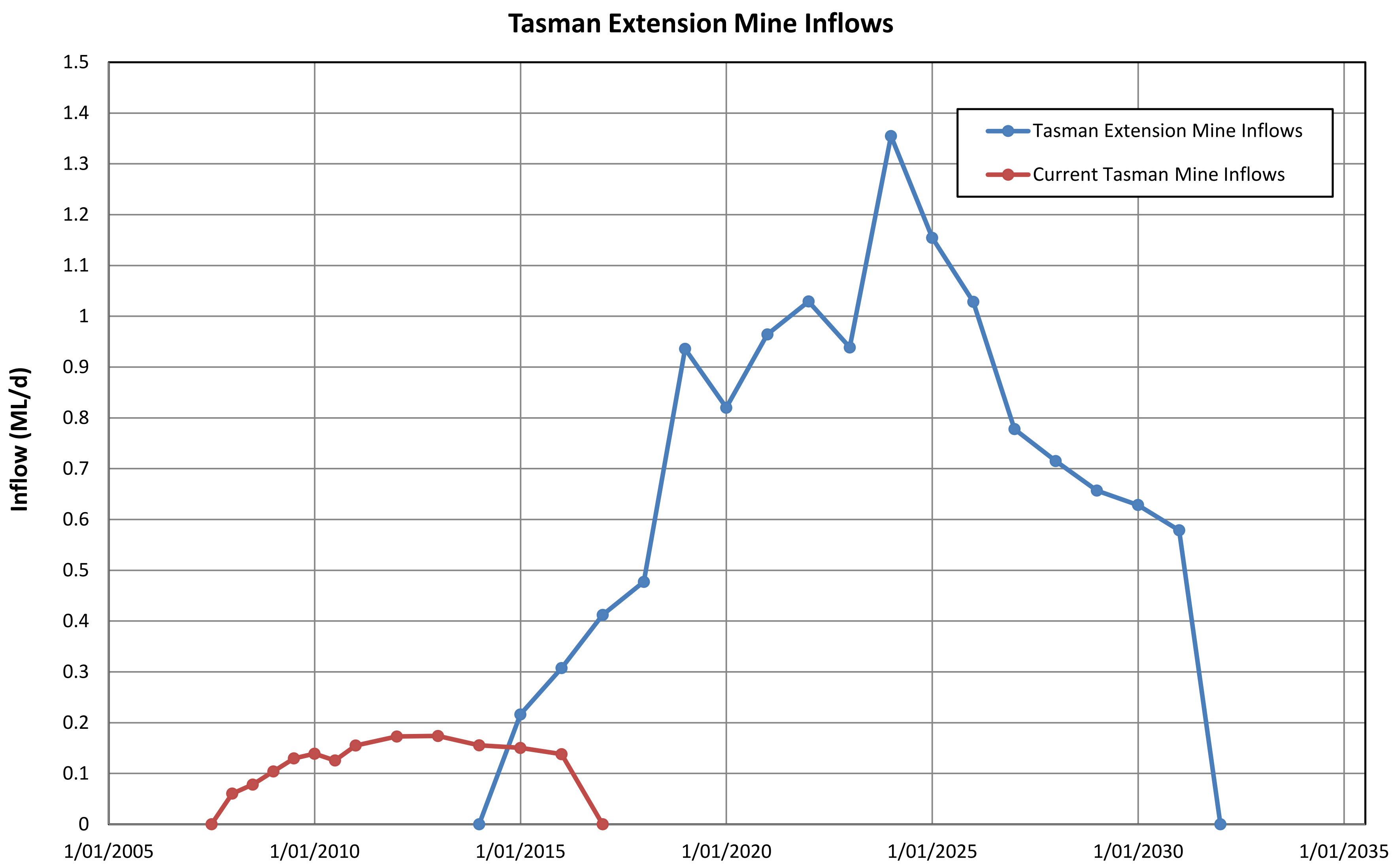
F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\323_Sensitivity\[D9_autosens.xlsx]Kv



RPS Aquaterra

Auto Sensitivity Results for Recharge FIGURE 7.15

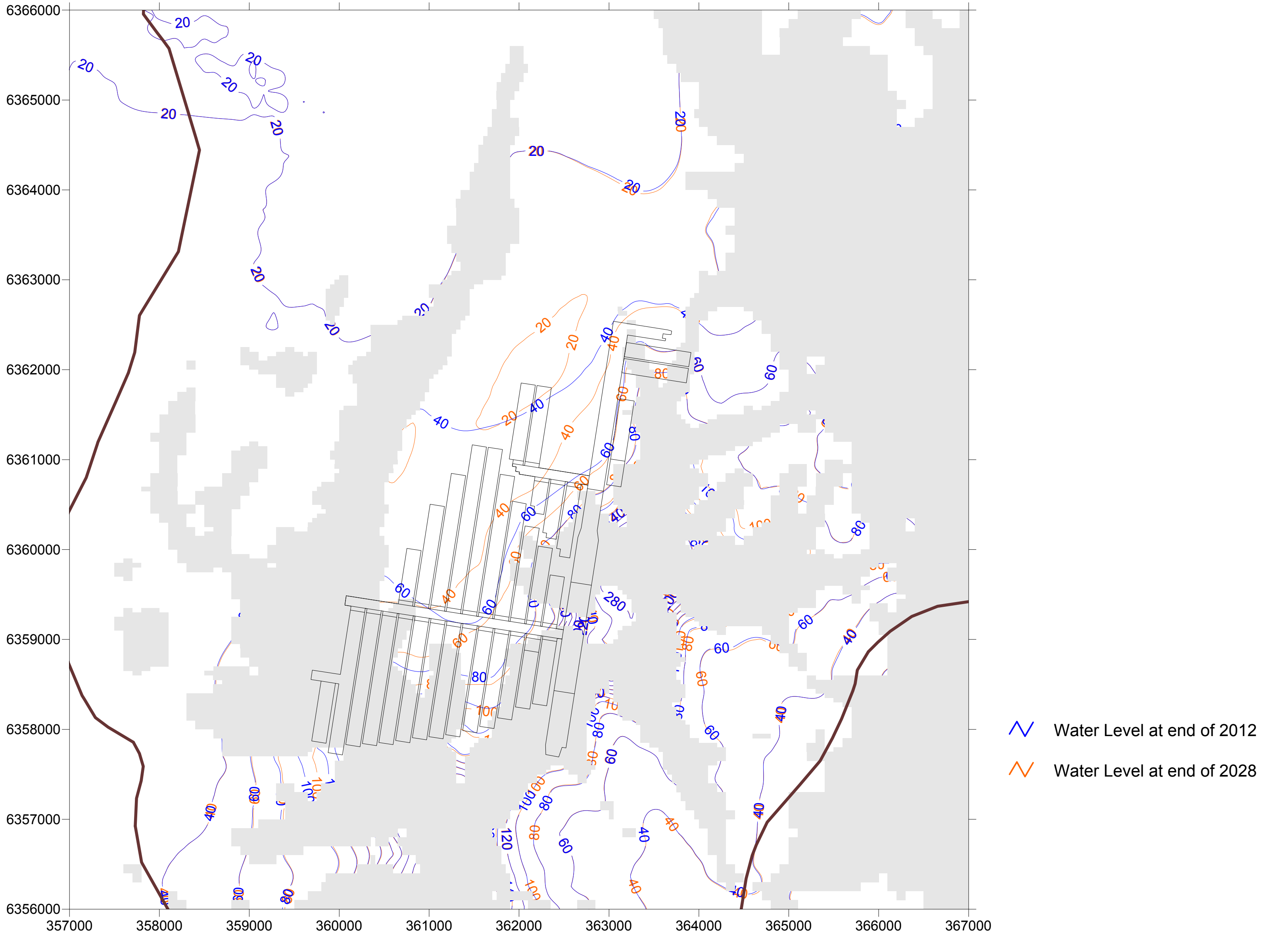
F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\323_Sensitivity\[D9_autosens.xlsx]Recharge



RPS Aquaterra

Tasman Extension Mine Inflows FIGURE 7.16

F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v3.xlsx]7.16



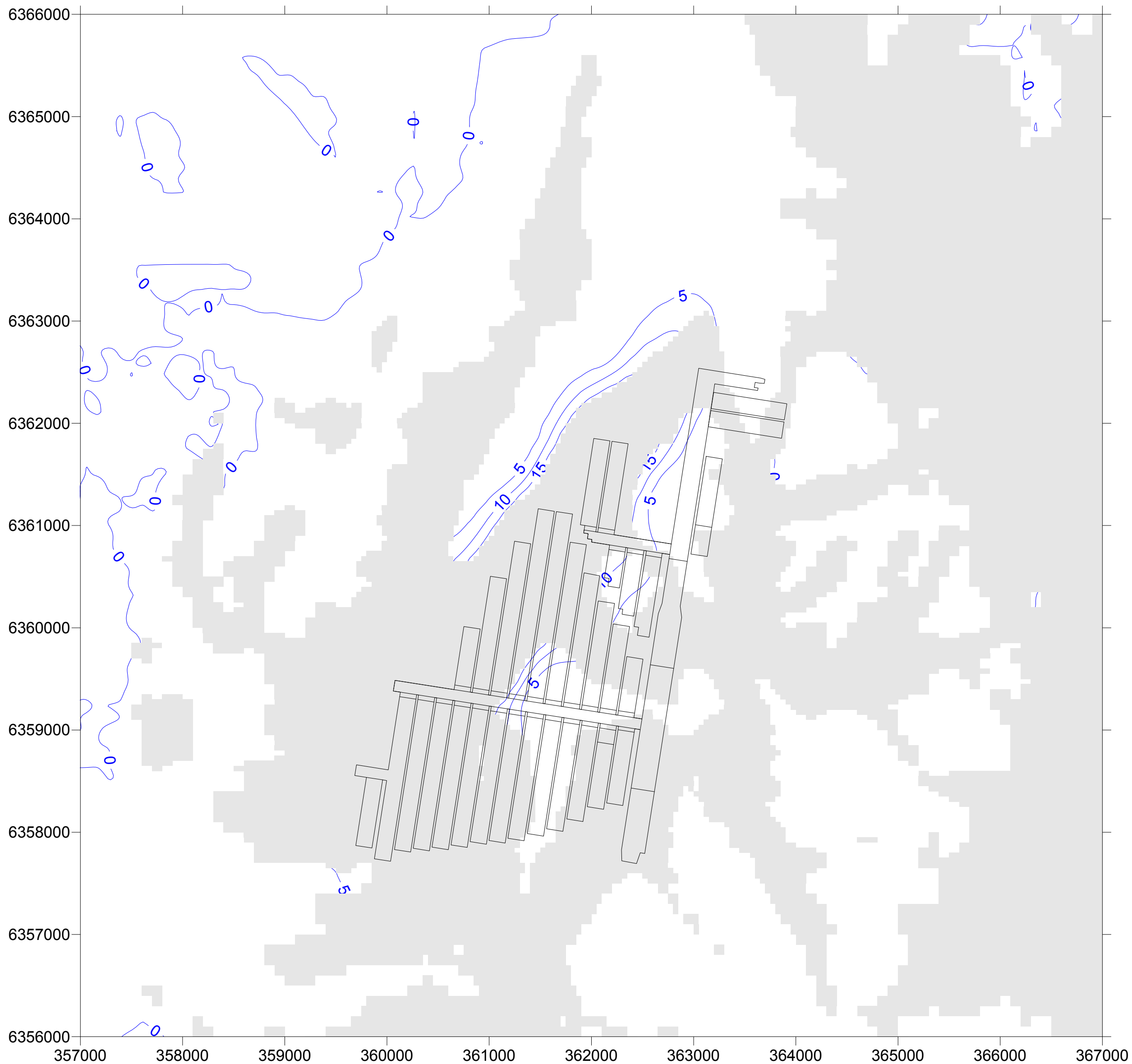
Mine Plan	Date	16/04/2012	Scale	As Shown
Main Road	Initials	HZ	Project	S35
Dry Cells	Drawing Number	S35-009a	Revision	A
Predicted Groundwater Levels (mAHD)				

RPS Aquaterra

Donaldson Coal Pty Ltd

Predicted Groundwater Level at Start (2013) and End (2028) of Tasman Extension Project in the Alluvium and Regolith (Layer 1)

Figure 7.17



Mine Plan

Dry Cells

50 Predicted Groundwater Drawdown (m)

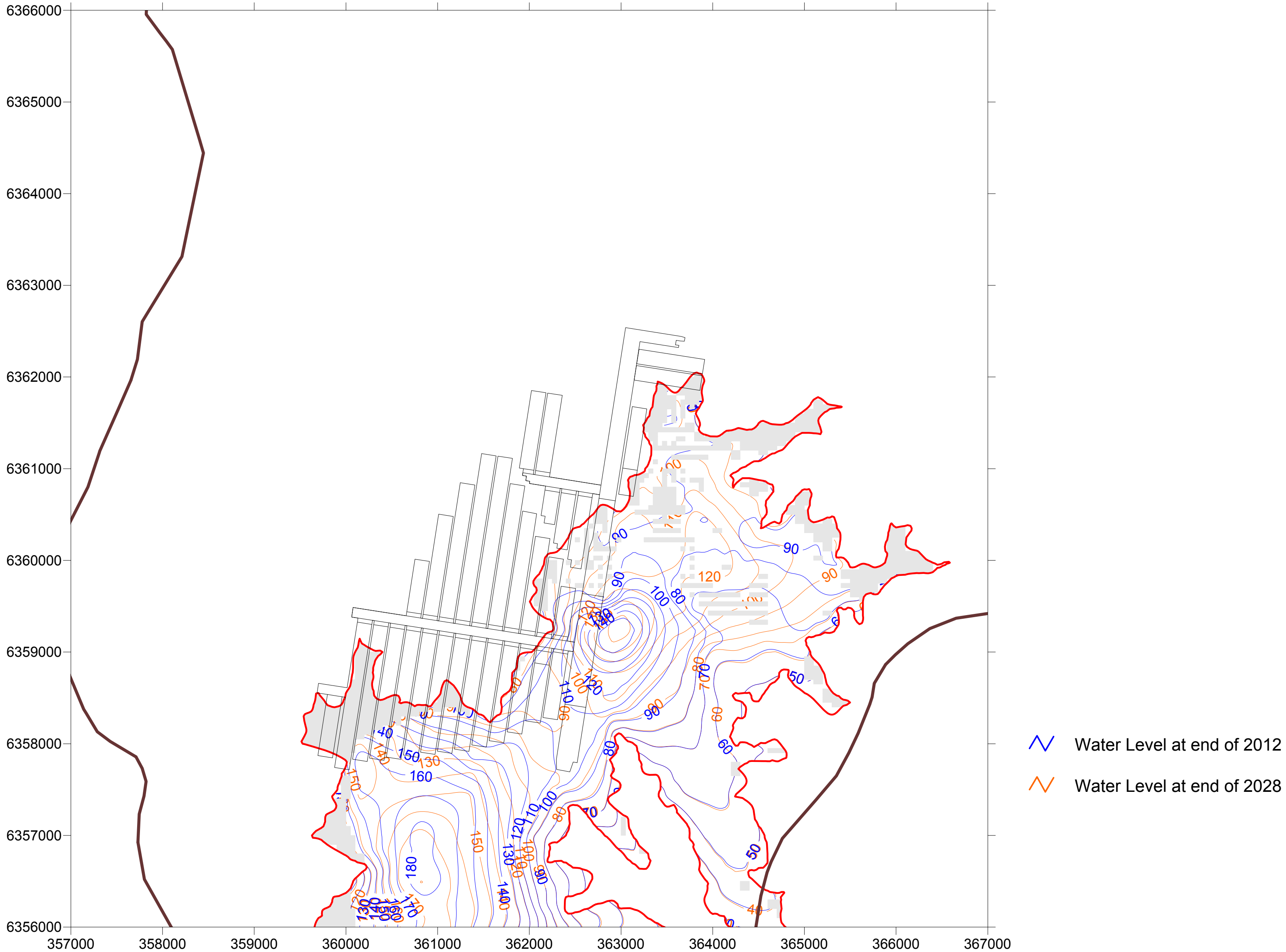
Date	16/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-010a	Revision	A

RPS Aquaterra

Donaldson Coal Pty Ltd

Predicted Groundwater Drawdown Due to Tasman Extension from Commencement (2013) to Completion (2028) in the Alluvium and Regolith (Layer 1)

Figure 7.18



Mine Plan

Main Road

Dry Cells

Predicted Groundwater Levels (mAHD)

Boundary of Fassifern Seam

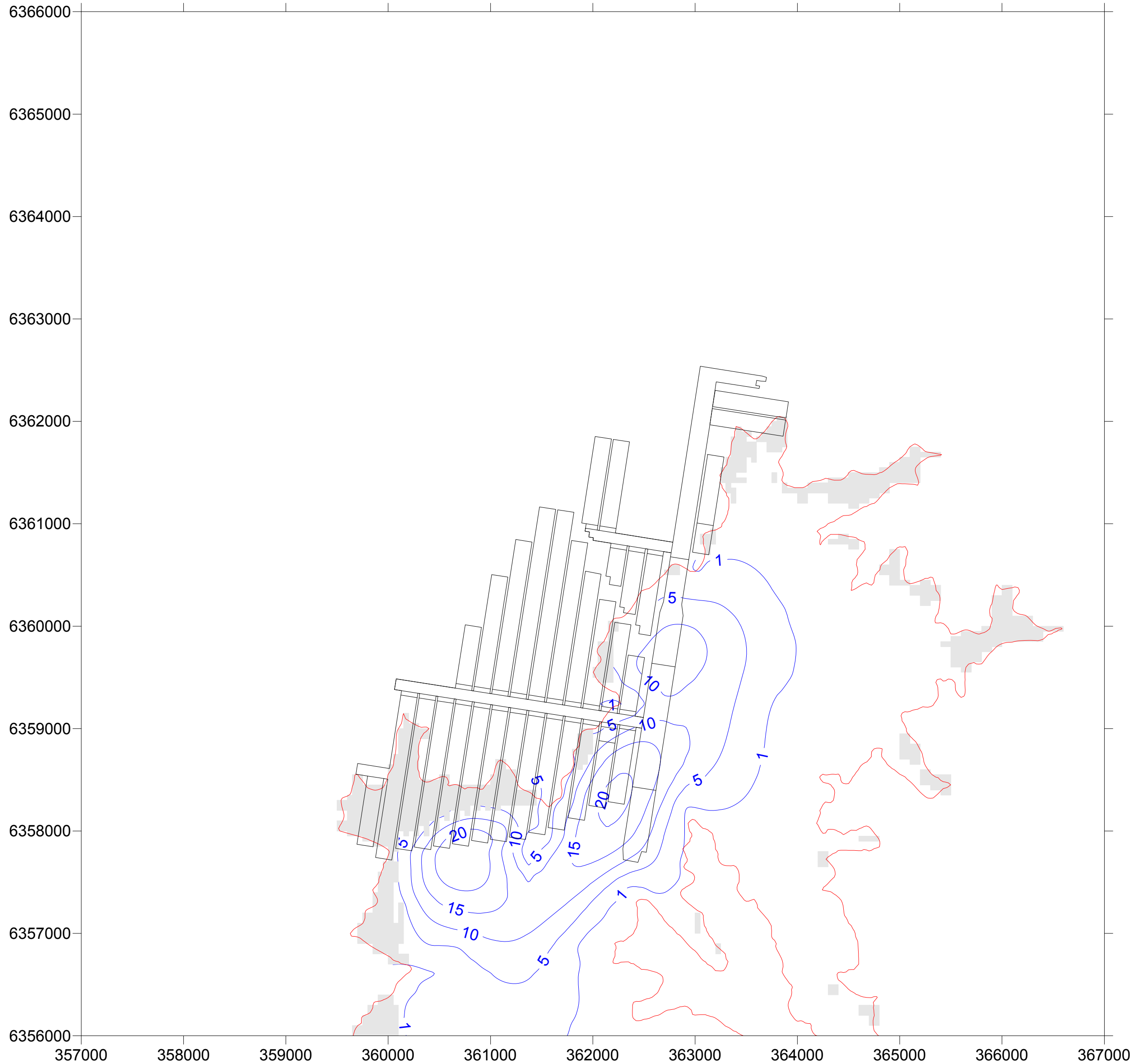
Date	16/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-022a	Revision	A

RPS Aquaterra

Donaldson Coal Pty Ltd

Predicted Groundwater Level at Start (2013) and End (2028) of Tasman Extension Project in the Fassifern Seam (Layer 3)

Figure 7.19



Mine Plan

Boundary of Fassifern Seam

Dry Cells

Predicted Groundwater Drawdown (m)

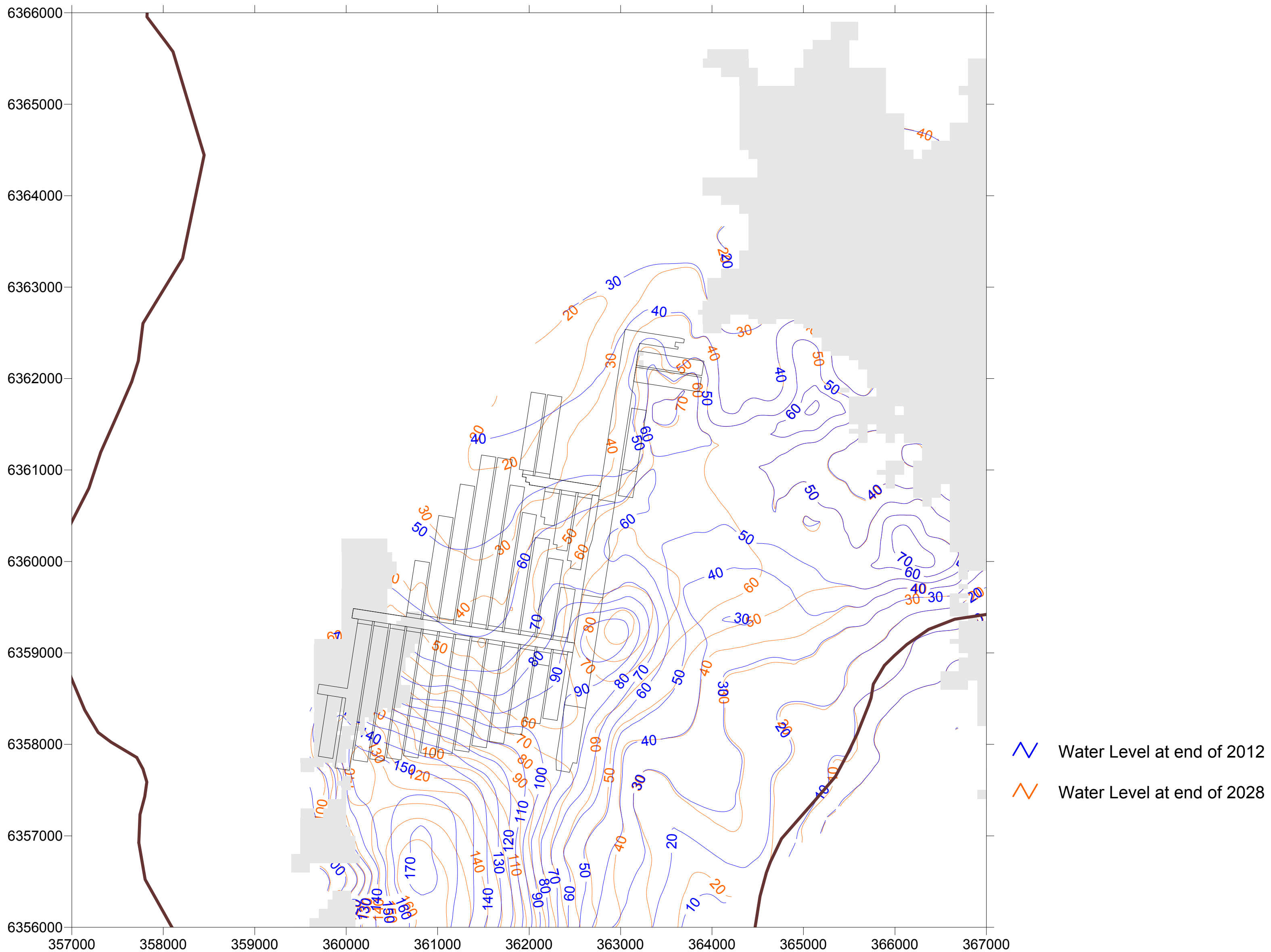
Date	16/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-023a	Revision	A

RPS Aquaterra

Donaldson Coal Pty Ltd

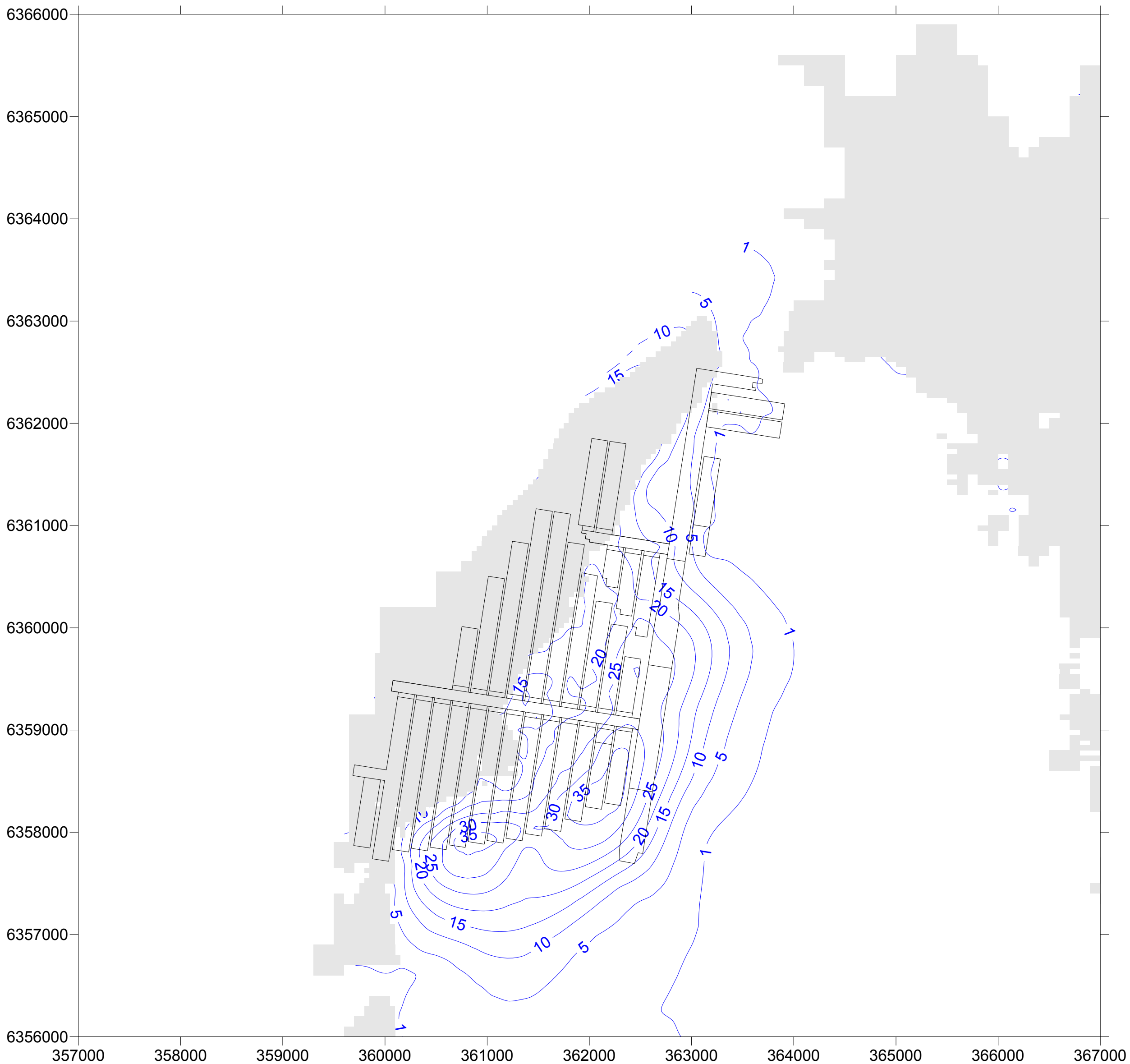
Predicted Groundwater Drawdown
Due to Tasman Extension
from Commencement (2013) to Completion (2028)
in the Fassifern Seam (Layer 3)

Figure 7.20



Mine Plan
Main Road
Dry Cells
Predicted Groundwater Levels (mAHD)

Date	16/04/2012	Scale	As Shown	**Donaldson Coal Pty Ltd**
Initials	HZ	Project	S35	**Predicted Groundwater Level at Start (2013) and End (2028) of Tasman Extension Project West Borehole Seam Overburden - not fractured (Layer 4)**
Drawing Number	S35-005a	Revision	A	
RPS Aquaterra				**Figure 7.21**



Mine Plan

Dry Cells

Predicted Groundwater Drawdown (m)

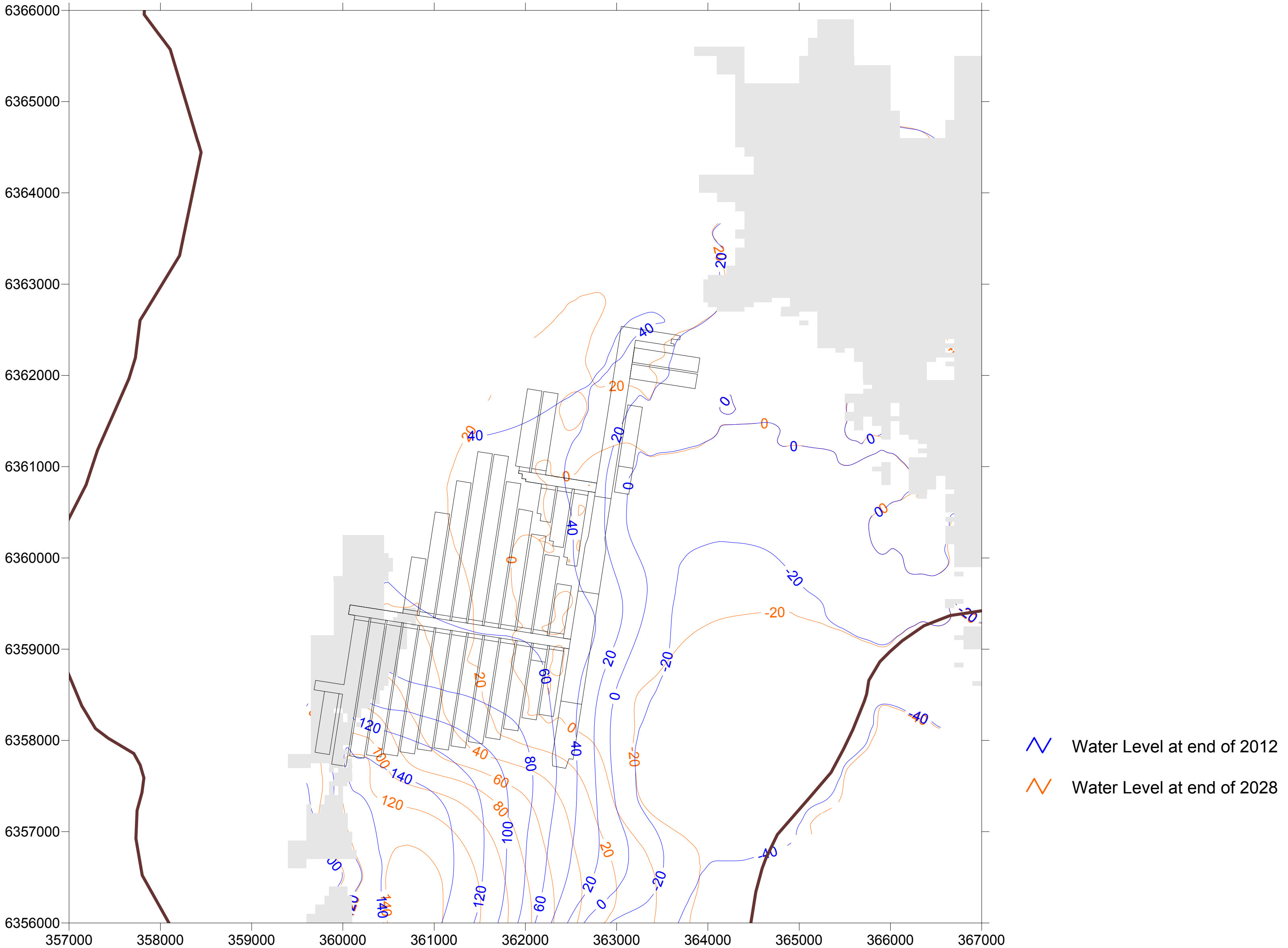
Date	16/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-006a	Revision	A

RPS Aquaterra

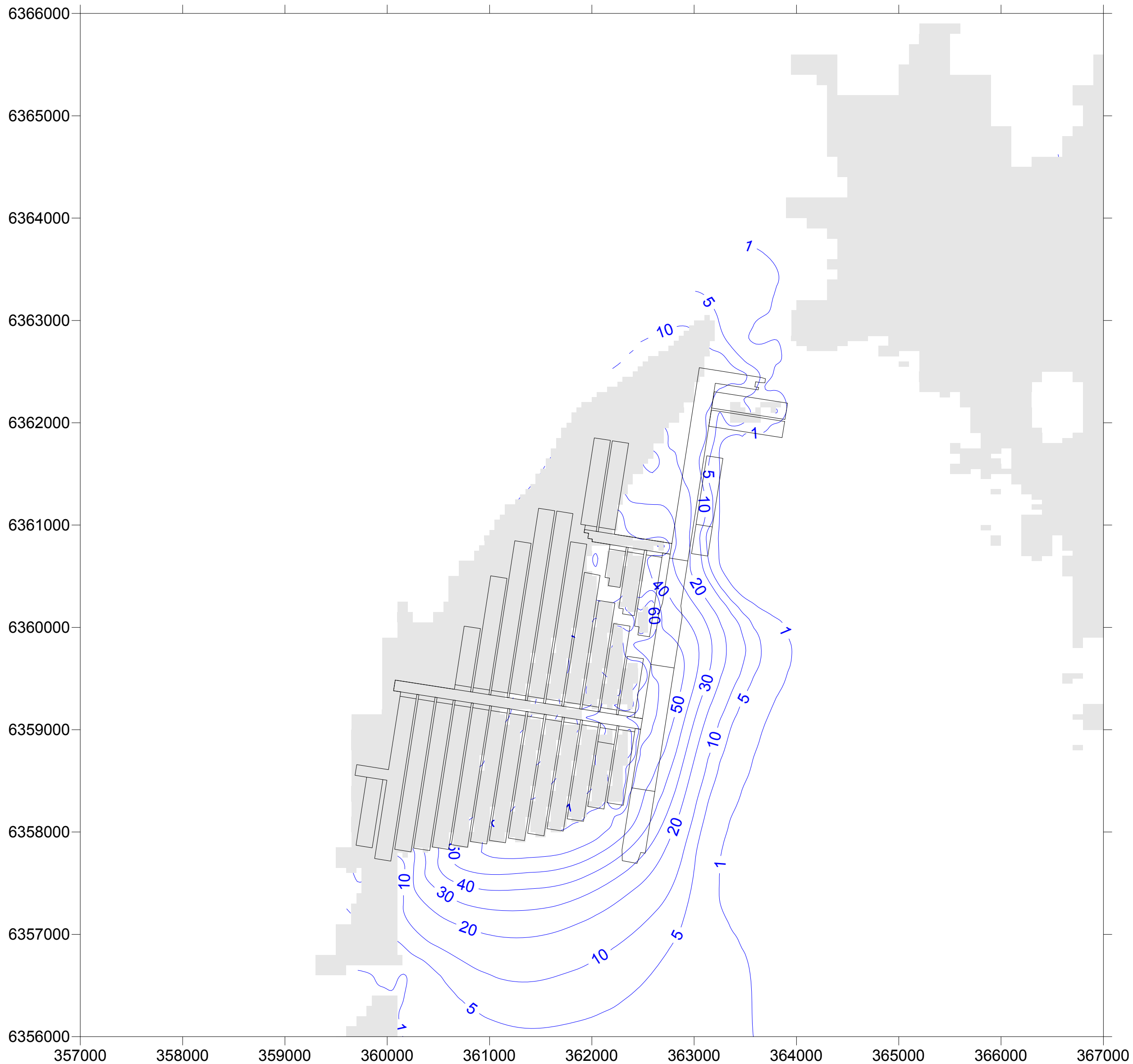
Donaldson Coal Pty Ltd

Predicted Groundwater Drawdown Due to Tasman Extension from Commencement (2013) to Completion (2028) West Borehole Seam Overburden - not fractured (Layer 4)

Figure 7.22



Mine Plan Main Road Dry Cells Predicted Groundwater Levels (mAHD)	Date **16/04/2012**	Scale **As Shown**	**Donaldson Coal Pty Ltd**	
	Initials **HZ**	Project **S35**	**Predicted Groundwater Level at Start (2013) and End (2028) of Tasman Extension Project West Borehole Seam Overburden - fractured (Layer 5)**	
	Drawing Number **S35-003a**	Revision **A**		**Figure 7.23**
	RPS Aquaterra			



Mine Plan

Dry Cells

50 Predicted Groundwater Drawdown (m)

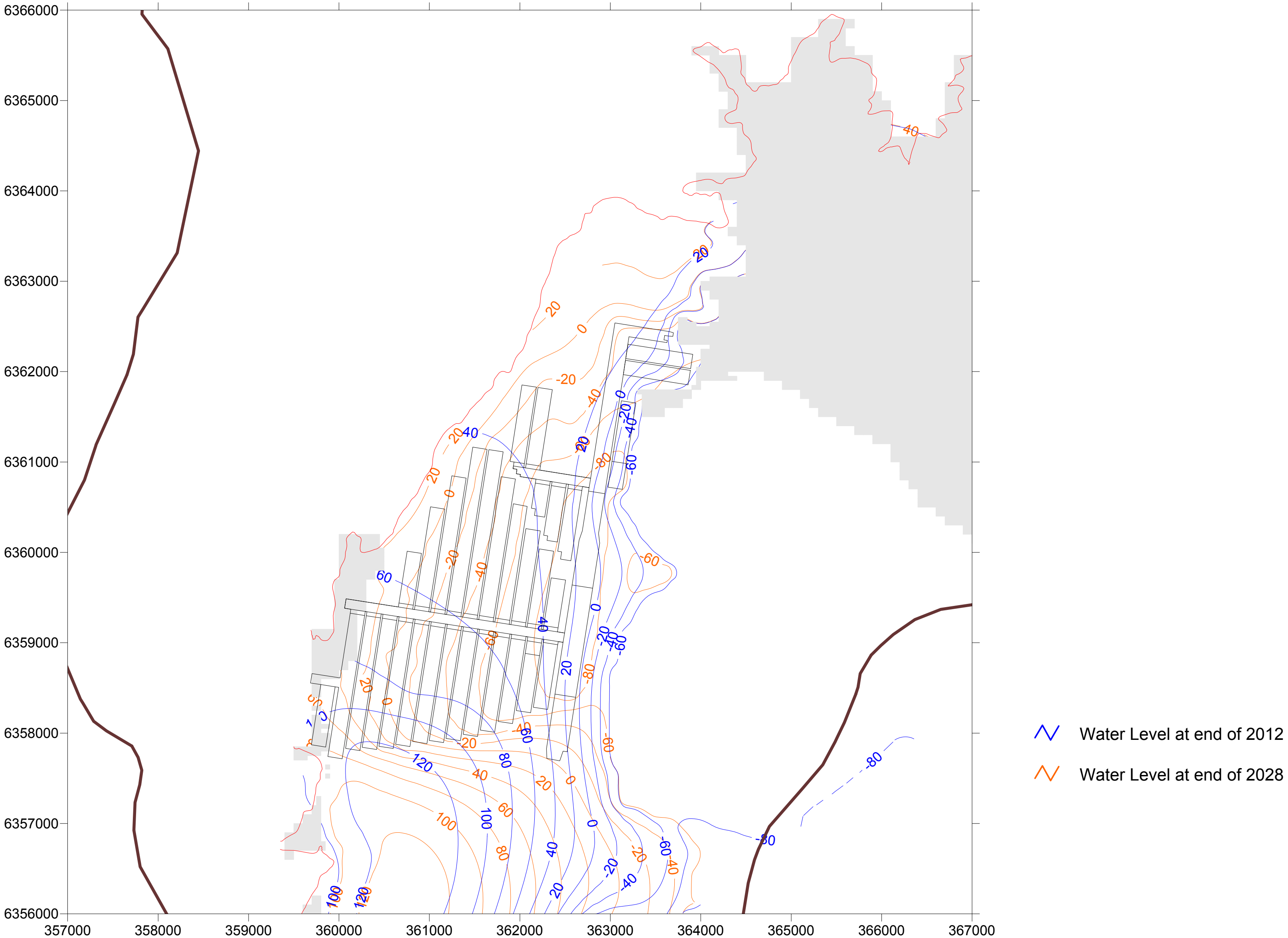
Date	16/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-004a	Revision	A

RPS Aquaterra

Donaldson Coal Pty Ltd

Predicted Groundwater Drawdown
Due to Tasman Extension
from Commencement (2013) to Completion (2028)
West Borehole Seam Overburden - fractured
(Layer 5)

Figure 7.24



Mine Plan

Main Road

Dry Cells

Predicted Groundwater Levels (mAHD)

Boundary of West Borehole Seam

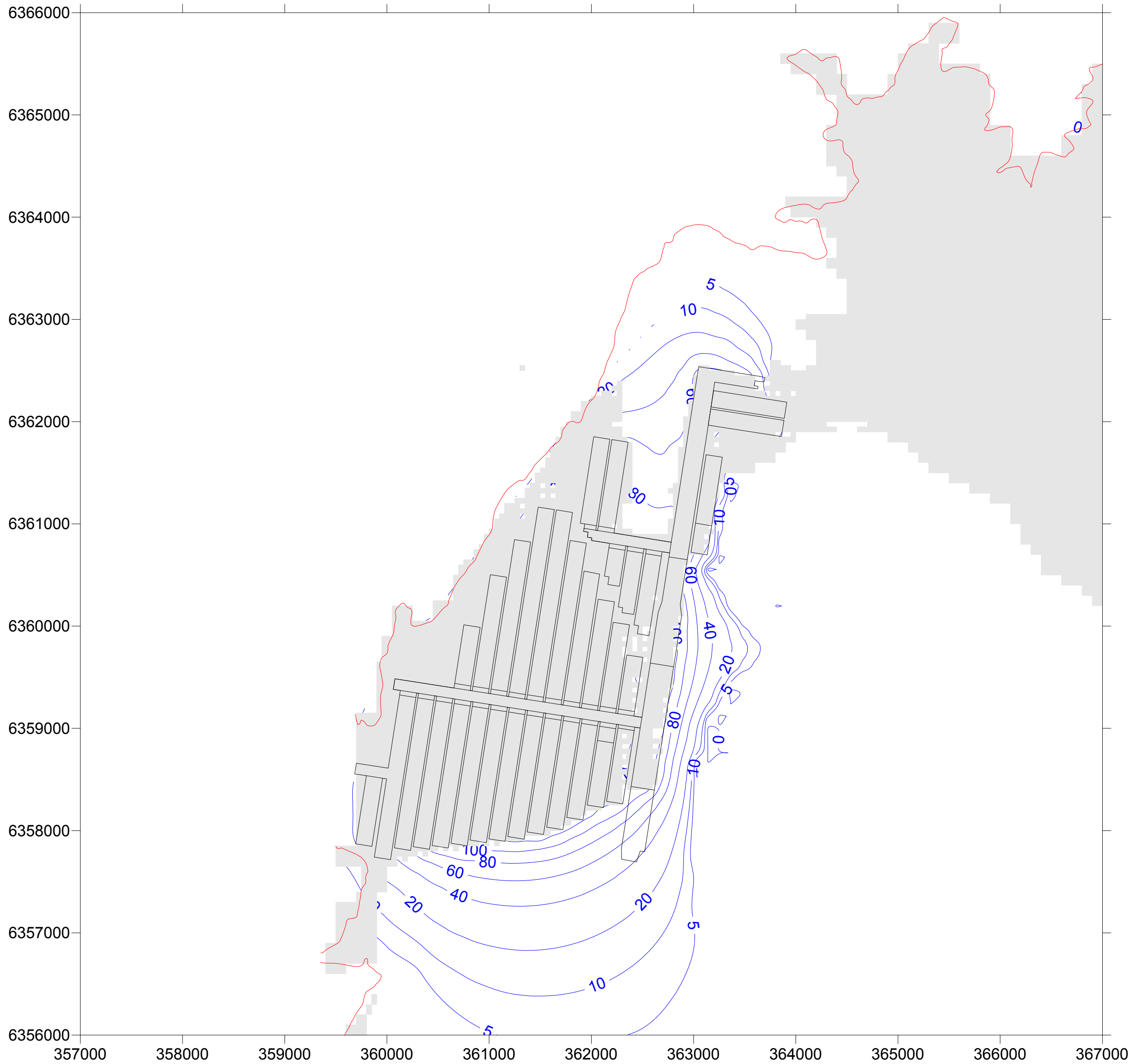
Date	16/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-001a	Revision	A

RPS Aquaterra

Donaldson Coal Pty Ltd

Predicted Groundwater Level at Start (2013) and End (2028) of Tasman Extension Project in the West Borehole Seam (Layer 7)

Figure 7.25



Mine Plan

Boundary of West Borehole Seam

Dry Cells

Predicted Groundwater Drawdown (m)

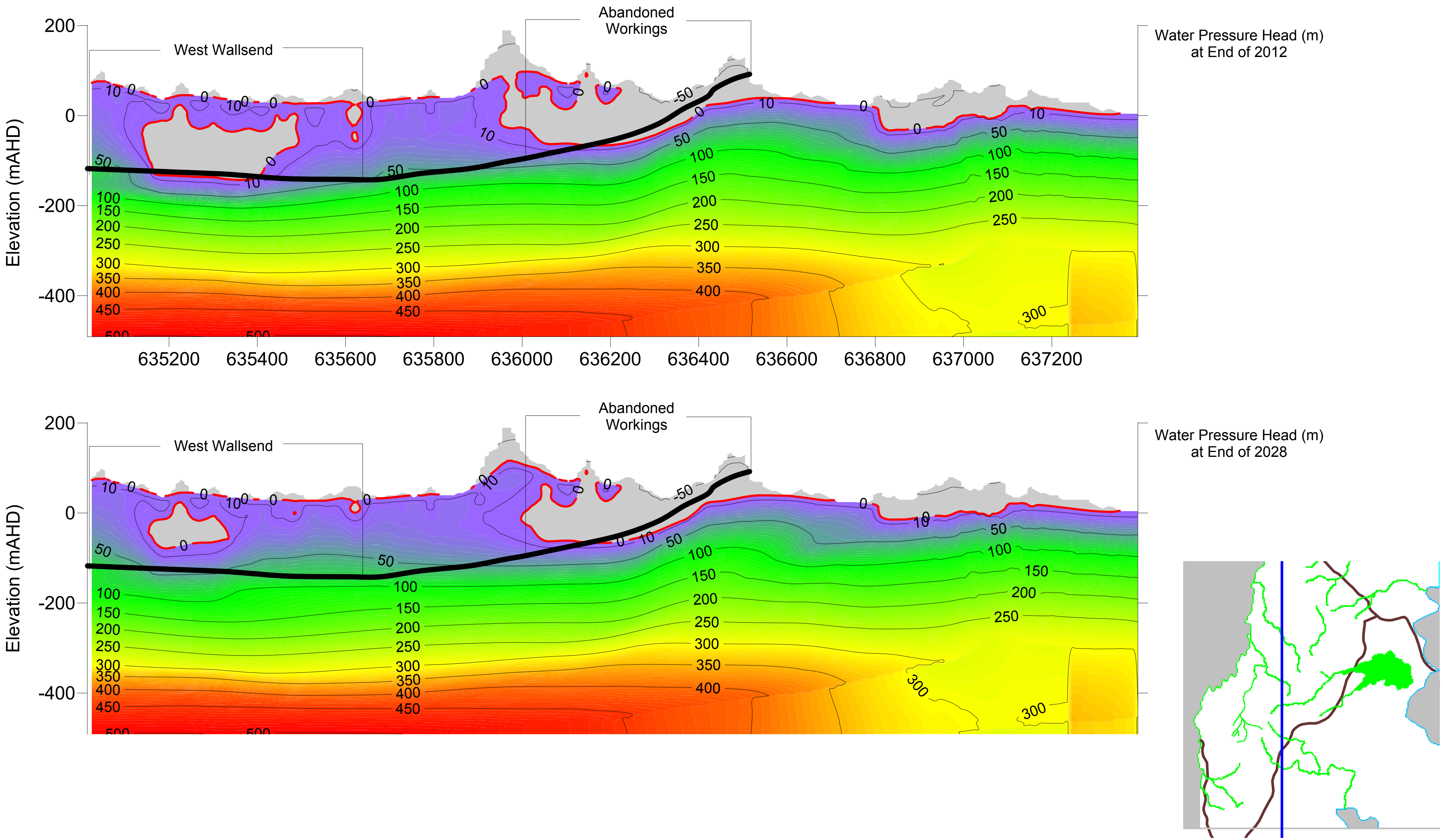
Date	16/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-002a	Revision	A

RPS Aquaterra

Donaldson Coal Pty Ltd

Predicted Groundwater Drawdown Due to Tasman Extension from Commencement (2013) to Completion (2028) in the West Borehole Seam (Layer 7)

Figure 7.26



	West Borehole Seam
	Rivers or Creeks
	No Flow
	General Head Boundary
	Main Road

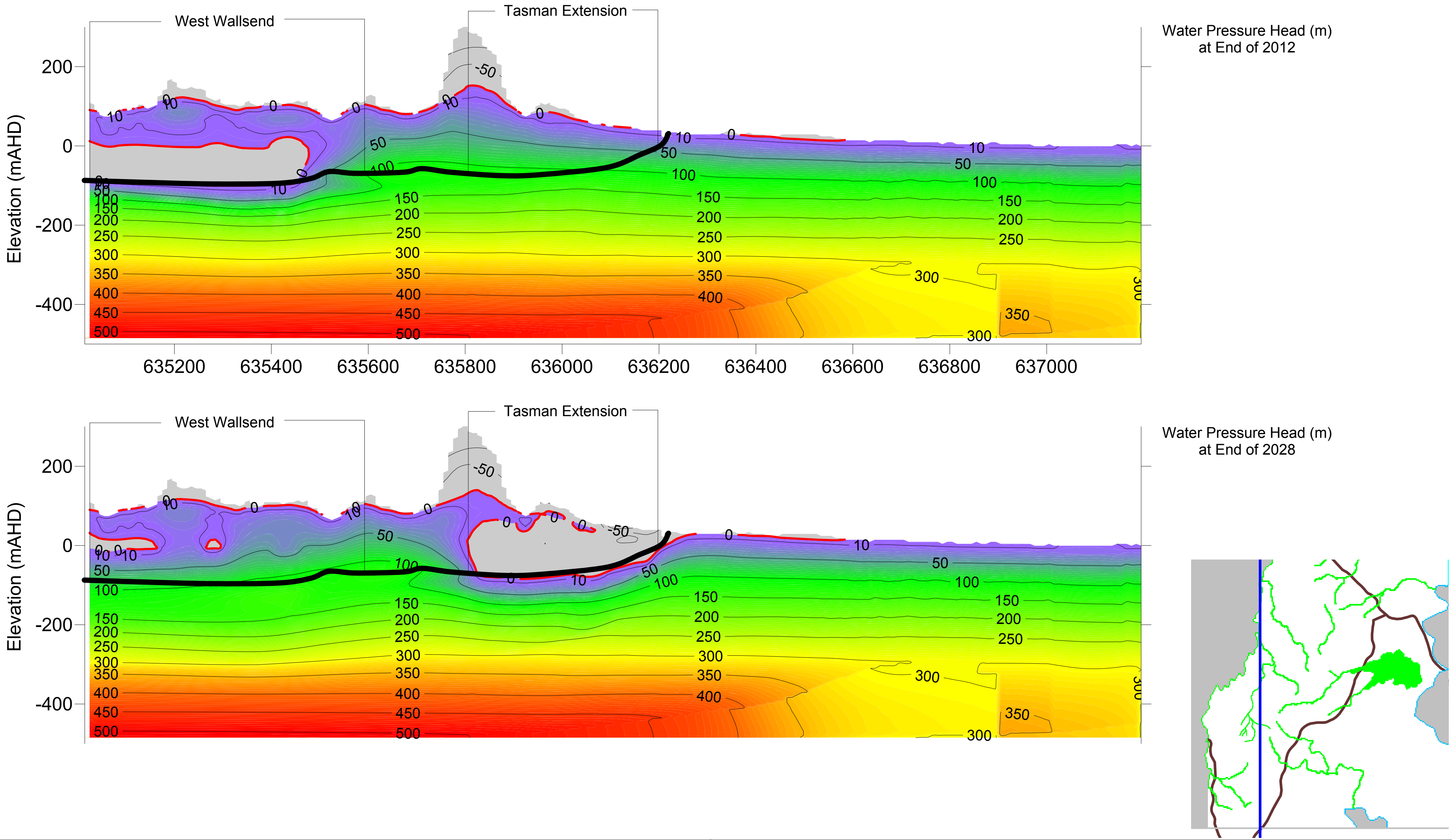
Date	18/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-012a	Revision	A

RPS Aquaterra

Donaldson Coal Pty Ltd

Water Pressure Heads
Along Easting 364850 (column 133)
at Start and End of Mining

Figure 7.27



- West Borehole Seam
- Rivers or Creeks
- No Flow
- General Head Boundary
- Main Road

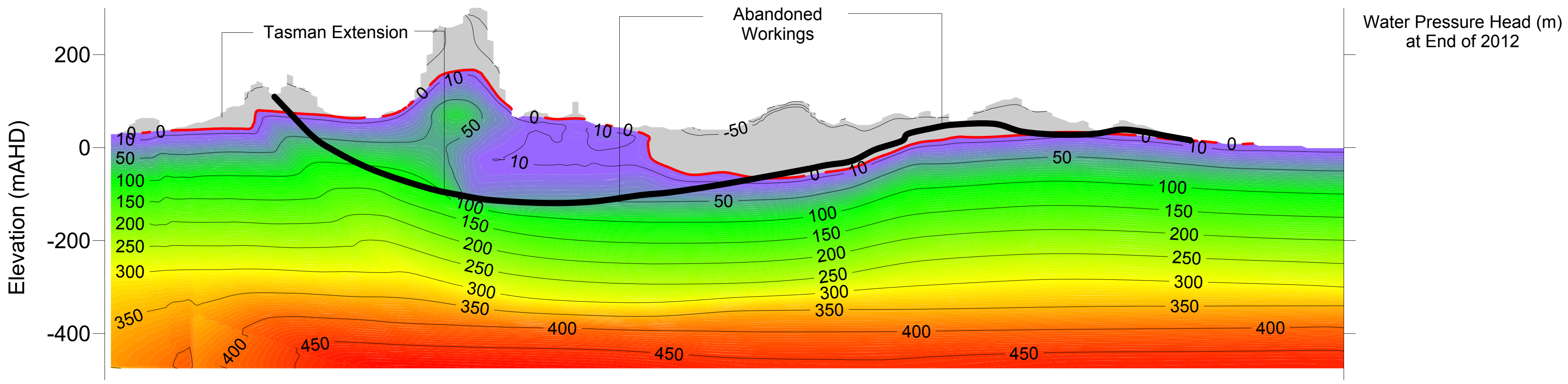
Date	18/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-011a	Revision	A

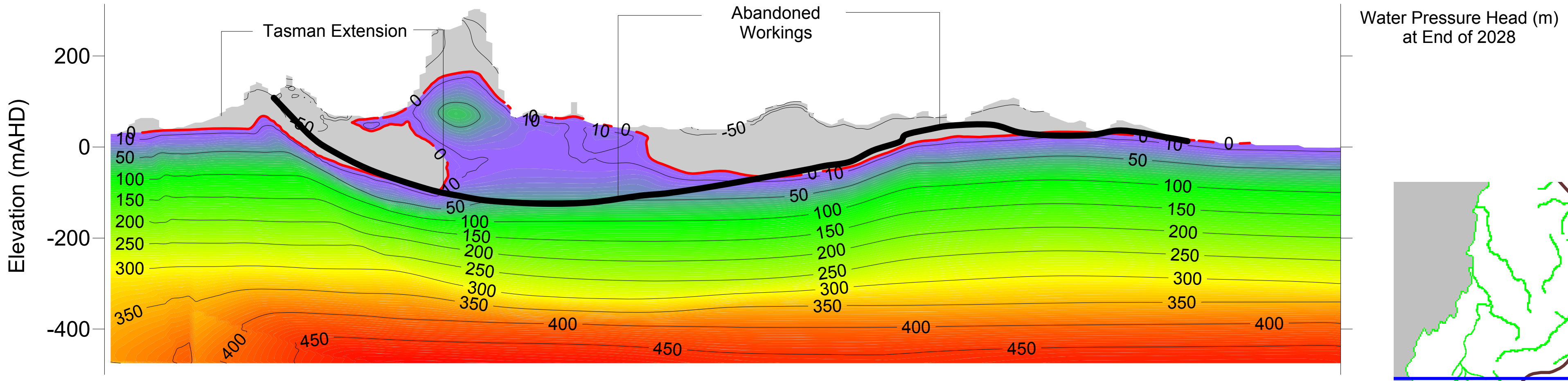
RPS Aquaterra

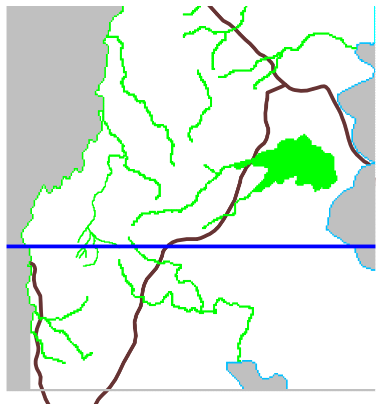
Donaldson Coal Pty Ltd

Water Pressure Heads
Along Easting 362175 (Column 88)
at Start and End of Mining

Figure 7.28







- West Borehole Seam
- Rivers or Creeks
- No Flow
- General Head Boundary
- Main Road

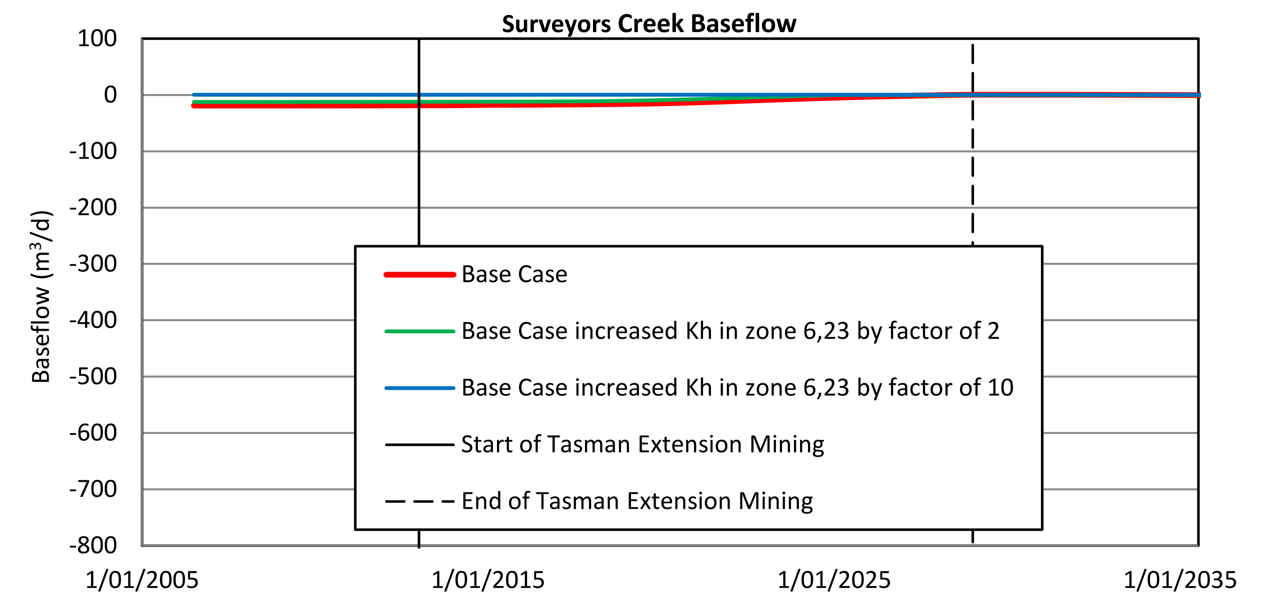
Date	14/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-013a	Revision	A

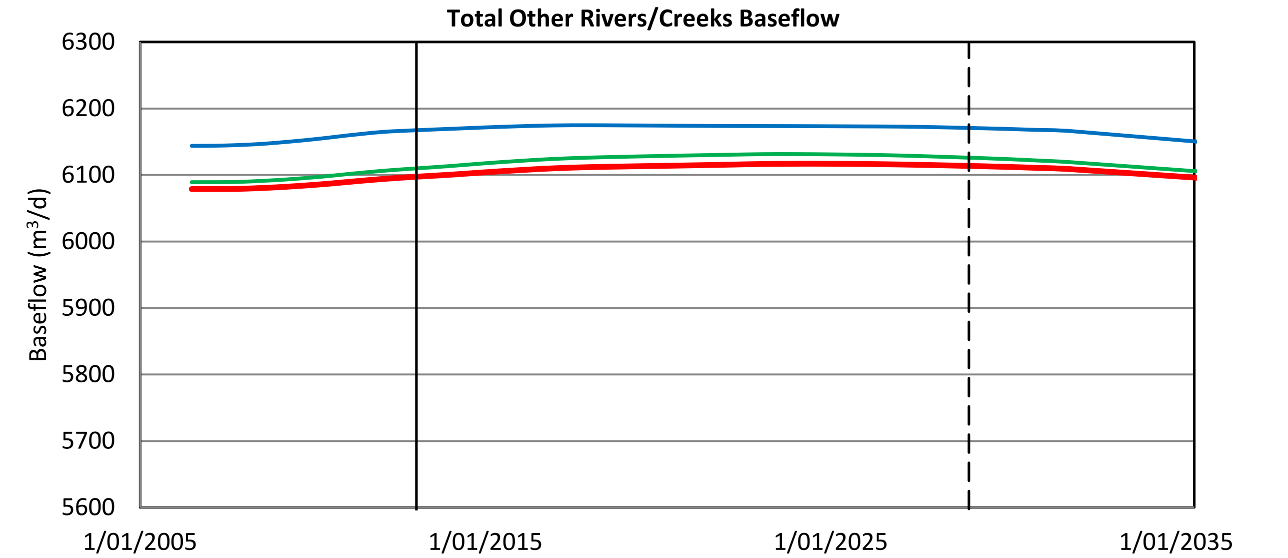
RPS Aquaterra

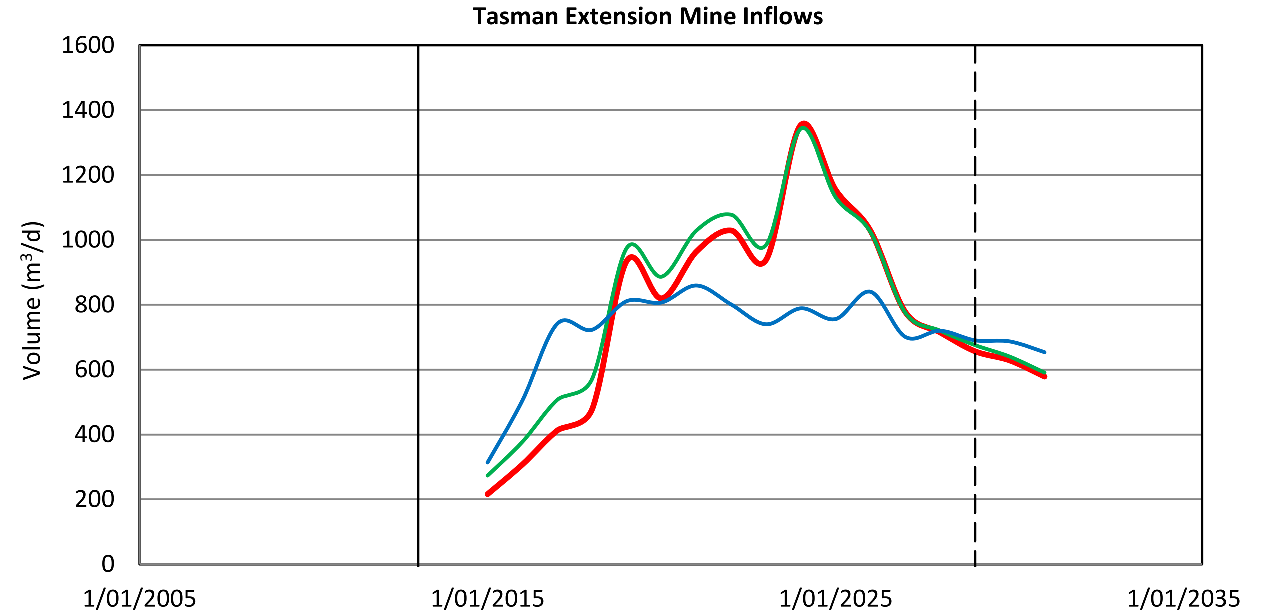
Donaldson Coal Pty Ltd

Water Pressure Heads
Along Northing 6359025 (Row 192)
at Start and End of Mining

Figure 7.29



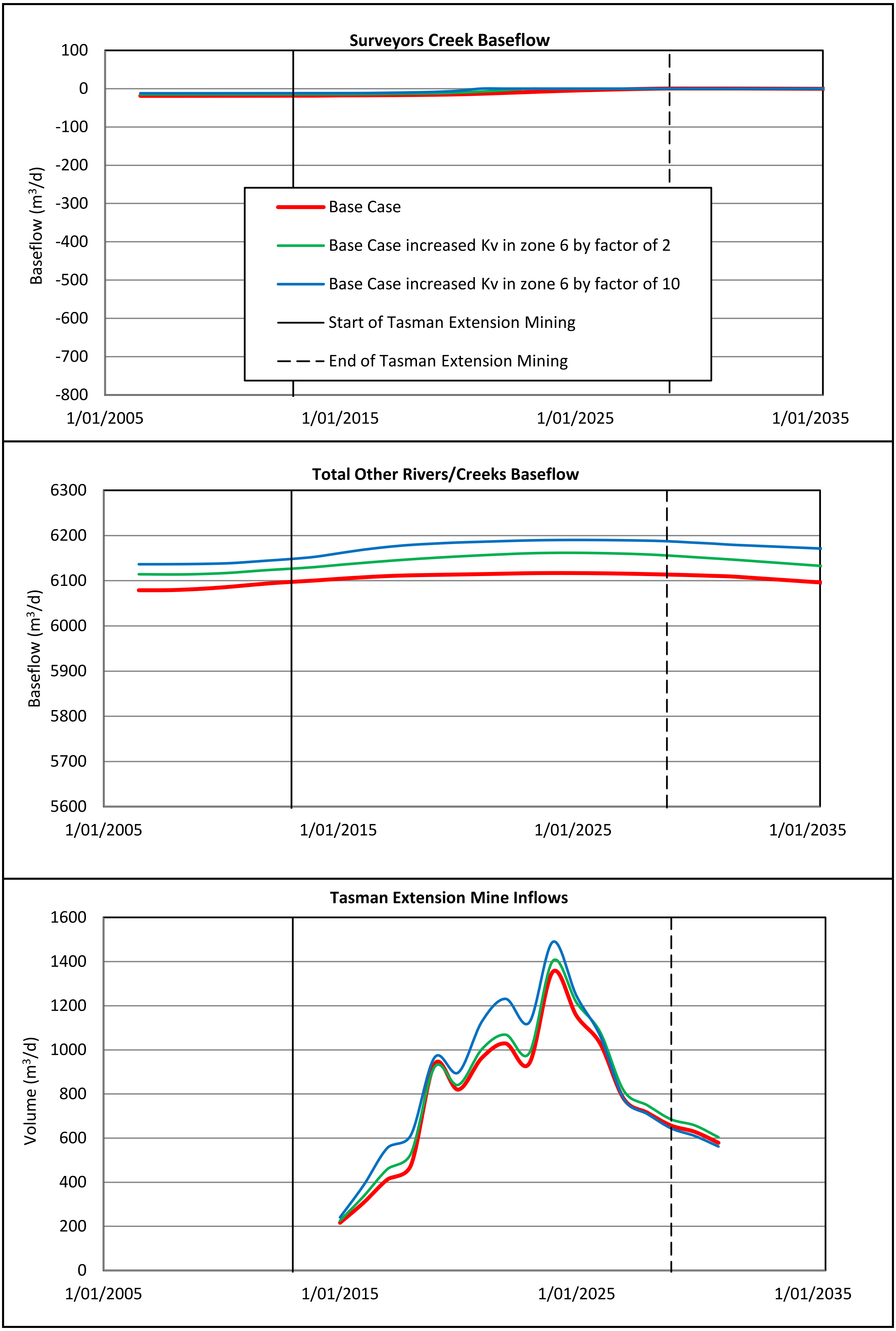




RPS Aquaterra

Uncertainty Analysis Results - Horizontal Hydraulic Conductivity (Kh) FIGURE 7.30

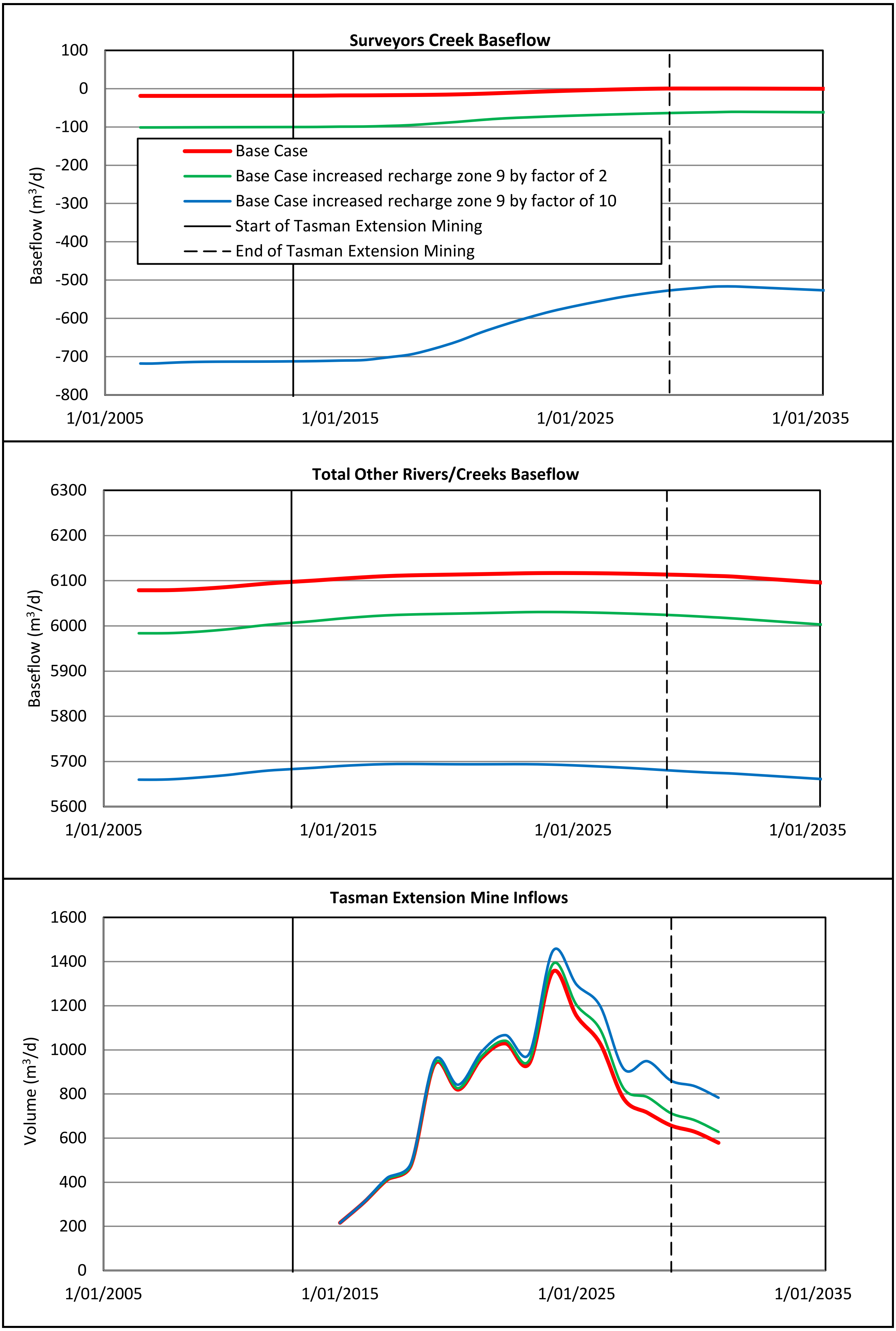
F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v3.xlsx]7.30a



RPS Aquaterra

Uncertainty Analysis Results - Vertical Hydraulic Conductivity (Kv) FIGURE 7.31

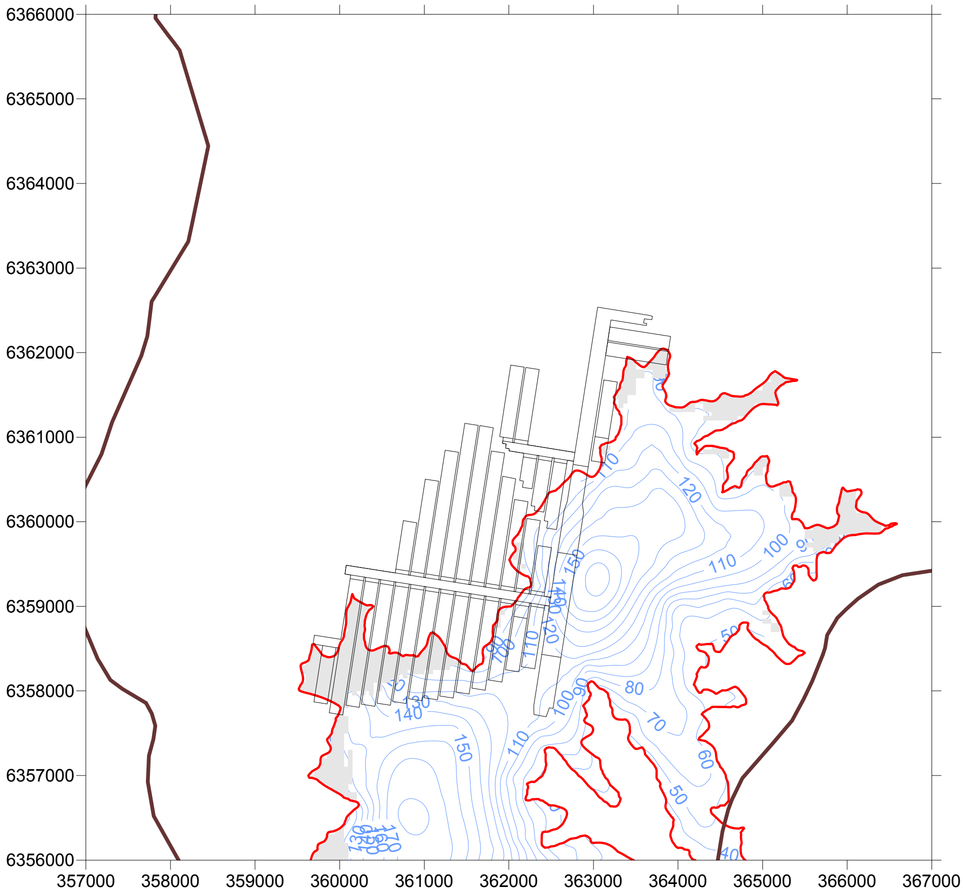
F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v3.xlsx]7.30b

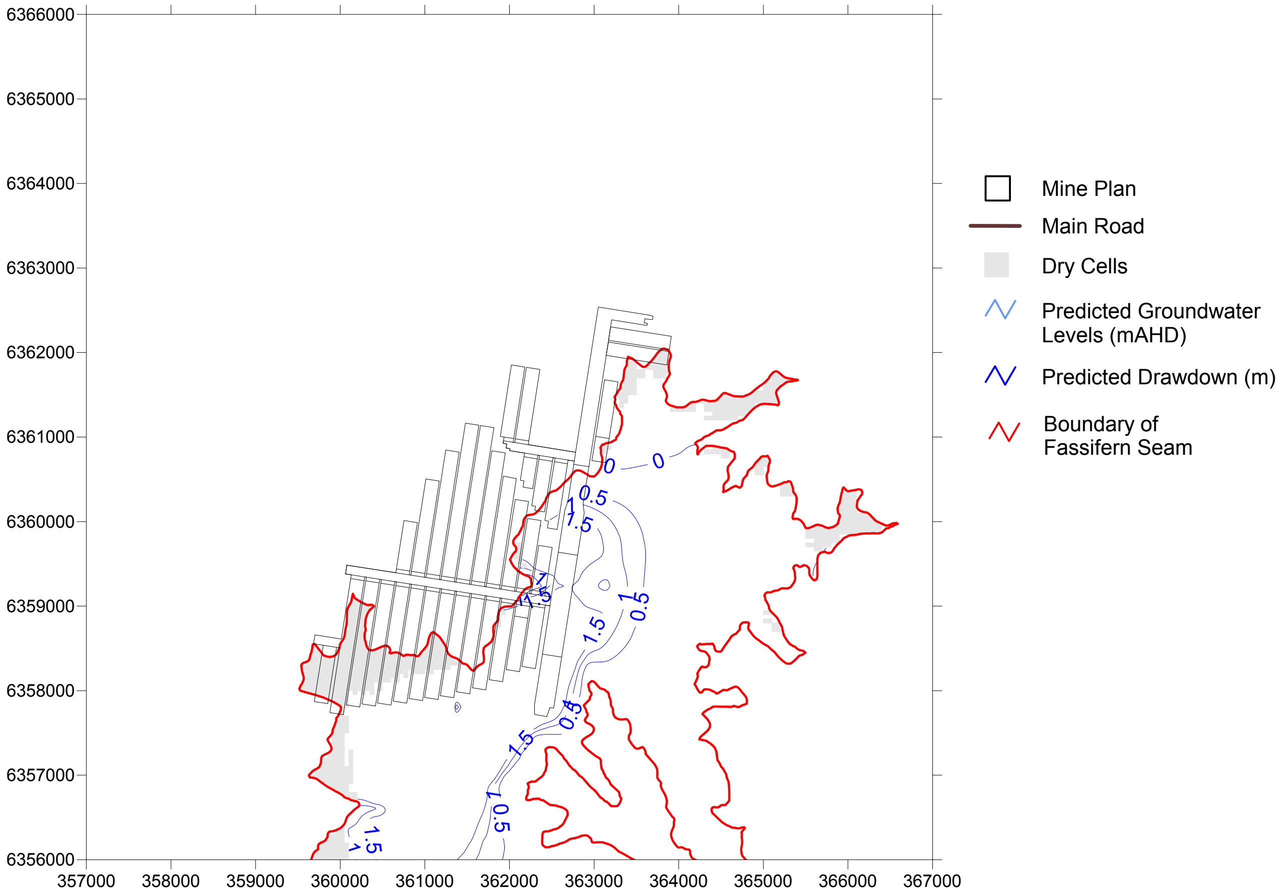


RPS Aquaterra

Uncertainty Analysis Results - Recharge FIGURE 7.32

F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v3.xlsx]7.30c





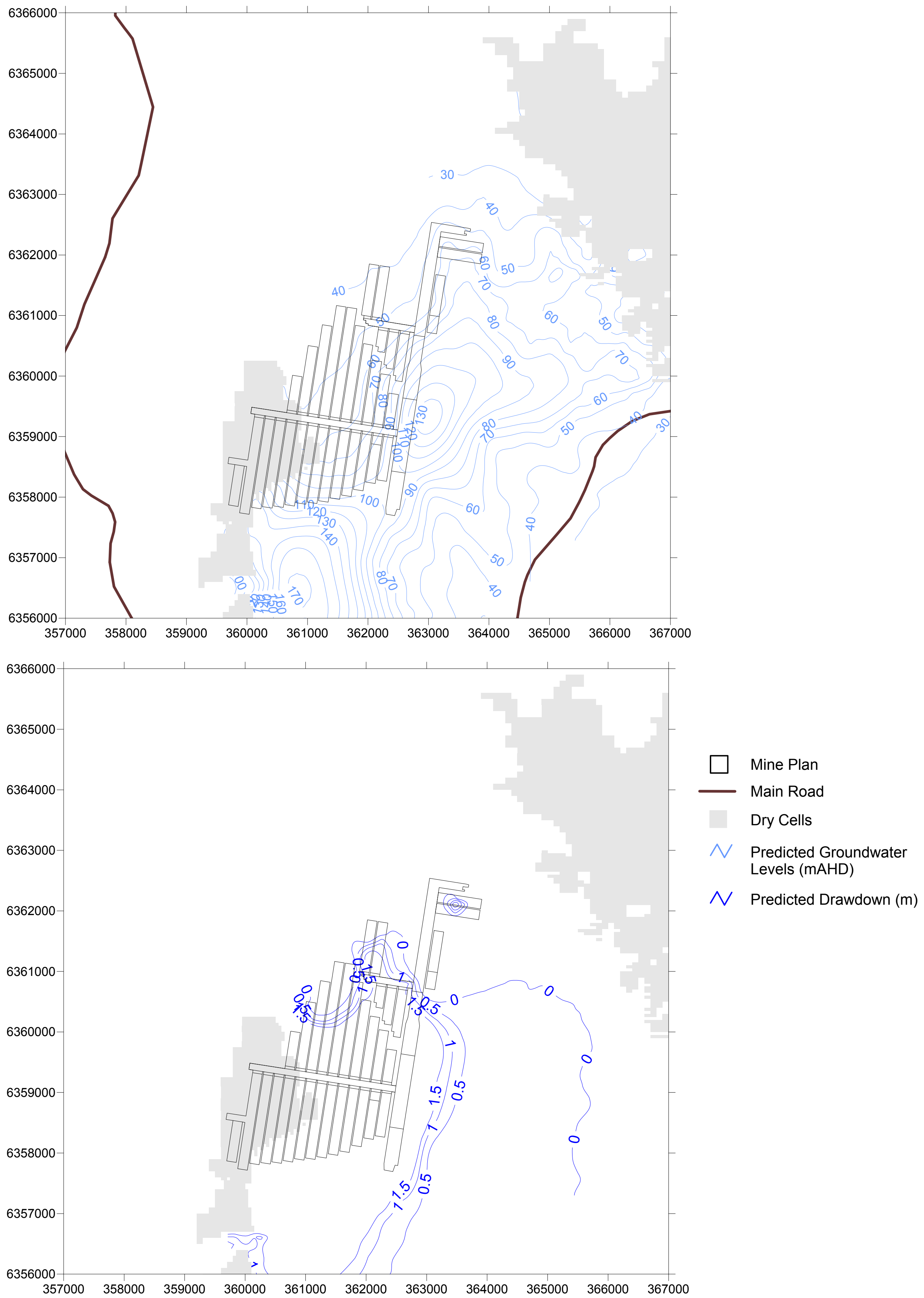
Date	16/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-029a	Revision	A

RPS Aquaterra

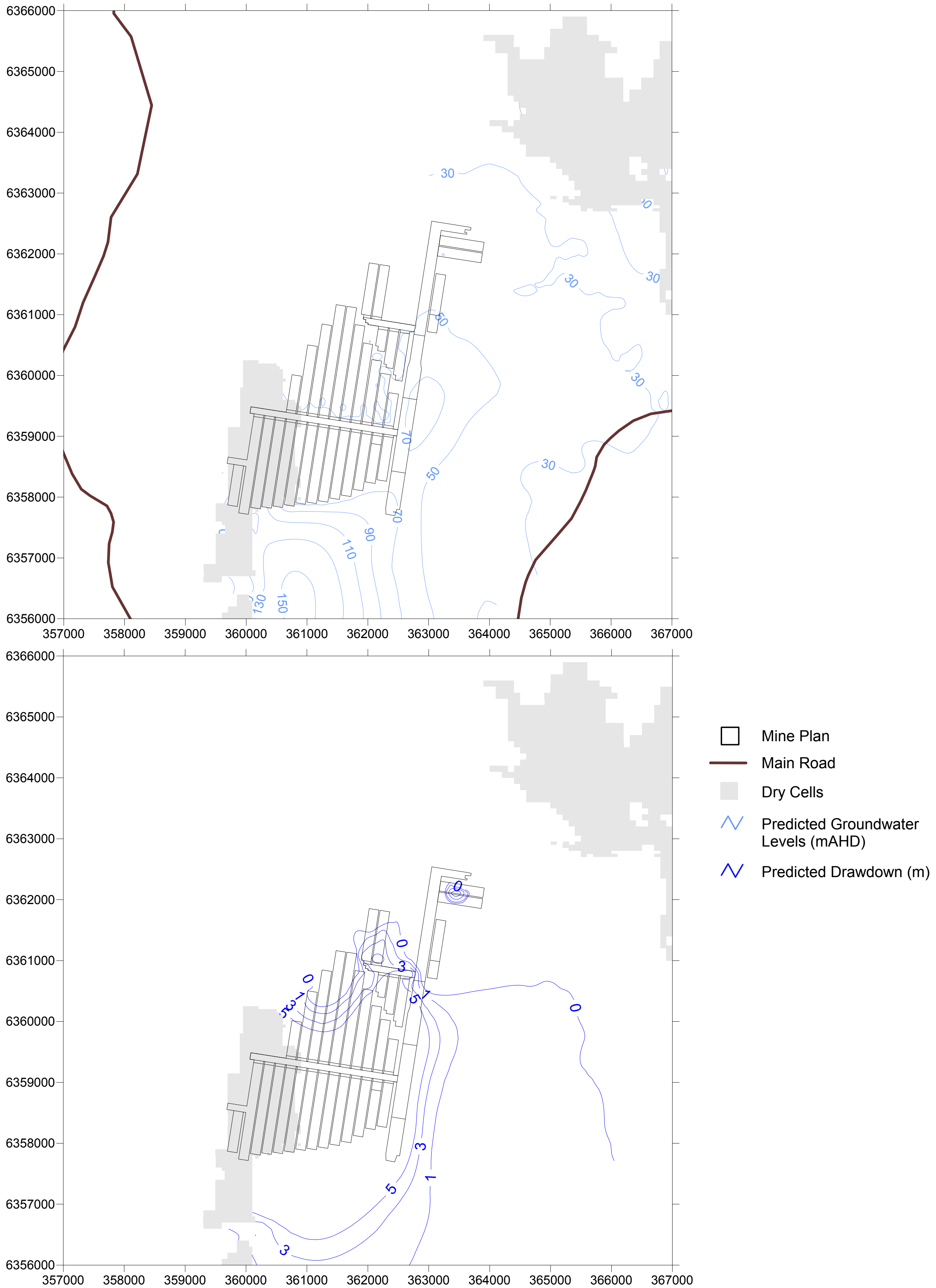
Donaldson Coal Pty Ltd

Predicted Groundwater Level and Drawdown at 100 Years Recovery in the Fassifern Seam (Layer 3)

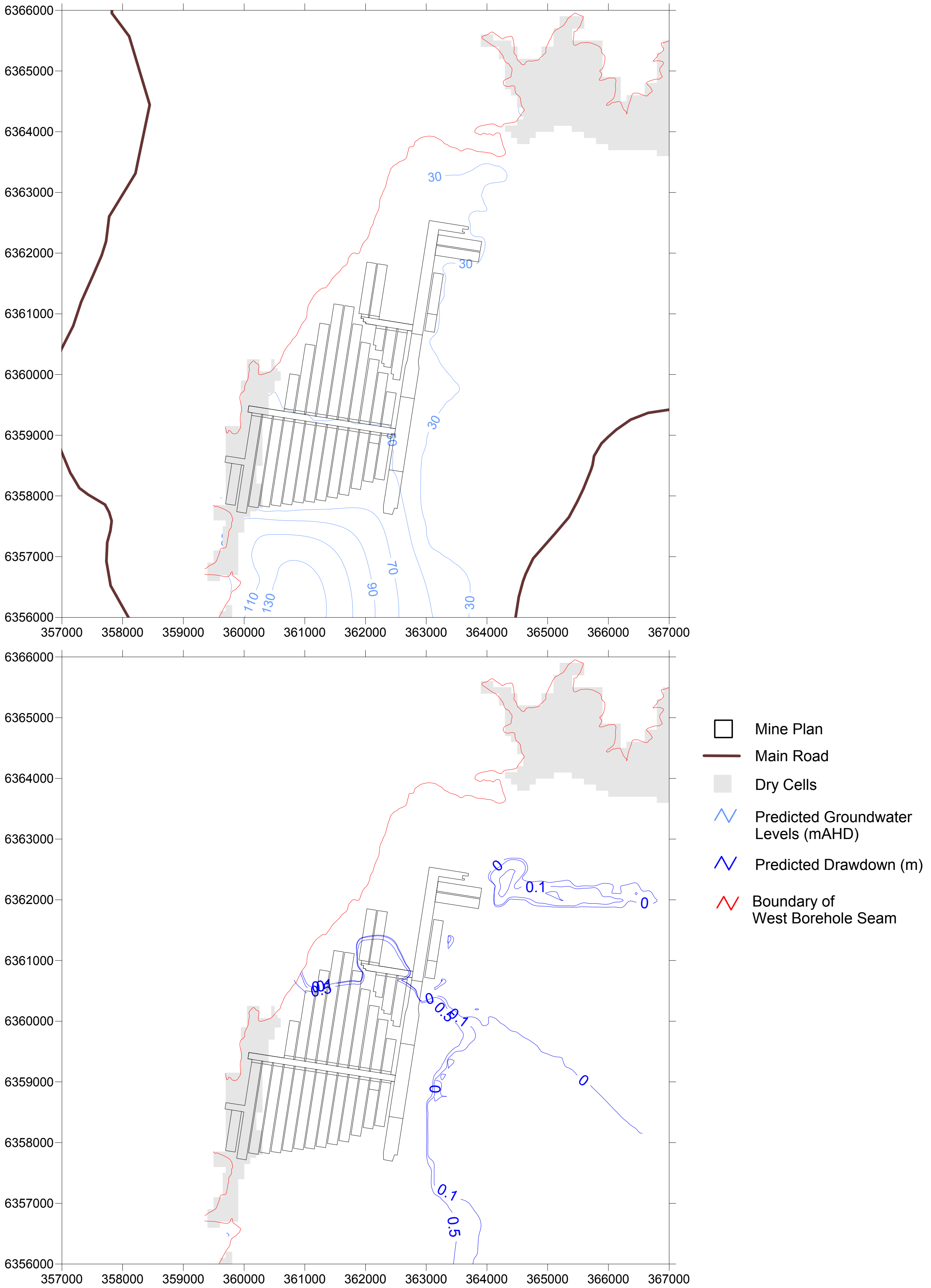
Figure 8.1



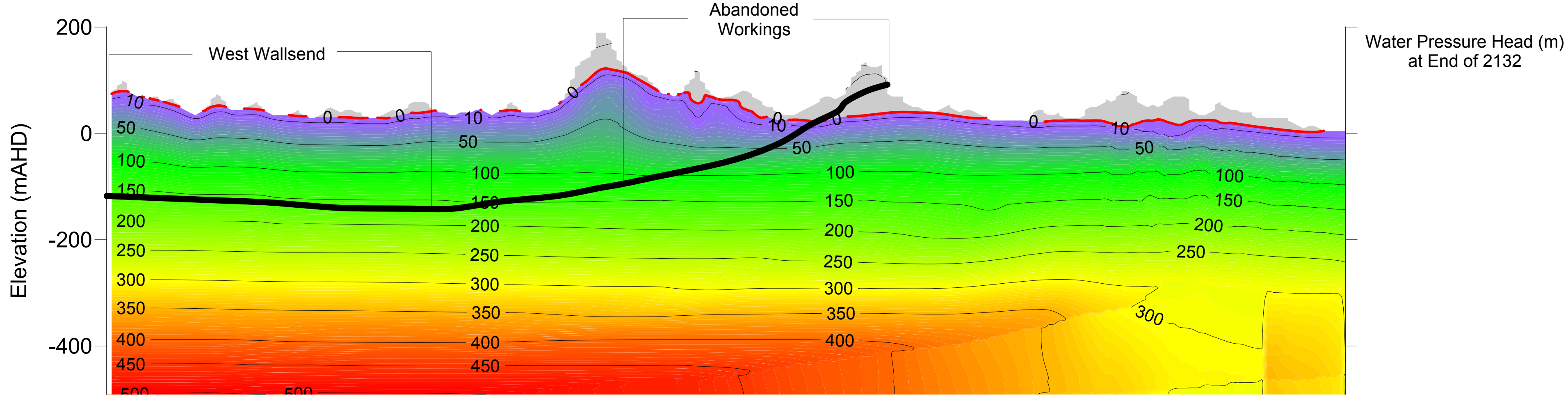
Date	16/04/2012	Scale	As Shown	**Donaldson Coal Pty Ltd**
Initials	HZ	Project	S35	**Predicted Groundwater Level and Drawdown at 100 Years Recovery West Borehole Seam Overburden - not fractured (Layer 4)**
Drawing Number	S35-030a	Revision	A	
RPS Aquaterra				**Figure 8.2**

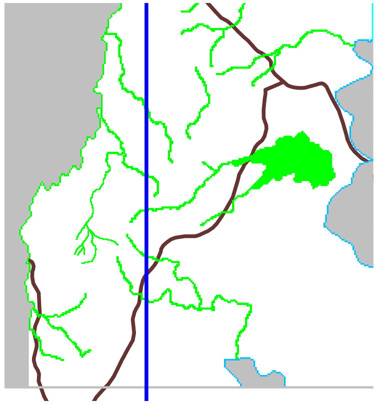


Date	**16/04/2012**	Scale	**As Shown**	**Donaldson Coal Pty Ltd**
Initials	**HZ**	Project	**S35**	**Predicted Groundwater Level and Drawdown at 100 Years Recovery West Borehole Seam Overburden - fractured (Layer 5)**
Drawing Number	**S35-031a**	Revision	**A**	
RPS Aquaterra				**Figure 8.3**



Date	16/04/2012	Scale	As Shown	**Donaldson Coal Pty Ltd**
Initials	HZ	Project	S35	**Predicted Groundwater Level and Drawdown at 100 Years Recovery in the West Borehole Seam (Layer 7)**
Drawing Number	S35-032a	Revision	A	
RPS Aquaterra				**Figure 8.4**





West Borehole Seam
Rivers or Creeks
No Flow
General Head Boundary
Main Road

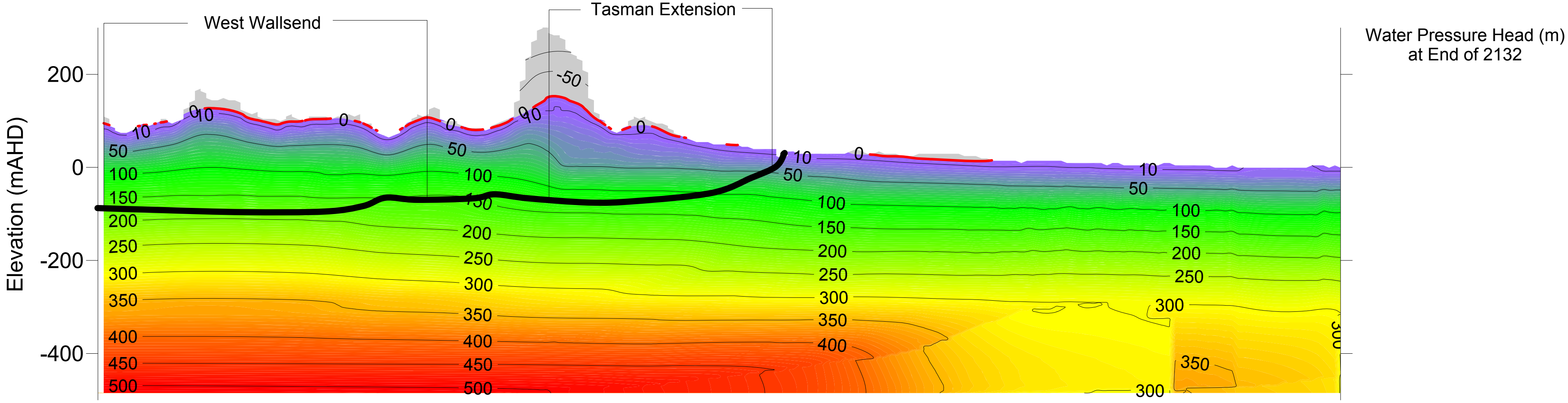
Date	18/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-034	Revision	A

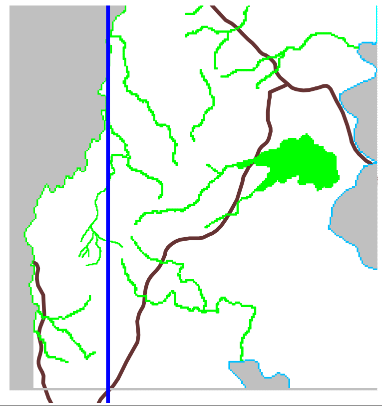
RPS Aquaterra

Donaldson Coal Pty Ltd

Water Pressure Heads
Along Easting 364850 (column 133)
at End of Recovery

Figure 8.5





West Borehole Seam
Rivers or Creeks
No Flow
General Head Boundary
Main Road

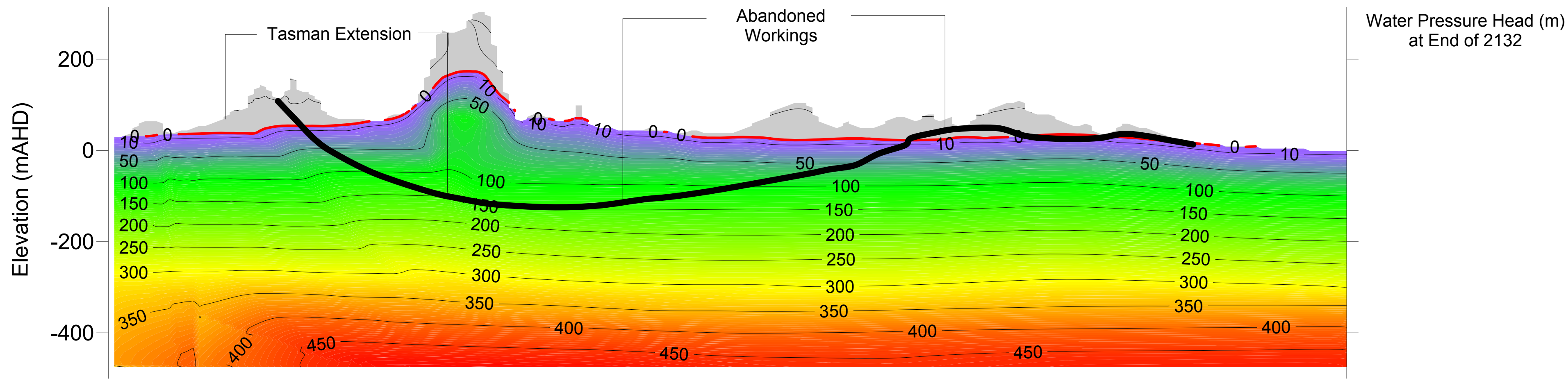
Date	18/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-035	Revision	A

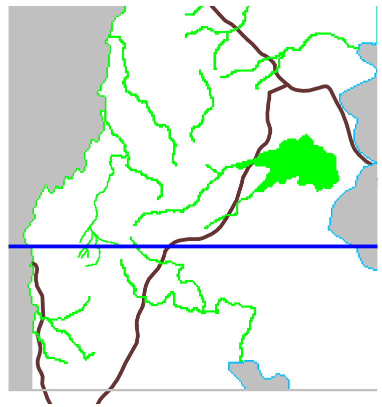
RPS Aquaterra

Donaldson Coal Pty Ltd

Water Pressure Heads
Along Easting 362175 (Column 88)
at End of Recovery

Figure 8.6





West Borehole Seam
Rivers or Creeks
No Flow
General Head Boundary
Main Road

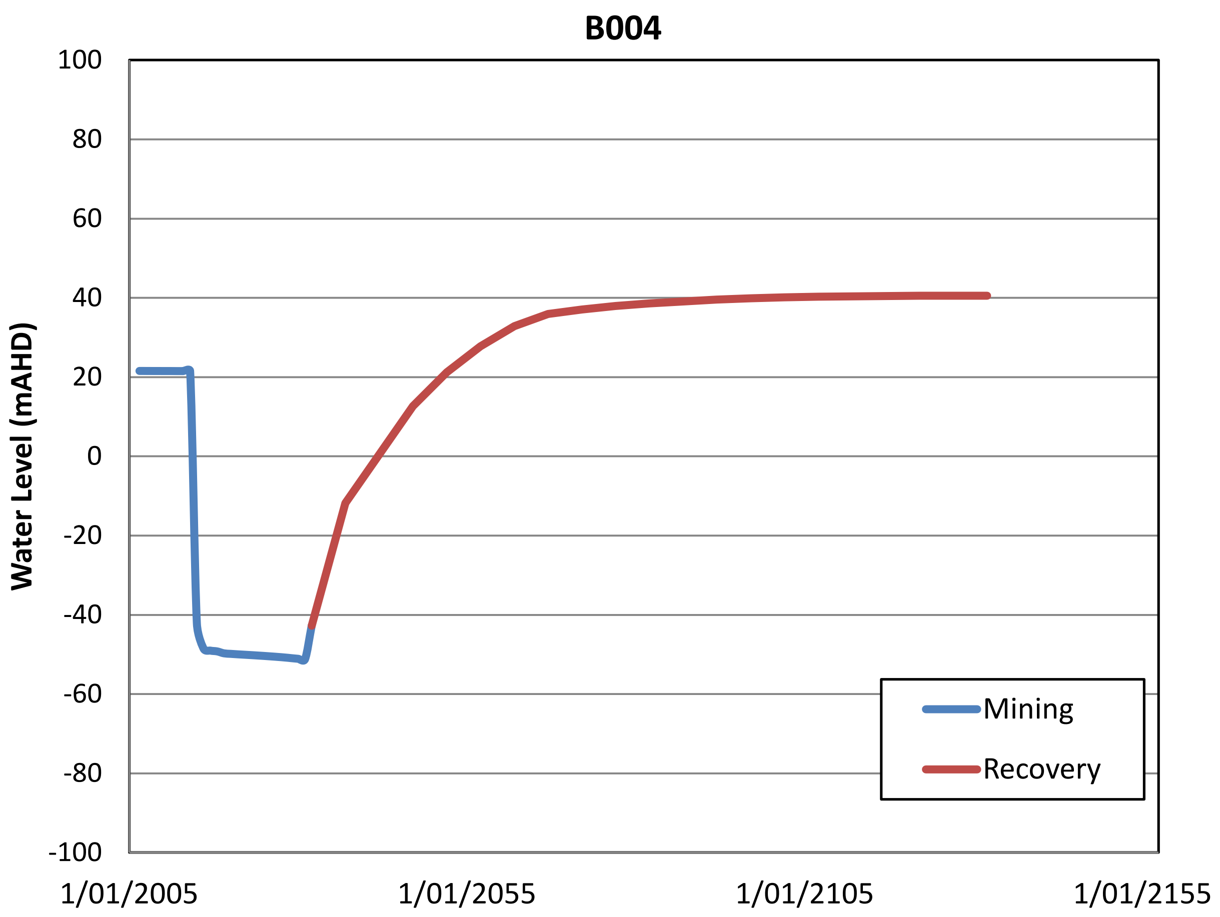
Date	18/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-036	Revision	A

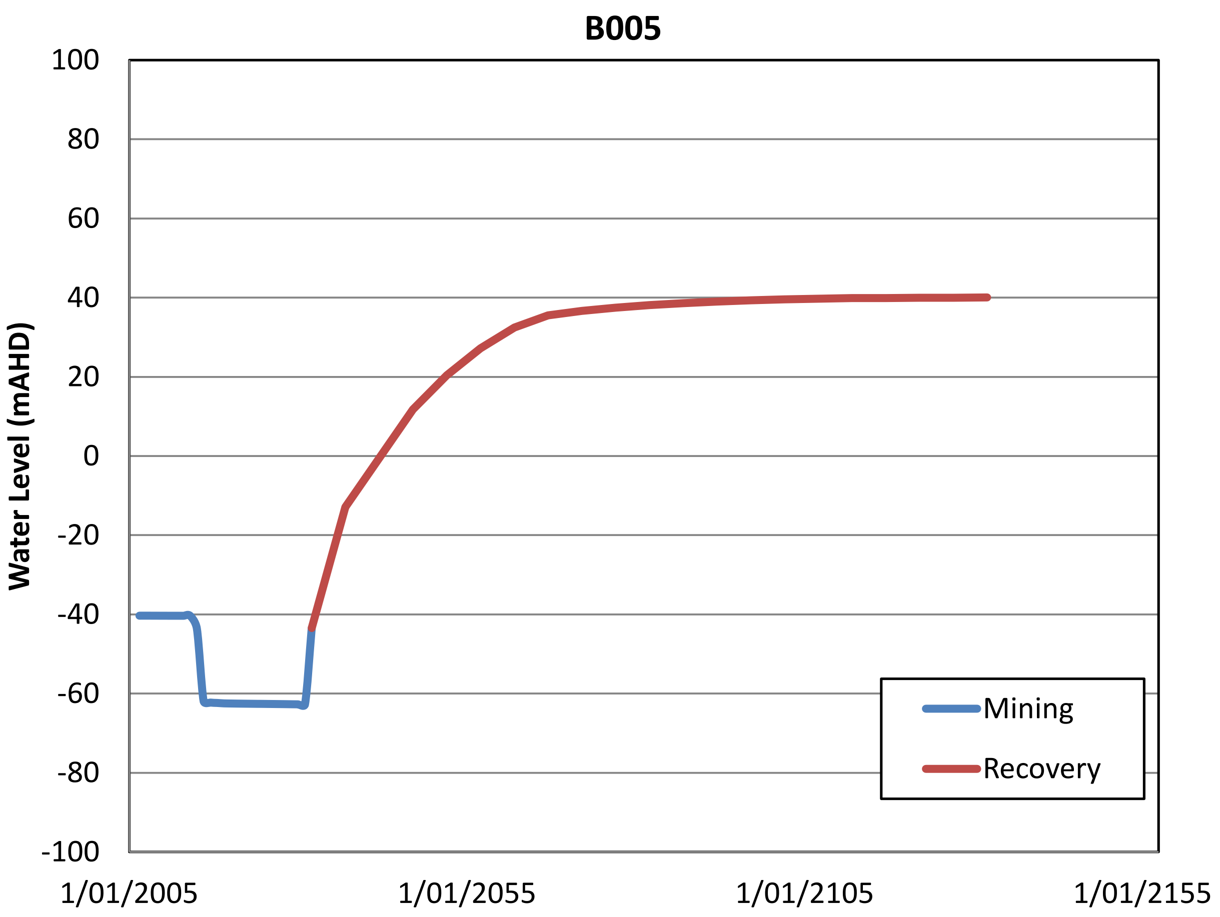
RPS Aquaterra

Donaldson Coal Pty Ltd

Water Pressure Heads Along Northing 6359025 (Row 192) at End of Recovery

Figure 8.7

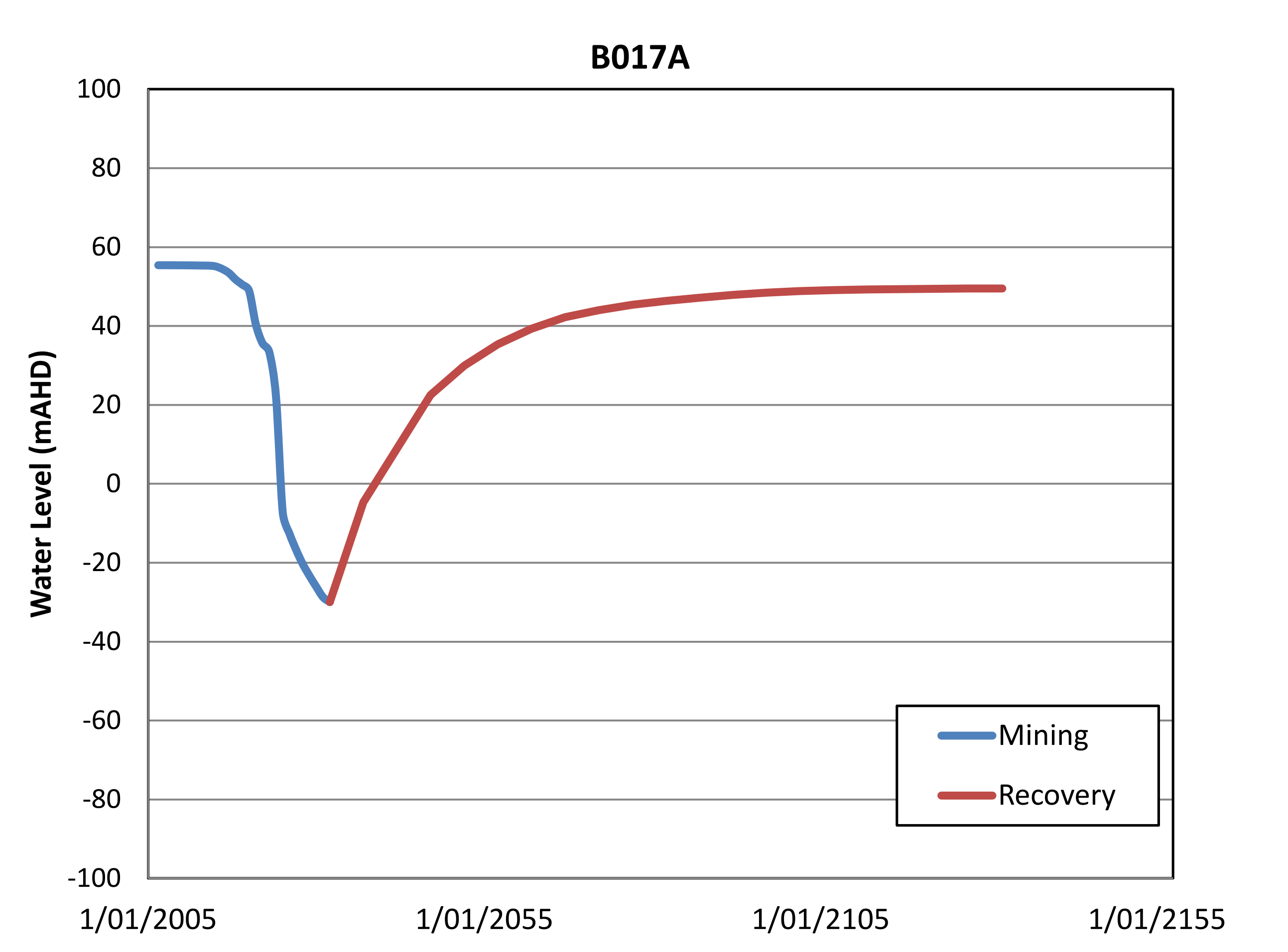


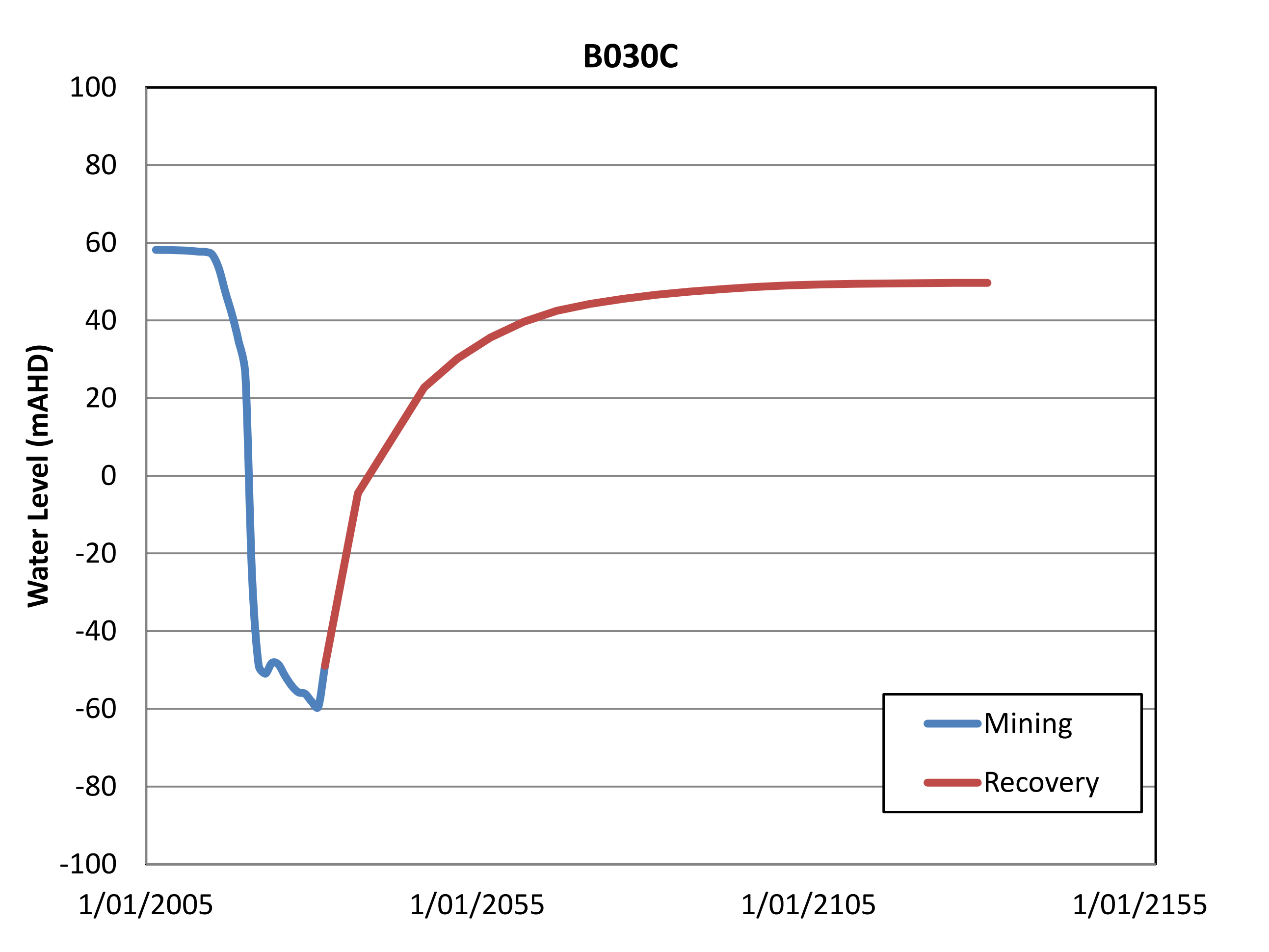


RPS Aquaterra

Simulated Recovery Hydrographs for B004 and B005 FIGURE 8.8

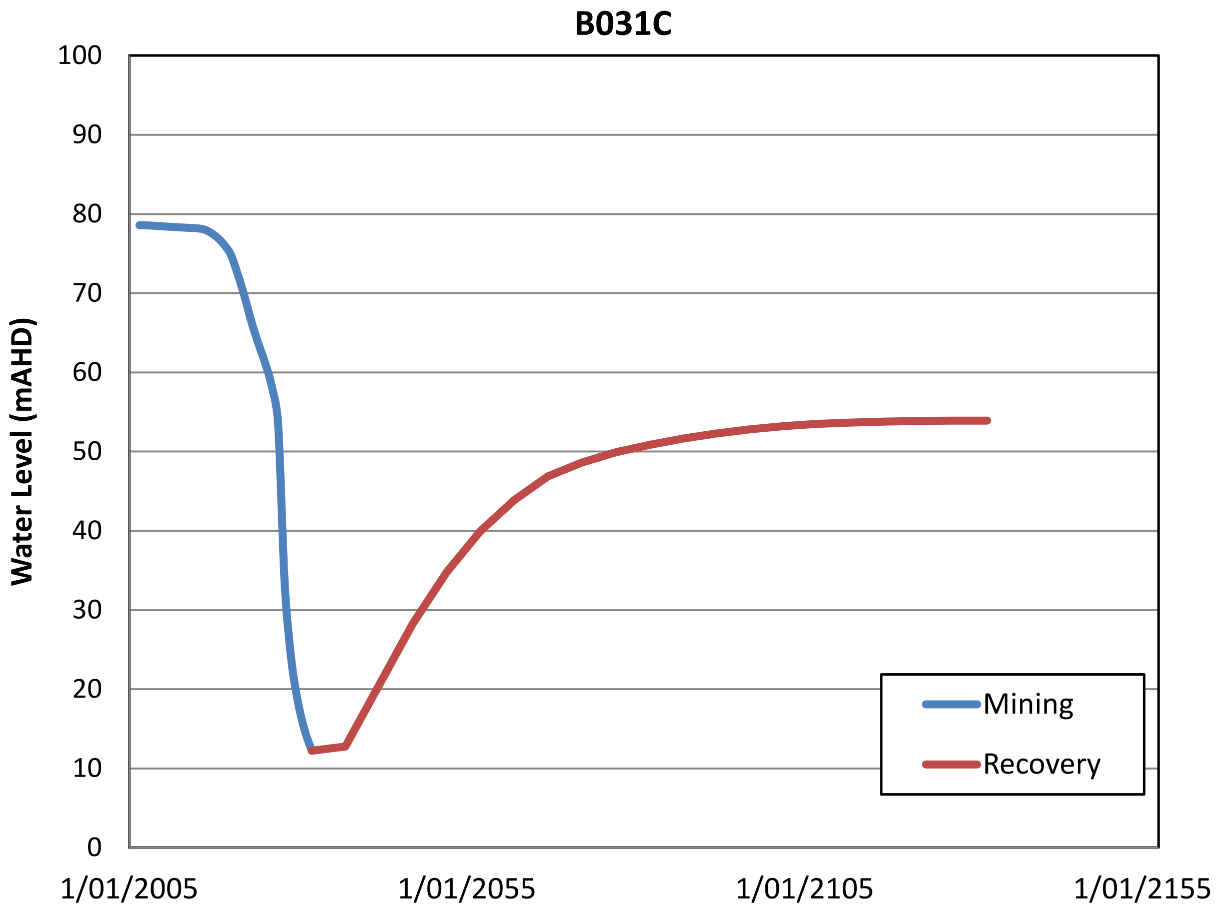
F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v3.xlsx]8.8





Simulated Recovery Hydrographs for B017A and B030C FIGURE 8.9

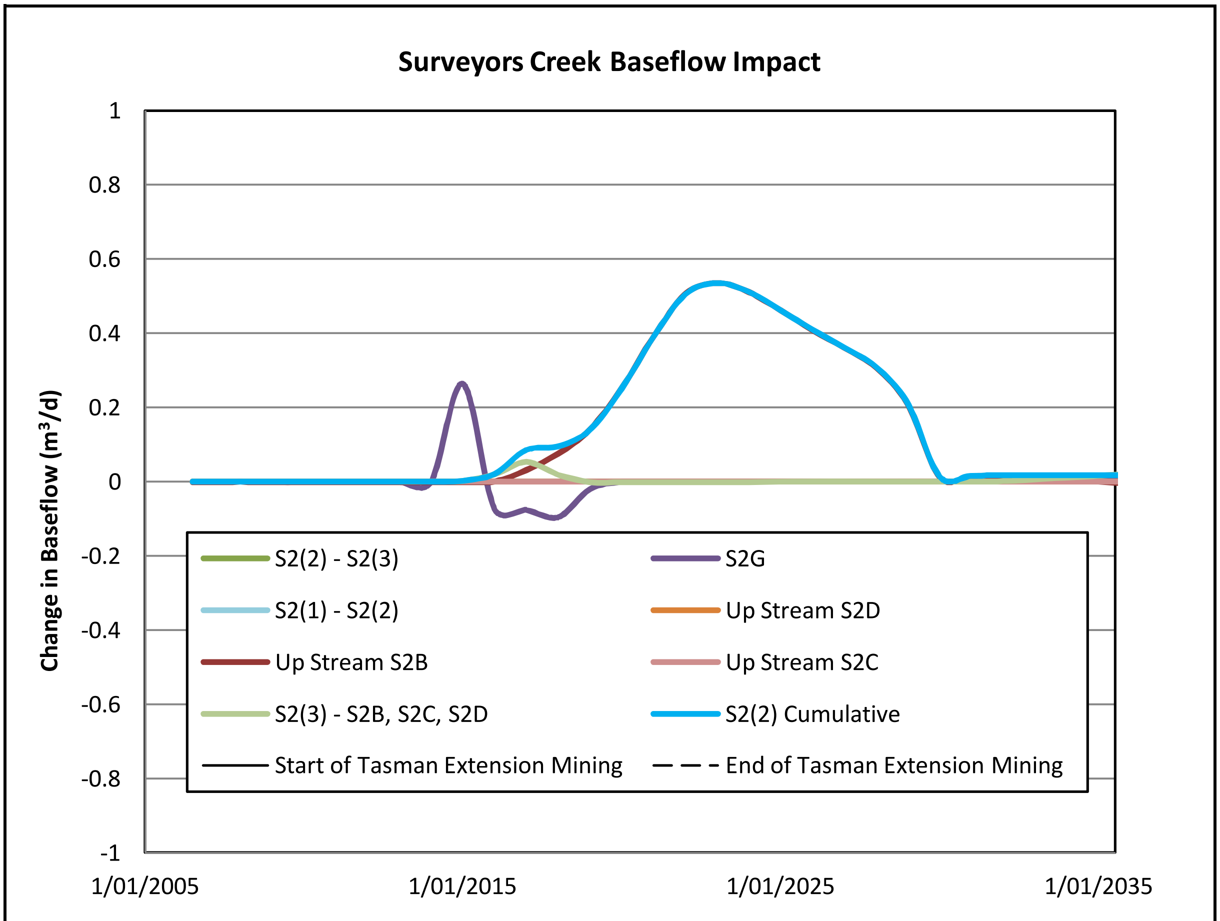
F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v3.xlsx]8.9

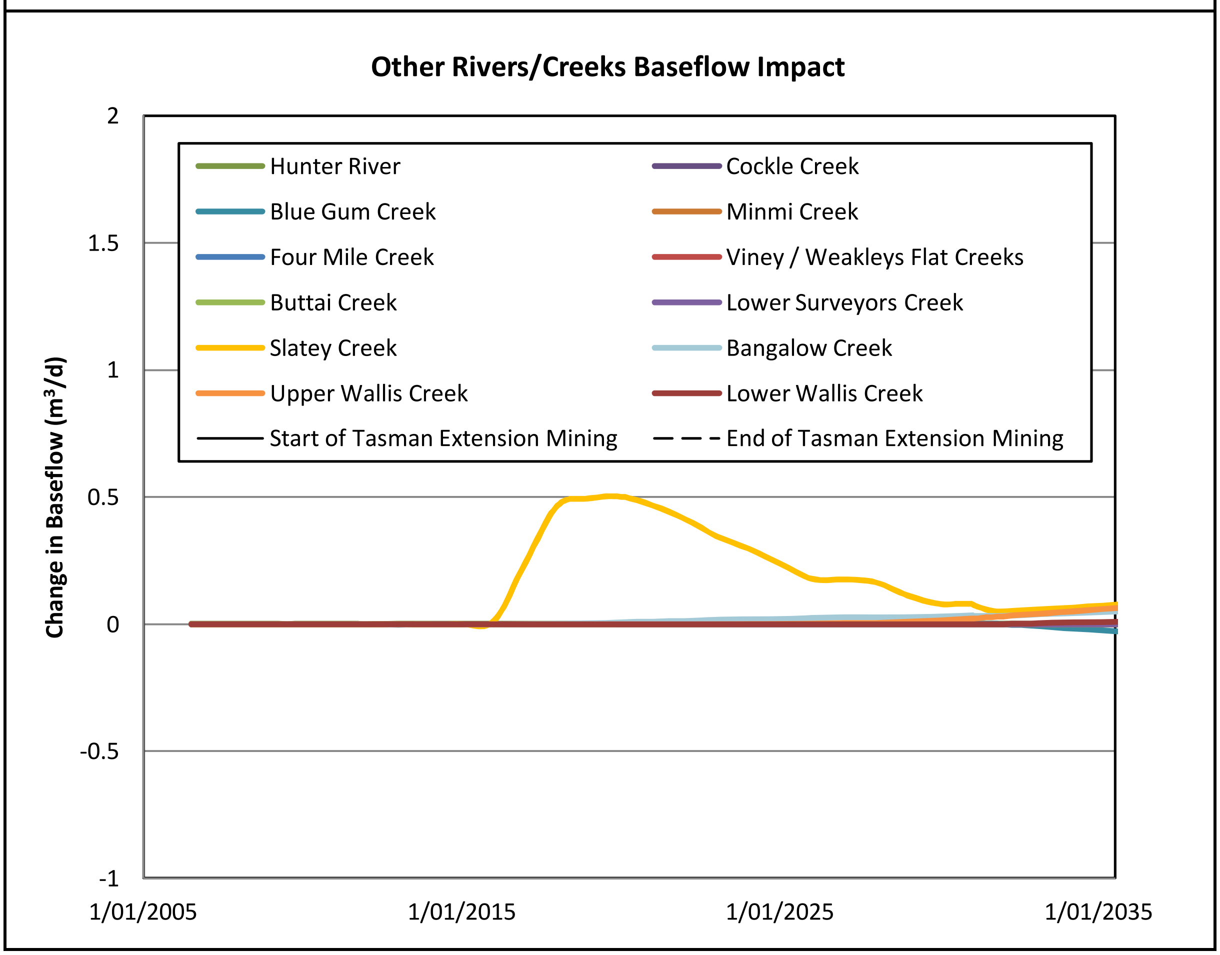


RPS Aquaterra

Simulated Recovery Hydrographs for B031C FIGURE 8.10

F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v3.xlsx]8.10

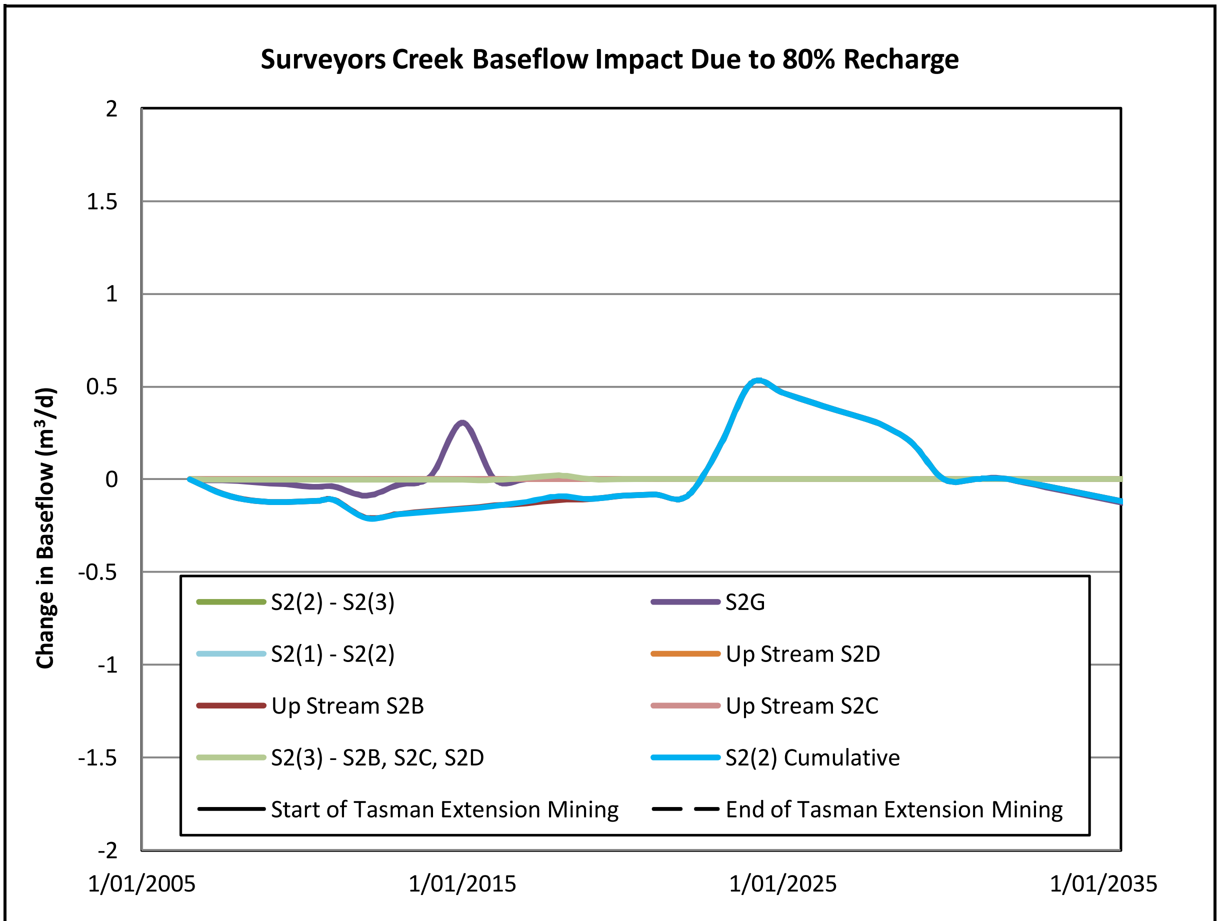


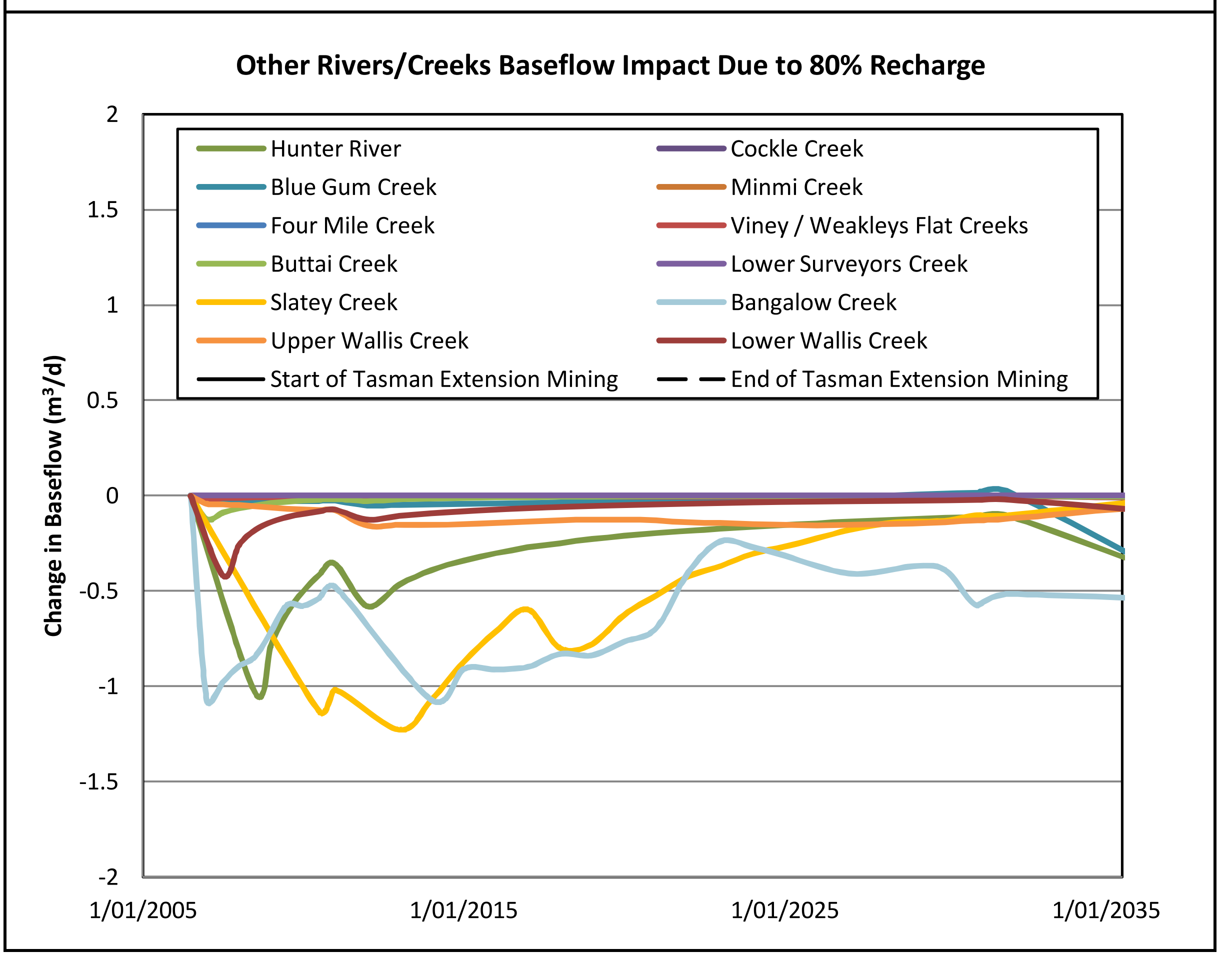


RPS Aquaterra

Baseflows Impact Due to Tasman Extension (to aquifer) FIGURE 8.11

F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v3.xlsx]8.11

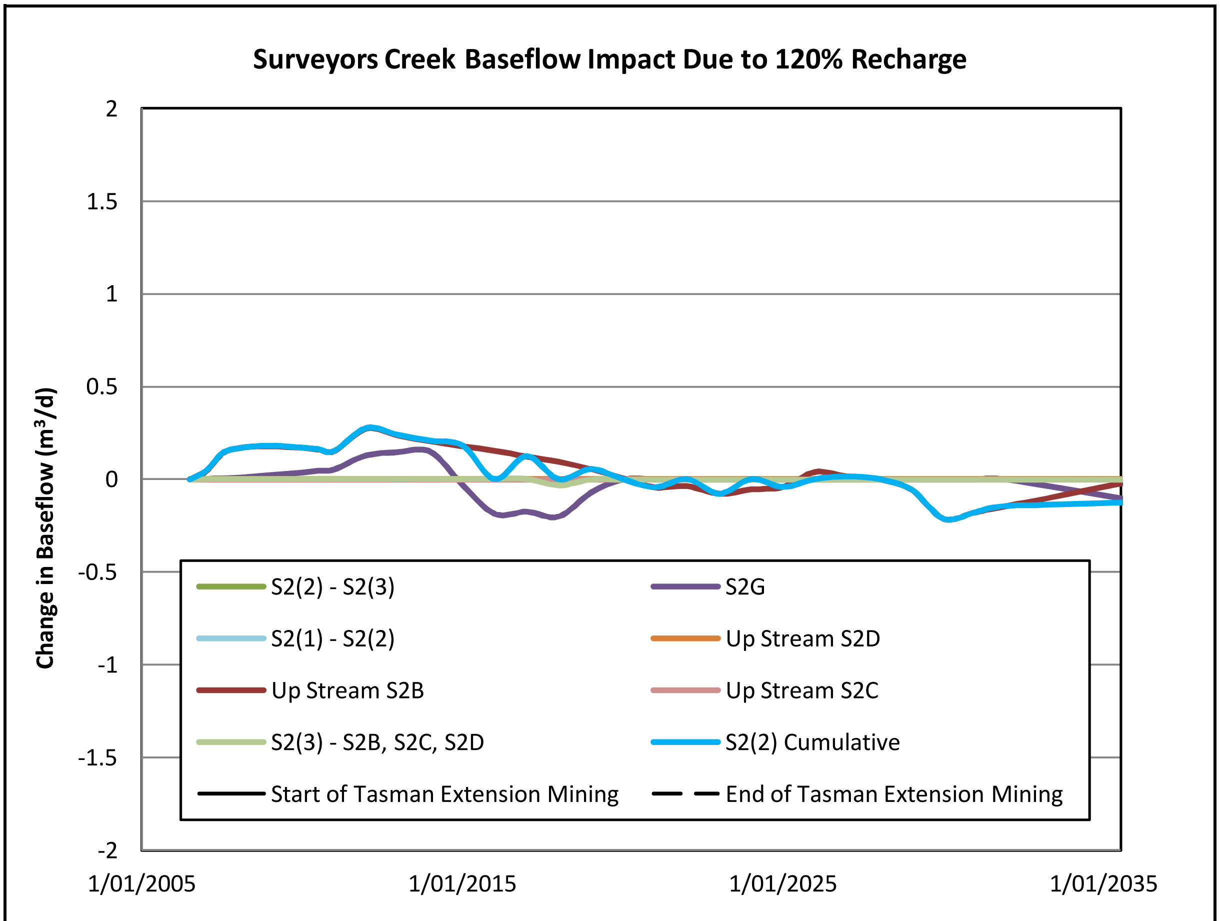


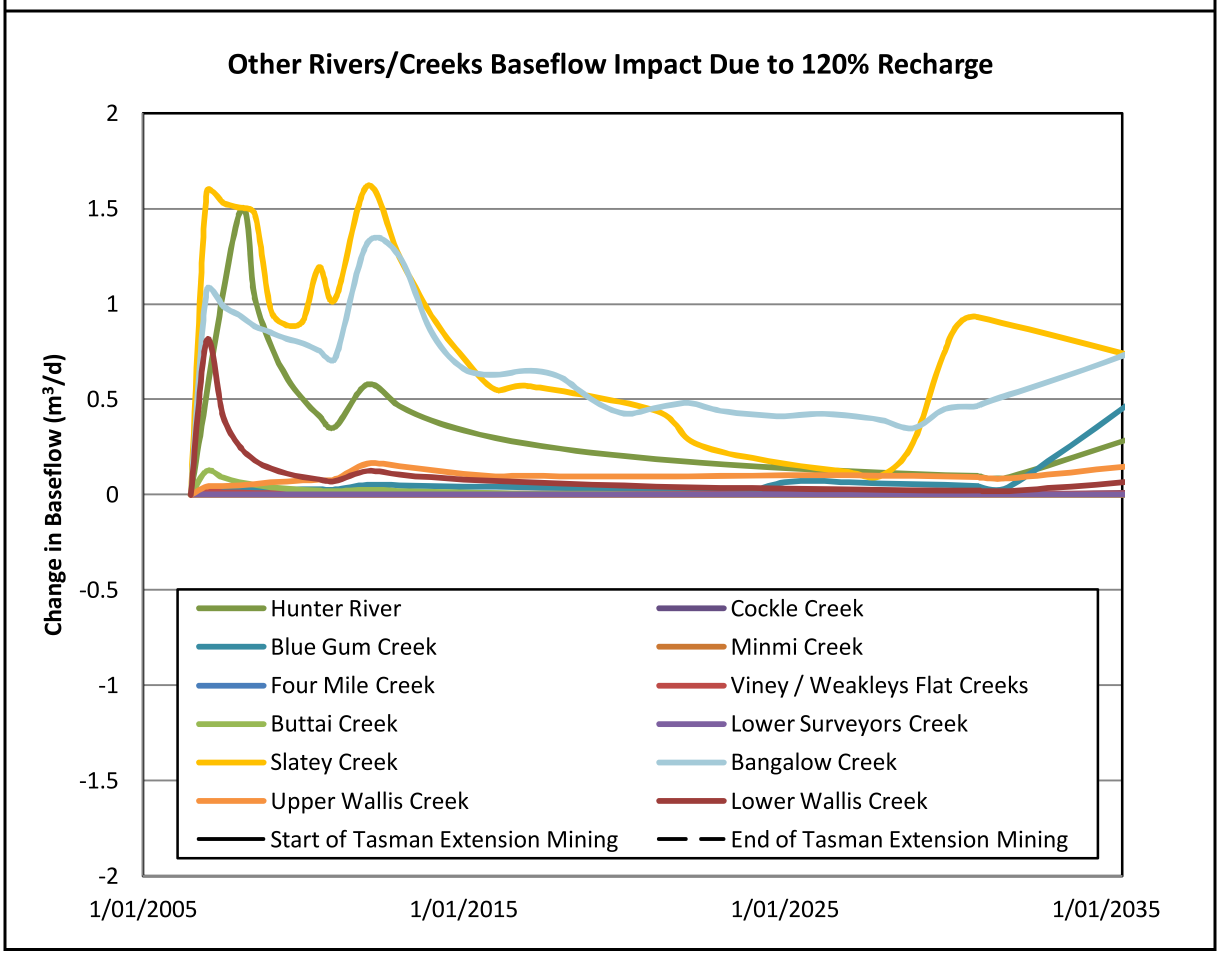


RPS Aquaterra

Baseflows Impact Due to 80% Recharge (to aquifer) FIGURE 8.12

F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v3.xlsx]8.12

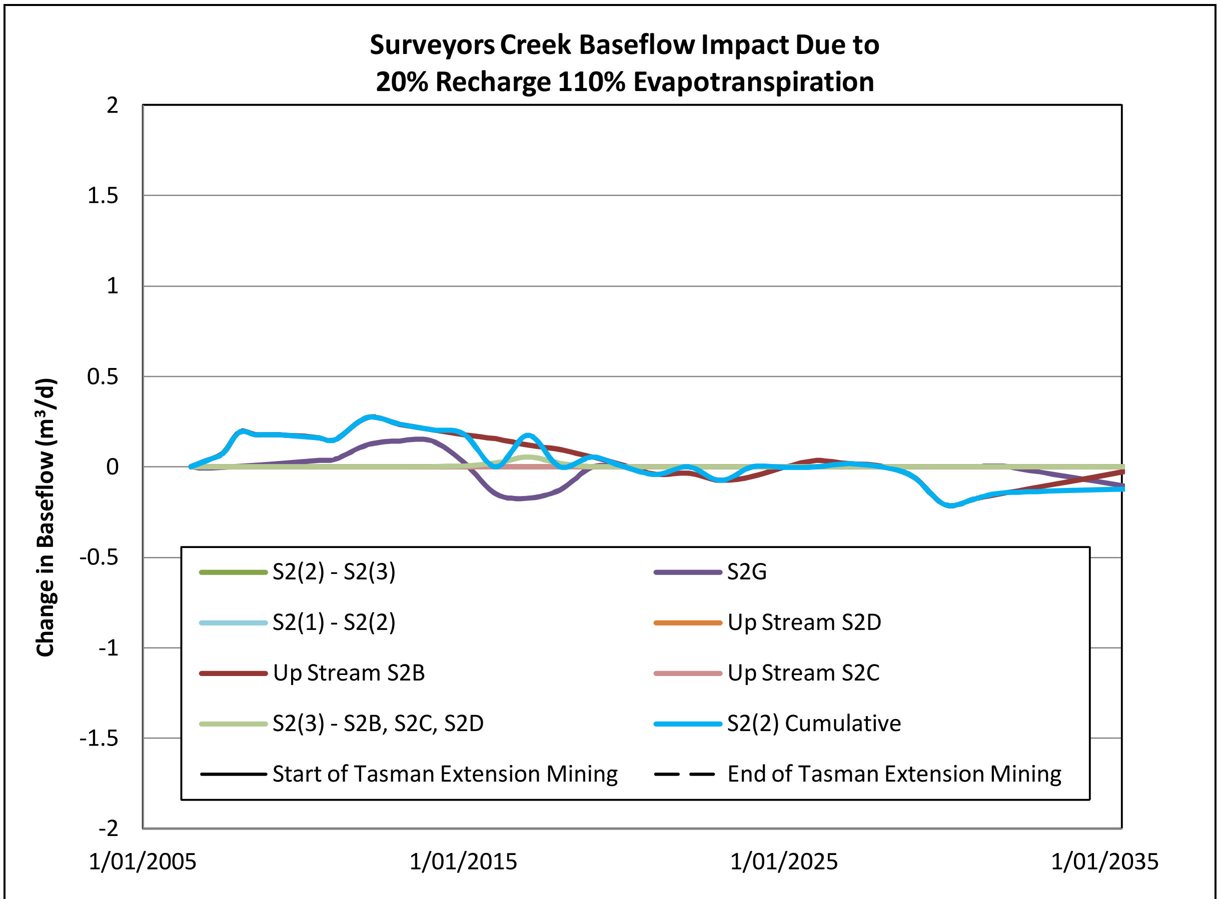


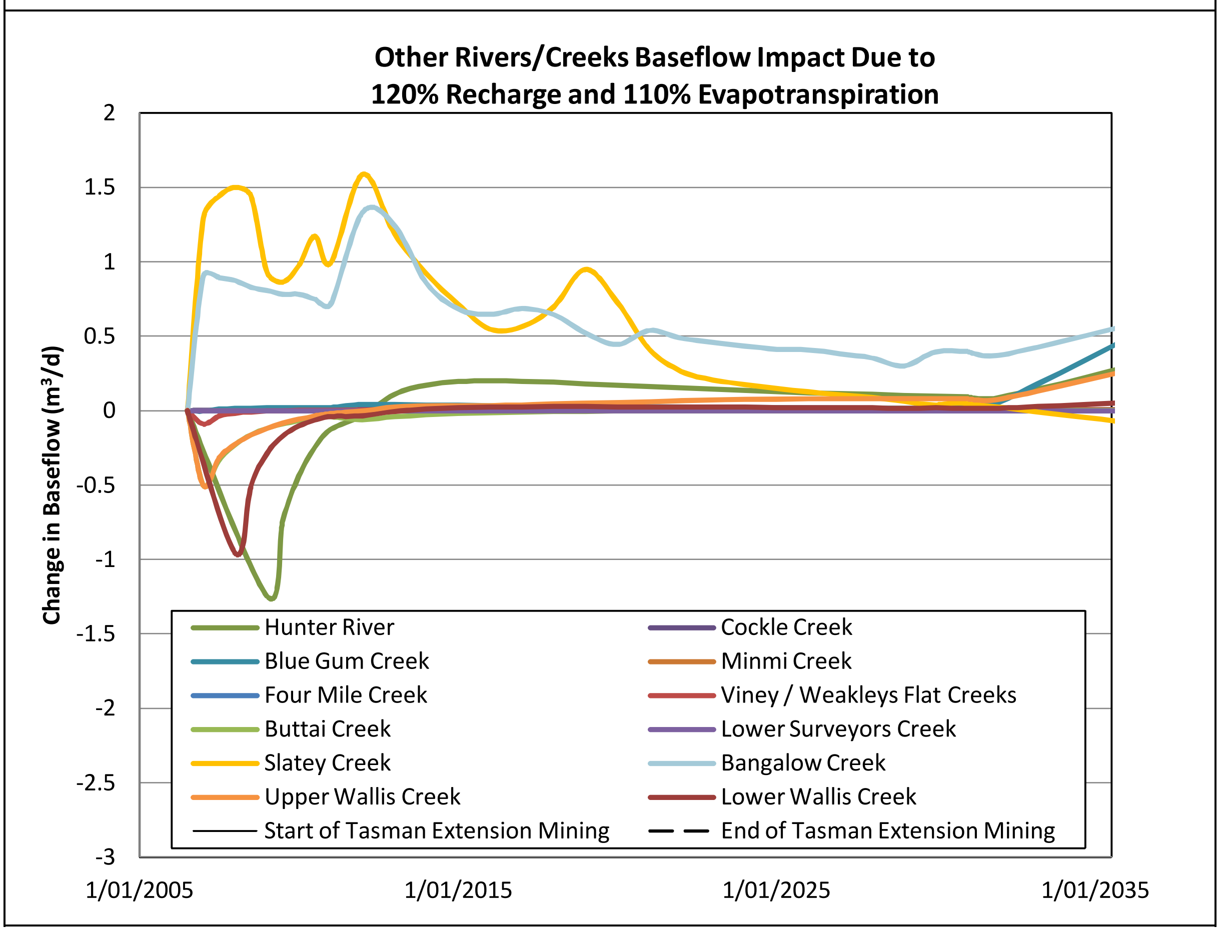


RPS Aquaterra

Baseflows Impact Due to 120% Recharge (to aquifer) FIGURE 8.13

F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v3.xlsx]8.13





RPS Aquaterra

Baseflows Impact Due to 120% Recharge and 110% Evapotranspiration (to aquifer) FIGURE 8.14

F:\Jobs\S35\400 Modelling\MODFLOW model\300\320_Model_Output\[Figure_v3.xlsx]8.14

APPENDIX A:
BORE LOGS

Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ1

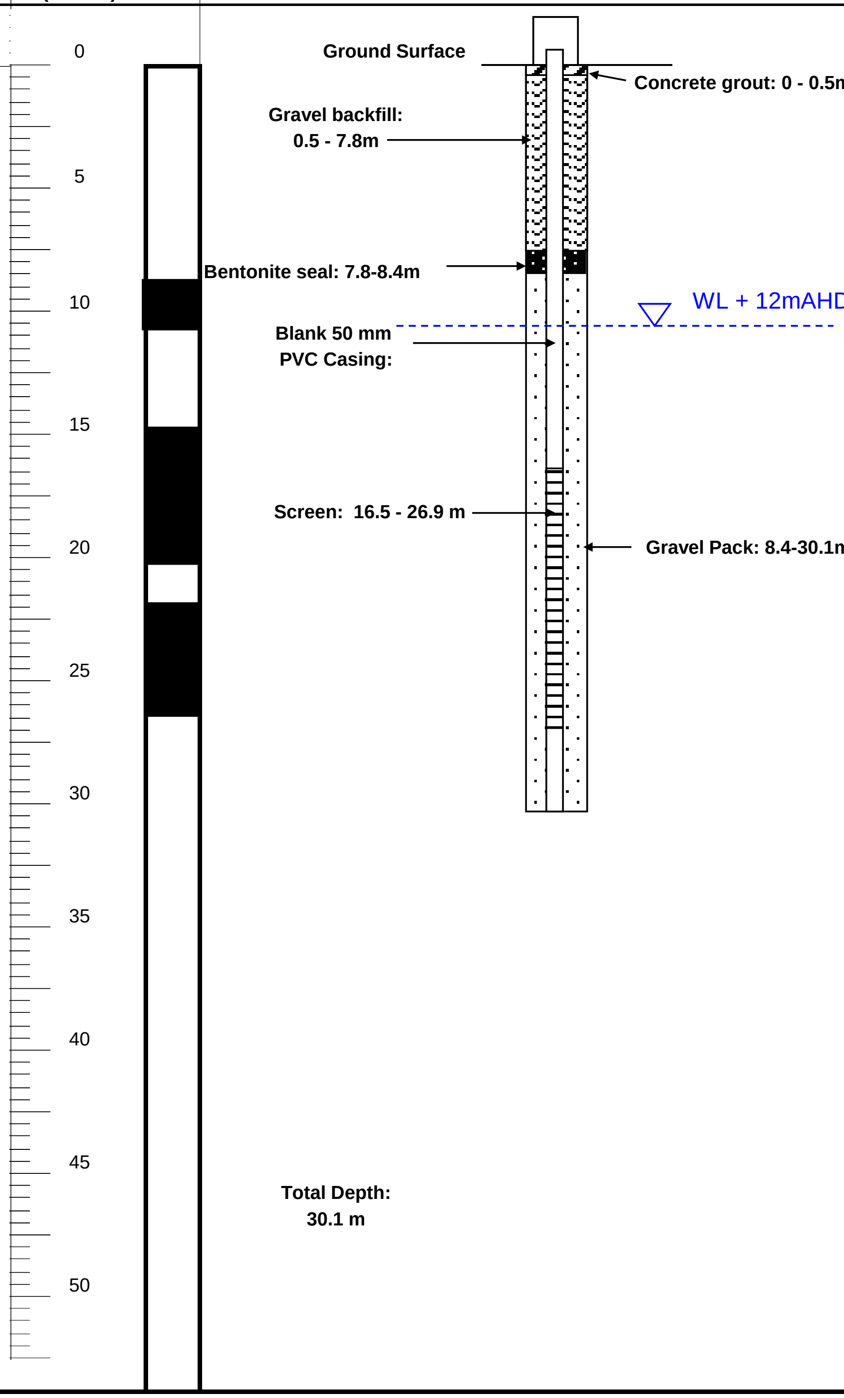
			Project No:	05-0163
Client: Donaldson Coal Pty Ltd	Elevation (GL):	23.08mAHD		
	Elevation (TOC	23.56mAHD		
Location: Abel Coal Project	Stickup:	0.48m		
	Hole Depth:	30.1m		
Drilling Contractor:	Date Started:		Supervised By:	
	Date Completed			

Description	Depth (metres)	Well Construction Details:

Upper Donaldson Seam

Lower Donaldson Seam

Big Ben Seam



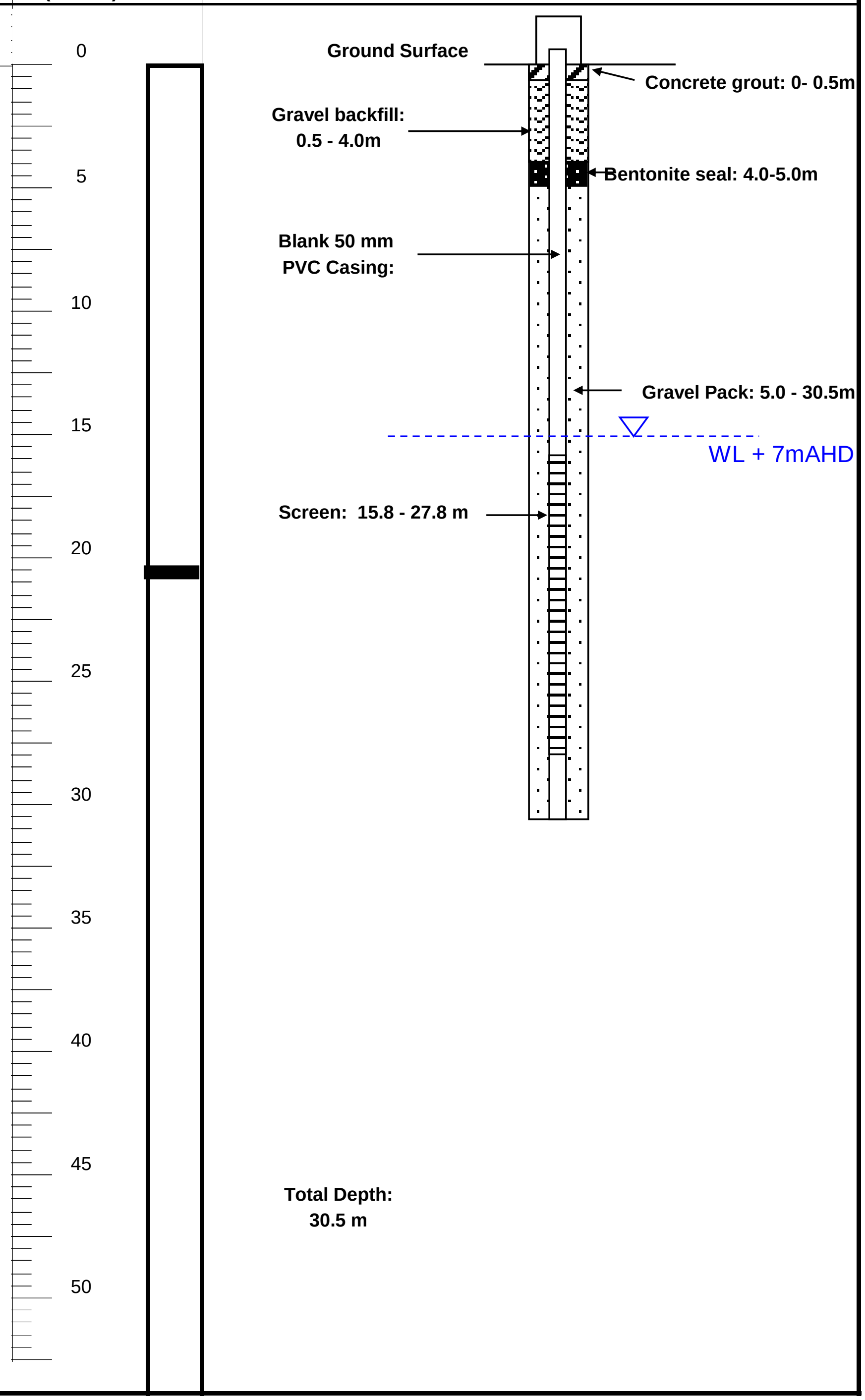
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ2

		Project No:		05-0163
Client: Donaldson Coal Pty Ltd	Elevation (GL):	22.3 mAHD		
	Elevation (TOC)	23.37mAHD		
Location: Abel Coal Projecy	Stickup:	1.07m		
	Hole Depth:	30.5m		
Drilling Contractor:	Date Started:		Supervised By:	
	Date Completed			

Description	Depth (metres)	Well Construction Details:
Beresfield Seam		



Peter Dundon and Assoc.

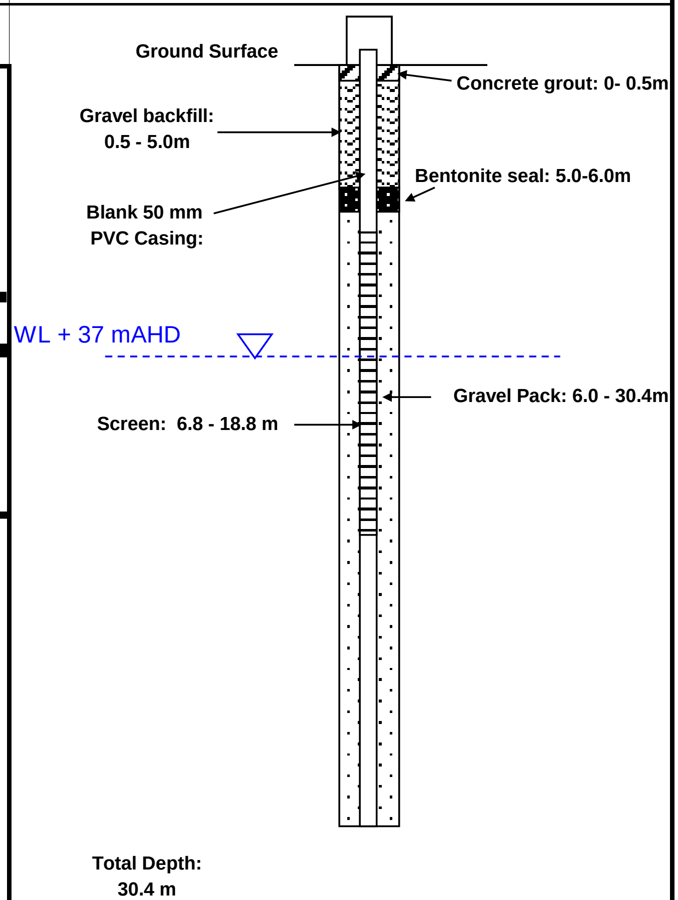
Logging Sheet

BORE: DPZ3

		Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**49.09mAHD**	
	Elevation (TOC)	**49.62 mAHD**	
Location: **Abel Coal Project**	Stickup:	**0.53m**	
	Hole Depth:	**30.4m**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed		

Description	Depth (metres)	Well Construction Details:
Undifferentiated Coal		
Undifferentiated Coal		
Undifferentiated Coal		

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50



Peter Dundon and Assoc.

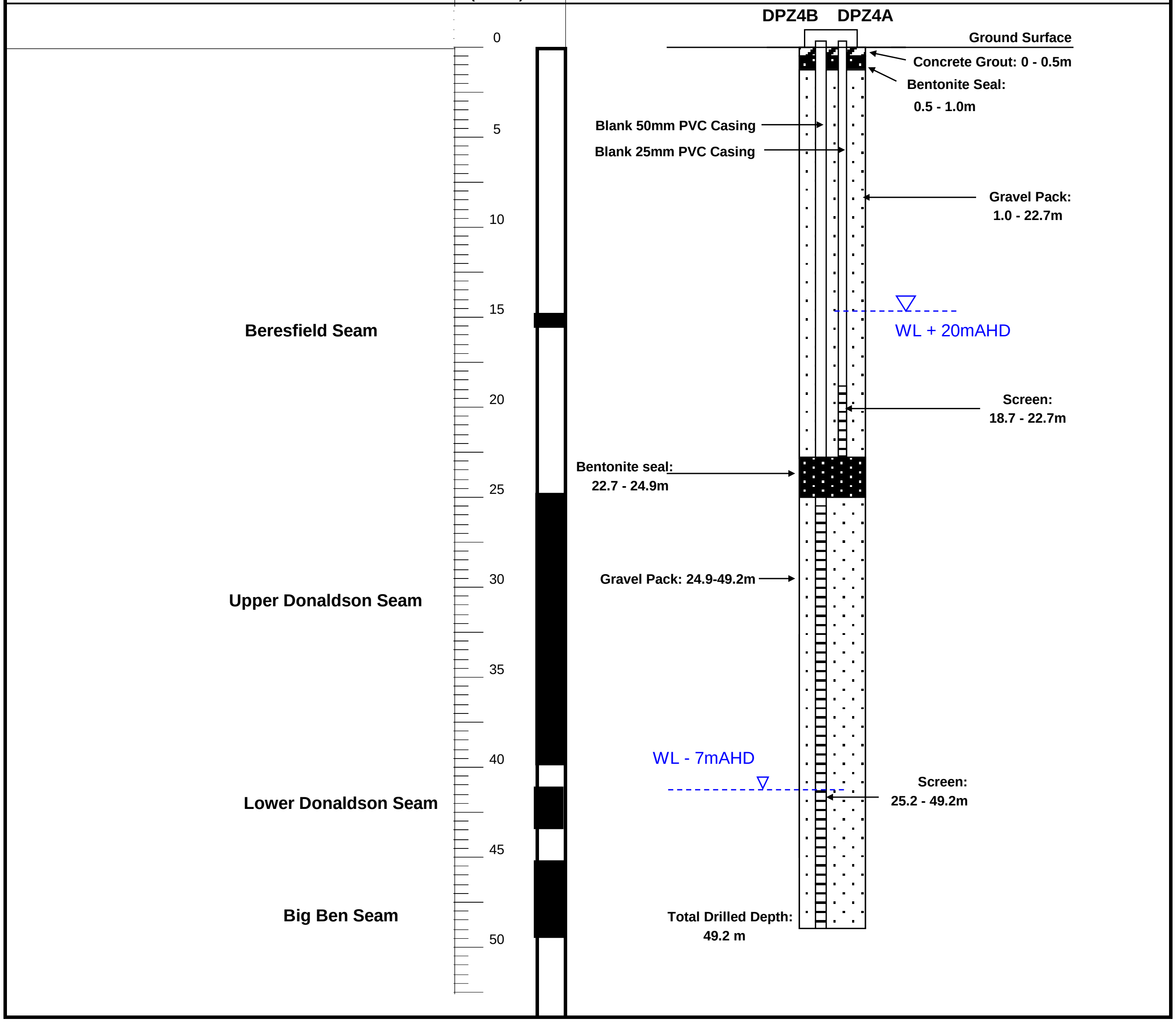
Logging Sheet

BORES: DPZ4A and DPZ4B

05-0163

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Date Finished:
Donaldson Coal Pty Ltd	DPZ4A	35.01mAHD	35.74 mAHD	0.73m	
Locationt:	DPZ4B	35.01mAHD	35.74 mAHD	0.73m	
Abel Coal Project					
			Hole depths: As shown		

Description	Depth (metres)	Well Construction Details:

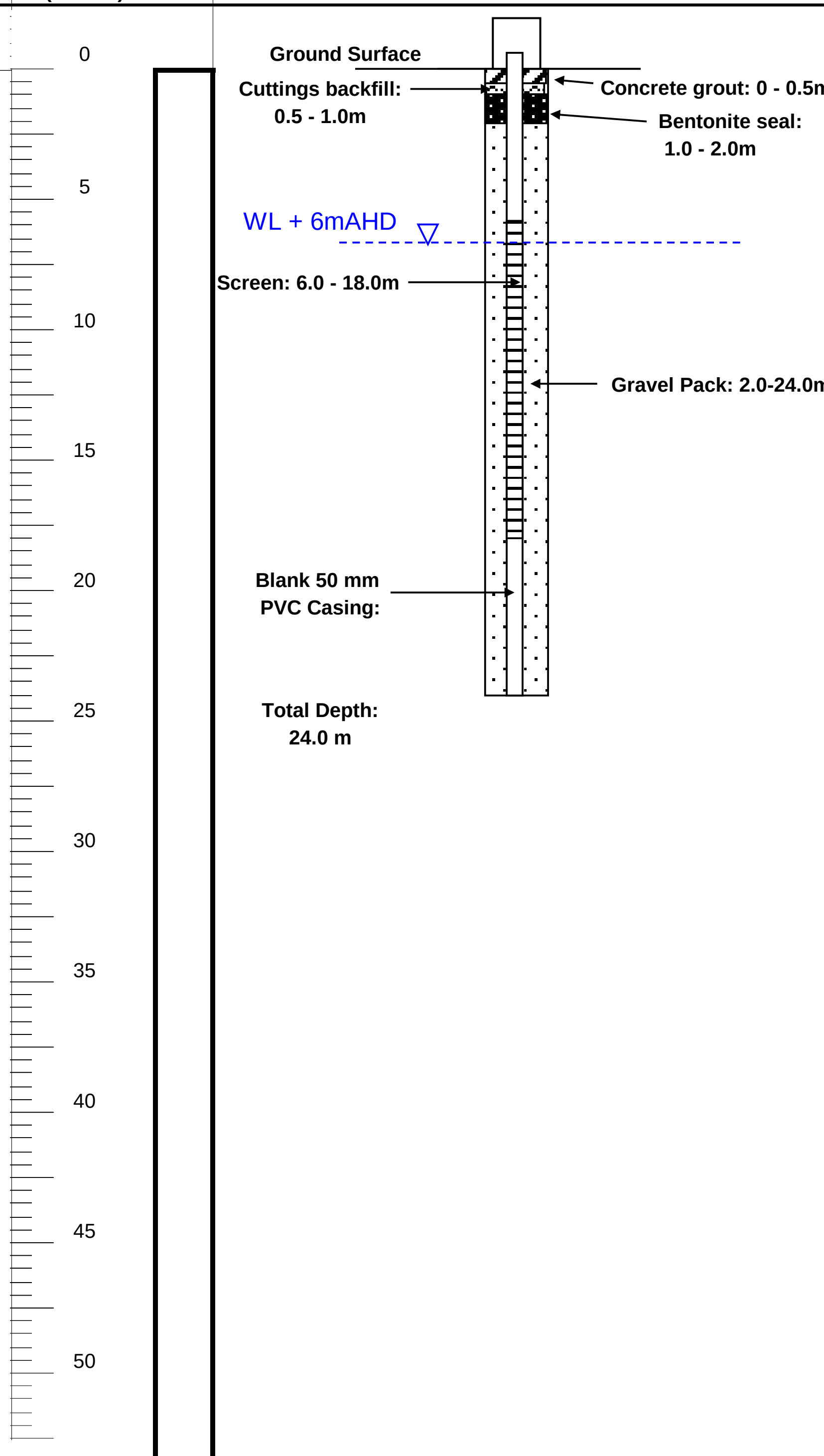


Peter Dundon and Assoc.
Logging Sheet

BORE: DPZ5

		Project No:	05-0163
Client: Donaldson Coal Pty Ltd	Elevation (GL):	12.8 mAHD	
	Elevation (TOC	13.58mAHD	
Location: Abel Coal Project	Stickup:	0.78m	
	Hole Depth:	24.0m	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed		

Description	Depth (metres)	Well Construction Details:



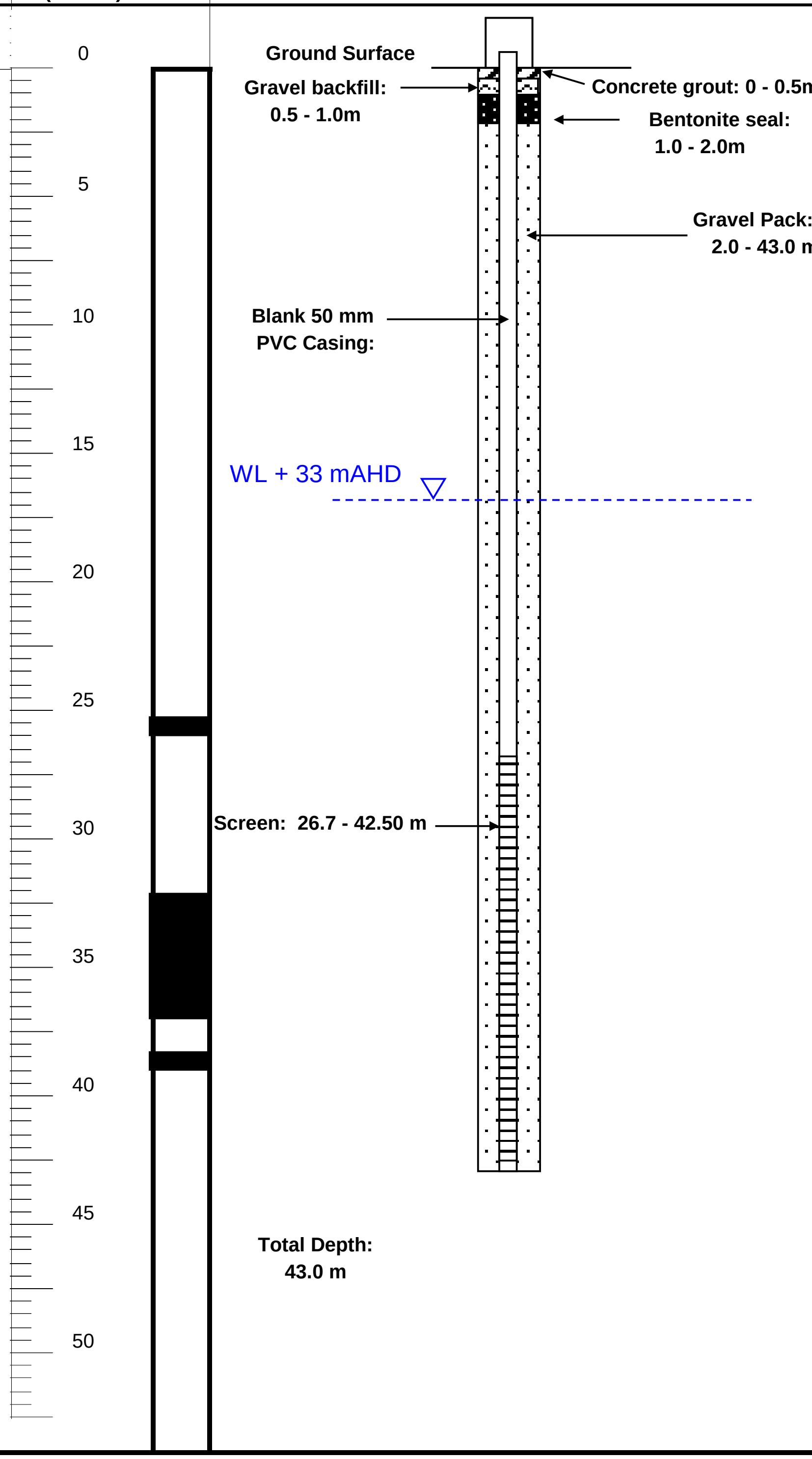
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ6

			Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**57.7 mAHD**		
	Elevation (TOC	**58.3mAHD**		
Location: **Abel Coal Project**	Stickup:	**0.6m**		
	Hole Depth:	**43.0m**		
Drilling Contractor:	Date Started:		Supervised By:	
	Date Completed			

Description	Depth (metres)	Well Construction Details:
Beresfield Seam		
Upper Donaldson Seam		
Lower Donaldson Seam		

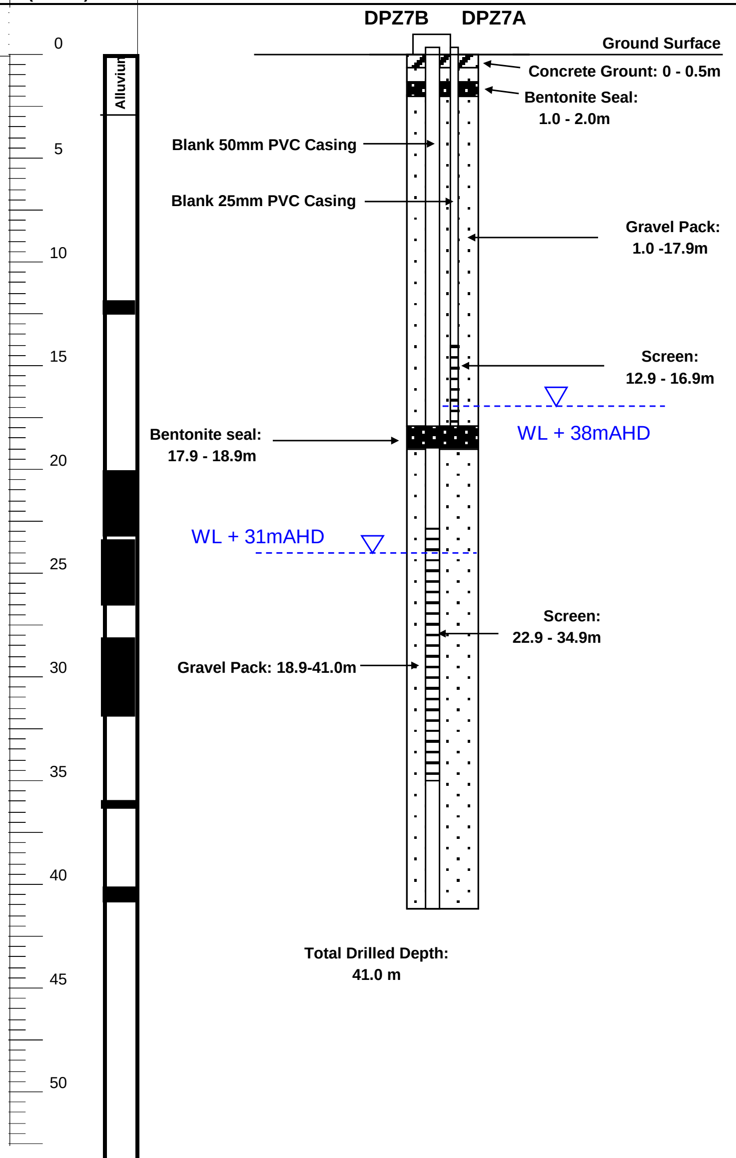


Peter Dundon and Assoc.
Logging Sheet

BORES: DPZ7A and DPZ7B

					Project No:	05-0163
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Date Started:	Date Finished:
Donaldson Coal Pty Ltd	DPZ7A	428.270 mAHD	428.44 mAHD	0.78m		
Location:	DPZ7B	428.404 mAHD	428.63 mAHD	0.78m		
Abel Coal Project						
			Hole depths: As shown		Supervised By:	

Description	Depth (metres)	Well Construction Details:
Beresfield Seam		
Upper Donaldson Seam		
Lower Donaldson Seam		
Big Ben Seam		
Ashtonfields Seam		



Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ8

			Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**51.8 mAHD**		
	Elevation (TOC)	**52.43 mAHD**		
Location: **Abel Coal Project**	Stickup:	**0.63m**		
	Hole Depth:	**33.0m**		
Drilling Contractor:	Date Started:		Supervised By:	
	Date Completed			

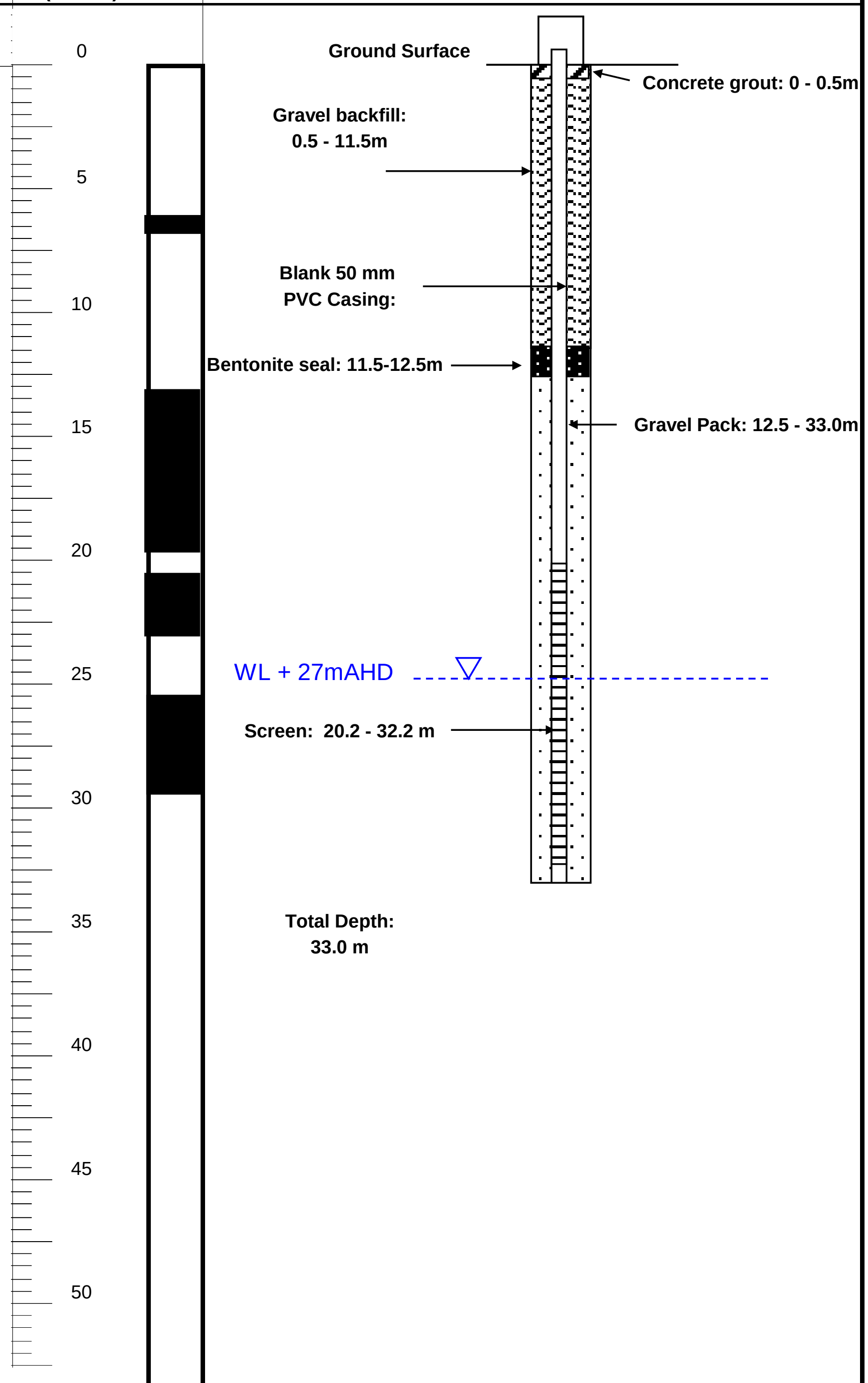
Description	Depth (metres)	Well Construction Details:

Beresfield Seam

Upper Donaldson Seam

Lower Donaldson Seam

Big Ben Seam



Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ9

			Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**36.36 mAHD**		
	Elevation (TOC)	**36.85 mAHD**		
Location: **Abel Coal Project**	Stickup:	**0.49m**		
	Hole Depth:	**40.0m**		
Drilling Contractor:	Date Started:		Supervised By:	
	Date Completed			

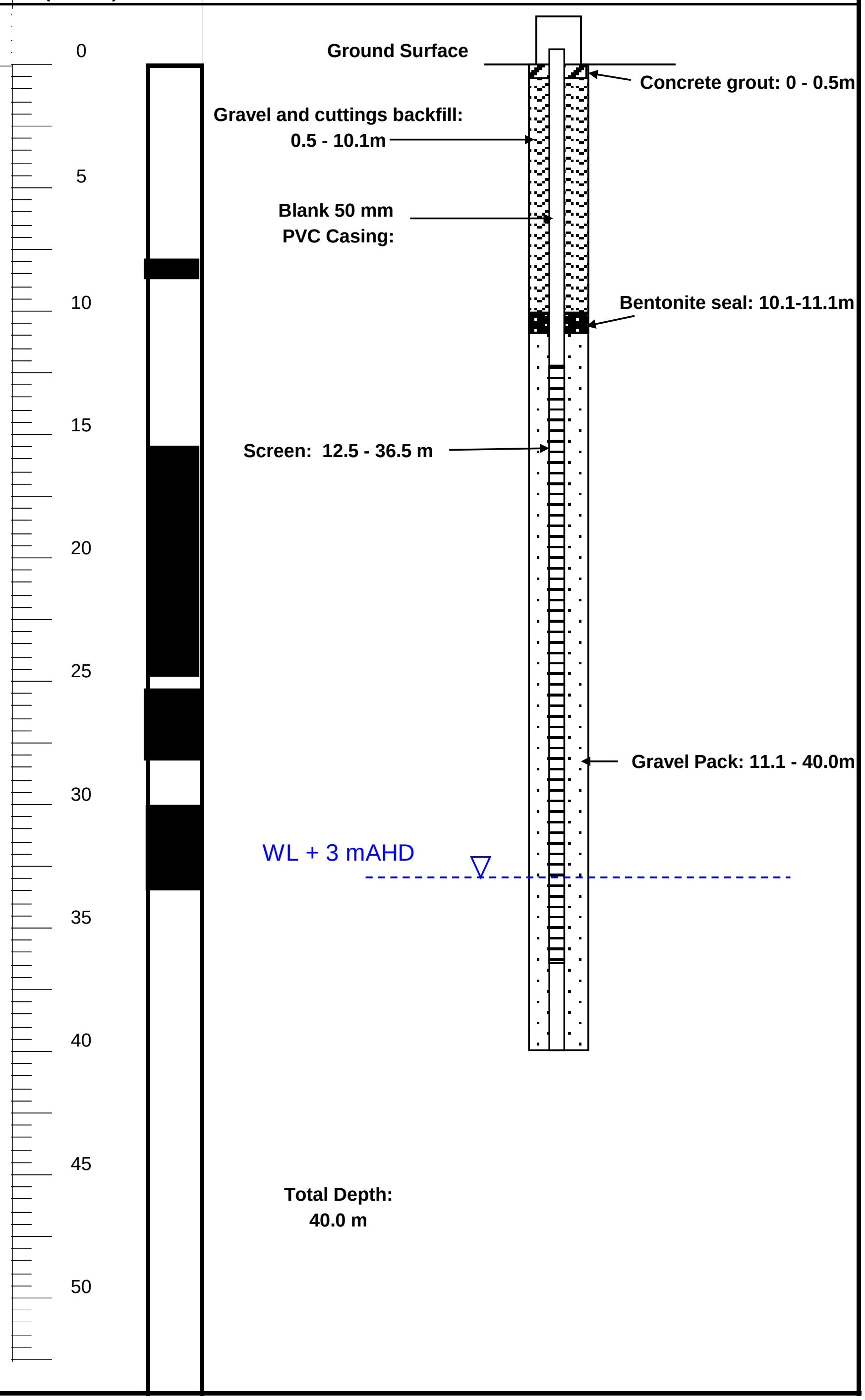
Description	Depth (metres)	Well Construction Details:

Beresfield Seam

Upper Donaldson Seam

Lower Donaldson Seam

Big Ben Seam



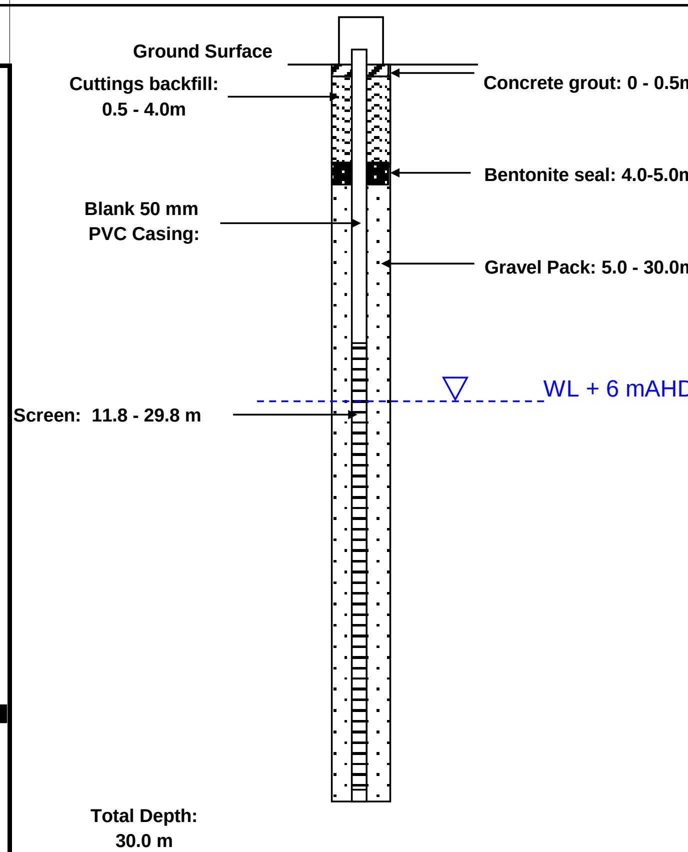
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ10

		Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**19.81 mAHD**	
	Elevation (TOC)	**20.1 mAHD**	
Location: **Abel Coal Project**	Stickup:	**0.29m**	
	Hole Depth:	**30.0m**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed		

Description	Depth (metres)	Well Construction Details:
	0	
	5	
	10	
	15	
	20	
	25	
Beresfield Seam		
	30	
	35	
	40	
	45	
	50	



Peter Dundon and Assoc.

Logging Sheet

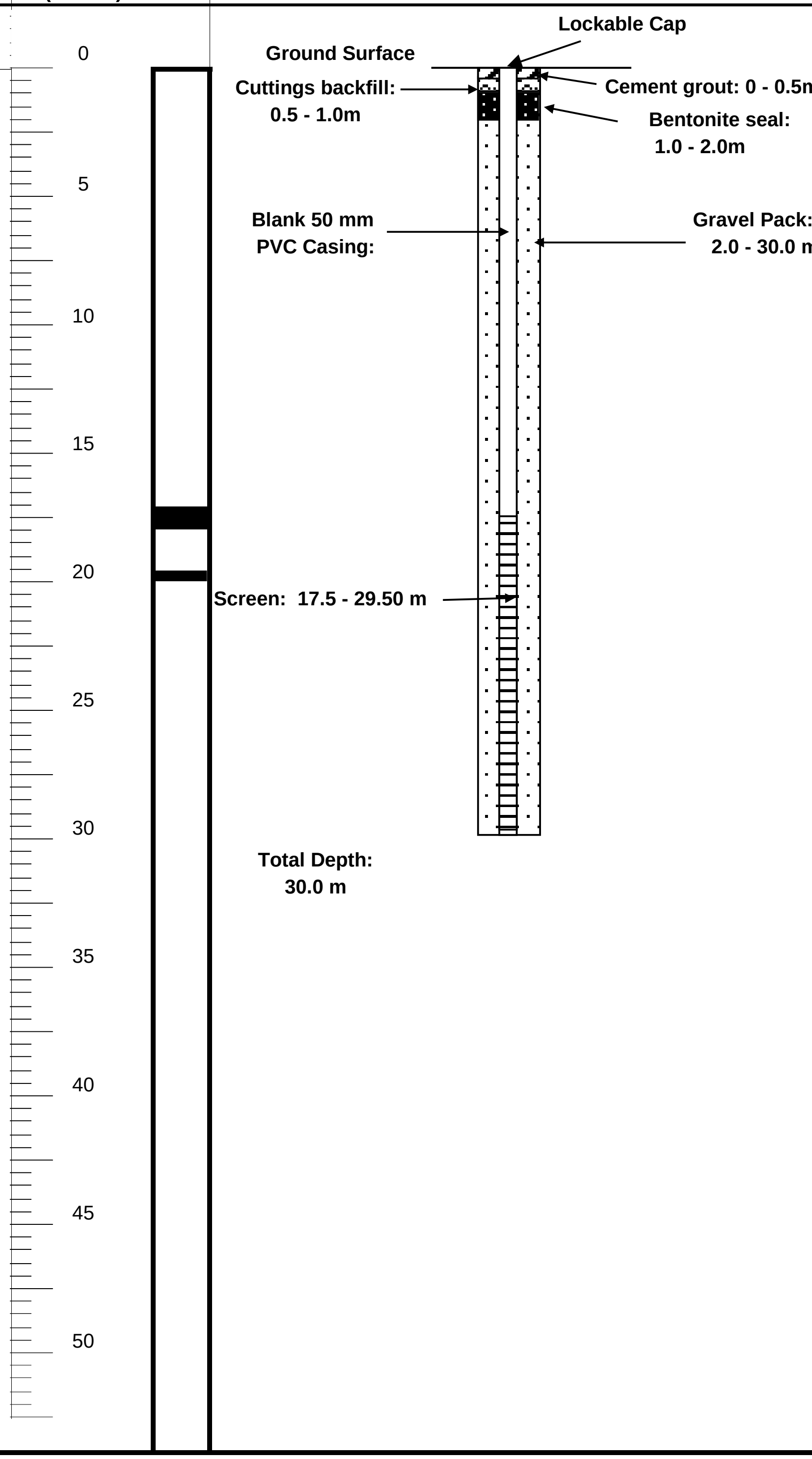
BORE: DPZ11

Project No:	05-0163		
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	19 mAHD	
	Elevation (TOC	19 mAHD	
Location: **Abel Coal Project**	Stickup:	0m	
	Hole Depth:	30.0m	
Drilling Contractor:	Date Started:		Supervised By:
	Date Complete(		

Description	Depth (metres)	Well Construction Details:

Undifferentiated Coal

Undifferentiated Coal



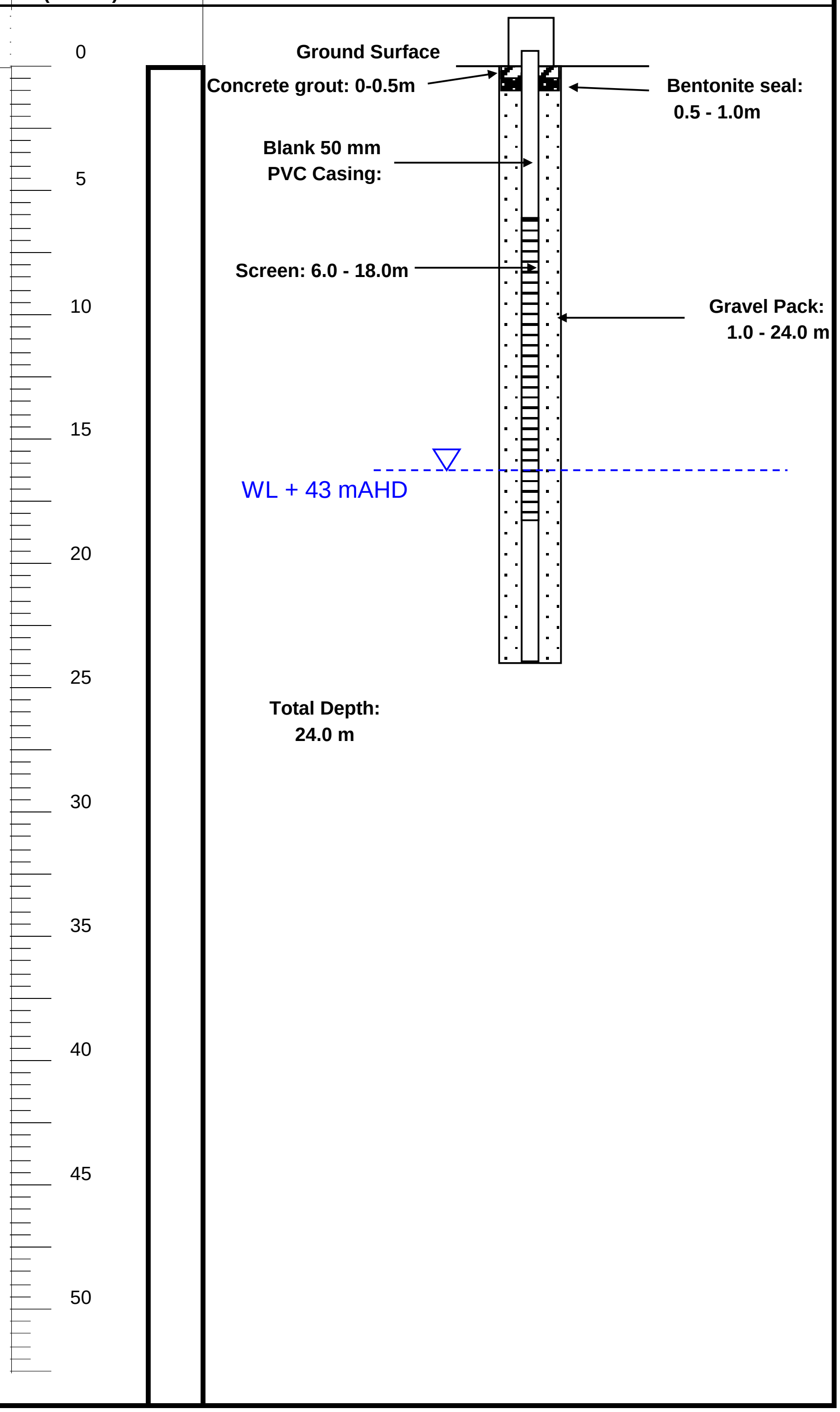
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ12

		Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	59.5mAHD	
	Elevation (TOC	60 mAHD	
Location: **Abel Coal Project**	Stickup:	0.5m	
	Hole Depth:	24.0m	
Drilling Contractor:	Date Started:		Supervised By:
	Date Complete(		

Description	Depth (metres)	Well Construction Details:



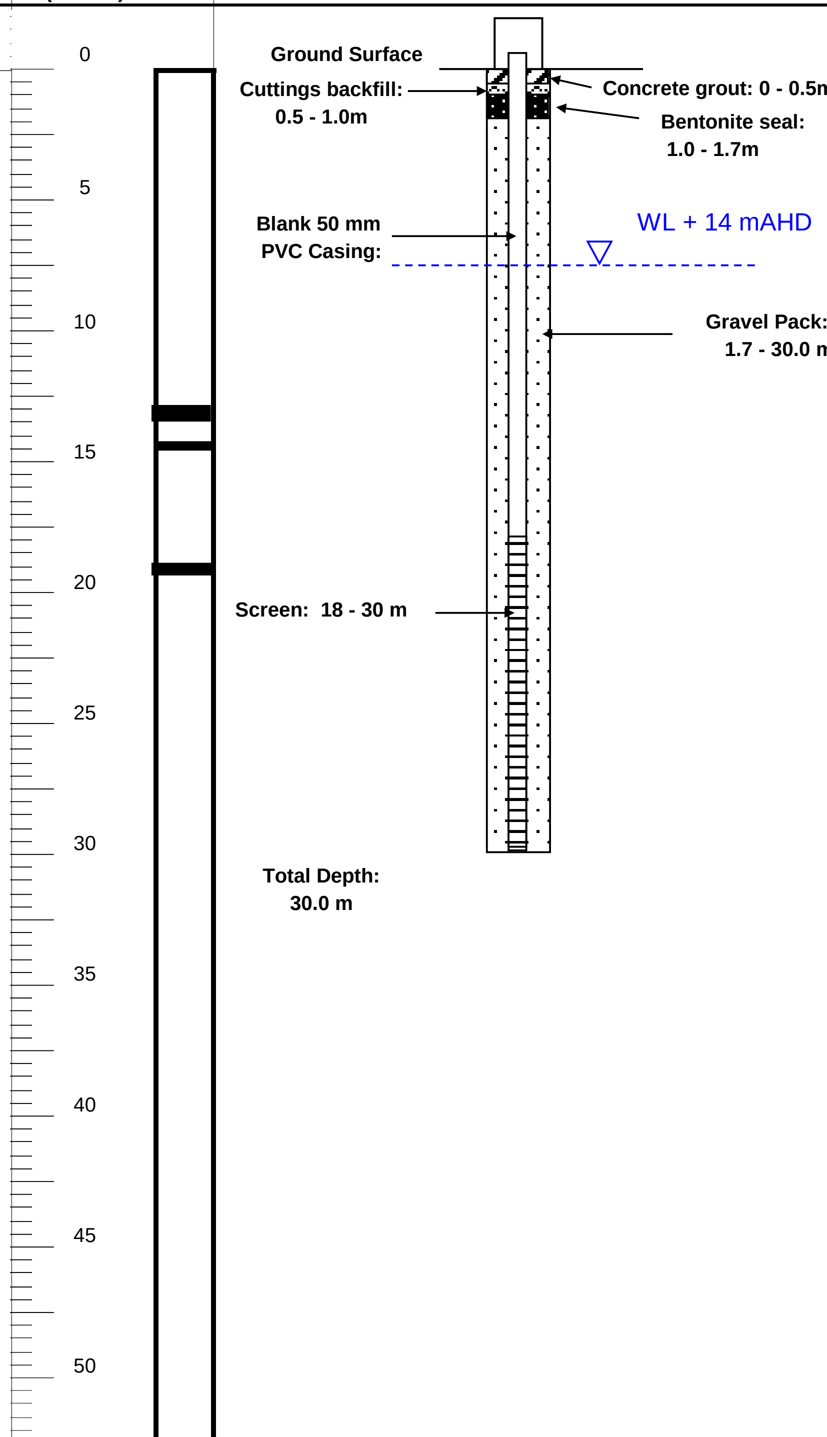
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ13

		Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL): 21.48 mAHD Elevation (TOC 21.97 mAHD		
Location: **Abel Coal Project**	Stickup: 0.49m Hole Depth: 30.0m		
Drilling Contractor:	Date Started: Date Completed:		Supervised By:

Description	Depth (metres)	Well Construction Details:
Undifferentiated Coal Undifferentiated Coal Undifferentiated Coal		



Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ14

			Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	47.44 mAHD		
	Elevation (TOC)	47.94 mAHD		
Location: **Abel Coal Project**	Stickup:	0.5m		
	Hole Depth:	32.3 m		
Drilling Contractor:	Date Started:		Supervised By:	
	Date Completed			

Description	Depth (metres)	Well Construction Details:

Upper Donaldson Seam

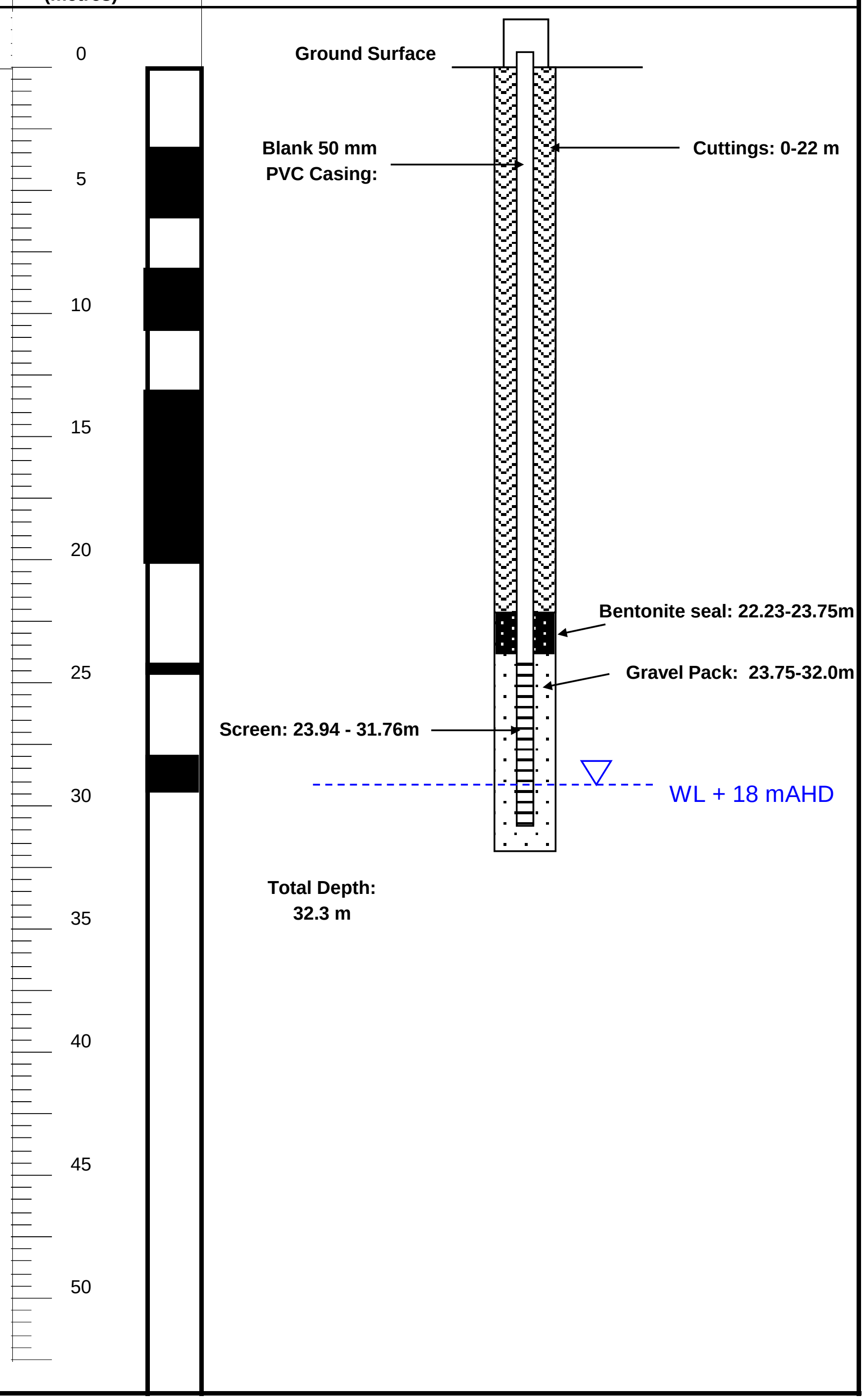
Lower Donaldson Seam

Big Ben Seam

R **Buchanan Seam**

S

Ashtonfields Seam



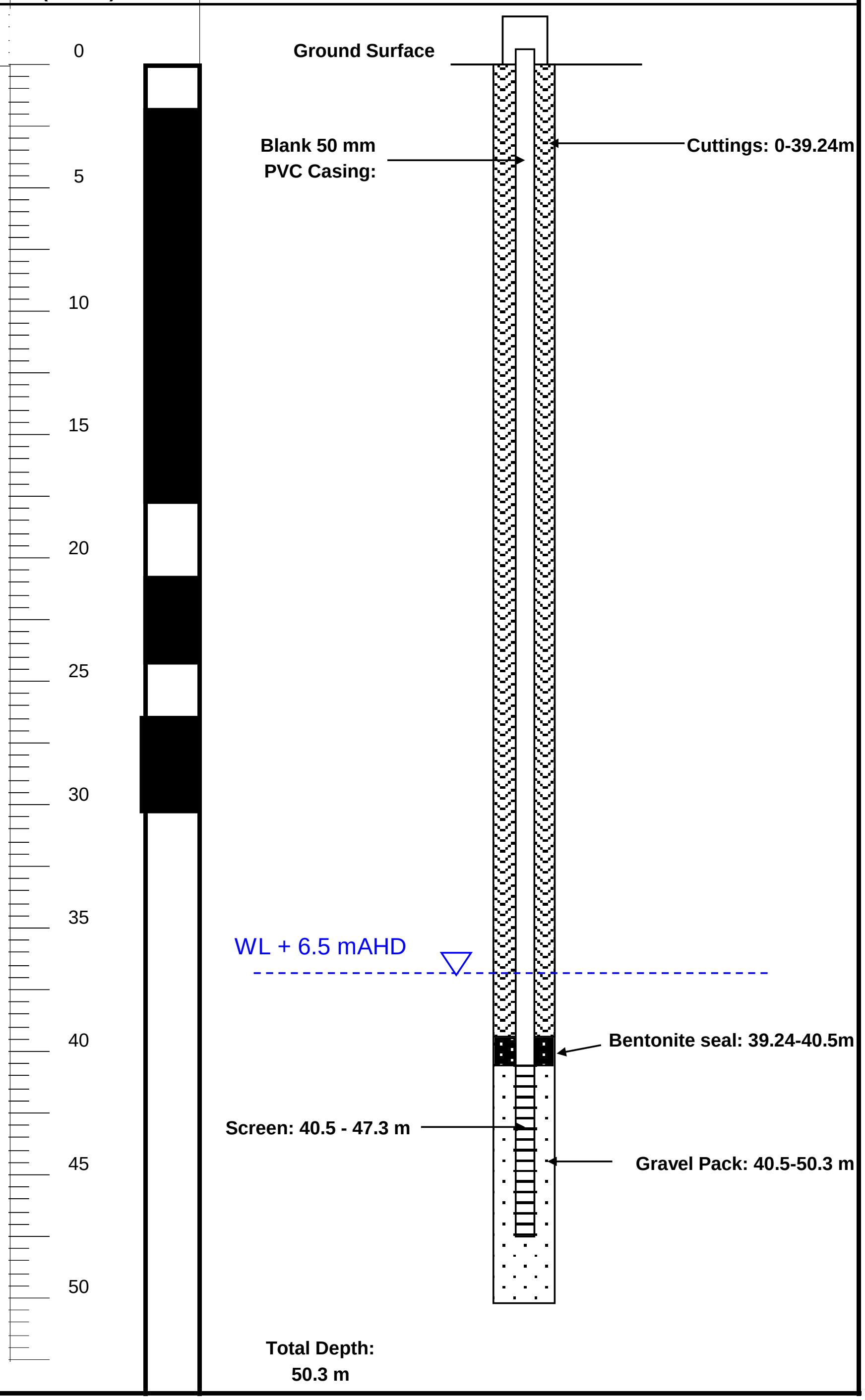
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ15

		Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**43.4mAHD**	
	Elevation (TOC)	**43.9 mAHD**	
Location: **Abel Coal Project**	Stickup:	**0.5m**	
	Hole Depth:	**50.3**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed		

Description	Depth (metres)	Well Construction Details:
Upper Donaldson Seam		
Lower Donaldson Seam		
Big Ben Seam		



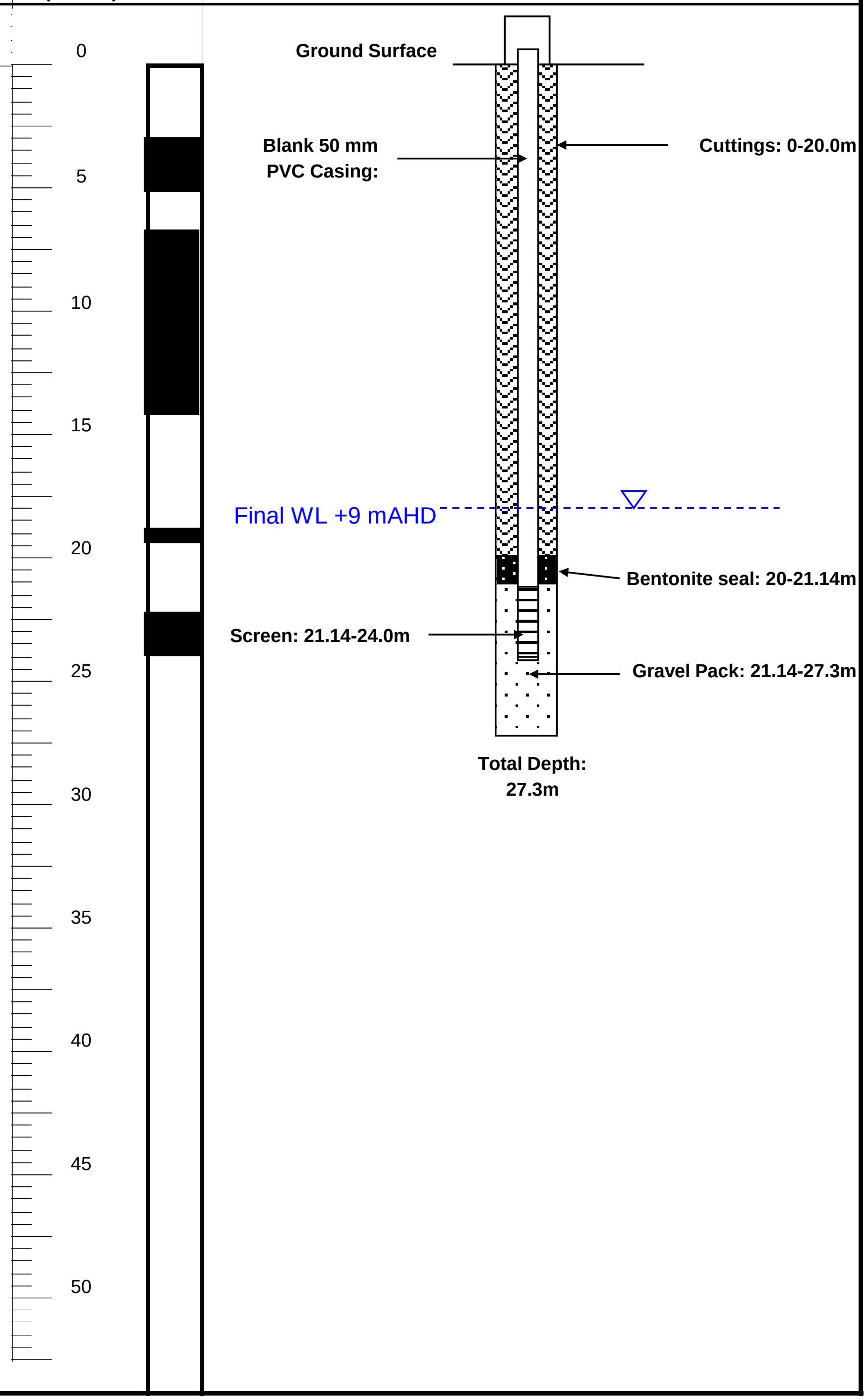
Peter Dundon and Assoc.

Logging Sheet

BORE: DPZ16

		Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**26.83 mAHD**	
	Elevation (TOC)	**27.33 mAHD**	
Location: **Donaldson Coal Project**	Stickup:	**0.5m**	
	Hole Depth:	**27.3 m**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed		

Description	Depth (metres)	Well Construction Details:
Lower Donaldson Seam		
Big Ben Seam		
Buchanan Seam		
Ashtonfield Seam		



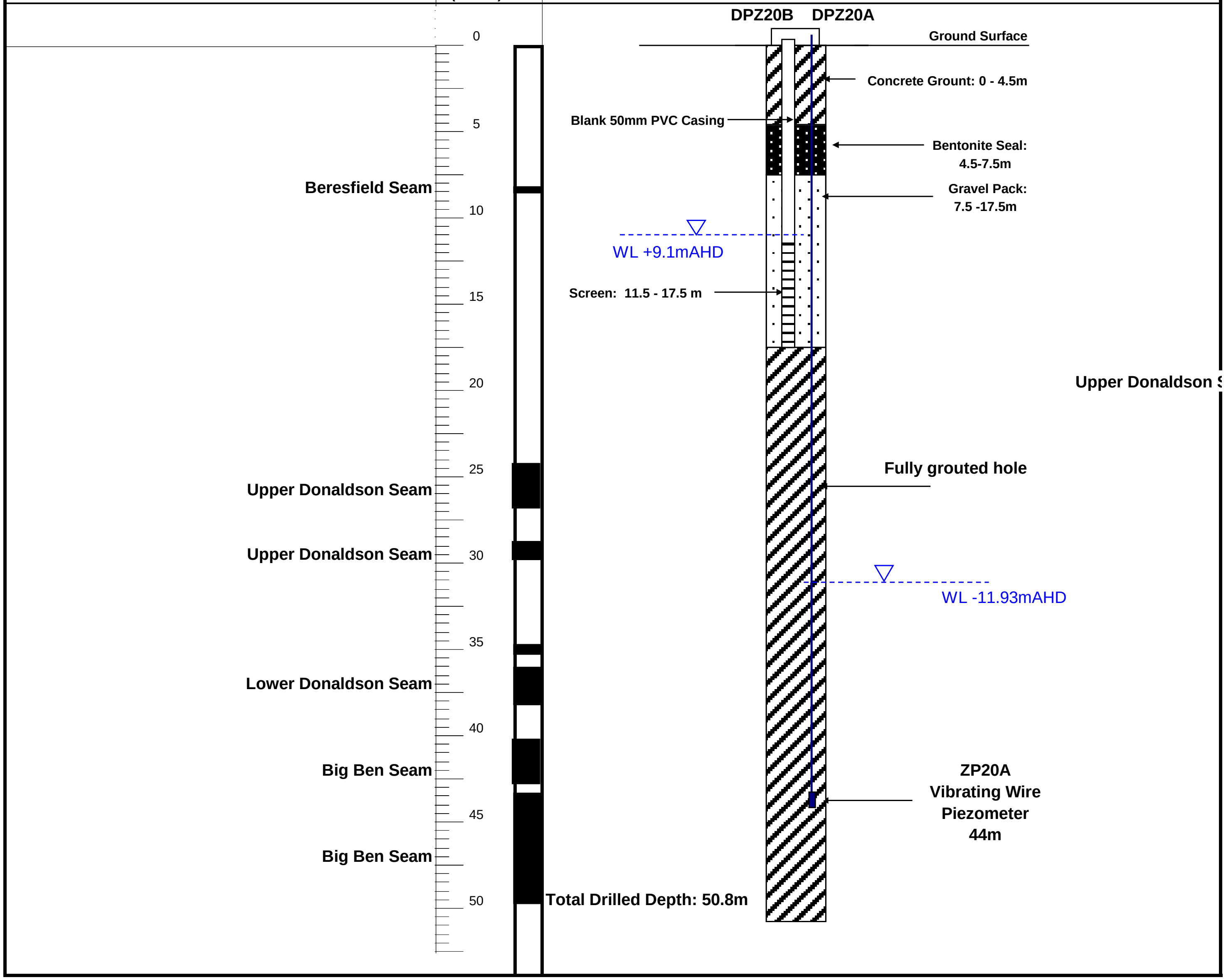
Peter Dundon and Assoc.
Logging Sheet

BORES: DPZ20A and DPZ20B

Project No:	05-0163

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Date Started:	Date Finished:
Donaldson Coal Pty Ltd	**DPZ20A**	**20.124 mAHD**	**….mAHD**	**…..m**		
Location:	**DPZ20B**	**20.124 mAHD**	**….mAHD**	**…..m**		
Abel Coal Project						
			Hole depths: **As shown**		Supervised By:	

Description	Depth (metres)	Well Construction Details:



COMPOSITE WELL LOG

Well No: TA23

RPS Aquaterra

Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
NSW, 2067
Australia
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 24/12/2005	**Method:**	**Area:**
Completed: 24/12/2005	**Fluid:**	**East:** 360597.000
Drilled:	**Bit Record:** (0-240.000)	**North:** 6357716.000
Logged By:		**Collar (RL):** 380.4

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion: Diagram	Well Completion: Notes
0			Soil	No longer reading water depth. Borehole has been cemented		
			Sandstone			
120			Shale			
			Sandstone			
			Shale			

Depth scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140

RPS Aquaterra

Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
NSW, 2067
Australia
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Fax: (+61) (02) 9412 4805

COMPOSITE WELL LOG

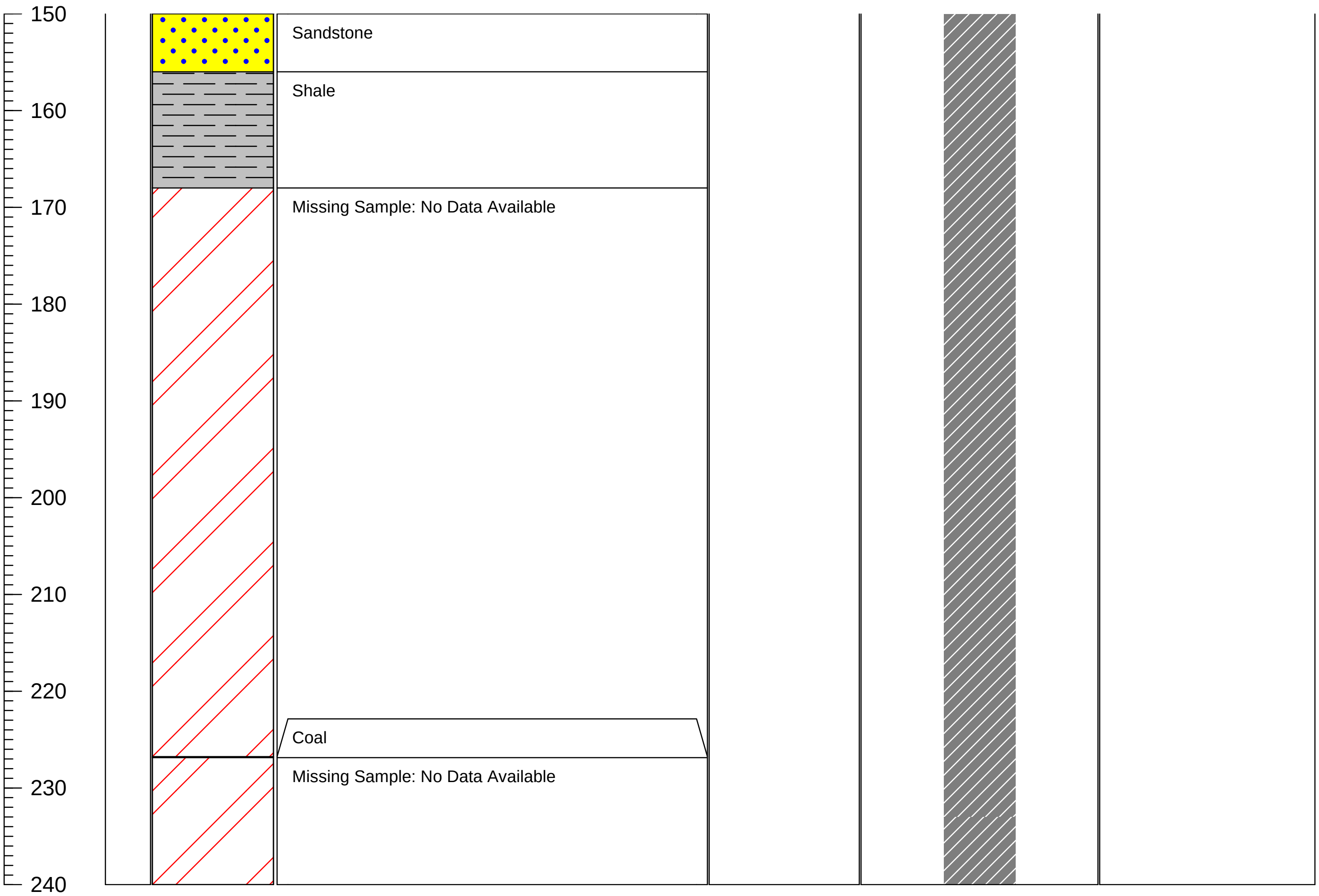
Well No: TA23

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 24/12/2005	**Method:**	**Area:**
Completed: 24/12/2005	**Fluid:**	**East:** 360597.000
Drilled:	**Bit Record:** (0-240.000)	**North:** 6357716.000
Logged By:		**Collar (RL):** 380.4

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion: Diagram	Well Completion: Notes



COMPOSITE WELL LOG

Well No: TA24

RPS Aquaterra

Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
NSW, 2067
Australia
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

Client: Donaldson Coal Operations **Project:** Tasman Extension

Commenced:
Completed:
Drilled: MCD
Logged By: AJM

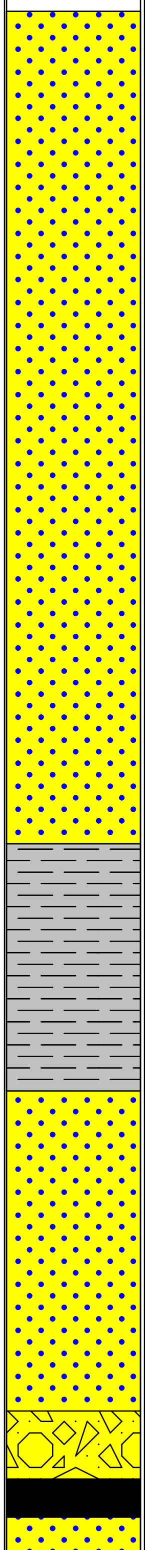
Method: Conventional
Fluid:
Bit Record: HQ (0-146.5m)

Area: Tasman Mine Lease
East: 364943.699
North: 6359786.431
Collar (RL):

Static Water Level: NA **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion: Diagram	Well Completion: Notes

Depth scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90



Sandstone: With Claystone and Conglomerate

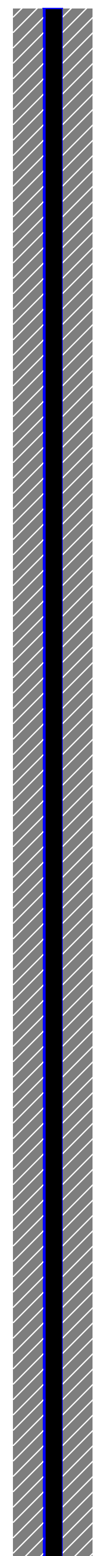
SHALE: With Claystone and Sandstone

Sandstone: With Shale Layer

CONGLOMERATE

COAL: with Carbonacous shale/mudstone

Sandstone



COMPOSITE WELL LOG

Well No: TA24

RPS Aquaterra

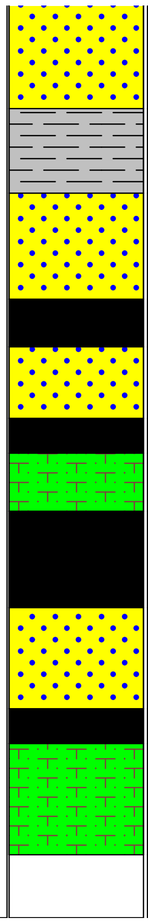
Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
NSW, 2067
Australia
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

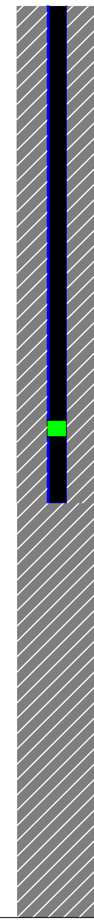
Client: Donaldson Coal Operations **Project:** Tasman Extension

Commenced:	**Method:** Conventional	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 364943.699
Drilled: MCD	**Bit Record:** HQ (0-146.5m)	**North:** 6359786.431
Logged By: AJM		**Collar (RL):**

Static Water Level: NA **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
100			SHALE			
			Sandstone			
110			COAL: with little core loss			
			Sandstone: with little Coal and Claystone layers			
120			Coal: with Claystone and Sandstone Layers	Monitored unit Fassifern Seam(120m)		Vibrating Wire piezometer (120m) TA24A
			Claystone: with woven Coal layers			
			Coal: with little Sandstone and Claystone layers			
130			Sandstone			
			COAL			
140			CLAYSTONE			
150						





RPS Aquaterra
Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
NSW, 2067
Australia
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

COMPOSITE WELL LOG

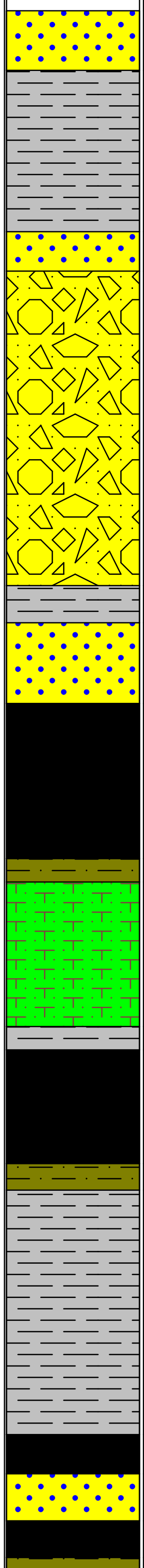
Well No: TA28

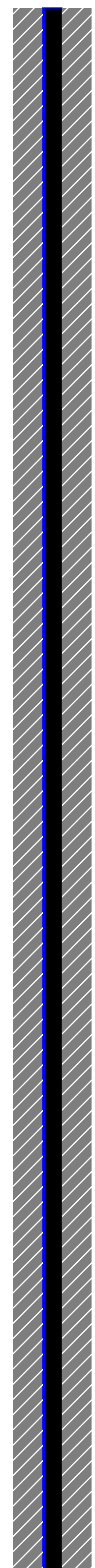
Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 7/7/2006	**Method:**	**Area:**
Completed: 7/7/2006	**Fluid:**	**East:** 364167.000
Drilled:	**Bit Record:** (0-303.250)	**North:** 6361241.000
Logged By:		**Collar (RL):** 157.9

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0			Sandstone			
10			SHALE: With Conglomerate and Sandstone			
20			Sandstone: With Conglomerate			
			Conglomerate: With Sandstone			
30						
40						
50						
			SHALE			
60			Sandstone			
			COAL: With Shale			
70						
80			MUDSTONE: with Claystone and Shale			
			CLAYSTONE			
90						
			SHALE			
100			COAL: with Shale			
			MUDSTONE			
110			SHALE: With Claystone and Mudstone			
120						
130						
			COAL: With Sandstone ,Mudstone and Shale			
140			Sandstone: with woven Shale layers			
			Coal: with Carbonacous shale/mudstone layers			





RPS Aquaterra

Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
NSW, 2067
Australia
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

COMPOSITE WELL LOG

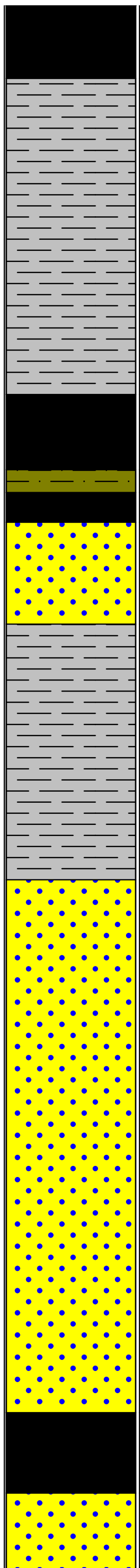
Well No: TA28

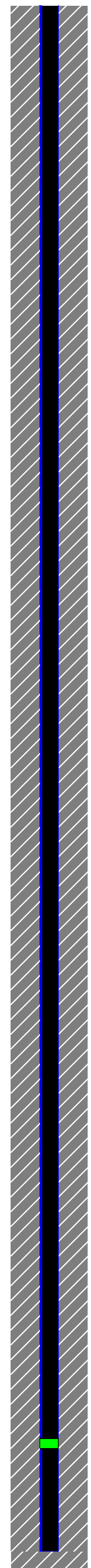
Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 7/7/2006	**Method:**	**Area:**
Completed: 7/7/2006	**Fluid:**	**East:** 364167.000
Drilled:	**Bit Record:** (0-303.250)	**North:** 6361241.000
Logged By:		**Collar (RL):** 157.9

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion: Diagram	Well Completion: Notes
150						
			Coal: with Mudstone and Sandstone layers			
160			Shale: with woven Claystone layers			
170						
180						
190			Coal: with Mudstone, Shale and Sandstone layers			
			Mudstone: with Coal and little Shale			
200			Coal: with minor Mudstone layers			
			Sandstone: with woven Shale layers			
210			SHALE			
220						
230						
			Sandstone			
240						
250						
260						
270						
280						
			COAL: Donaldson Seam			
290				Monitored unit Donaldson Seam (290m)		Vibrating Wire piezometer (290m) TA28A
			Sandstone			
300			Missing sample: No data Available			





COMPOSITE WELL LOG

Well No: TA32

RPS Aquaterra

Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
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Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

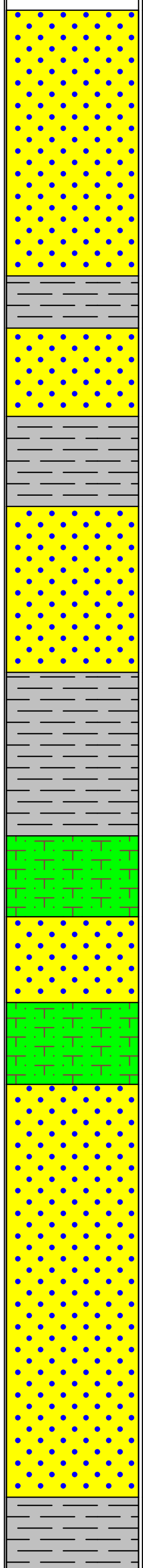
Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

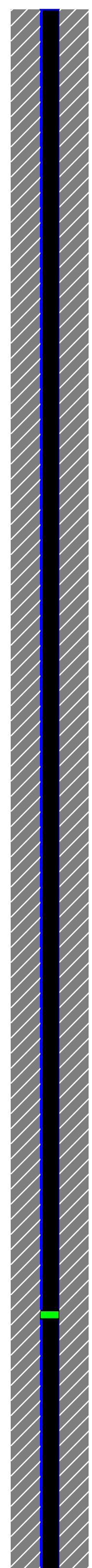
Commenced: 26/03/2007	**Method:** Conventional	**Area:** Tasman Mine Lease
Completed: 26/03/2007	**Fluid:**	**East:** 363281.000
Drilled: MCD2	**Bit Record:** HQ (0-420.42)	**North:** 6359562.000
Logged By: AJM		**Collar (RL):** 326

Static Water Level: 185 **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0			Sandstone: With Shale layer			
30			SHALE			
40			Sandstone			
50			SHALE			
60			Sandstone			
80			SHALE			
100			CLAYSTONE			
110			Sandstone			
120			CLAYSTONE			
130			Sandstone: with Shale			
160				Monitored Unit Sandstone (160m)		Vibrating Wire piezometer (160m)
180			SHALE			

Depth scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190





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COMPOSITE WELL LOG

Well No: TA32

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 26/03/2007	**Method:** Conventional	**Area:** Tasman Mine Lease
Completed: 26/03/2007	**Fluid:**	**East:** 363281.000
Drilled: MCD2	**Bit Record:** HQ (0-420.42)	**North:** 6359562.000
Logged By: AJM		**Collar (RL):** 326

Static Water Level: 185 **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion: Diagram	Well Completion: Notes
200			CLAYSTONE			
210			SHALE			
			Coal: with little Shale	Monitored Unit Coal (216m)		Vibrating Wire piezometer (216m)
220			Sandstone: with Claystone			
230						
240						
250						
			COAL: with woven Claystone layers	Monitored Unit Coal (258m)		Vibrating Wire piezometer (258m)
260			Shale: with little Sandstone and few Carbonacous shale/mudstone layers			
270						
280						
290			Sandstone: with Carbonacous shale/mudstone layers			
300			Missing sample: No Data available			
310						
320						
330						
340						
350						
360						
370						
380						
390						

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COMPOSITE WELL LOG

Well No: TA32

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 26/03/2007	**Method:** Conventional	**Area:** Tasman Mine Lease
Completed: 26/03/2007	**Fluid:**	**East:** 363281.000
Drilled: MCD2	**Bit Record:** HQ (0-420.42)	**North:** 6359562.000
Logged By: AJM		**Collar (RL):** 326

Static Water Level: 185 **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
400			SHALE			
410			Sandstone: With Calcite/Carbonate			
			CONGLOMERATE			
420			CLAYSTONE			

COMPOSITE WELL LOG

Well No: TA41

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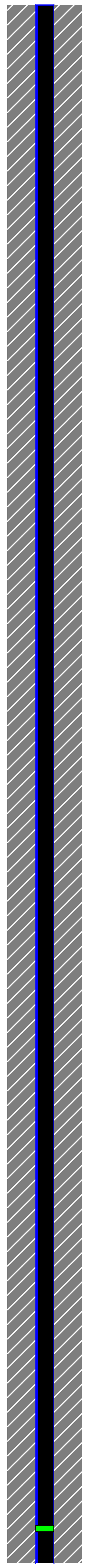
Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 30/04/2009	**Method:** (0-663.5)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 361231.22
Drilled:	**Bit Record:**	**North:** 6354125.71
Logged By:		**Collar (RL):** 315.65

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0						
10						
20						
30						
40						
50						
60						
70						
80						
90						
100						
110						
120						
130						
140						
150						
160						
170						
180						
190						
200						
210						
220						
230						
240				Monitored Unit C (240m)		Vibrating Wire piezometer (240m) TA41C



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COMPOSITE WELL LOG

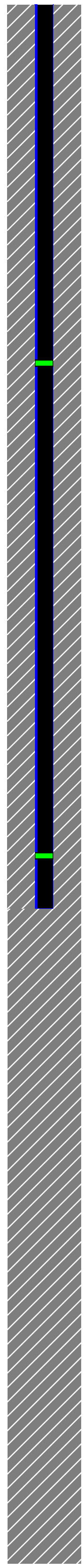
Well No: TA41

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 30/04/2009	**Method:** (0-663.5)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 361231.22
Drilled:	**Bit Record:**	**North:** 6354125.71
Logged By:		**Collar (RL):** 315.65

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
250						
260						
270						
280						
290						
300				Monitored Unit B (303m)		Vibrating Wire piezometer (303m) TA41B
310						
320						
330						
340						
350						
360						
370						
380				Monitored Unit A (382m)		Vibrating Wire piezometer (382m) TA41A
390						
400						
410						
420						
430						
440						
450						
460						
470						
480						
490						



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COMPOSITE WELL LOG

Well No: TA41

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 30/04/2009	**Method:** (0-663.5)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 361231.22
Drilled:	**Bit Record:**	**North:** 6354125.71
Logged By:		**Collar (RL):** 315.65

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
500						
510						
520						
530						
540						
550						
560						
570						
580						
590						
600						
610						
620						
630						
640						
650						
660						

Peter Dundon and Assoc.

Logging Sheet

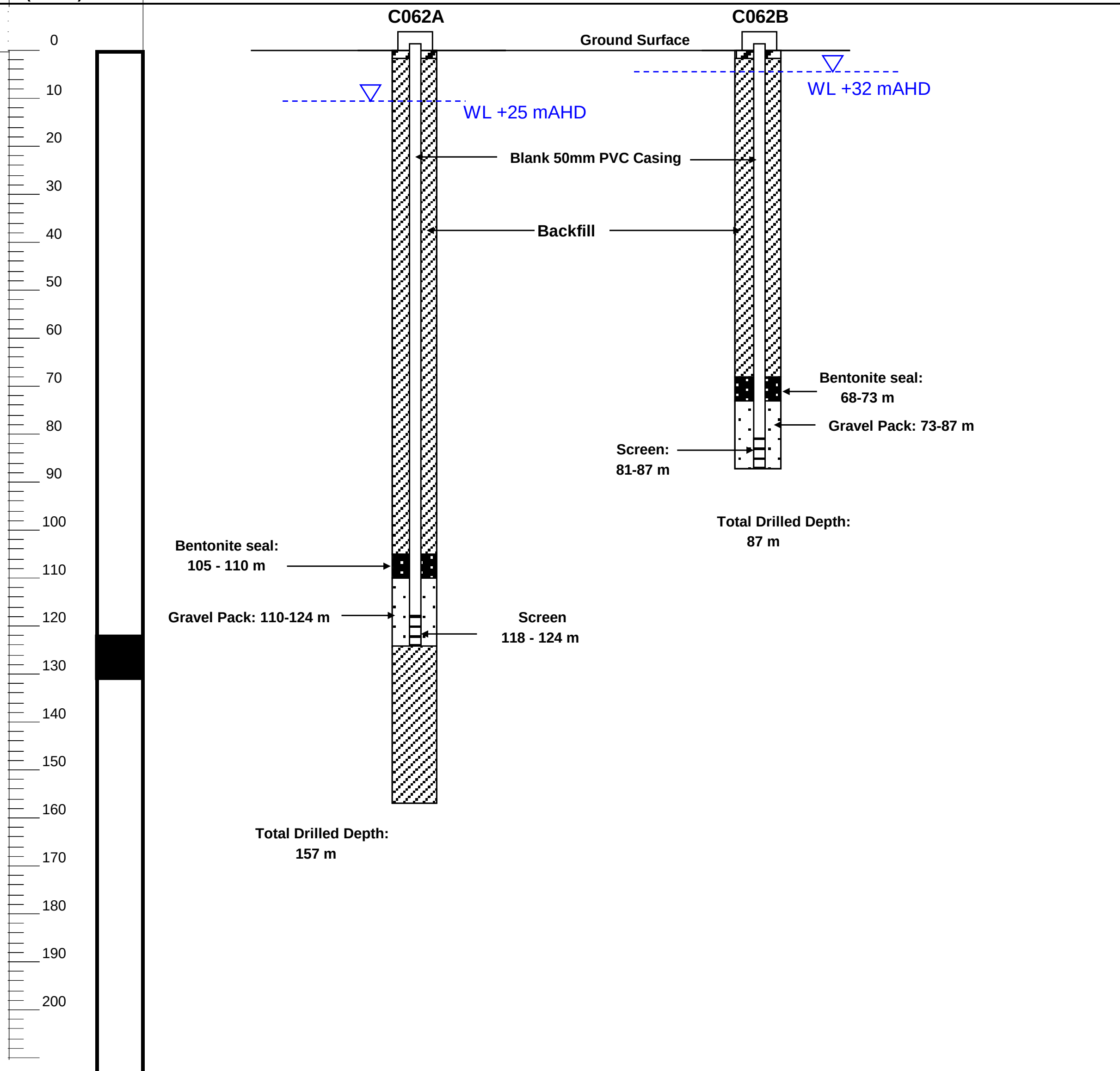
BORES: C062A and C062B

Project No:	05-0163

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Donaldson Coal Pty Ltd	C062A	36 mAHD		.. m			
Locationt:	C062B	36 mAHD		.. m			
Abel Coal Project							
			Hole depths: As shown			Supervised By:	

Description	Depth (metres)	Well Construction Details:

Donaldson Seams



Peter Dundon and Assoc.

Logging Sheet

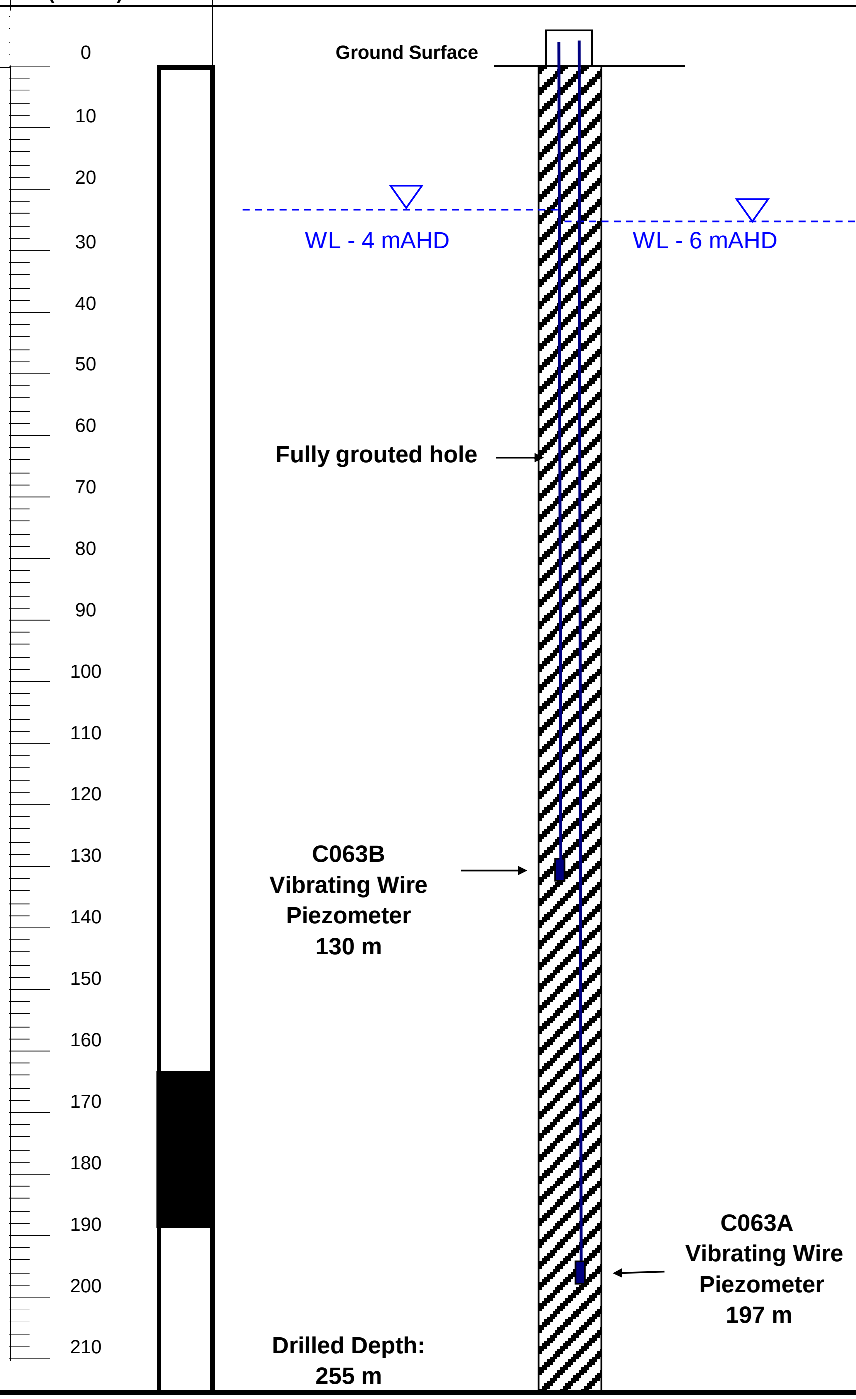
BORE: C063A and C063B

		Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**19.67 mAHD**	
	Elevation (TOC):	**… mAHD**	
Location: **Abel Coal Project**	Stickup:	**… m**	
	Hole Depth:	**255 m**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed:		

Description	Depth (metres)	Well Construction Details:

Upper Donaldson Seam

Lower Donaldson Seam



Peter Dundon and Assoc.

Logging Sheet

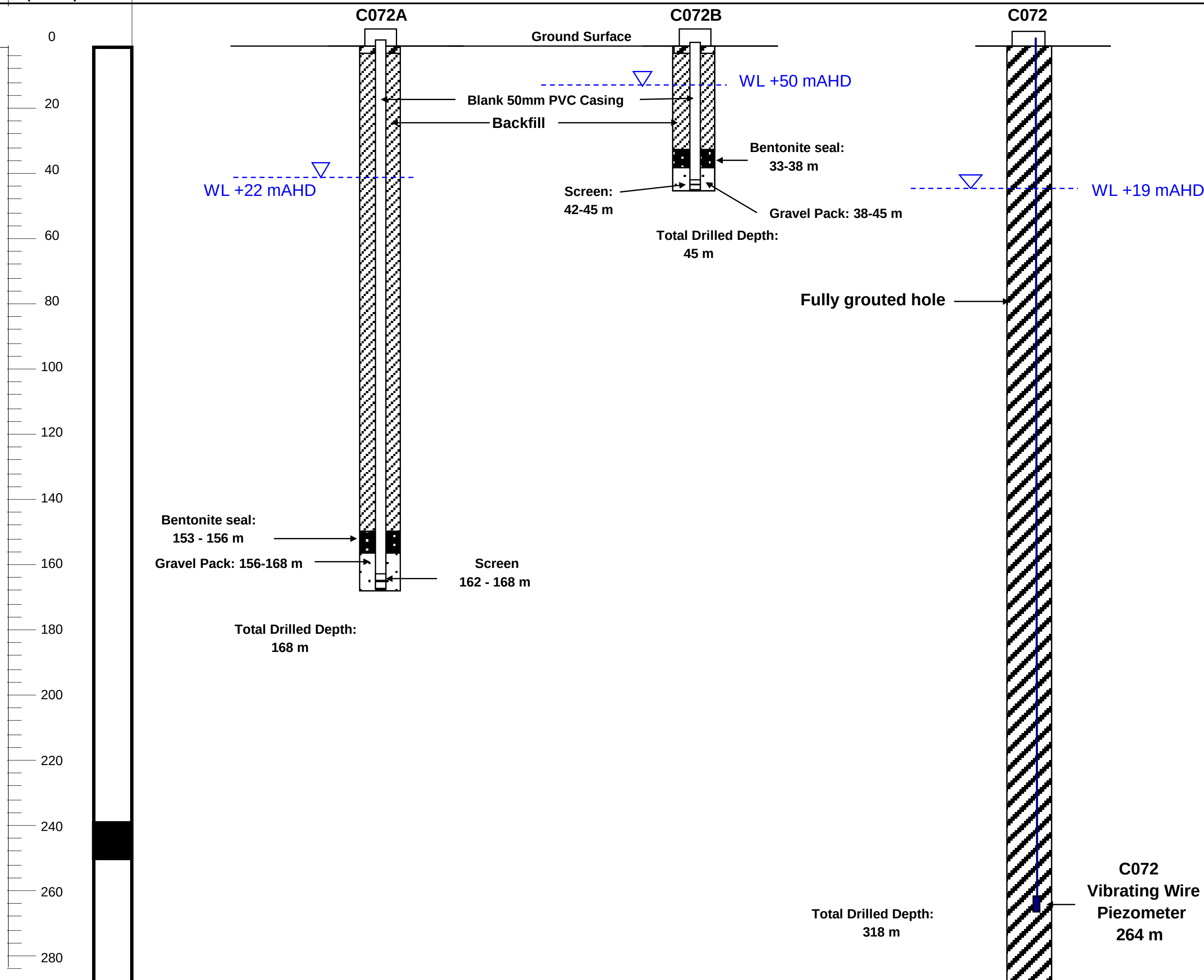
BORES: C072, C072A and C072B

Project No:	05-0163

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Donaldson Coal Pty Ltd	C072	63 mAHD		.. m			
Locationt:	C072A	63 mAHD		.. m			
Abel Coal Project	C072B	63 mAHD					
			Hole depths: As shown			Supervised By:	

Description	Depth (metres)	Well Construction Details:

Donaldson Seams



Peter Dundon and Assoc.

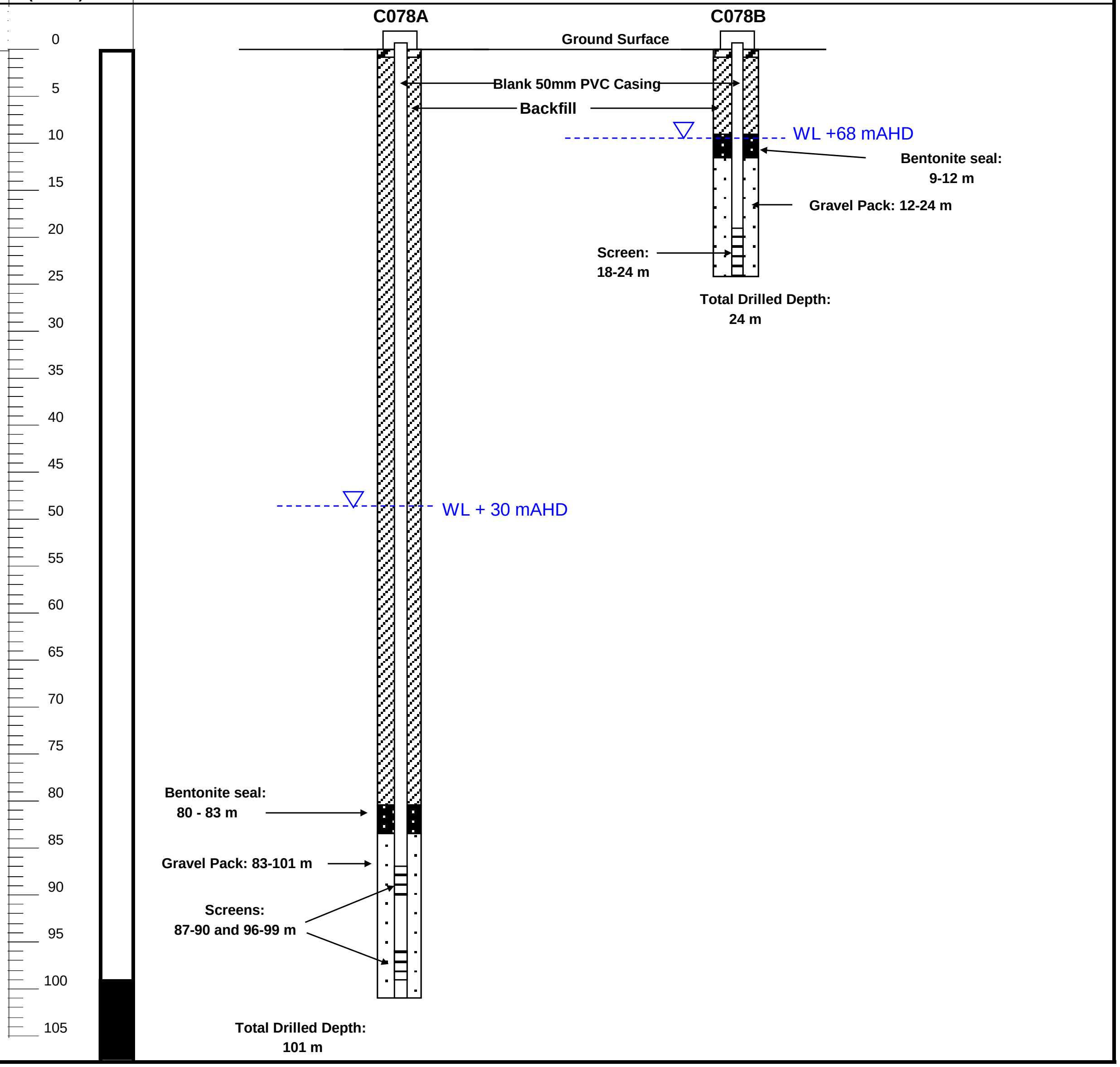
Logging Sheet

BORES: C078A and C078B

Project No:	05-0163

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Donaldson Coal Pty Ltd	**C078A**	**77 mAHD**		**.. m**			
Locationt:	**C078B**	**77 mAHD**		**.. m**			
Abel Coal Project							
			Hole depths: **As shown**			Supervised By:	

Description	Depth (metres)	Well Construction Details:



Donaldson Seams

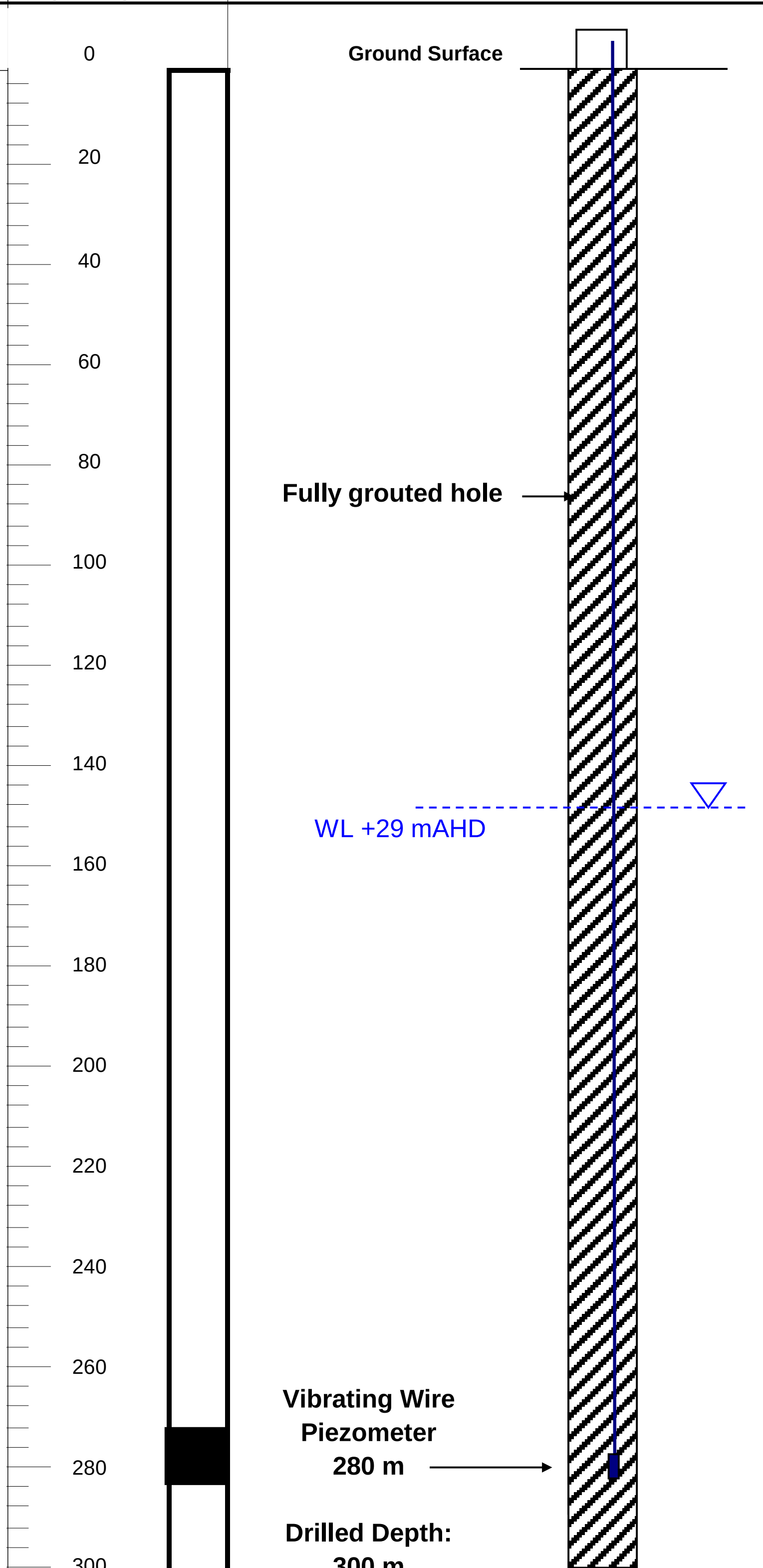
Peter Dundon and Assoc.

Logging Sheet

BORE: C080

		Project No:	**05-0163**
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	**177 mAHD**	
	Elevation (TOC):	**… mAHD**	
Location: **Abel Coal Project**	Stickup:	**… m**	
	Hole Depth:	**300 m**	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed:		

Description	Depth (metres)	Well Construction Details:
Donaldson Seams (280 m)		



Peter Dundon and Assoc.

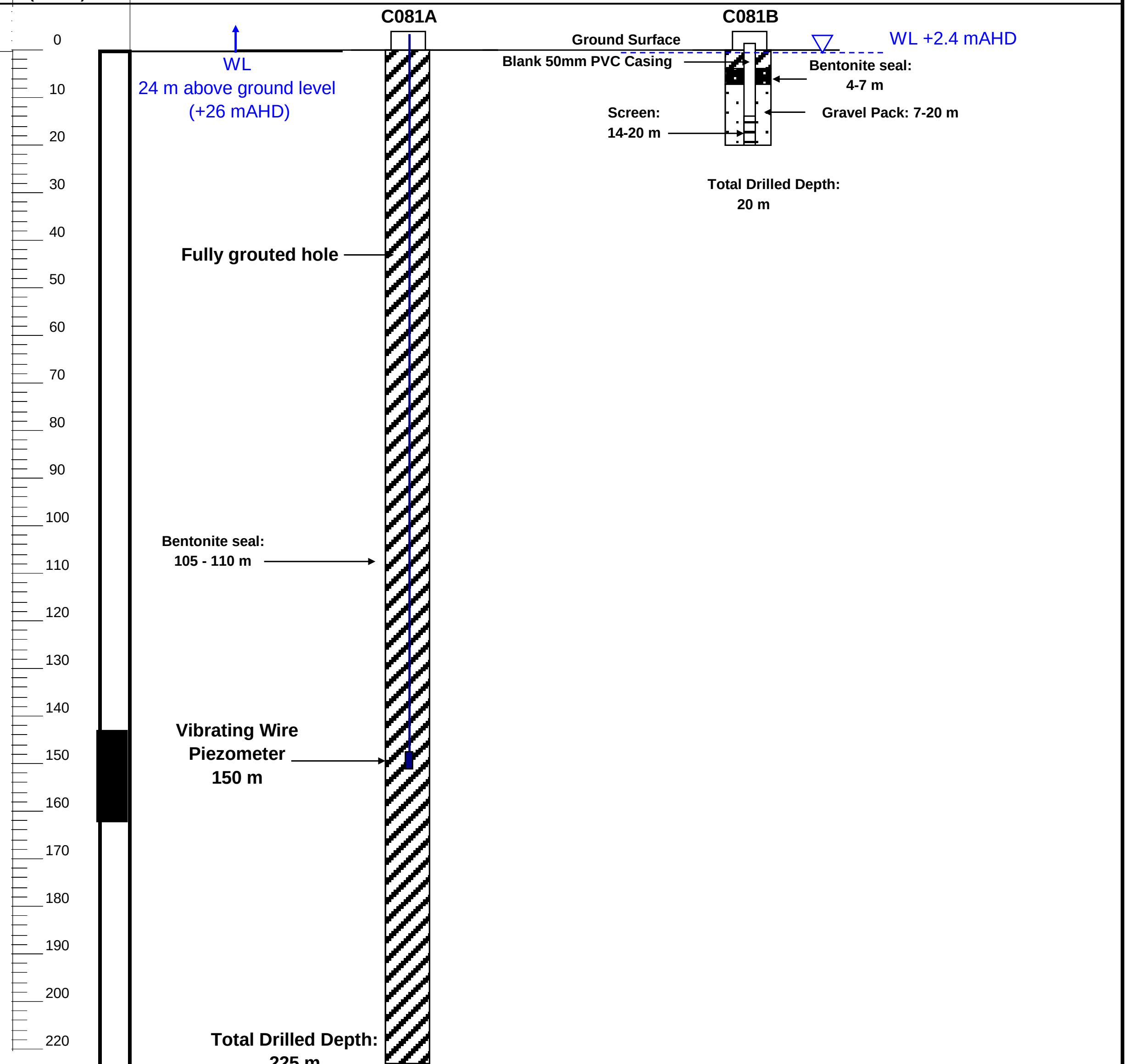
Logging Sheet

BORES: C081A and C081B

Project No:	05-0163

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Donaldson Coal Pty Ltd	**C081A**	**2.3 mAHD**		**.. m**			
Locationt:	**C081B**	**2.3 mAHD**		**.. m**			
Abel Coal Project							
			Hole depths: **As shown**			Supervised By:	

Description	Depth (metres)	Well Construction Details:
Donaldson Seams		

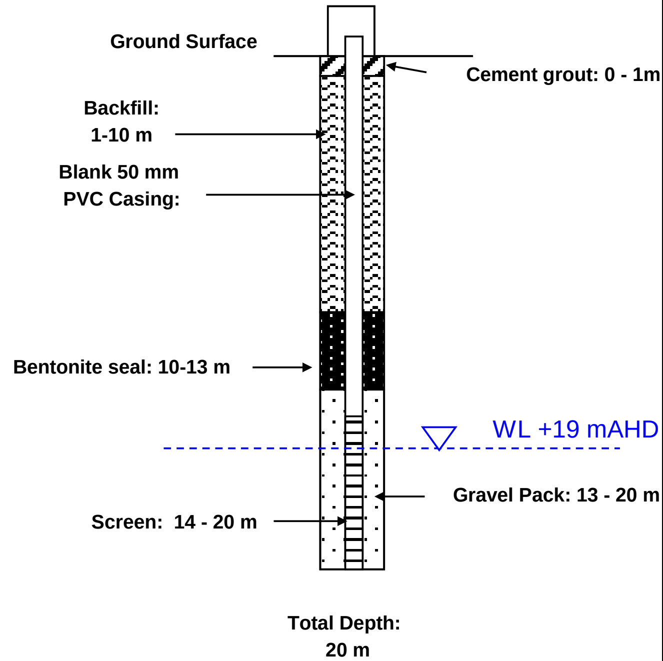


Peter Dundon and Assoc.
Logging Sheet

BORE: C082

		Project No:	05-0163
Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	34 mAHD	
	Elevation (TOC):	… mAHD	
Location: **Abel Coal Project**	Stickup:	… m	
	Hole Depth:	20 m	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed:		

Description	Depth (metres)	Well Construction Details:
	0	
	5	
	10	
	15	
	20	
	25	
	30	
	35	
	40	
	45	
	50	



Peter Dundon and Assoc.

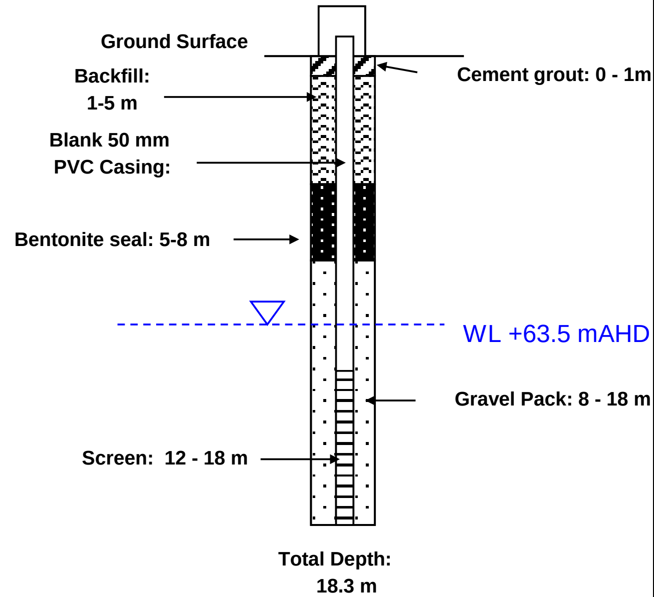
Logging Sheet

BORE: C087

Project No:	05-0163

Client: **Donaldson Coal Pty Ltd**	Elevation (GL):	74 mAHD	
	Elevation (TOC):	… mAHD	
Location: **Abel Coal Project**	Stickup:	… m	
	Hole Depth:	18.3 m	
Drilling Contractor:	Date Started:		Supervised By:
	Date Completed:		

Description	Depth (metres)	Well Construction Details:
	0	
	5	
	10	
	15	
	20	
	25	
	30	
	35	
	40	
	45	
	50	



COMPOSITE WELL LOG

Well No: C123

RPS Aquaterra
Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
NSW, 2067
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Tel: (+61) (02) 9412 4630
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Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 25/09/2008
Completed: 25/09/2008
Drilled: MCD1
Logged By: AJM

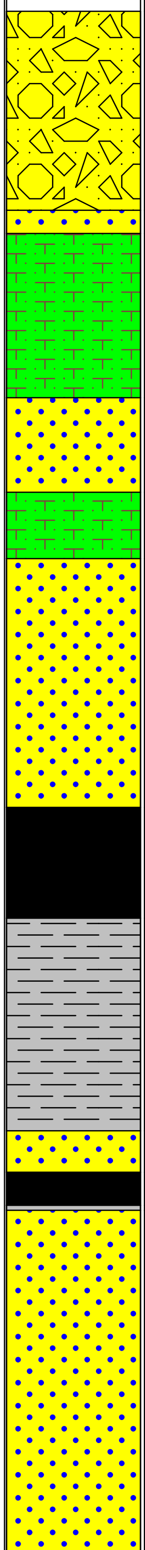
Method: CONVENTIONAL
Fluid:
Bit Record: HQ (0-332.58)

Area: Tasman Mine Lease
East: TBA
North: TBA
Collar (RL): TBA

Static Water Level: 6.0 **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes

Depth scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90



Conglomerate

SANDSTONE

CLAYSTONE

SANDSTONE: with thin shale bands.

CLAYSTONE

SANDSTONE: and shale.

COAL: with sandstone Layers ,shale,minor claystone and Carbonaceous shale

Shale: with woven Sandstone layers

SANDSTONE

COAL

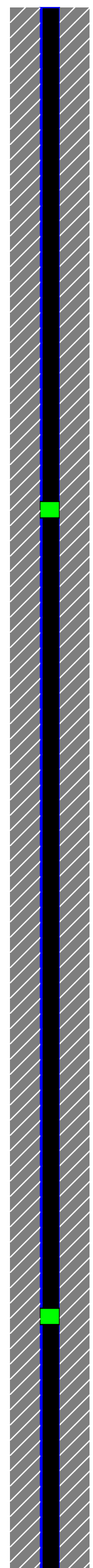
SHALE: and sanstone conglomerate.

Sandstone: and coal and shale

Field Notes:

Monitored Unit Fassifern- West Borehole Interburden (29m)

Monitored Unit Sandgate-Donaldson Interburden (78m)



Notes:

Vibrating Wire piezometer (29m) C123F

Vibrating Wire piezometer (78m) C123E

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COMPOSITE WELL LOG

Well No: C123

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 25/09/2008	**Method:** CONVENTIONAL	**Area:** Tasman Mine Lease
Completed: 25/09/2008	**Fluid:**	**East:** TBA
Drilled: MCD1	**Bit Record:** HQ (0-332.58)	**North:** TBA
Logged By: AJM		**Collar (RL):** TBA

Static Water Level: 6.0 **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
100						
110			Shale: with Sandstone layers between			
120			Sandstone: with woven Shale layers			
130						
140						
			Coal	Monitored Unit Upper Buttai (148m)		Vibrating Wire piezometer (148m) C123D
150			Shale: with woven Sandstone and Claystone layers			
160			Coal	Monitored Unit Beresfield Seam (162m)		Vibrating Wire piezometer (162m) C123C
170			Shale: with woven Sandstone layers			
180						
190						

COMPOSITE WELL LOG

Well No: C123

RPS Aquaterra

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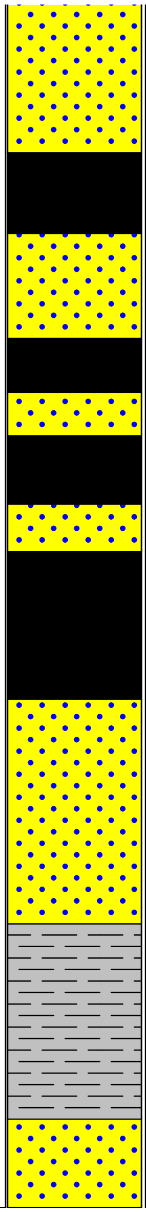
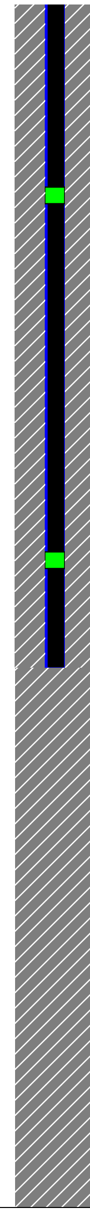
Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 25/09/2008	**Method:** CONVENTIONAL	**Area:** Tasman Mine Lease
Completed: 25/09/2008	**Fluid:**	**East:** TBA
Drilled: MCD1	**Bit Record:** HQ (0-332.58)	**North:** TBA
Logged By: AJM		**Collar (RL):** TBA

Static Water Level: 6.0 **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
200						
			Coal: with Shale and Claystone layers	Monitored Unit Upper Donaldson (207m)		Vibrating Wire piezometer (207m) C123B
210			Sandstone			
			Coal			
220			Sandstone: with minor Shale and little Coal			
			Coal: with little Sandstone, Shale and Carbonaceous shale			
			Sandstone			
230			Coal: with little Sandstone and Shale	Monitored Unit Lower Donaldson(229m)		Vibrating Wire piezometer (229m) C123A
240			Sandstone: with Shale layers, minor coal and little Carbonaceous shale			
250			Shale: with Sandstone and coal layers			
260			Sandstone: with Core loss and Shale			





COMPOSITE WELL LOG

Well No: C138

RPS Aquaterra

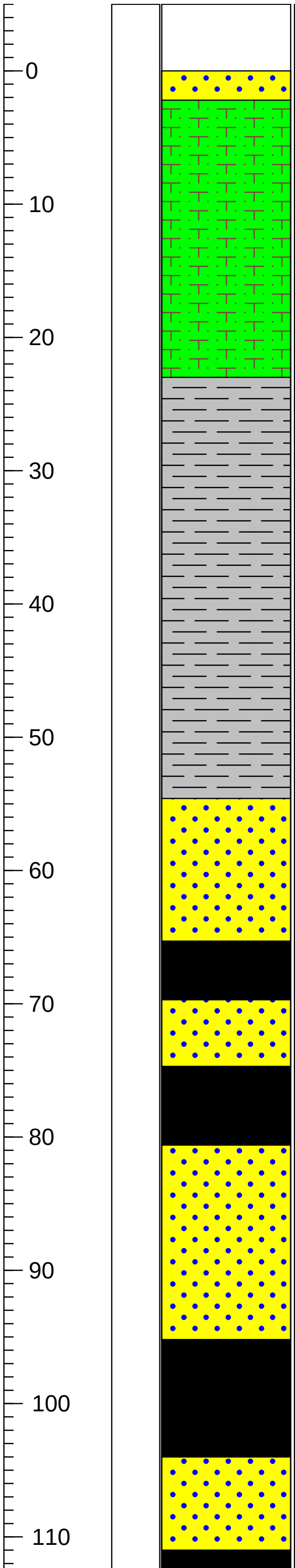
Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
NSW, 2067
Australia
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

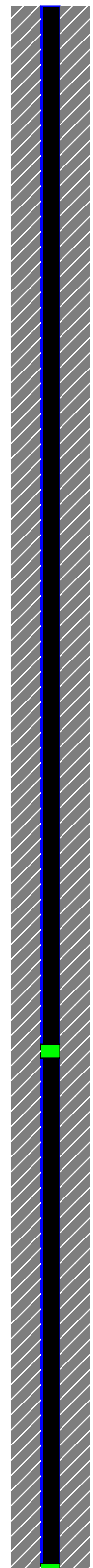
Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 25/09/2008	**Method:** CONVENTIONAL	**Area:** Tasman Mine Lease
Completed: 25/09/2008	**Fluid:**	**East:** TBA
Drilled: MCD1	**Bit Record:** HQ (0-332.58)	**North:** TBA
Logged By: AJM		**Collar (RL):** TBA

Static Water Level: 6.0 **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
			SANDSTONE: with very little Shale and Conglomerate			
			Claystone: With Siderite bands, Caving layers			
			SHALE: Shale layers with Claystone, Caving, Sandstone and very little Coal			
			SANDSTONE: With Shale and Claystone woven Layers			
			COAL: with Sandstone, Shale and Conglomerate layers			
			SANDSTONE: with Shale and Conglomerate			
			Coal: With many Sandstone Layers and minor Shale and Claystone	Monitored Unit Sandgate-Donaldson Interburden (75m)		Vibrating Wire piezometer (75m) C138A
			SANDSTONE: With Shale, Conglomerate and Claystone Layers			
			COAL: with Shale and Sandstone			
			SANDSTONE: With Shale and Claystone			
			COAL: With Shale, Pyrite, Claystone and little			





COMPOSITE WELL LOG

Well No: C138

RPS Aquaterra

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NSW, 2067
Australia
Tel: (+61) (02) 9412 4630
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Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 25/09/2008	**Method:** CONVENTIONAL	**Area:** Tasman Mine Lease
Completed: 25/09/2008	**Fluid:**	**East:** TBA
Drilled: MCD1	**Bit Record:** HQ (0-332.58)	**North:** TBA
Logged By: AJM		**Collar (RL):** TBA

Static Water Level: 6.0 **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
				Donaldson Seam (113m)		(113m) C138A
120			SANDSTONE: with Coal, Sandstone,Siderite and shale			
			Shale			
130			COAL: With Sandstone, Shale and Claystone			
			Sandstone: with Coal	Monitored Unit Ashtonfield Seam (136m)		Vibrating Wire piezometer (136m) C138A
140			Coal	Monitored Unit Big Ben - Ashtonfield Interburden (142m)		Vibrating Wire piezometer (142m) C138B
150			SANDSTONE			
160			COAL: With Sandstone and Shale Layers	Monitored Unit Big Ben Seam (163m)		Vibrating Wire piezometer (163m) C138C
			SHALE: With Sandstone layers and very little Siderite			
170			SANDSTONE: With Coal Layers			
			COAL: With Claystone,Shale and Siderite			
180			SANDSTONE: With Shale and Coal			
190			SHALE: With Claystone and little Sandstone			
			SANDSTONE: With Shale, Siderite and little Coal			
200			COAL: With Shale,Core loss ,Claystone and little Sandstone			
			SANDSTONE: With little Shale			
210						
220						
230			SHALE: With Sandstone and Claystone			

COMPOSITE WELL LOG

Well No: C138

RPS Aquaterra

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Tel: (+61) (02) 9412 4630
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Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 25/09/2008
Completed: 25/09/2008
Drilled: MCD1
Logged By: AJM

Method: CONVENTIONAL
Fluid:
Bit Record: HQ (0-332.58)

Area: Tasman Mine Lease
East: TBA
North: TBA
Collar (RL): TBA

Static Water Level: 6.0 **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion: Diagram	Well Completion: Notes
240			SANDSTONE: With Shale and Coal			
250						
260			SHALE: With Coal and Sandstone layers			
			SANDSTONE: With Coal layers and Shale			
270						
280						
			COAL: With Claystone and Shale layers			
290			SANDSTONE: With little coal and Shale			
300						
310						
320						
330			SHALE: With Sandstone			

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COMPOSITE WELL LOG

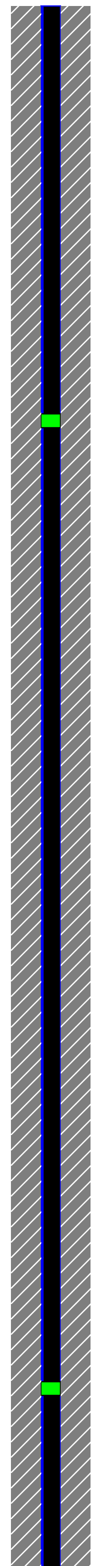
Well No: C141

Client: Donaldson Coal Operations | **Project:** Tasman Extension

Commenced: 29/10/2008	**Method:** (0-303m)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 363872.69
Drilled:	**Bit Record:**	**North:** 6364369.65
Logged By:		**Collar (RL):** 30.25

Static Water Level: | **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0						
10						
20						
30				Monitored Unit Sandgate Seam (30m)		Vibrating Wire piezometer (30m) C141E
40						
50						
60						
70						
80						
90						
100				Monitored Unit Layer 11 (100m)		Vibrating Wire piezometer (100m) C141D
110						



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COMPOSITE WELL LOG

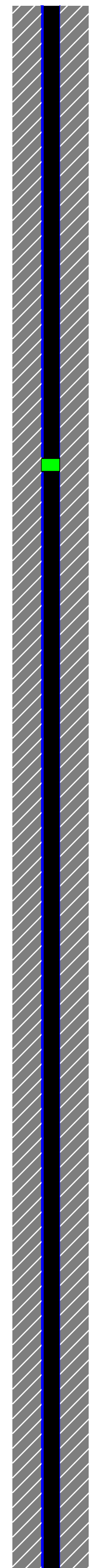
Well No: C141

Client: Donaldson Coal Operations **Project:** Tasman Extension

Commenced: 29/10/2008	**Method:** (0-303m)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 363872.69
Drilled:	**Bit Record:**	**North:** 6364369.65
Logged By:		**Collar (RL):** 30.25

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
120						
130						
140						
150				Monitored Unit XC (150m)		Vibrating Wire piezometer (150m) C141C
160						
170						
180						
190						
200						
210						
220						
230						



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COMPOSITE WELL LOG

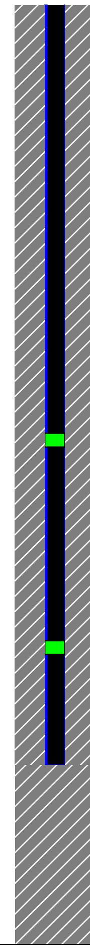
Well No: C141

Client: Donaldson Coal Operations **Project:** Tasman Extension

Commenced: 29/10/2008	**Method:** (0-303m)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 363872.69
Drilled:	**Bit Record:**	**North:** 6364369.65
Logged By:		**Collar (RL):** 30.25

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
240						
250						
260						
267				Monitored Unit Big Ben (267m)		Vibrating Wire piezometer (267m) C141B
270						
280						
282				Monitored unit Layer 17 (282m)		Vibrating Wire piezometer (282m) C141A
290						
300						



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COMPOSITE WELL LOG

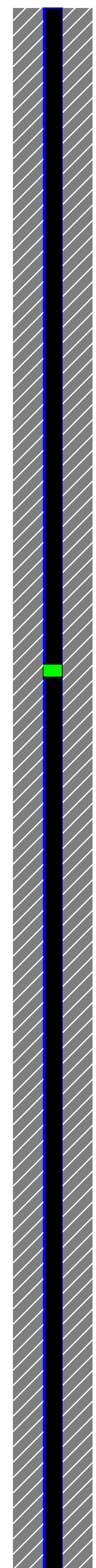
Well No: C148

Client: Donaldson Coal Operations | **Project:** Tasman Extension

Commenced: 25/02/2009	**Method:** (0-243.3m)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 362443.39
Drilled:	**Bit Record:**	**North:** 6364501.02
Logged By:		**Collar (RL):** 22.24

Static Water Level: | **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0						
10						
20						
30						
40						
50				Monitored unit West Borehole Seam (50m)		Vibrating Wire piezometer (50m) C141D
60						
70						
80						
90						
100						
110						



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COMPOSITE WELL LOG

Well No: C148

Client: Donaldson Coal Operations **Project:** Tasman Extension

Commenced: 25/02/2009
Completed:
Drilled:
Logged By:

Method: (0-243.3m)
Fluid:
Bit Record:

Area: Tasman Mine Lease
East: 362443.39
North: 6364501.02
Collar (RL): 22.24

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
120						
125				Monitored unit Buttai (125m)		Vibrating Wire piezometer (125m) C141C
130						
140						
150						
160						
170						
180						
190						
200				Monitored unit Big Ben (200m)		Vibrating Wire piezometer (200m) C148B
210						
220						
230						
237				Monitored unit Below Big Ben (237m)		Vibrating Wire piezometer (237m) C148A
240						

COMPOSITE WELL LOG

Well No: C223

RPS Aquaterra

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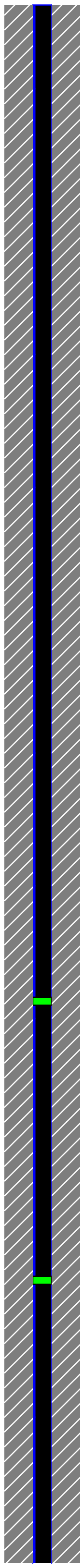
Client: Donaldson Coal Operations **Project:** Tasman Extension

Commenced: 26/02/2010	**Method:** (0-394.81m)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 365529.73
Drilled:	**Bit Record:**	**North:** 6364593.90
Logged By:		**Collar (RL):** 164.76

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0						
10						
20						
30						
40						
50						
60						
70						
80						
90						
100						
110						
120						
130				Monitored unit West Borehole Seam (125m)		Vibrating Wire piezometer (125m) C223E
140						
150						
160				Monitored unit Sandgate Seam (160m)		Vibrating Wire piezometer (160m) C223D
170						
180						
190						



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COMPOSITE WELL LOG

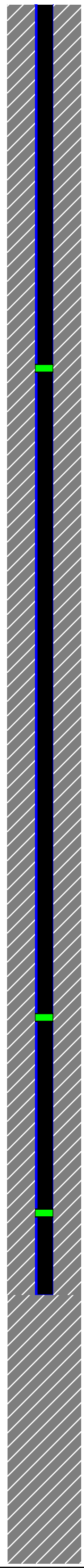
Well No: C223

Client: Donaldson Coal Operations **Project:** Tasman Extension

Commenced: 26/02/2010	**Method:** (0-394.81m)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 365529.73
Drilled:	**Bit Record:**	**North:** 6364593.90
Logged By:		**Collar (RL):** 164.76

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
200						
210						
220						
230						
240				Monitored unit Buttai (242m)		Vibrating Wire piezometer (242m) C223C
250						
260						
270						
280						
290						
300						
310						
320						
330				Monitored unit Upper Donaldson (325m)		Vibrating Wire piezometer (325m) C223B
340						
350				Monitored unit Lower Donaldson (350m)		Vibrating Wire piezometer (350m) C223A
360						
370						
380						
390						



COMPOSITE WELL LOG

Well No: C257

RPS Aquaterra

Suit 902, Level 9, North Tower
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Australia
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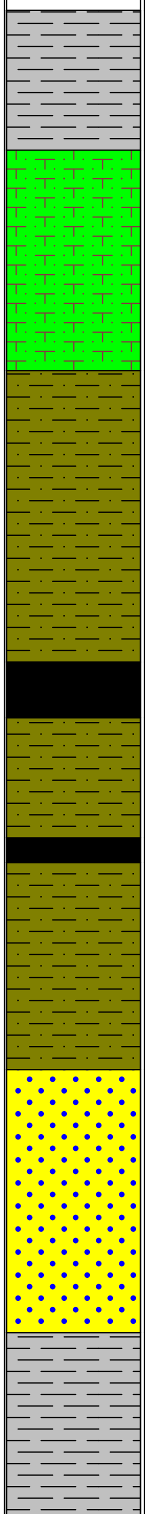
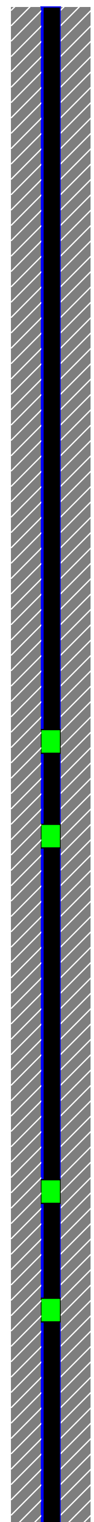
Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced:	**Method:**	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 370029.99
Drilled:	**Bit Record:**	**North:** 6366642.01
Logged By:		**Collar (RL):** 41.59

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0			Shale			
			Claystone			
10						
			Mudstone: Claystone			
20						
			Coal: With Mudstone and Claystone layers			
30			Mudstone: with Sandstone layers	Monitored Unit Mudstone (30m)		Vibrating Wire piezometer SN:13150 (30m)
			Coal: with Mudstone layers			
			Mudstone: with Sandstone layers	Monitored Unit Donaldson Seam (35m)		Vibrating Wire piezometer SN:13151 (35m)
40						
			Sandstone			
50				Monitored Unit Sandgate Donaldson Interburden (50m)		Vibrating Wire piezometer SN:13253 (50m)
			Shale: With Mudstone and Sandstone	Monitored Unit Sandgate Donaldson Interburden (55m)		Vibrating Wire piezometer SN:13254 (55m)
60						





RPS Aquaterra	COMPOSITE WELL LOG	Well No: C257

Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
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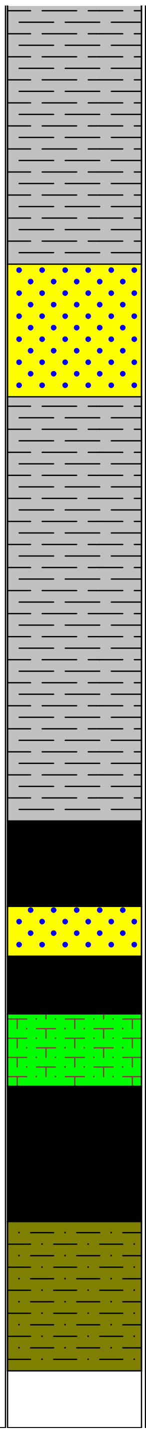
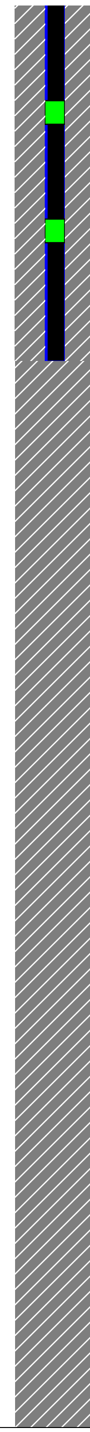
Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced:	**Method:**	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 370029.99
Drilled:	**Bit Record:**	**North:** 6366642.01
Logged By:		**Collar (RL):** 41.59

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
70				Monitored Unit Sandgate Donaldson Interburden (70m)		Vibrating Wire piezometer SN:13505 (70m)
			Sandstone: With very little Coal	Monitored unit Sandgate Donaldson Interburden(75m)		Vibrating Wire piezometer SN:13588 (75m)
80			Shale: with thin layers if Mudstone			
90						
100			Coal			
			Sandstone: with thin layers if Mudstone			
			Coal			
			Claystone			
110			Coal			
			Mudstone: Coal ,Claystone and Shale layers			
120						





COMPOSITE WELL LOG

Well No: C262

RPS Aquaterra

Suit 902, Level 9, North Tower
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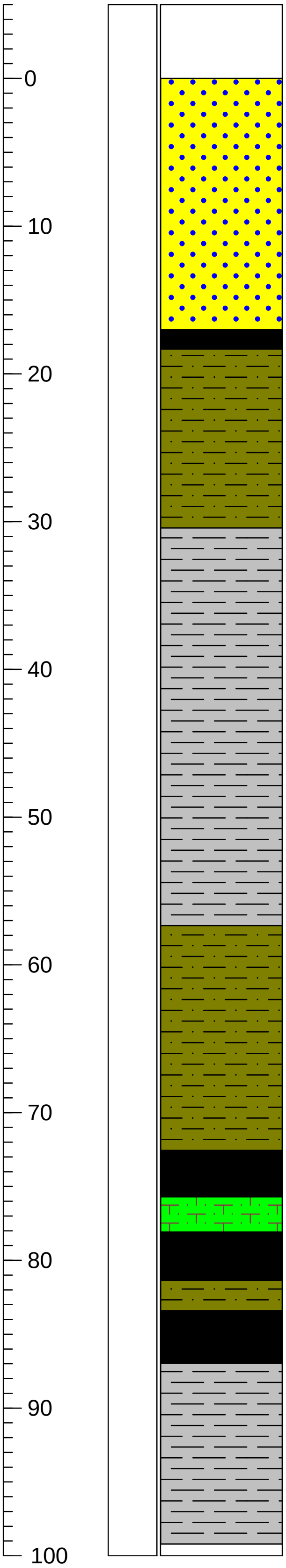
Australia
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

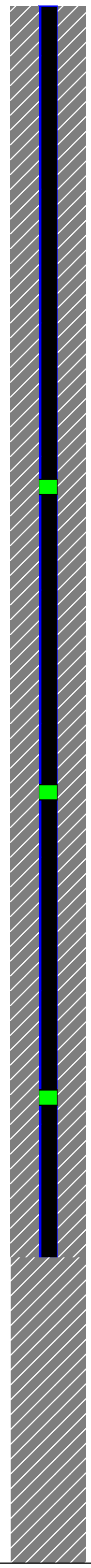
Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced:	**Method:** (0-100.0)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 370208.01
Drilled:	**Bit Record:**	**North:** 6367200.88
Logged By:		**Collar (RL):** 33.41

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
			Sandstone: with Mudstone, Shale and Clay layers			
			Coal			
			Mudstone: with Sandstone and Calciterbonaceous Mudstone Layers			
			Shale: with Mudstone and Sandstone layers	Monitered unit Mudstone (30m)		Vibrating Wire piezometer (30m) C262C
				Monitered unit Shale (50m)		Vibrating Wire piezometer (50m) C262B
			Mudstone: with Shale and Sandstone layers			
				Monitered unit Mudstone (70m)		Vibrating Wire piezometer (70m) C262A
			Coal: with Claystone and very little Mudstone layers			
			Claystone			
			Coal: with woven Claystone layers			
			Mudstone: with Calciterbonaceous Mudstone layers			
			Coal: with little Claystone, Mudstone and Siderite			
			Shale: with Mudstone,Claystone and Calciterbonaceous Mudstone layers			





COMPOSITE WELL LOG

Well No: B002A

RPS Aquaterra

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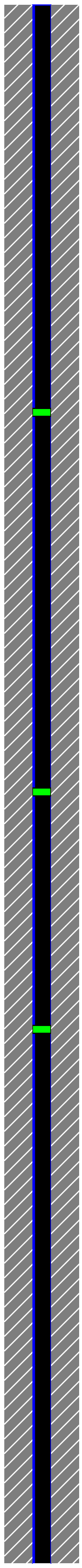
Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 30/04/2009	**Method:** (0-383.5)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 361942.35
Drilled:	**Bit Record:**	**North:** 6360970.96
Logged By:		**Collar (RL):** 51.34

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0						
10						
20						
30						
40						
50				Monitered Unit (50m)		Vibrating Wire piezometer (50m) B002AD
60						
70						
80						
90						
100				Monitered Unit West Borehole Seam (98m)		Vibrating Wire piezometer (98m) B002AC
110						
120						
130				Monitered Unit Sandgate Seam (128m)		Vibrating Wire piezometer (128m) B002AB
140						
150						
160						
170						
180						
190						



COMPOSITE WELL LOG

Well No: B002A

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Suit 902, Level 9, North Tower
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NSW, 2067
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Tel: (+61) (02) 9412 4630
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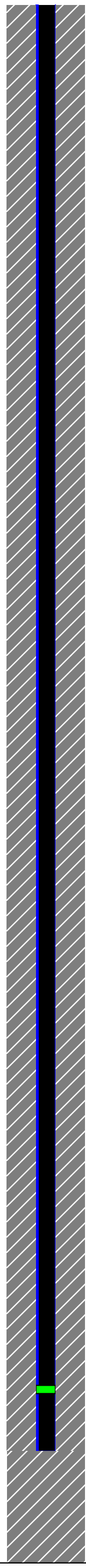
Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 30/04/2009	**Method:** (0-383.5)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 361942.35
Drilled:	**Bit Record:**	**North:** 6360970.96
Logged By:		**Collar (RL):** 51.34

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
200						
210						
220						
230						
240						
250						
260						
270						
280						
290						
300						
310						
320						
330						
340						
350						
360				Monitered Unit Big Ben Seam (363m)		Vibrating Wire piezometer (363m) B002AA
370						
380						



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COMPOSITE WELL LOG

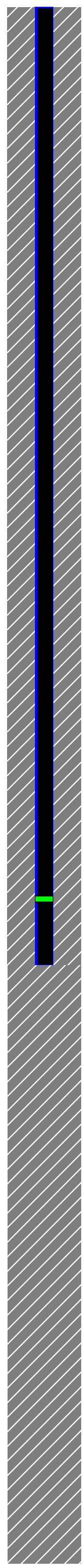
Well No: B004

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 30/08/2006	**Method:** (0-402.3)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 363,048
Drilled:	**Bit Record:**	**North:** 6,362,107
Logged By:		**Collar (RL):** 60.48

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0						
10						
20						
30						
40						
50						
60						
70						
80						
90						
100						
110						
120						
130						
140				Monitered Unit West Borehole Seam (140m)		Vibrating Wire piezometer (140m) B004
150						
160						
170						
180						
190						
200						
210						
220						
230						
240						



COMPOSITE WELL LOG

Well No: B004

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Fax: (+61) (02) 9412 4805

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 30/08/2006	**Method:** (0-402.3)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 363,048
Drilled:	**Bit Record:**	**North:** 6,362,107
Logged By:		**Collar (RL):** 60.48

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
250						
260						
270						
280						
290						
300						
310						
320						
330						
340						
350						
360						
370						
380						
390						
400						

COMPOSITE WELL LOG

Well No: B005

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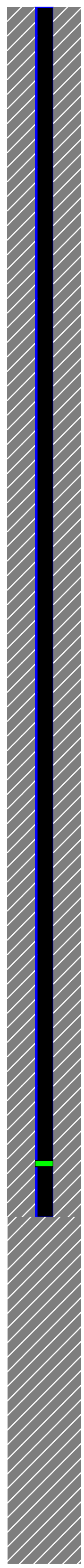
Fax: (+61) (02) 9412 4805

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 30/08/2006	**Method:** (0-476.1)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 363,760
Drilled:	**Bit Record:**	**North:** 6,362,001
Logged By:		**Collar (RL):** 125.73

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0 – 240				Monitered Unit West Borehole Seam (182m)		Vibrating Wire piezometer (182m) B005

Depth scale: 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240

COMPOSITE WELL LOG	Well No: B005

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Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 30/08/2006	**Method:** (0-476.1)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 363,760
Drilled:	**Bit Record:**	**North:** 6,362,001
Logged By:		**Collar (RL):**125.73

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
250						
260						
270						
280						
290						
300						
310						
320						
330						
340						
350						
360						
370						
380						
390						
400						
410						
420						
430						
440						
450						
460						
470						

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COMPOSITE WELL LOG

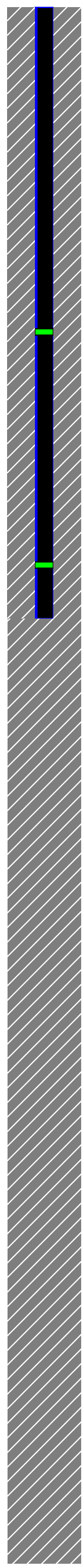
Well No: B017

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 30/04/2007	**Method:** (0-315.3)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:**
Drilled:	**Bit Record:**	**North:**
Logged By:		**Collar (RL):**58.59

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0						
10						
20						
30						
40						
50				Monitered Unit West Borehole Seam (50m)		Vibrating Wire piezometer (50m) B017B
60						
70						
80						
90				Monitered Unit Sandgate Seam (87m)		Vibrating Wire piezometer (87m) B017A
100						
110						
120						
130						
140						
150						
160						
170						
180						
190						
200						
210						
220						
230						
240						



COMPOSITE WELL LOG	Well No: B017

RPS Aquaterra

Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
NSW, 2067
Australia
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 30/04/2007	**Method:** (0-315.3)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:**
Drilled:	**Bit Record:**	**North:**
Logged By:		**Collar (RL):** 58.59

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
250						
260						
270						
280						
290						
300						
310						

RPS Aquaterra

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Fax: (+61) (02) 9412 4805

COMPOSITE WELL LOG

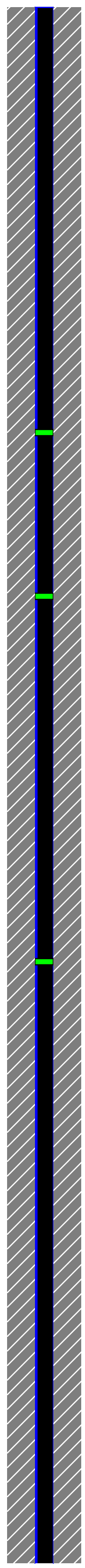
Well No: B029

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 23/12/2008	**Method:** (0-326.22)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 361361.60
Drilled:	**Bit Record:**	**North:** 6360638.75
Logged By:		**Collar (RL):** 47.01

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0						
10						
20						
30						
40						
50						
60						
70				Monitered Unit West Borehole Seam (66m)		Vibrating Wire piezometer (66m) B029E
80						
90				Monitered Unit Sandgate Seam (92m)		Vibrating Wire piezometer (92m) B029D
100						
110						
120						
130						
140						
150				Monitered Unit Buttai Seam (150m)		Vibrating Wire piezometer (150m) B029C
160						
170						
180						
190						
200						
210						
220						
230						
240						



COMPOSITE WELL LOG

Well No: B029

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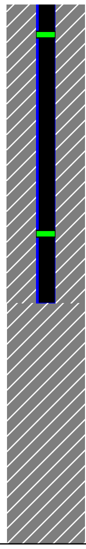
Fax: (+61) (02) 9412 4805

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: 23/12/2008	**Method:** (0-326.22)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 361361.60
Drilled:	**Bit Record:**	**North:** 6360638.75
Logged By:		**Collar (RL):** 47.01

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
250				Monitered Unit Upper Donaldson (250m)		Vibrating Wire piezometer (250m) B029B
260						
270						
280				Monitered Unit Lower Donaldson (280m)		Vibrating Wire piezometer (280m) B029A
290						
300						
310						
320						



COMPOSITE WELL LOG

Well No: B030

RPS Aquaterra

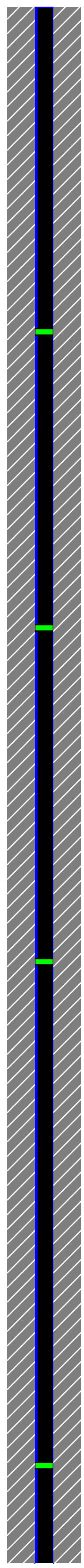
Suit 902, Level 9, North Tower
1-5 Railway Street, Chatswood
NSW, 2067
Australia
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: November 2009	**Method:** (0-360.8)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 361399.55
Drilled:	**Bit Record:**	**North:** 6359400.29
Logged By:		**Collar (RL):** 60.71

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
0						
10						
20						
30						
40						
50				Monitered Unit Layer 4 (50m)		Vibrating Wire piezometer (50m) B030E
60						
70						
80						
90						
100				Monitered Unit Layer 5 (97m)		Vibrating Wire piezometer (97m) B030D
110						
120						
130						
140						
150				Monitered Unit Sandgate (150m)		Vibrating Wire piezometer (150m) B030C
160						
170						
180						
190						
200						
210						
220						
230				Monitered Unit Upper Donaldson (230m)		Vibrating Wire piezometer (230m) B030B
240						



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Fax: (+61) (02) 9412 4805

COMPOSITE WELL LOG

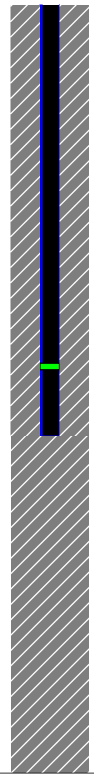
Well No: B030

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: November 2009	**Method:** (0-360.8)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 361399.55
Drilled:	**Bit Record:**	**North:** 6359400.29
Logged By:		**Collar (RL):** 60.71

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
250						
260						
270						
280						
290						
300				Monitered Unit Big Ben Interburden (300m)		Vibrating Wire piezometer (300m) B030A
310						
320						
330						
340						
350						
360						



COMPOSITE WELL LOG

Well No: B031

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NSW, 2067
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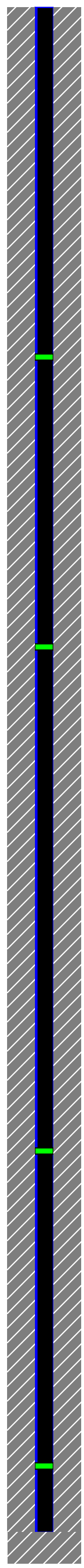
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: July 2010	**Method:** (0-294.8)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 360186.05
Drilled:	**Bit Record:**	**North:** 6358946.09
Logged By:		**Collar (RL):** 180.87

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
54				Monitered Unit Layer 4 (54m)		Vibrating Wire piezometer (54m) B031D
100				Monitered Unit West Borehole Seam (100m)		Vibrating Wire piezometer (100m) B031C
180				Monitered Unit Upper Buttai (180m)		Vibrating Wire piezometer (180m) B031B
230				Monitered Unit Upper Donaldson (230m)		Vibrating Wire piezometer (230m) B031A



COMPOSITE WELL LOG

Well No: B031

RPS Aquaterra

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Australia
Tel: (+61) (02) 9412 4630
Fax: (+61) (02) 9412 4805

Client: Donaldson Coal Operations Pty Ltd **Project:** Tasman Extension

Commenced: July 2010	**Method:** (0-294.8)	**Area:** Tasman Mine Lease
Completed:	**Fluid:**	**East:** 360186.05
Drilled:	**Bit Record:**	**North:** 6358946.09
Logged By:		**Collar (RL):** 180.87

Static Water Level: **Date:**

Depth (mbgl)	Bit Log	Graphic Log	Lithological Description	Field Notes	Well Completion Diagram	Well Completion Notes
250						
260						
270						
280						
290						

Aquaterra Consulting Pty Ltd
Logging Sheet

BORES: Site 1

Project No:	S05

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Bloomfield Collieries Pty Ltd	VW 1	17.4 mAHD			Hunter Drilling Services	27-Mar-07	12-Apr-07

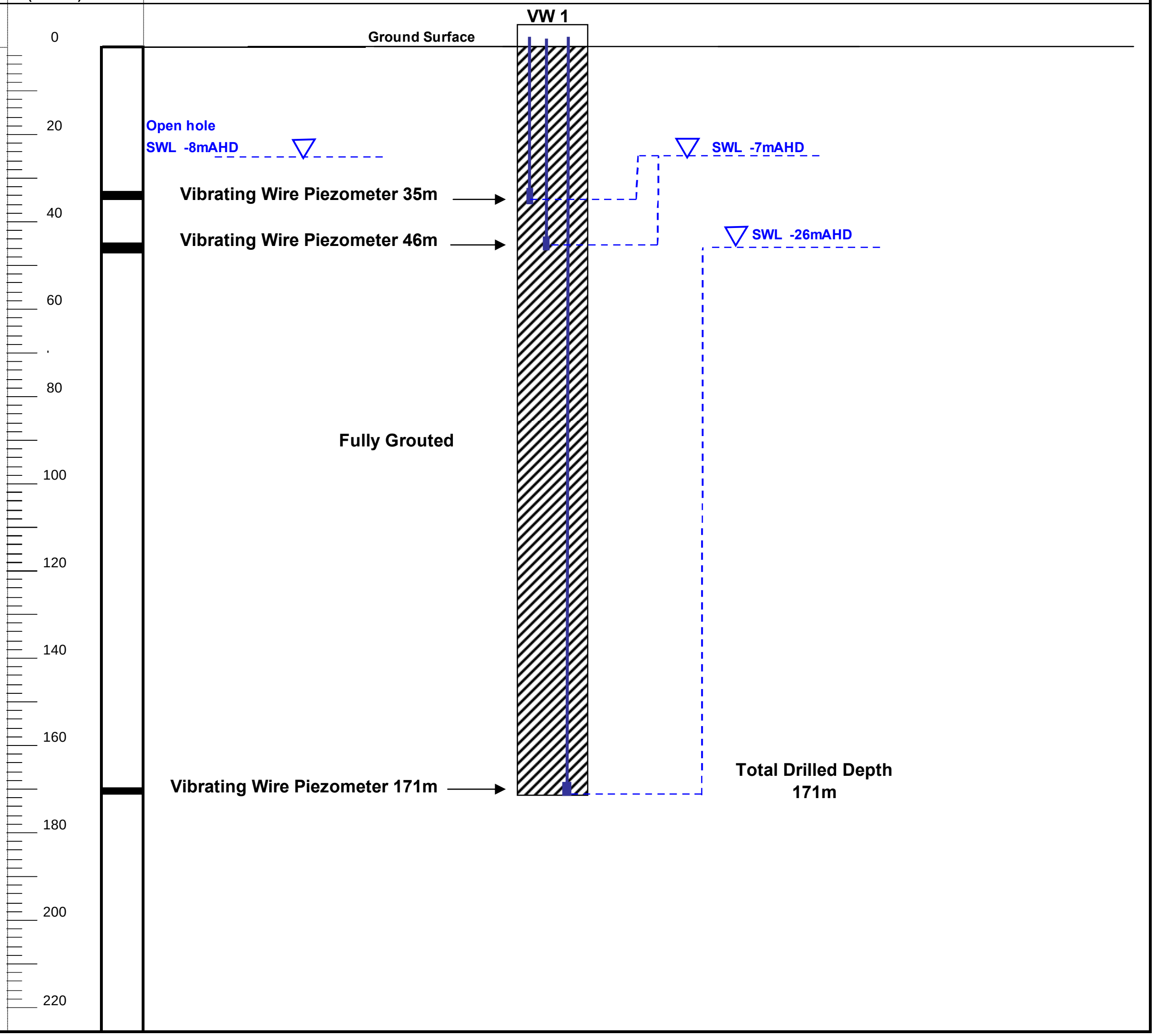
Location:	Hole depths:	Supervised By:
Bloomfield Project	As shown	R McCallum

Description	Depth (metres)	Well Construction Details:

Donaldson Seam (33.0 to 35.4m)

Big Ben Seam (44.3 to 47.2m)

Rathluba Seam (170 to 171.8m)

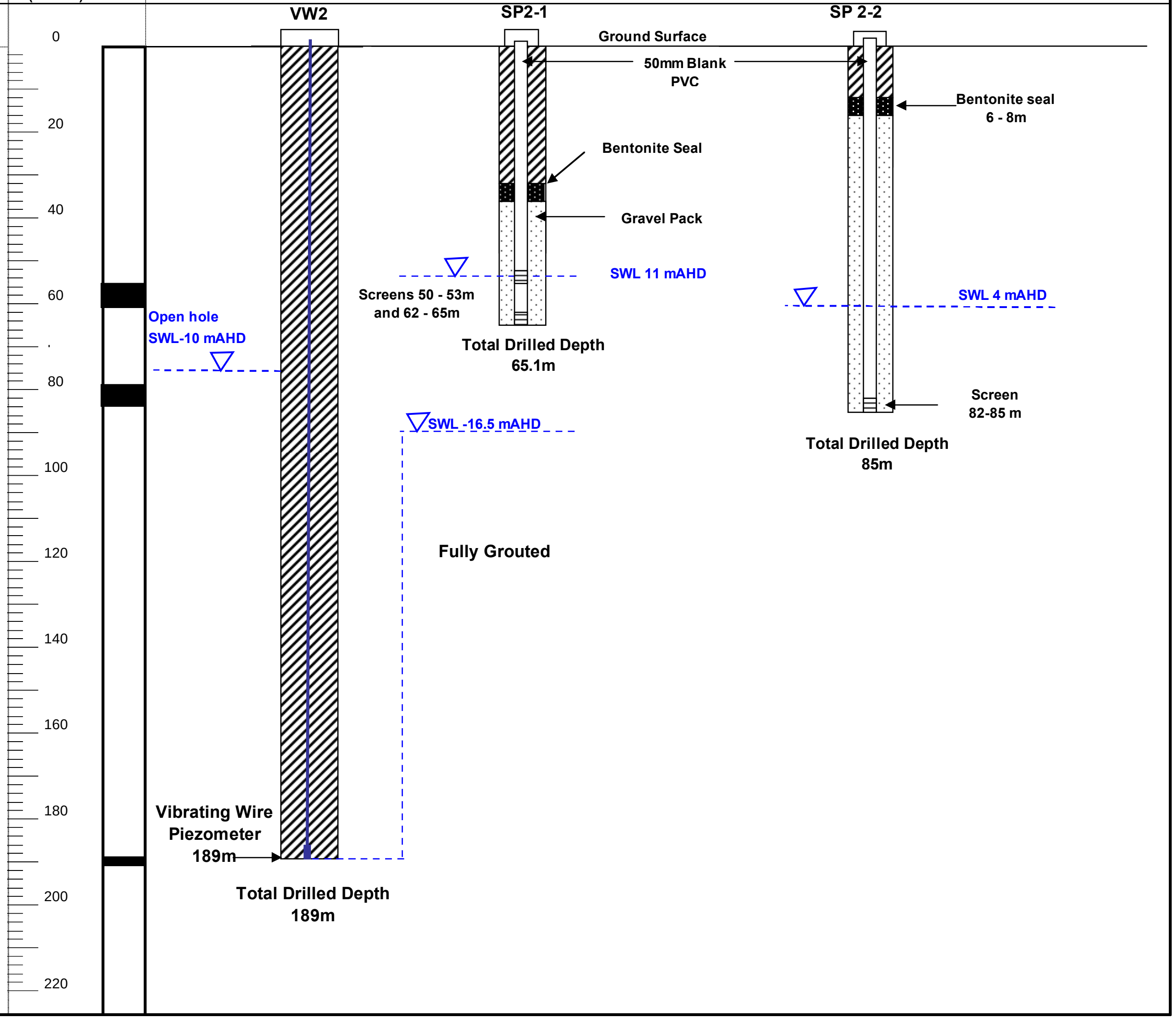


Aquaterra Consulting Pty Ltd
Logging Sheet

BORES: Site 2

						Project No:	S05
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Bloomfield Collieries Pty Ltd	**VW2**	**65.2 mAHD**			**Hunter Drilling Services**	**20-Mar-07**	**27-Mar-07**
Location:	**SP2-1**	**65.2 mAHD**			**Hunter Drilling Services**	**20-Mar-07**	**27-Mar-07**
Bloomfield Project	**SP2-2**	**65.2 mAHD**			**Hunter Drilling Services**	**20-Mar-07**	**27-Mar-07**
			Hole depths: **As shown**			Supervised By: **R McCallum**	

Description	Depth (metres)	Well Construction Details:
Donaldson Seam (55.2 to 61.4m)		
Big Ben Seam (79 to 84m)		
Rathluba Seam (187.8 to 191.3m)		

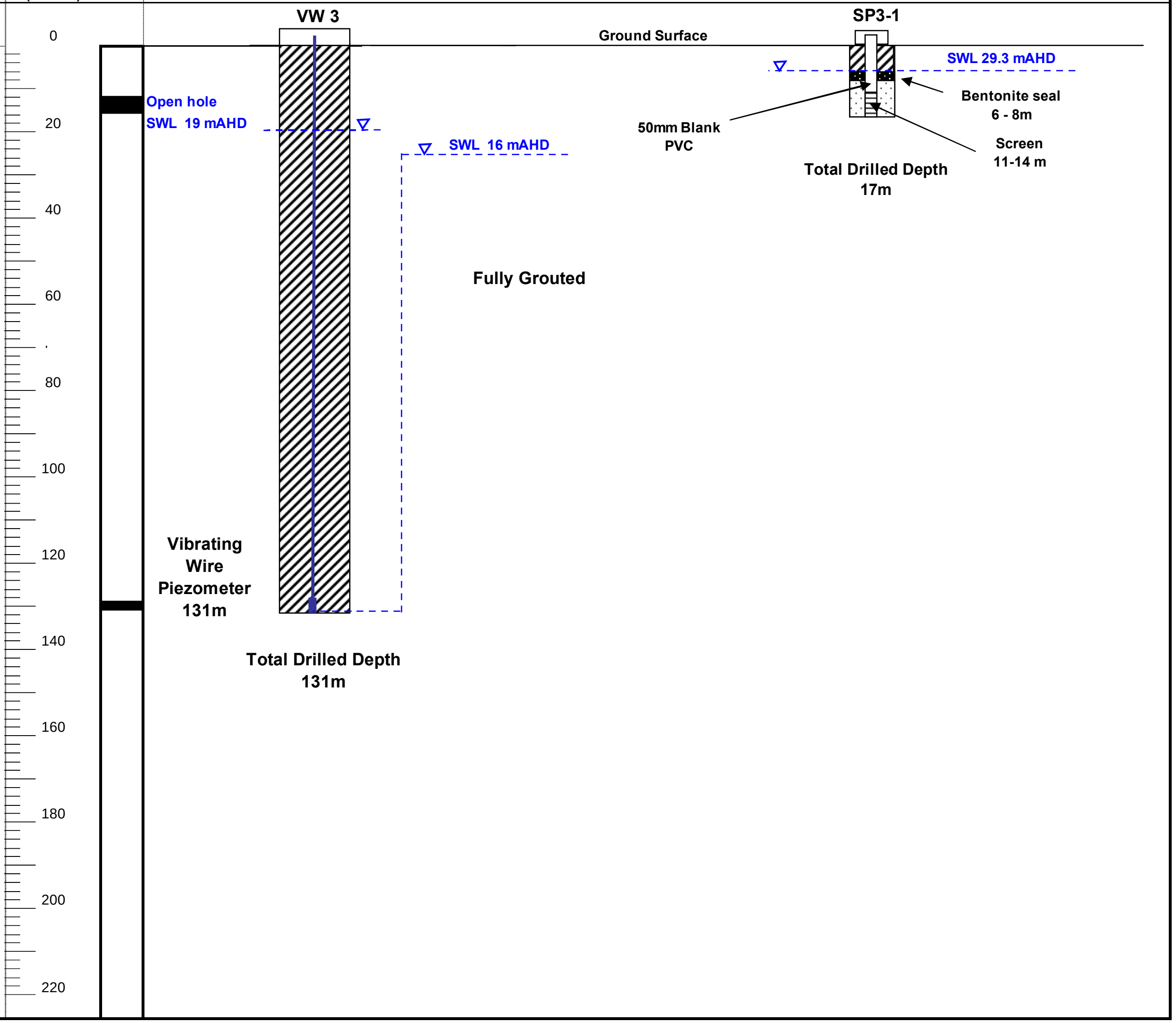


Aquaterra Consulting Pty Ltd
Logging Sheet

BORES: Site 3

						Project No:	**S05**
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Bloomfield Collieries Pty Ltd	**VW3**	**38.8 mAHD**			**Hunter Drilling Services**	**11-May-07**	**14-May-07**
Location:	**SP3-1**	**38.8 mAHD**			**Hunter Drilling Services**	**11-May-07**	**14-May-07**
Bloomfield Project							
			Hole depths: **As shown**			Supervised By: **R McCallum**	

Description	Depth (metres)	Well Construction Details:
Donaldson Seam (12 to 15.2m)		
Rathluba Seam (129.7 to 131.5m)		

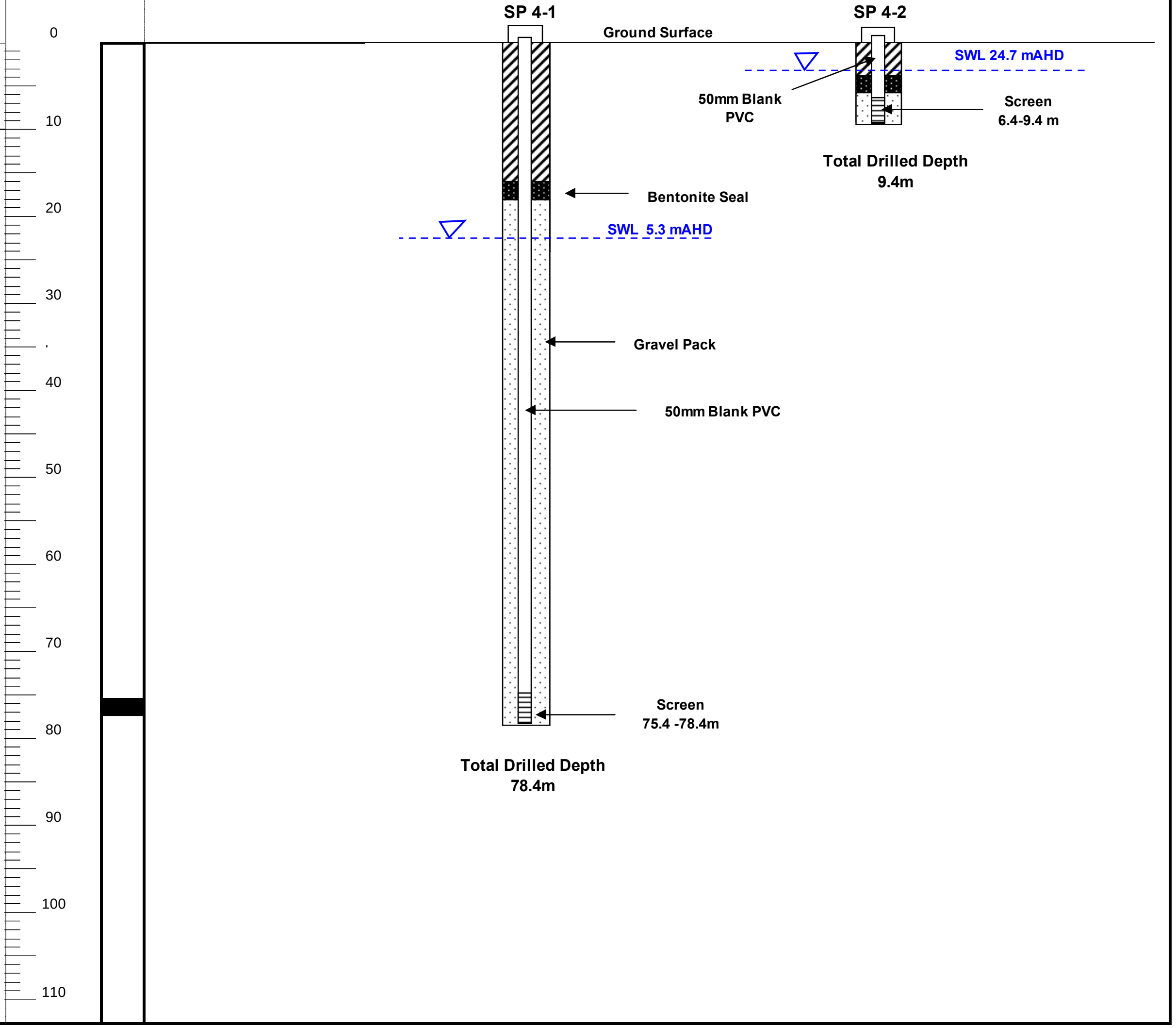


Aquaterra Consulting Pty Ltd
Logging Sheet

BORES: Site 4

						Project No:	S05
Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Bloomfield Collieries Pty Ltd	SP4-1	27.8 mAHD			Hunter Drilling Services	16-Mar-07	17-Mar-07
Location:	SP4-2	27.8 mAHD		0.25 m	Hunter Drilling Services	16-Mar-07	17-Mar-07
Bloomfield Project							
			Hole depths: As shown			Supervised By: R McCallum	

Description	Depth (metres)	Well Construction Details:
Alluvium / weathered Permian	0–10	
Rathluba Seam (75.4 to 77.4m)		



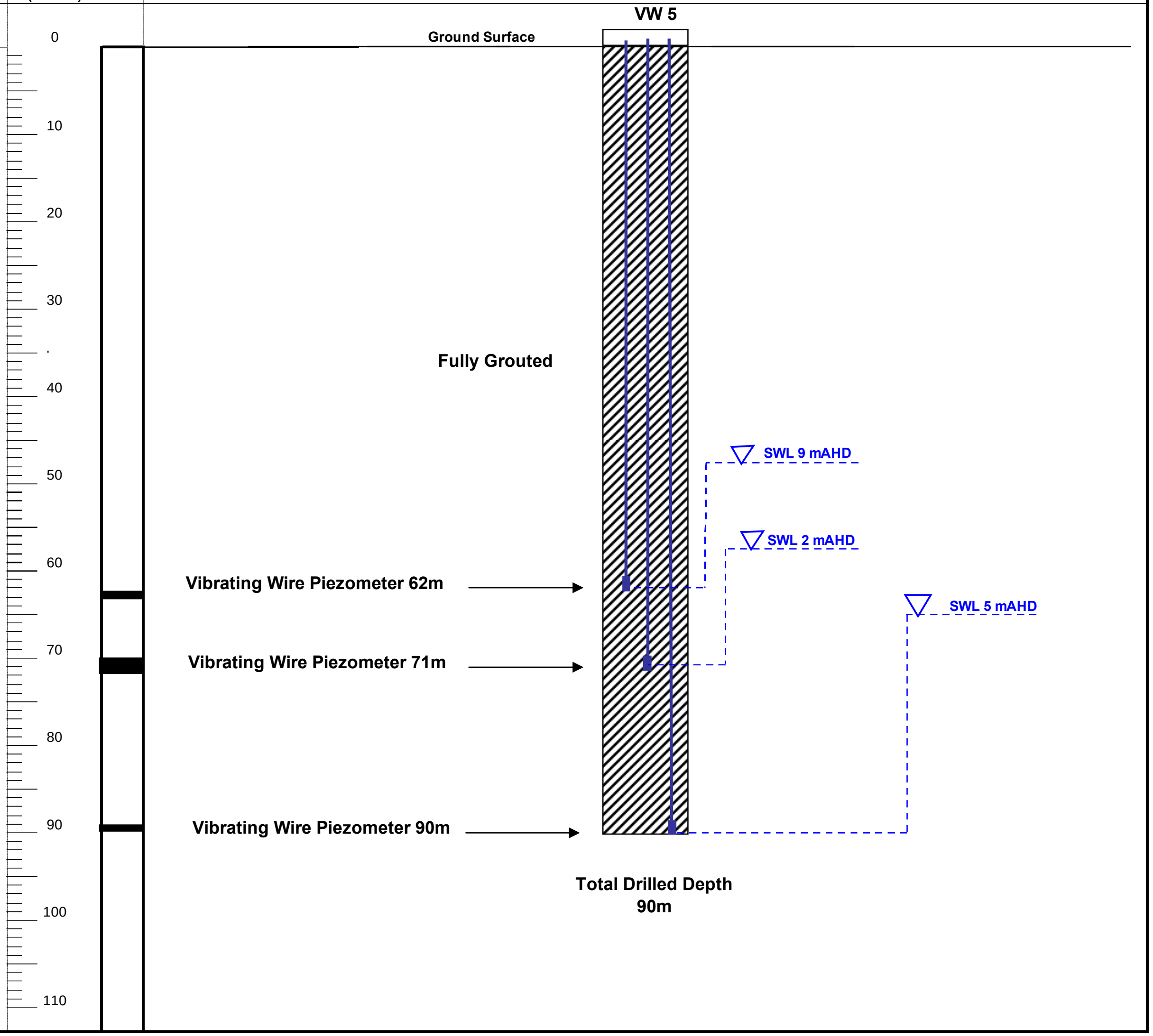
Aquaterra Consulting Pty Ltd
Logging Sheet

BORES: Site 5

Project No:	S05

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Bloomfield Collieries Pty Ltd	**VW5**	**55.7 mAHD**			**Hunter Drilling Services**	**05-Apr-07**	**27-Apr-07**
Location:						Supervised By:	
Bloomfield Project			**As shown**			**R McCallum**	

Description	Depth (metres)	Well Construction Details:
White Creek Seam (62.3 to 63.1m)		
Donaldson Seam (70.5 to 71.9m)		
Big Ben Seam (89.3 to 89.7m)		



Aquaterra Consulting Pty Ltd

Logging Sheet

BORES: Site 6

Project No:	S05

Client:	Bore:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Bloomfield Collieries Pty Ltd	**VW6**	**52.5 mAHD**	**52.75 mAHD**	**0.25 m**	**Hunter Drilling Services**	**24-Apr-07**	**27-Apr-07**

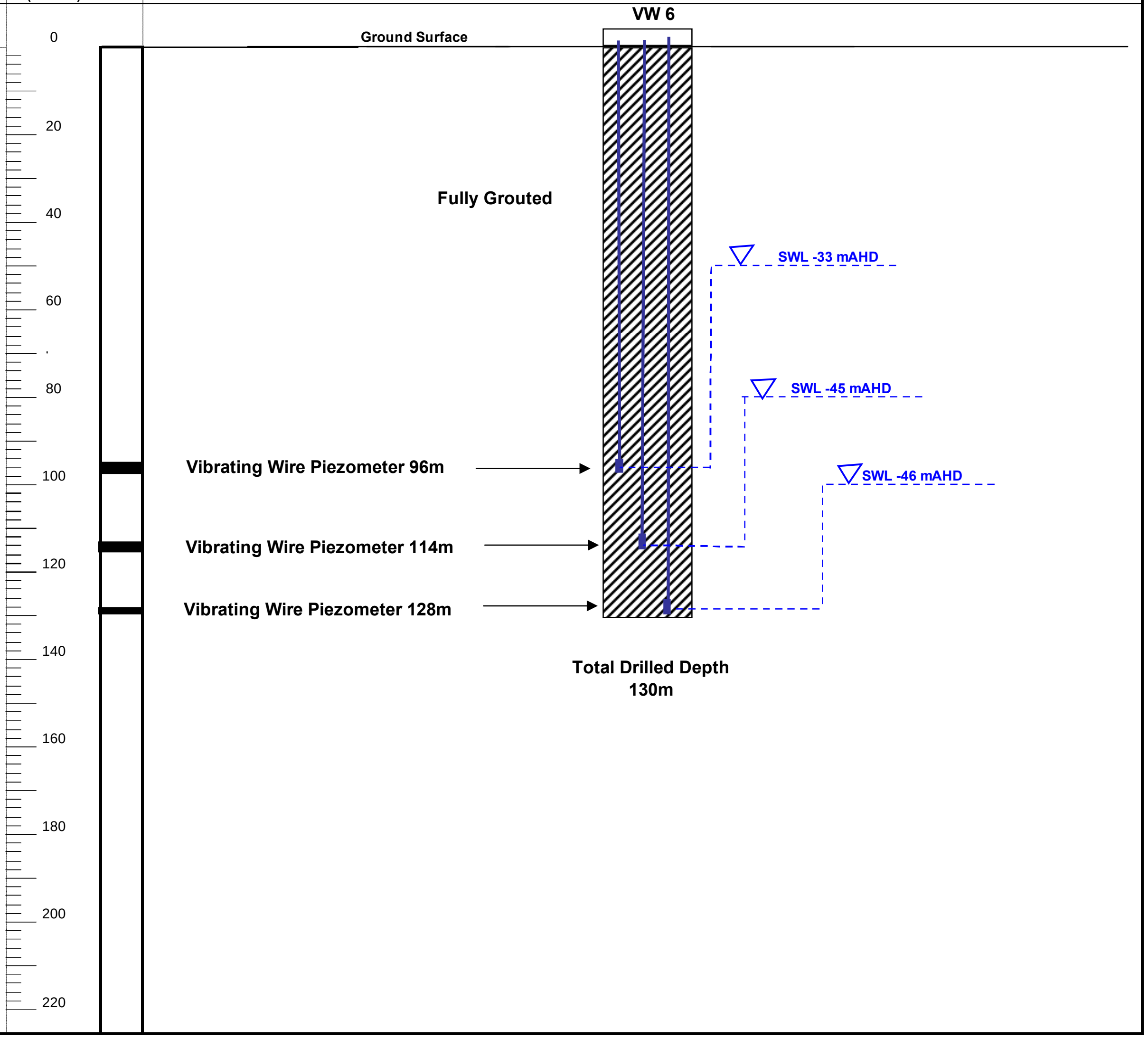
Location:	Hole depths:	Supervised By:
Bloomfield Project	**As shown**	**R McCallum**

Description	Depth (metres)	Well Construction Details:

White Creek Seam (95.1 to 96.7m)

Donaldson Seam (113.2 to 114.7m)

Big Ben Seam (128 to 129.3m)

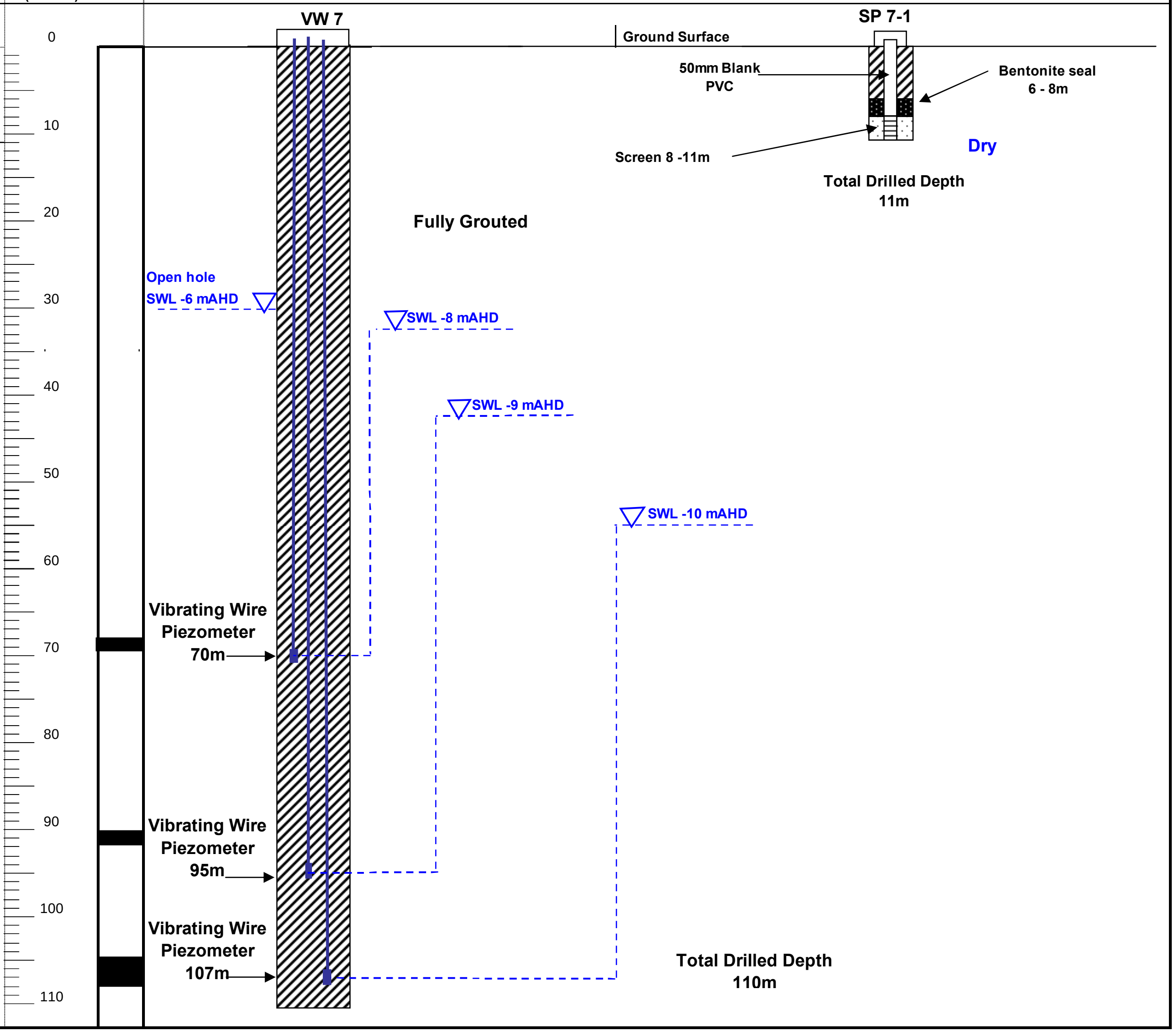


Aquaterra Consulting Pty Ltd
Logging Sheet

BORES: Site 7

							Project No:	**S05**
Client:	Bore:	Depth:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	Date Started:	Date Finished:
Bloomfield Collieries Pty Ltd	**VW7**		**24.9 mAHD**			**Hunter Drilling Services**	**18-Apr-07**	**24-Apr-07**
Location:	**SP7-1**		**24.9 mAHD**			**Hunter Drilling Services**		
Bloomfield Project				**As shown**			Supervised By: **R McCallum**	

Description	Depth (metres)	Well Construction Details:
Alluvium / weathered Permian		
White Creek Seam (67.9 to 69.8m)		
Donaldson Seam (90.0 to 91.8m)		
Big Ben Seam (104.7 to 107.7m)		

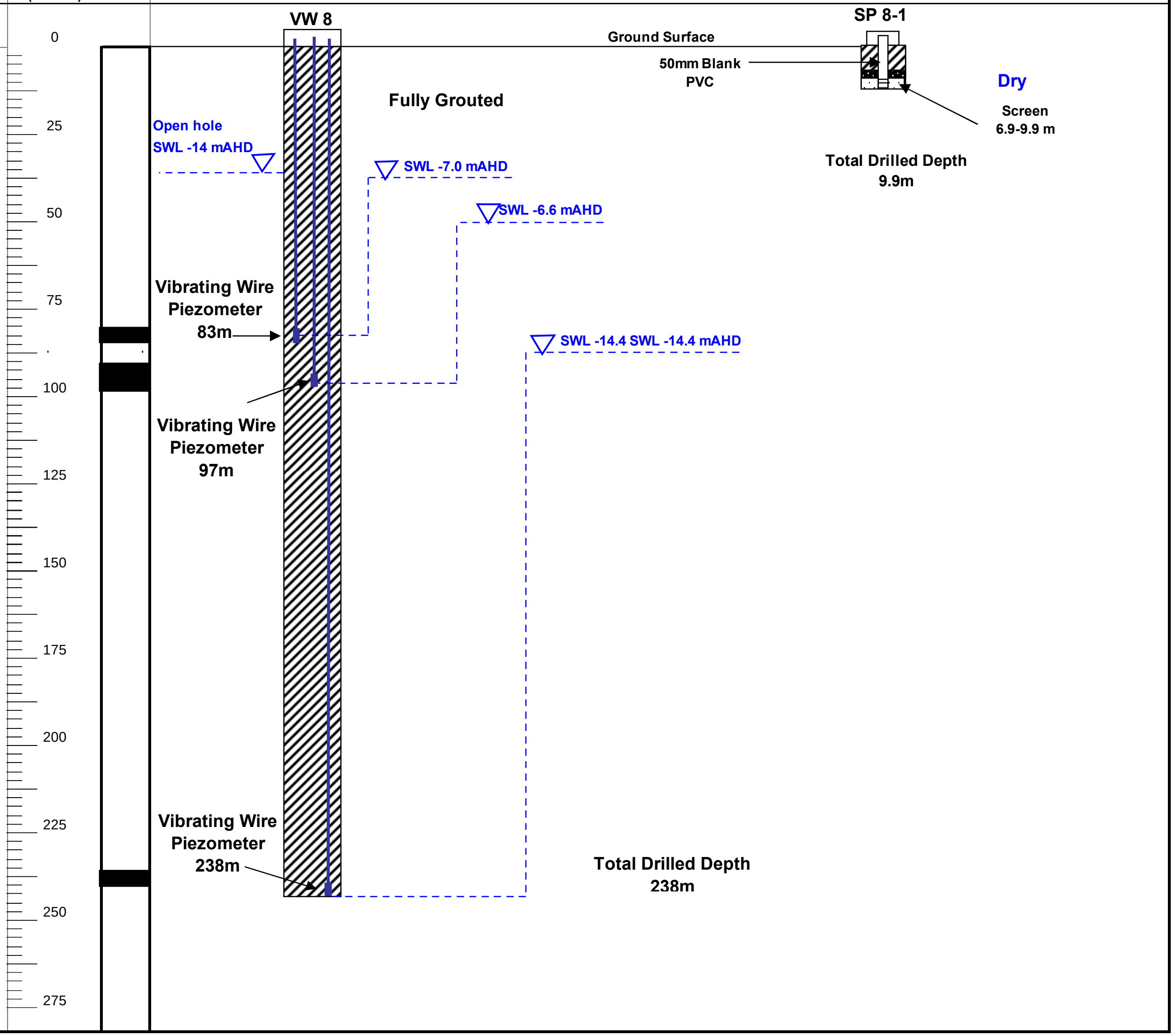


Aquaterra Consulting Pty Ltd
Logging Sheet

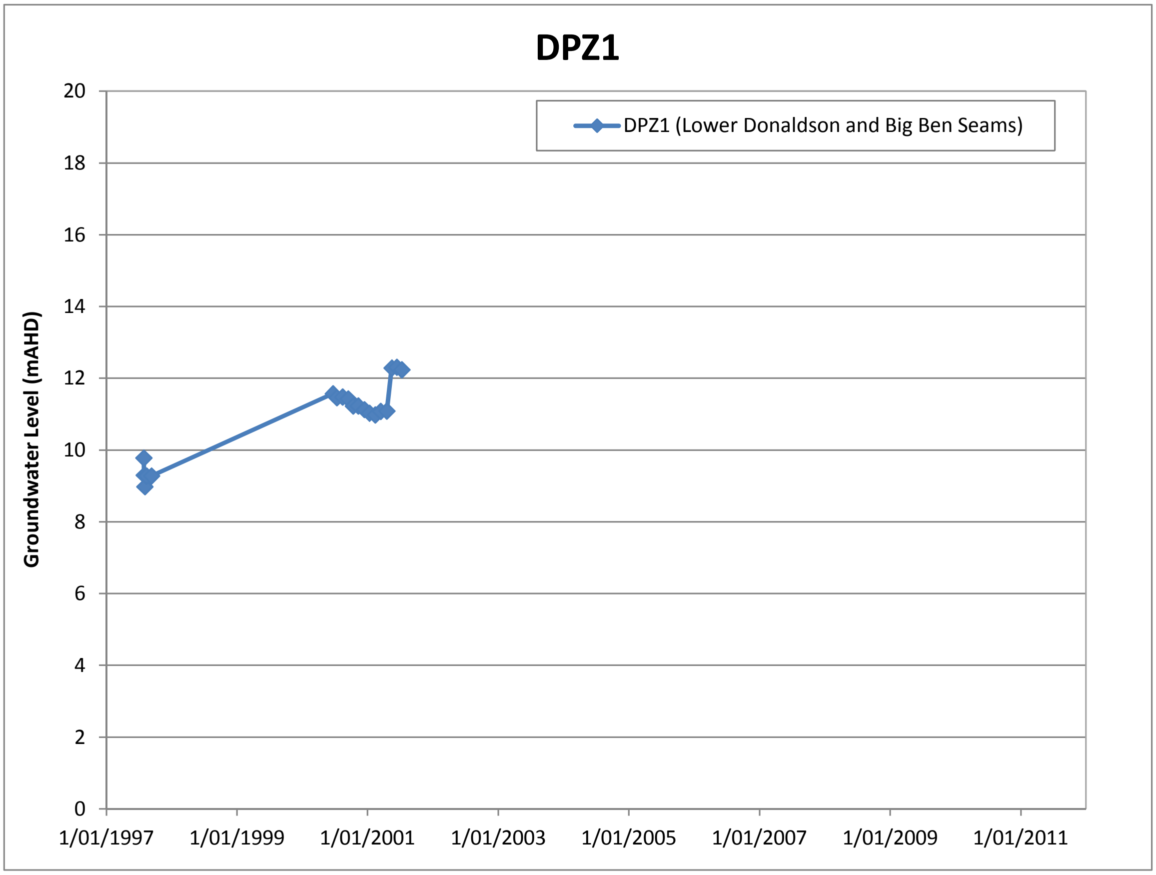
BORES: Site 8

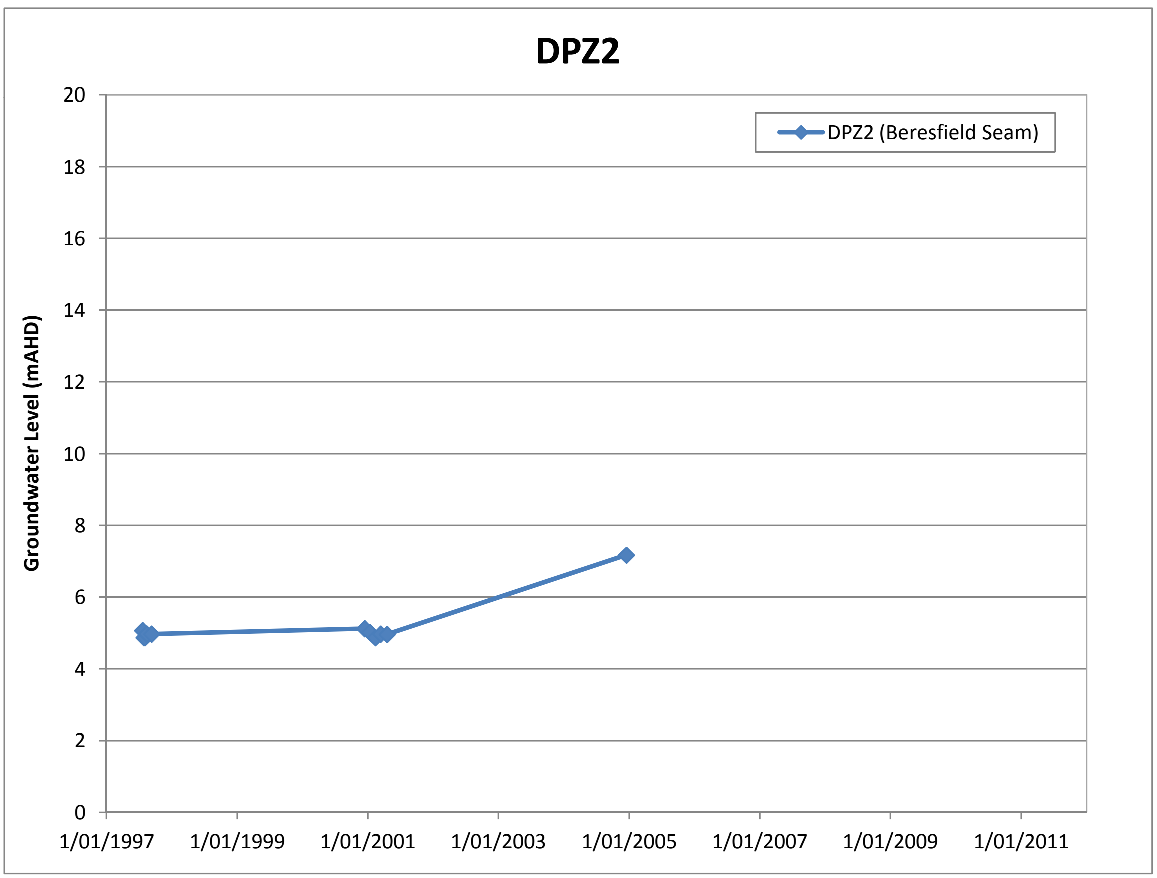
						Project No:	**S05**
Client:	Bore:	Depth:	Elevation (GL):	Elevation (TOC):	Stickup:	Drilling Contractor:	
Bloomfield Collieries Pty Ltd	**VW8**		**22.5 mAHD**			**Hunter Drilling Services**	
Location:	**SP8-1**		**22.5 mAHD**			Date Started: **29-Mar-07**	Date Finished: **18-Apr-07**
Bloomfield Project				**As shown**		Supervised By: **R McCallum**	

Description	Depth (metres)	Well Construction Details:
Alluvium		
Donaldson Seam (80.4 to 84m)		
Big Ben Seam (91.5 to 98.5m)		
Rathluba Seam (237.2 to 240.2m)		



APPENDIX B: GROUNDWATER HYDROGRAPHS AND HYDROSTATIC HEAD PROFILES


DPZ1
DPZ1 (Lower Donaldson and Big Ben Seams)
Groundwater Level (mAHD)
20
18
16
14
12
10
8
6
4
2
0
1/01/1997
1/01/1999
1/01/2001
1/01/2003
1/01/2005
1/01/2007
1/01/2009
1/01/2011


DPZ2
DPZ2 (Beresfield Seam)
Groundwater Level (mAHD)
20
18
16
14
12
10
8
6
4
2
0
1/01/1997
1/01/1999
1/01/2001
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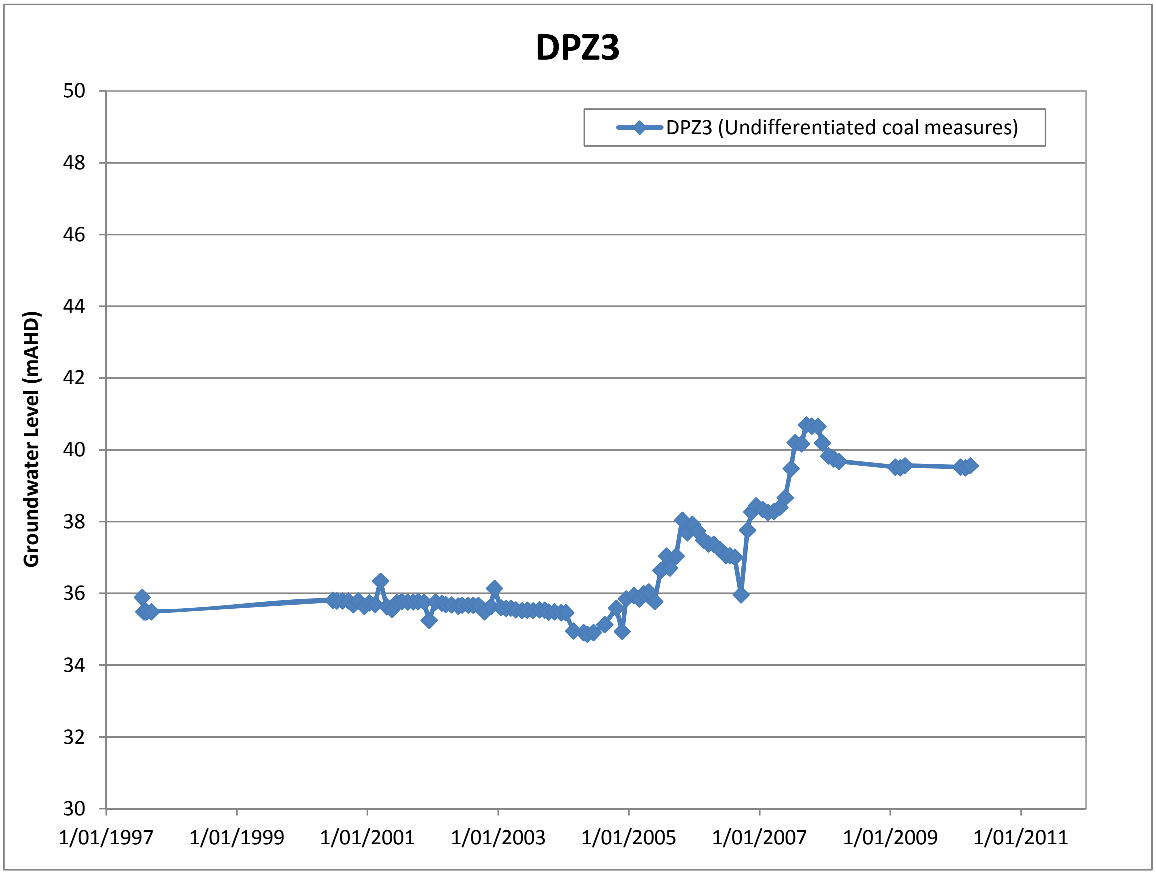
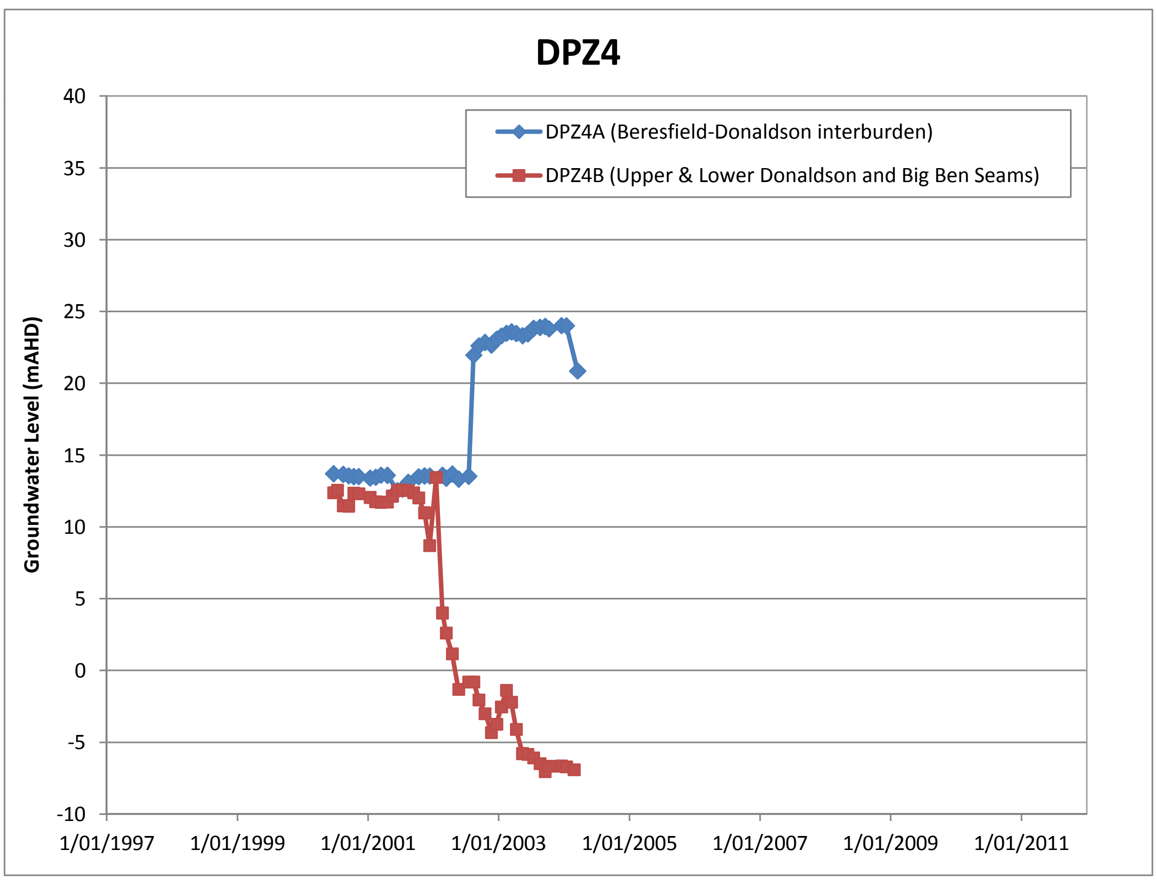
1/01/2009
1/01/2011





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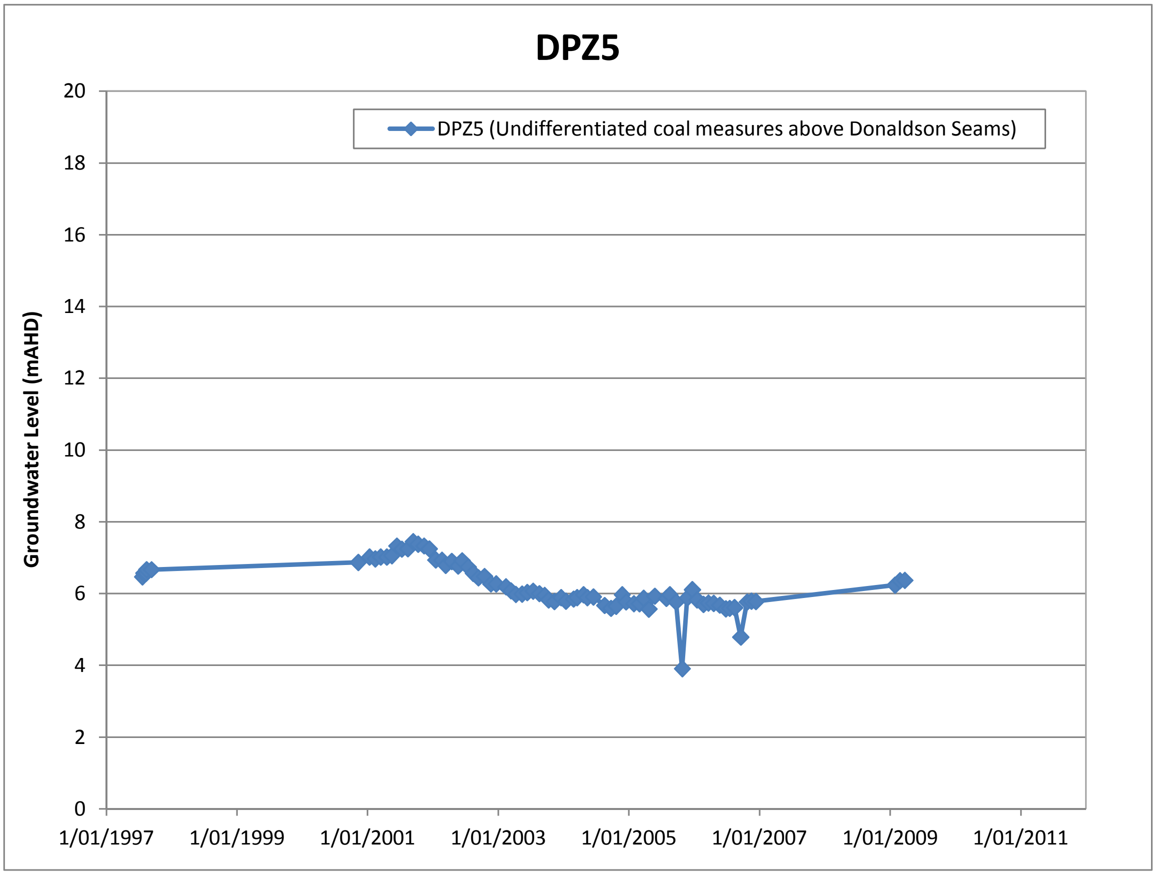
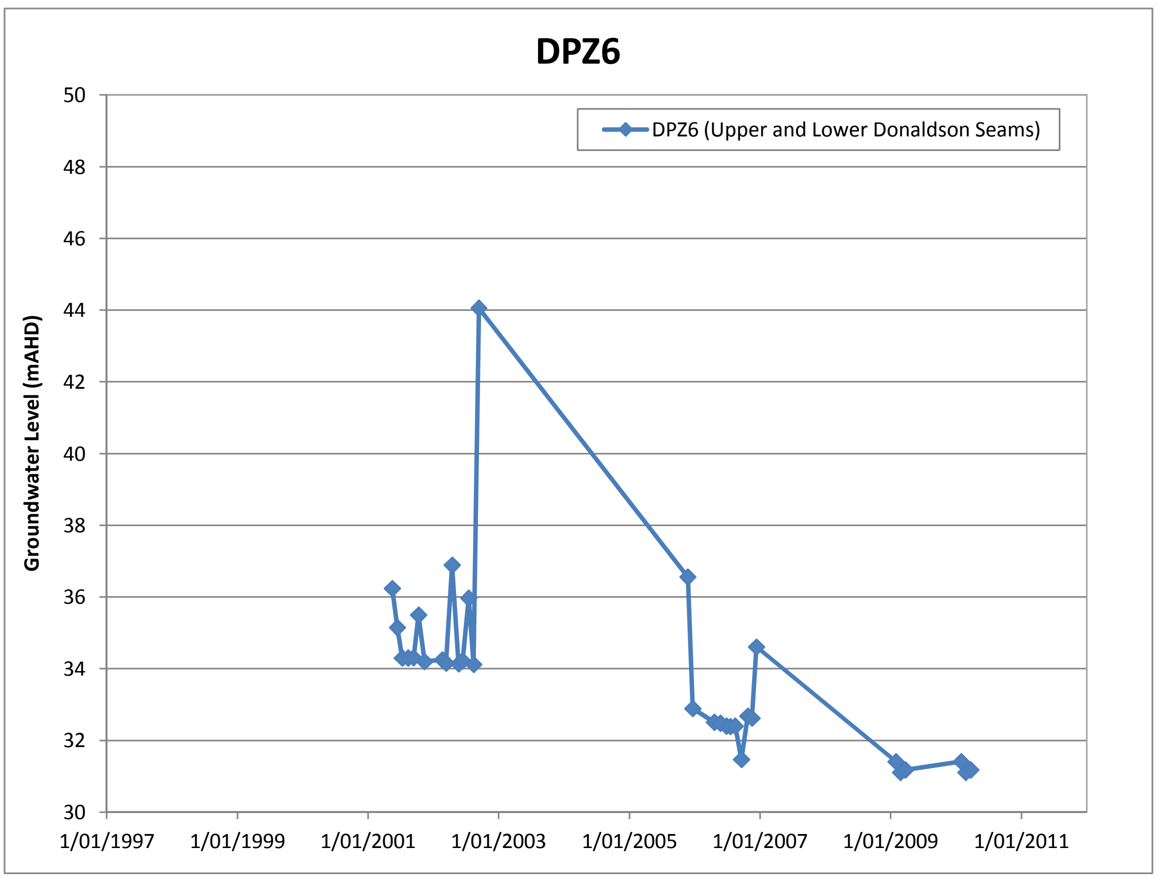
DPZ3 AND DPZ4 HISTORICAL HYDROGRAPHS FIGURE B2

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB2





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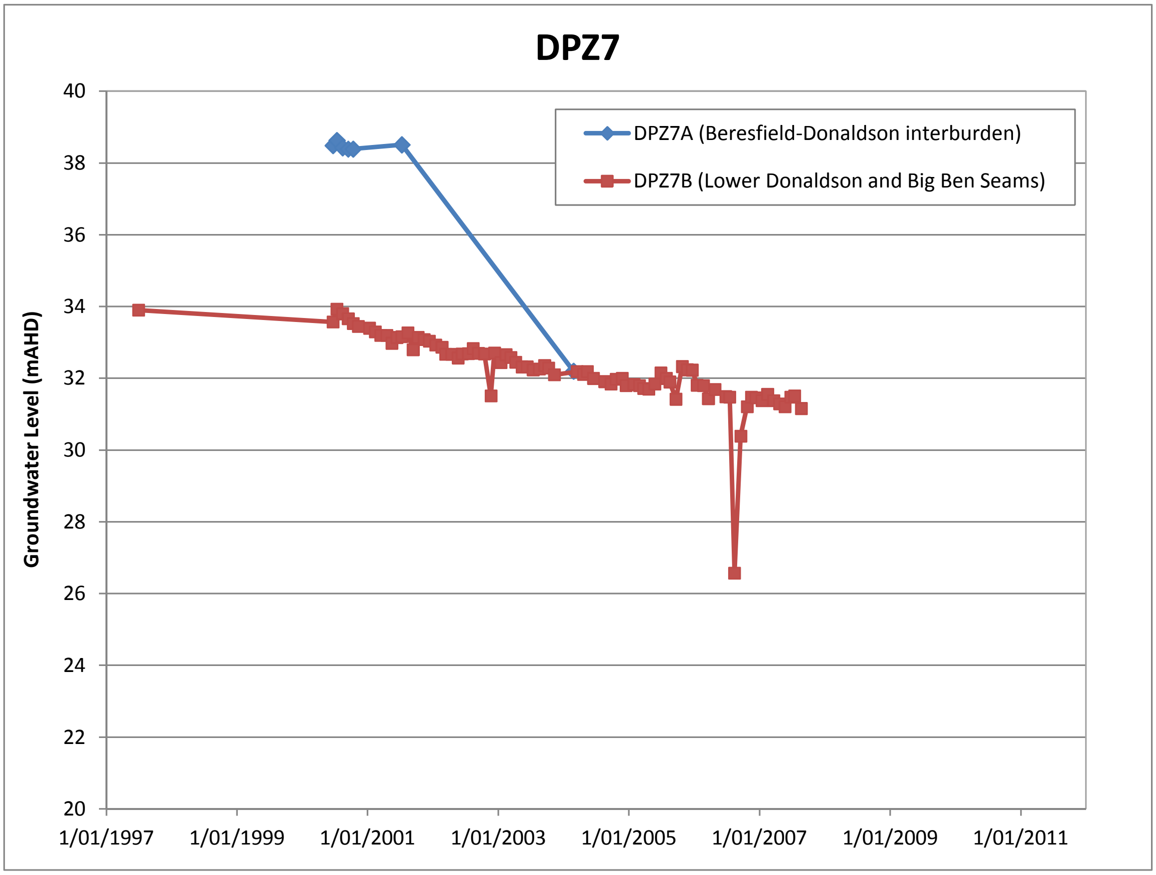
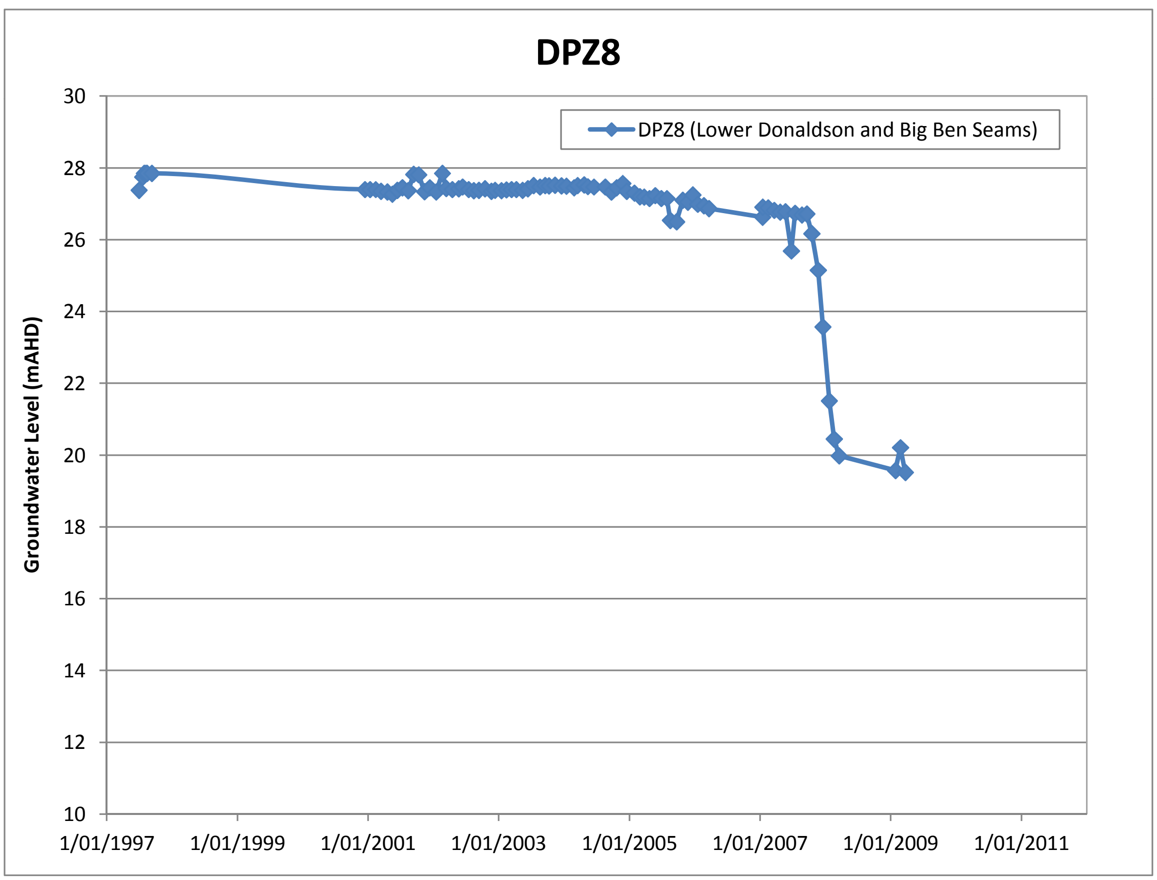
DPZ5 AND DPZ6 HISTORICAL HYDROGRAPHS FIGURE B3

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB3





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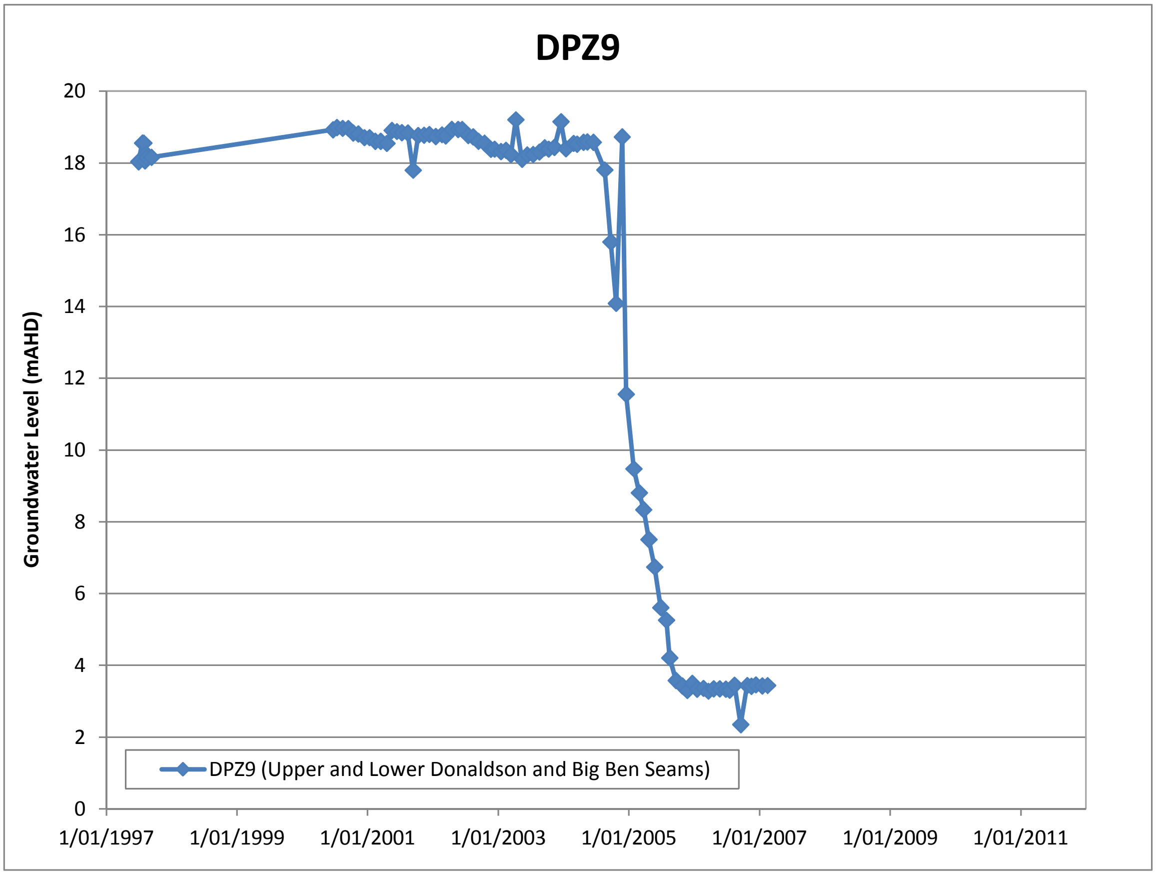
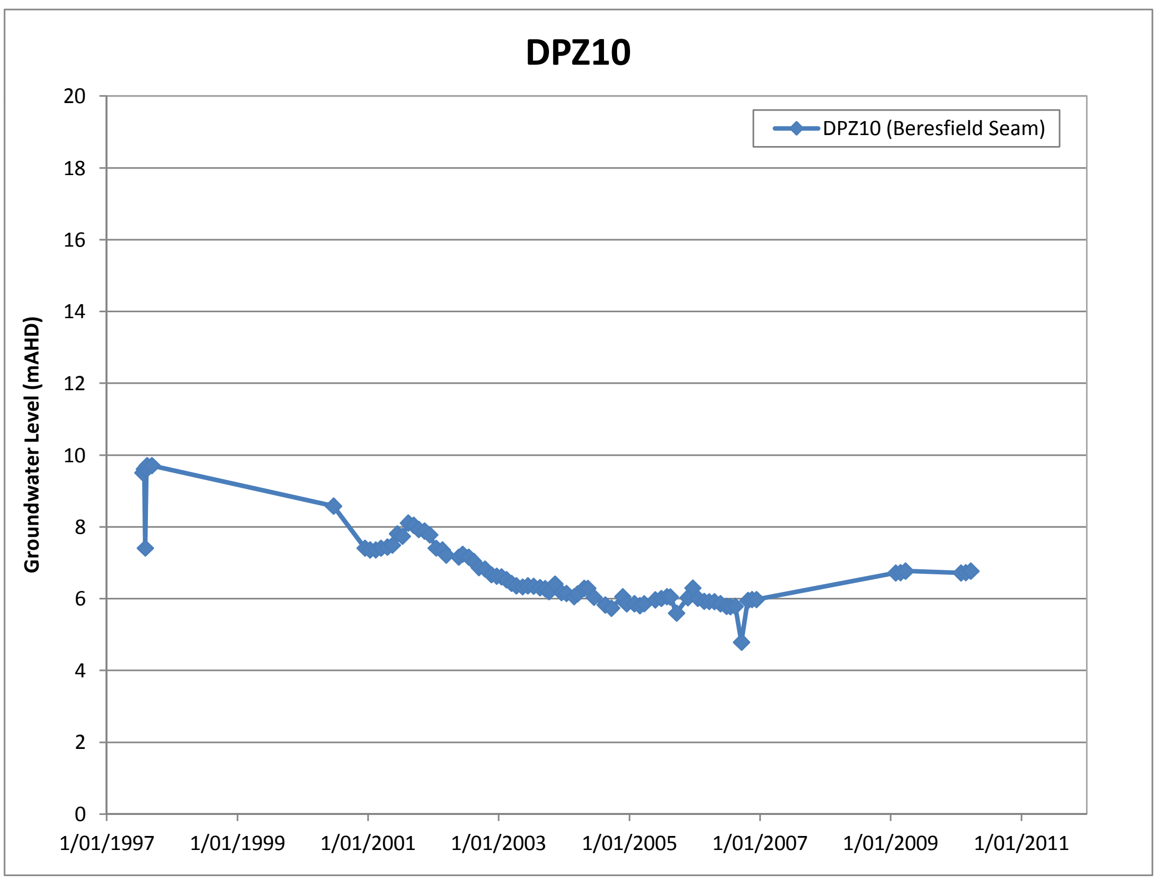
DPZ7 AND DPZ8 HISTORICAL HYDROGRAPHS FIGURE B4

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB4





RPS Aquaterra

DPZ9 AND DPZ10 HISTORICAL HYDROGRAPHS FIGURE B5

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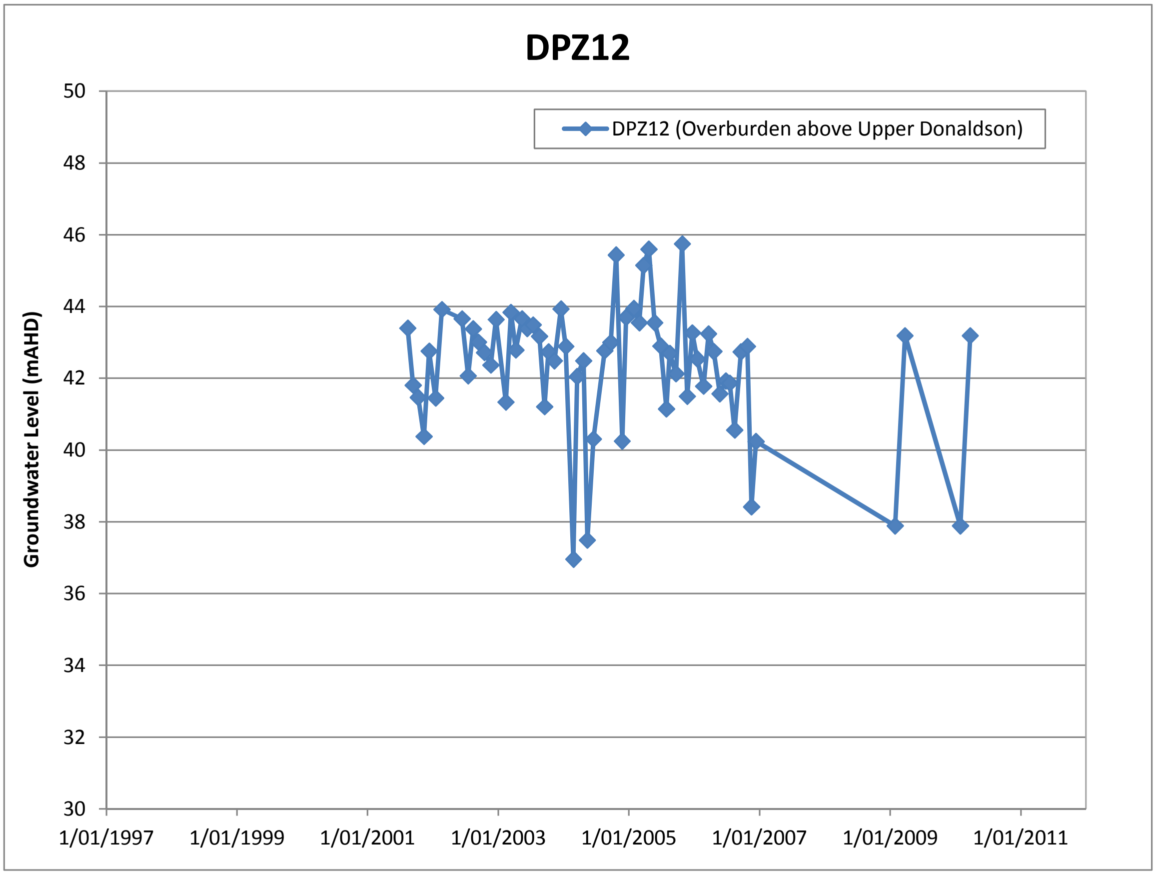
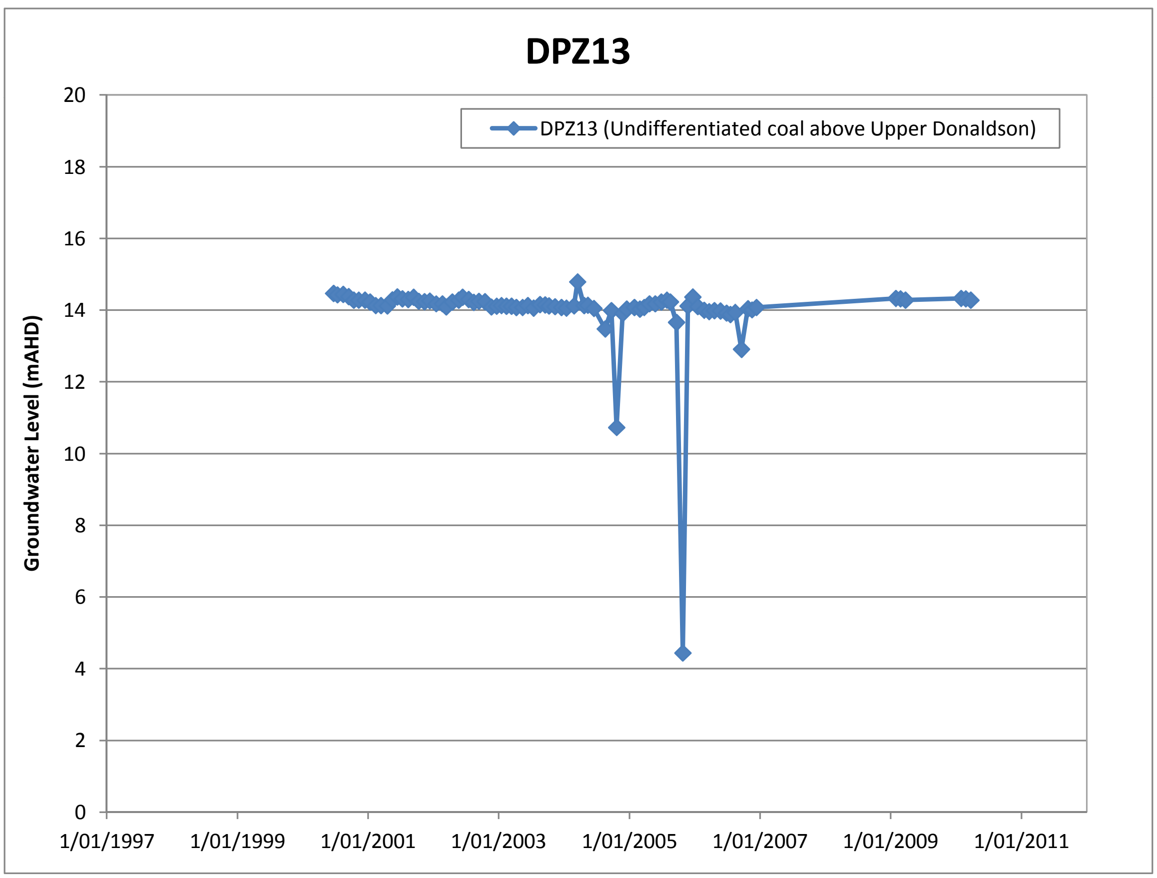
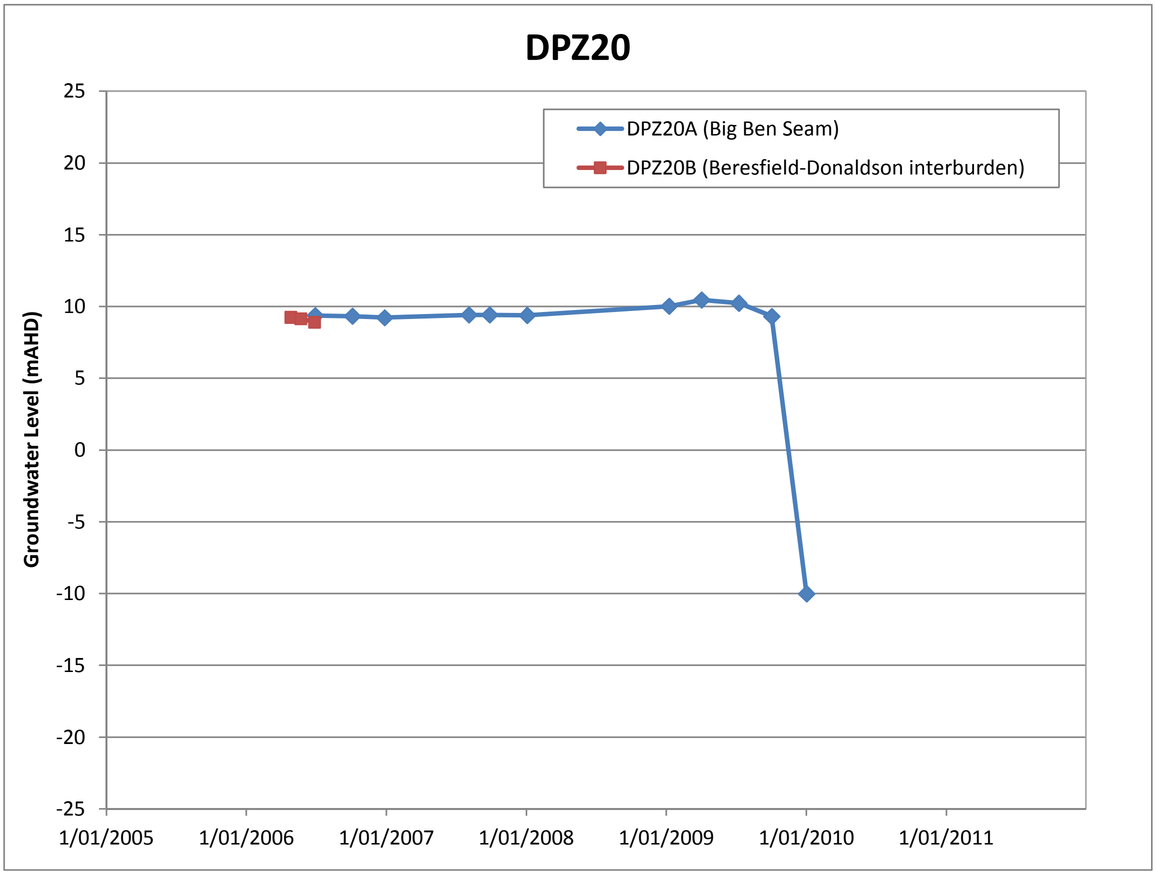


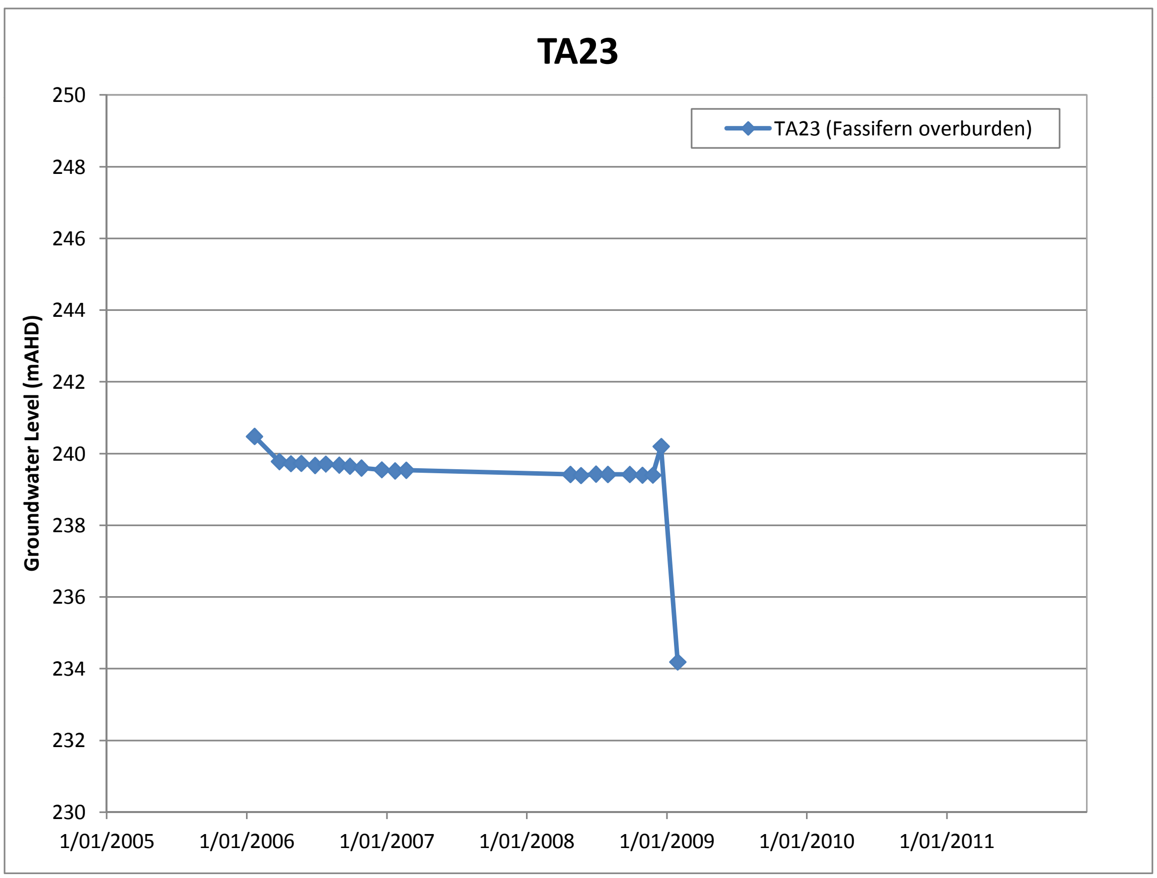


RPS Aquaterra

DPZ12 AND DPZ13 HISTORICAL HYDROGRAPHS FIGURE B6

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB6





RPS Aquaterra

DPZ20 AND TA23 HISTORICAL HYDROGRAPHS FIGURE B7

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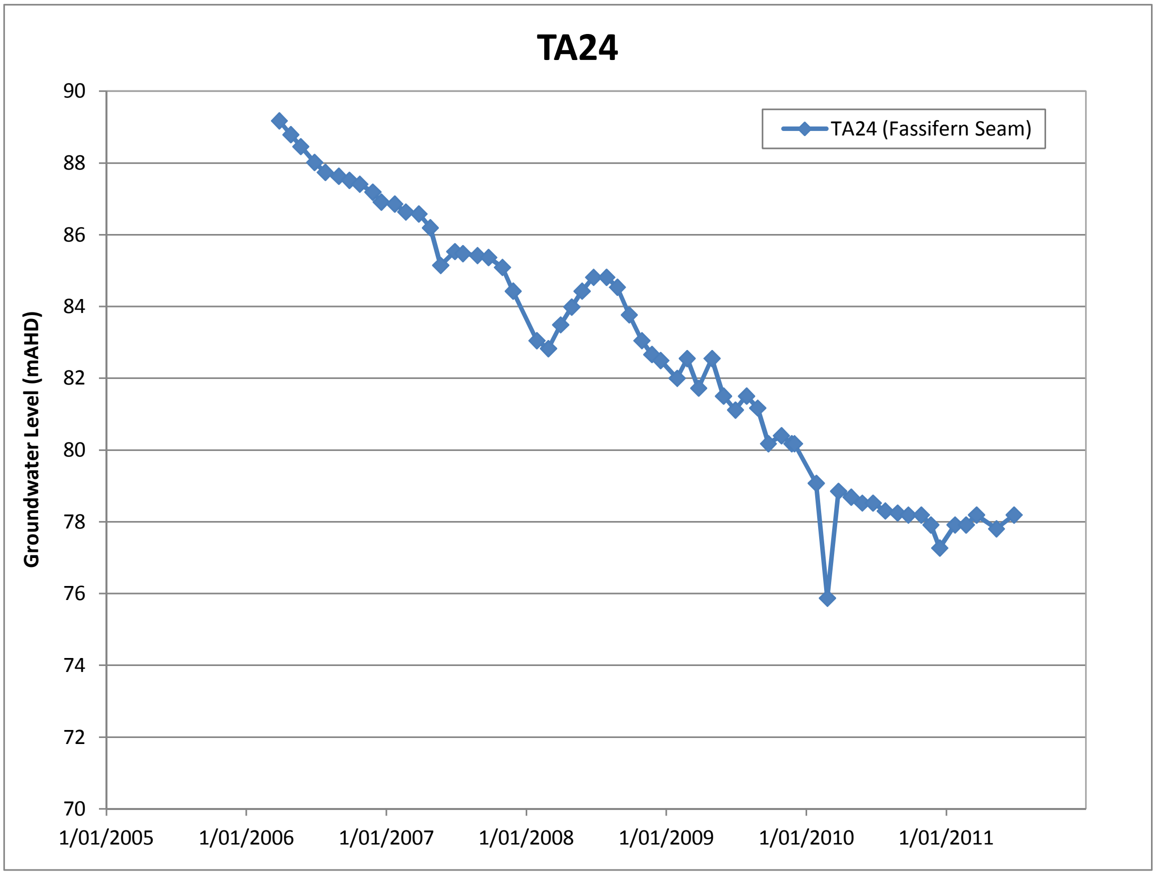
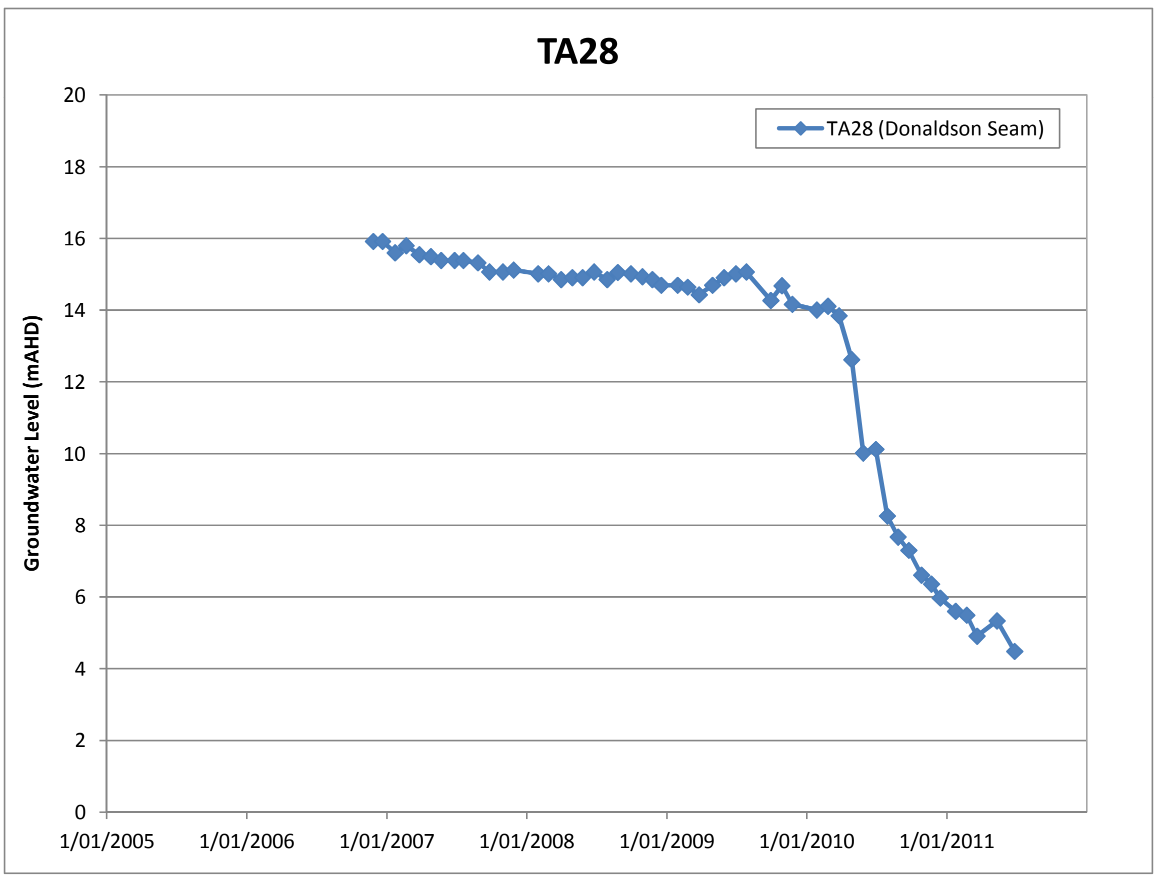
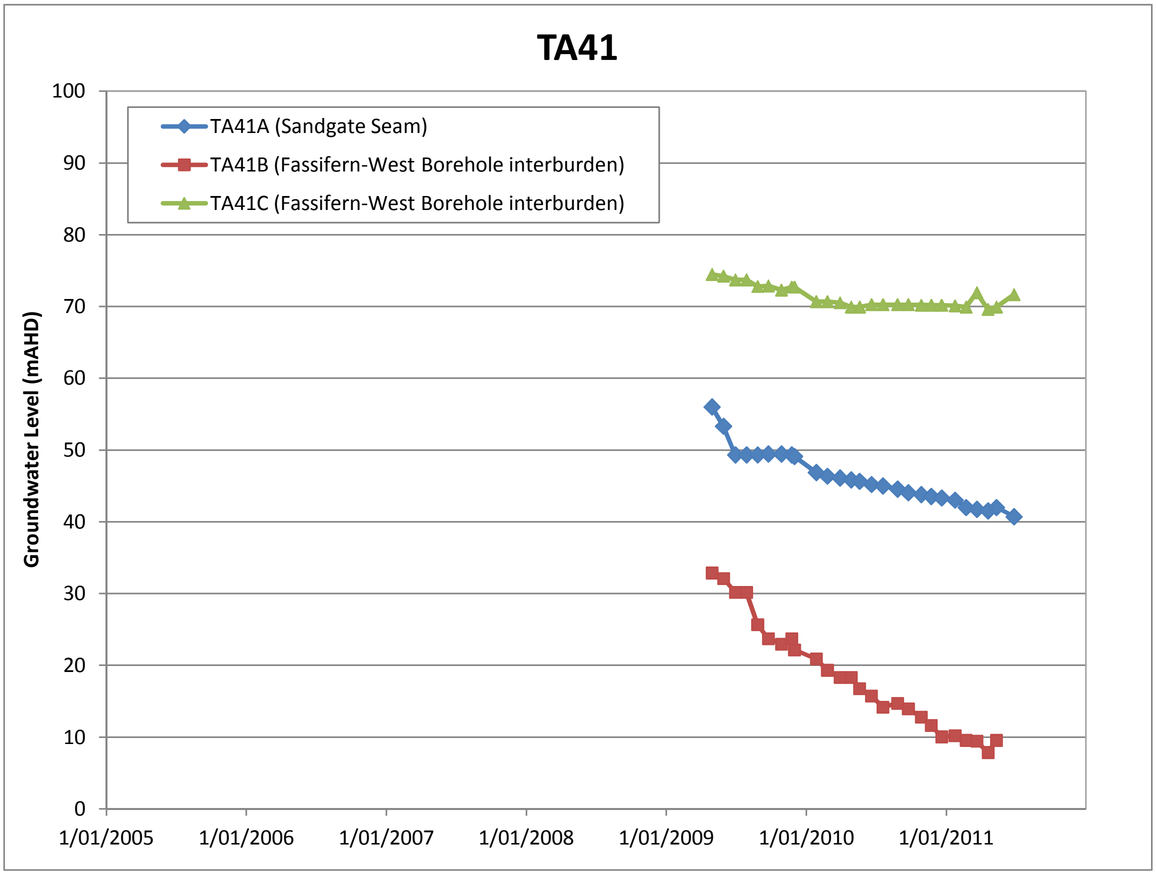


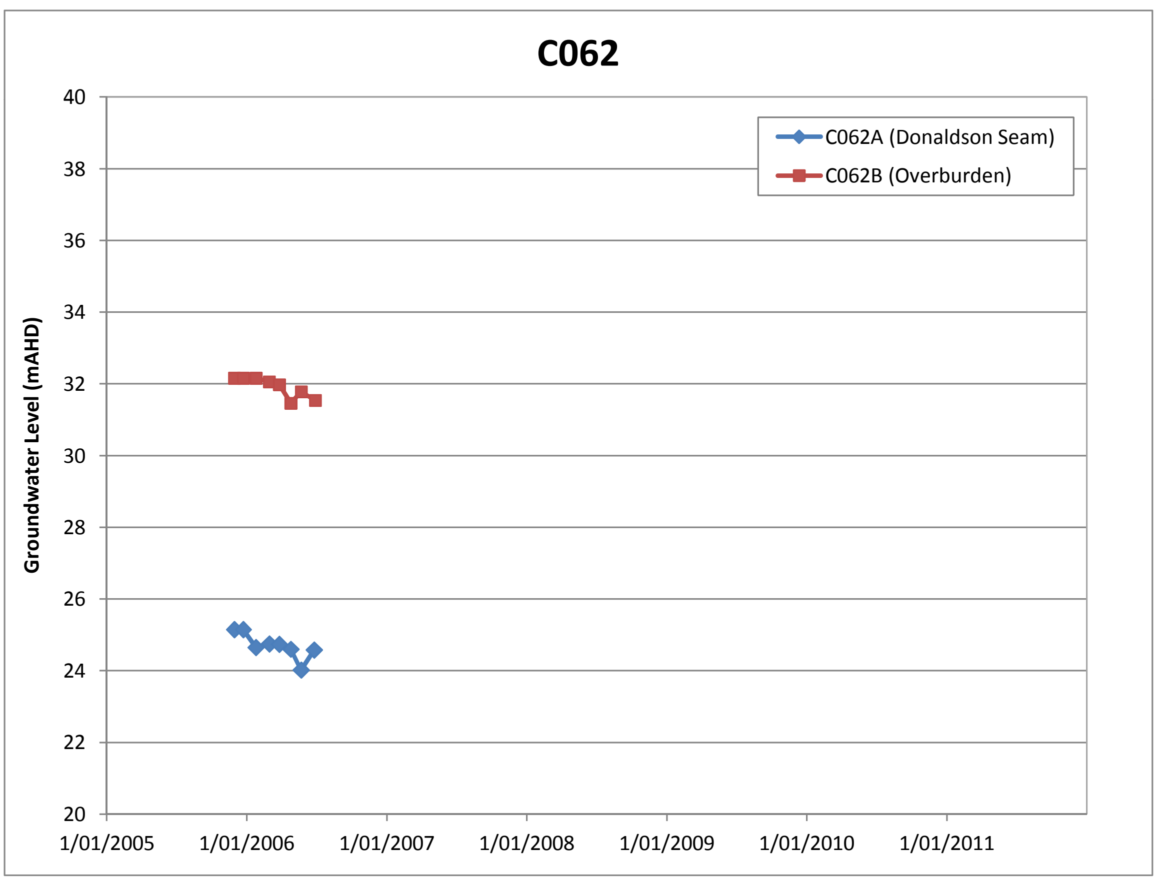


RPS Aquaterra

TA24 AND TA28 HISTORICAL HYDROGRAPHS FIGURE B8

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB8

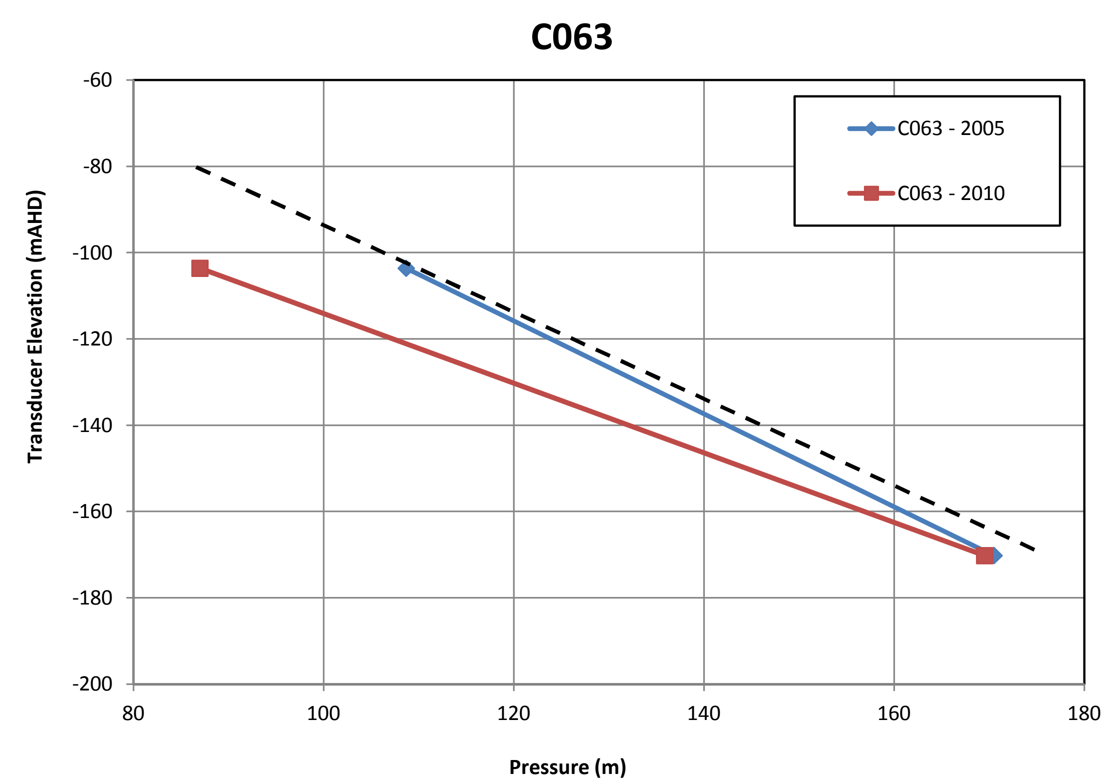


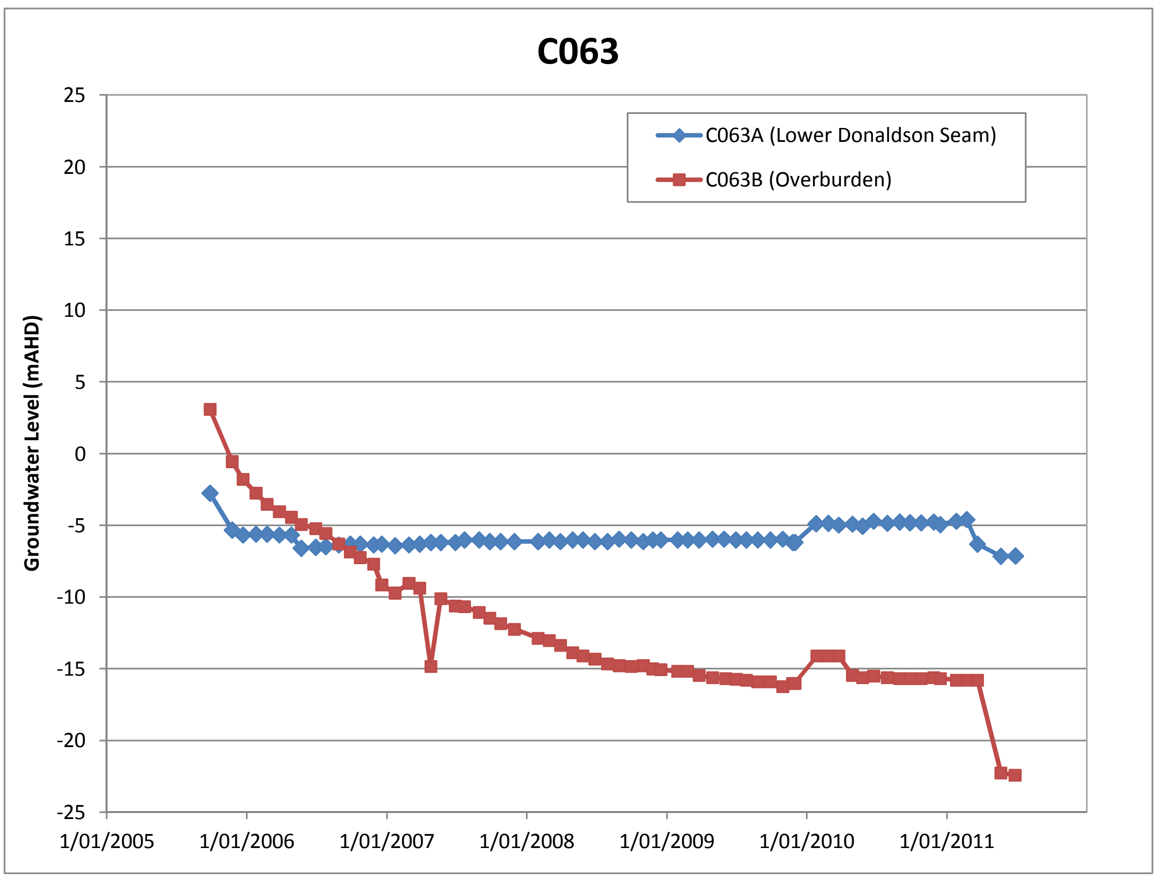


RPS Aquaterra

TA41 AND CO62 HISTORICAL HYDROGRAPHS FIGURE B9

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB9

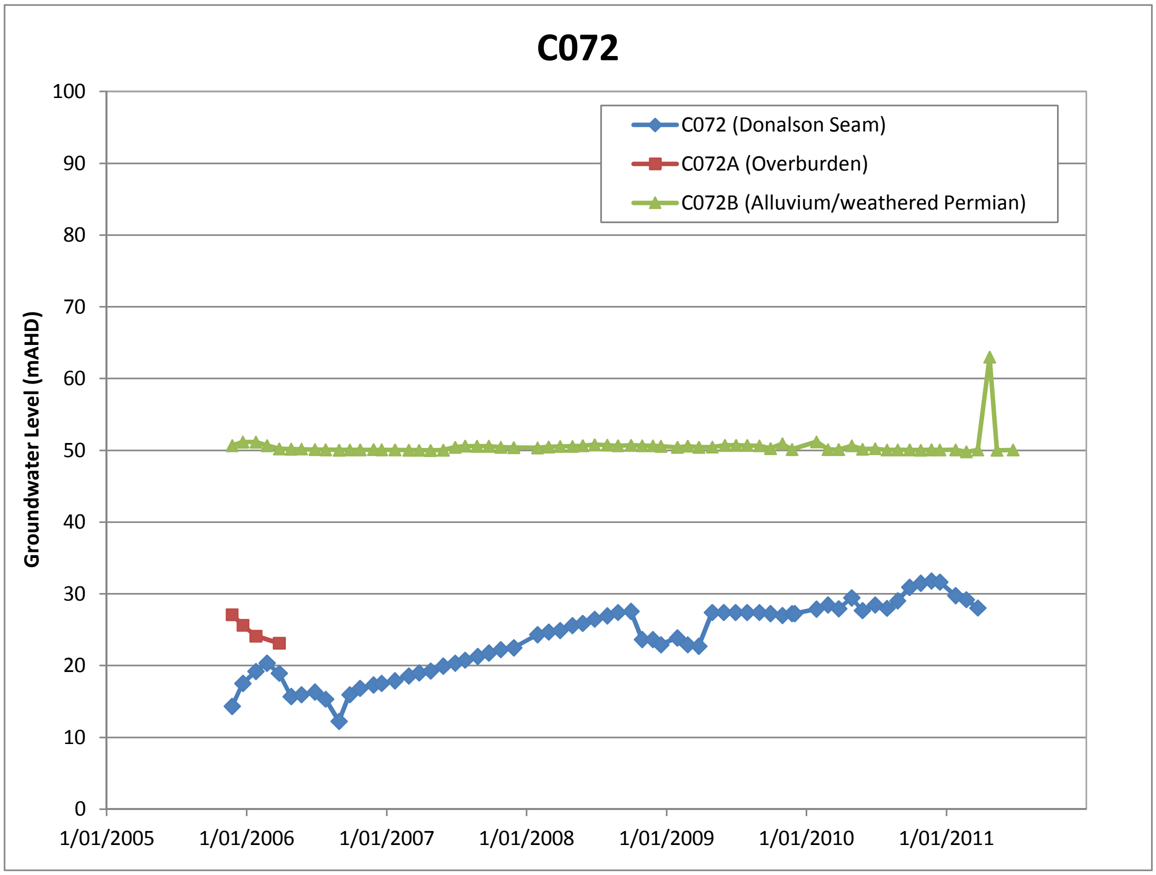


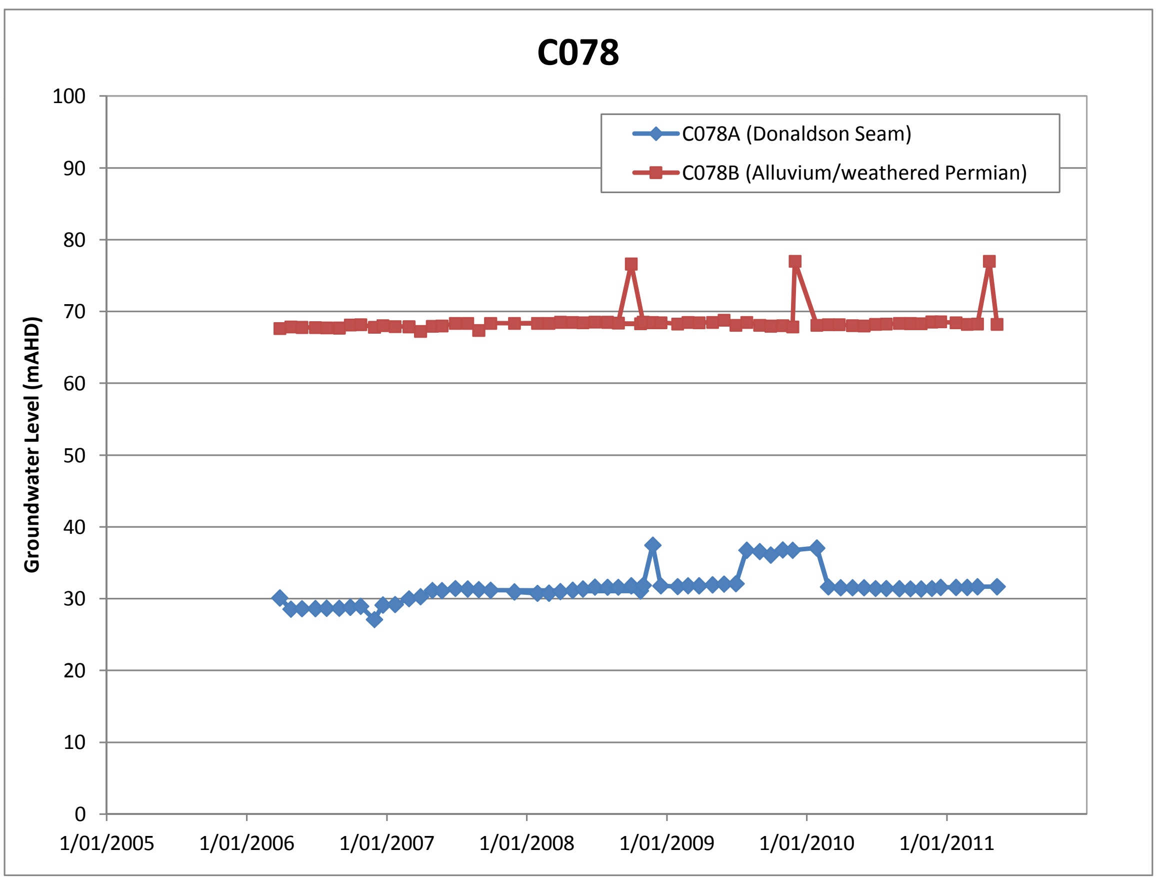


RPS Aquaterra

C063 PIEZOMETER HYDROSTATIC PROFILE AND HYDROGRAPHS FIGURE B10

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB10

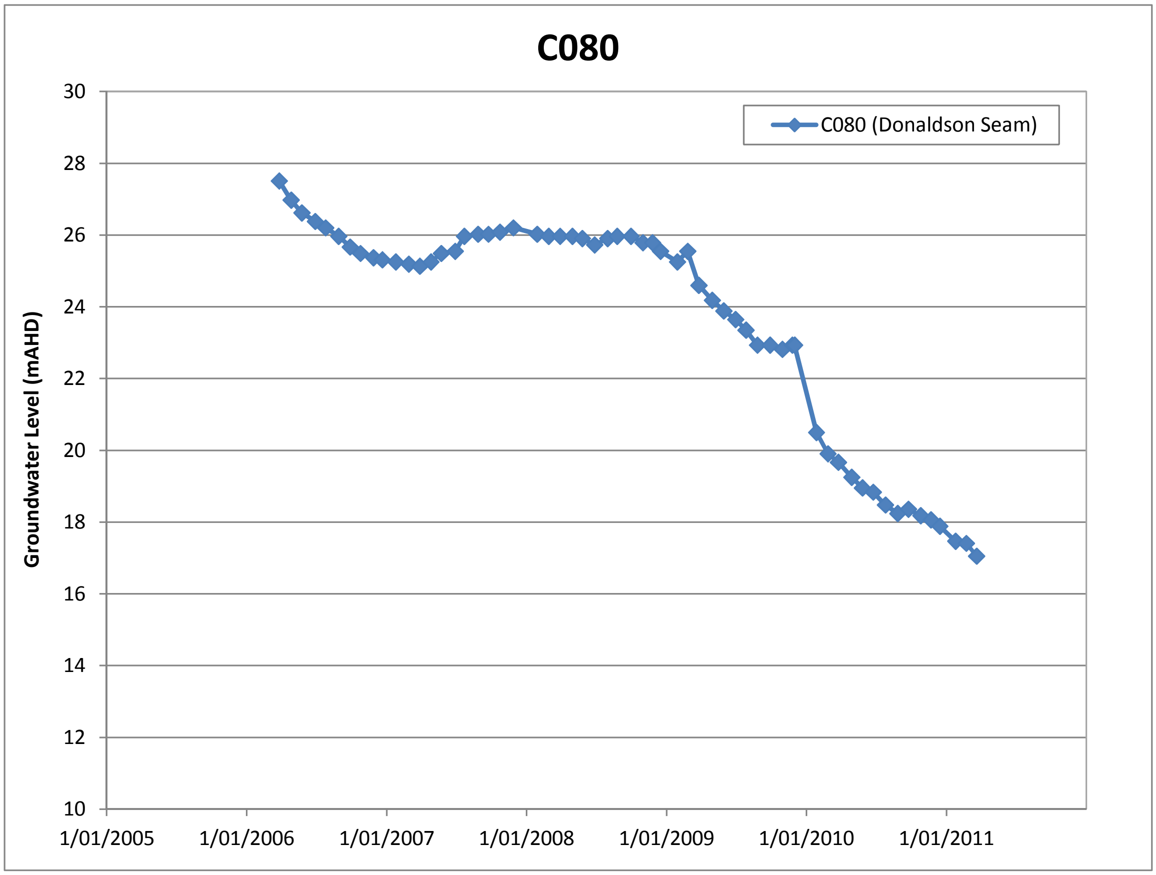


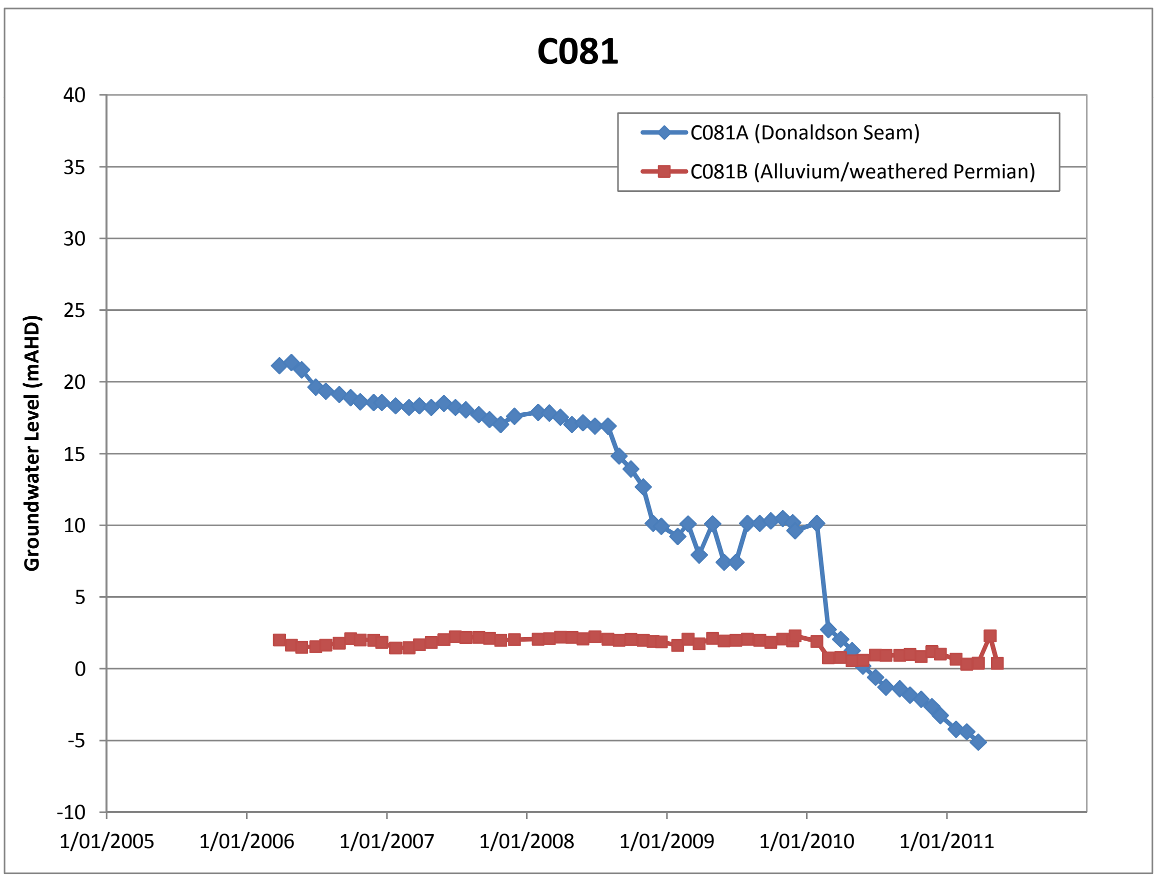


RPS Aquaterra

CO72 AND C078 HISTORICAL HYDROGRAPHS FIGURE B11

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB11

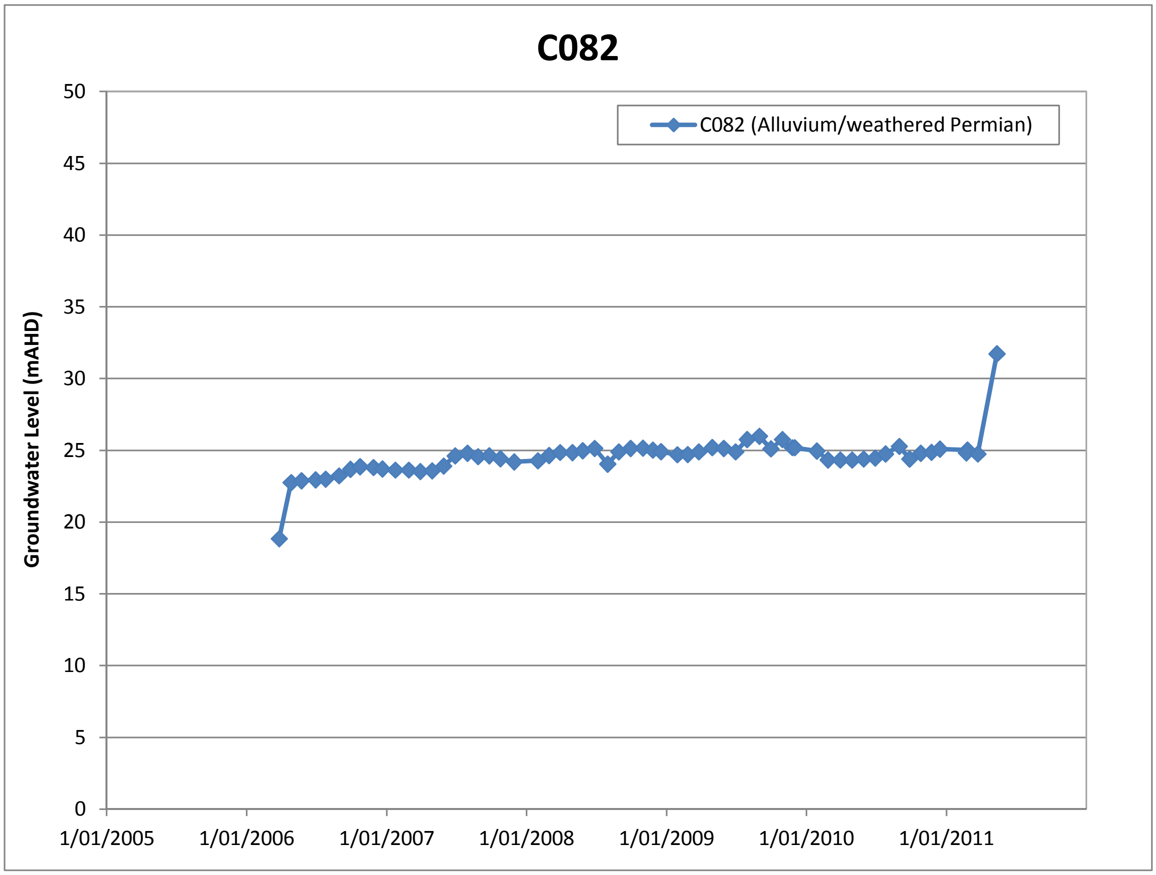


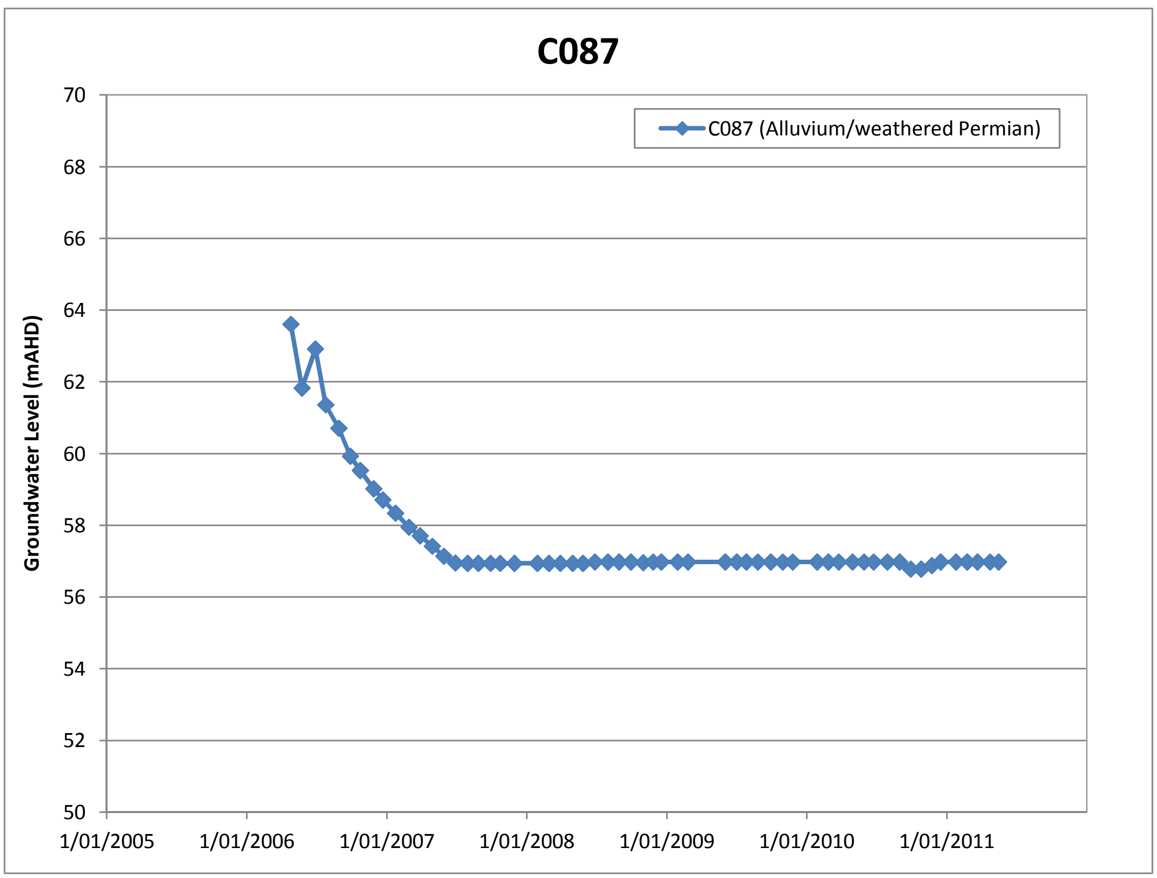


RPS Aquaterra

CO80 AND C081 HISTORICAL HYDROGRAPHS FIGURE B12

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB12

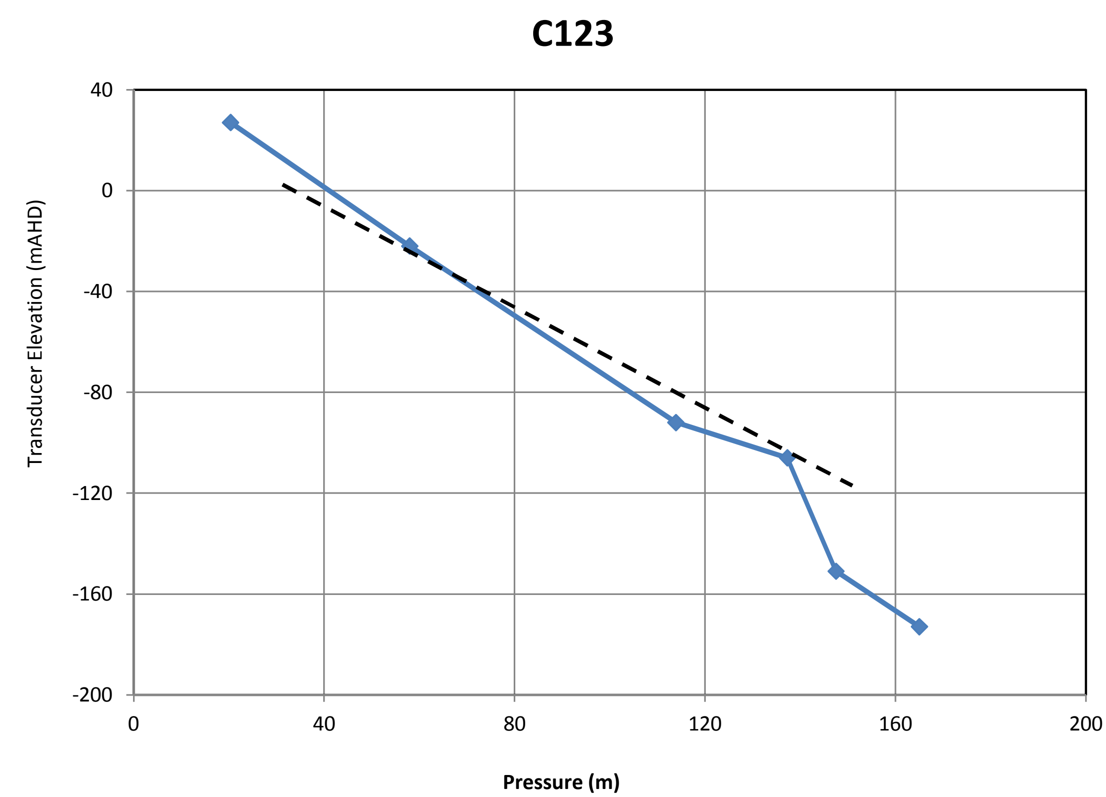


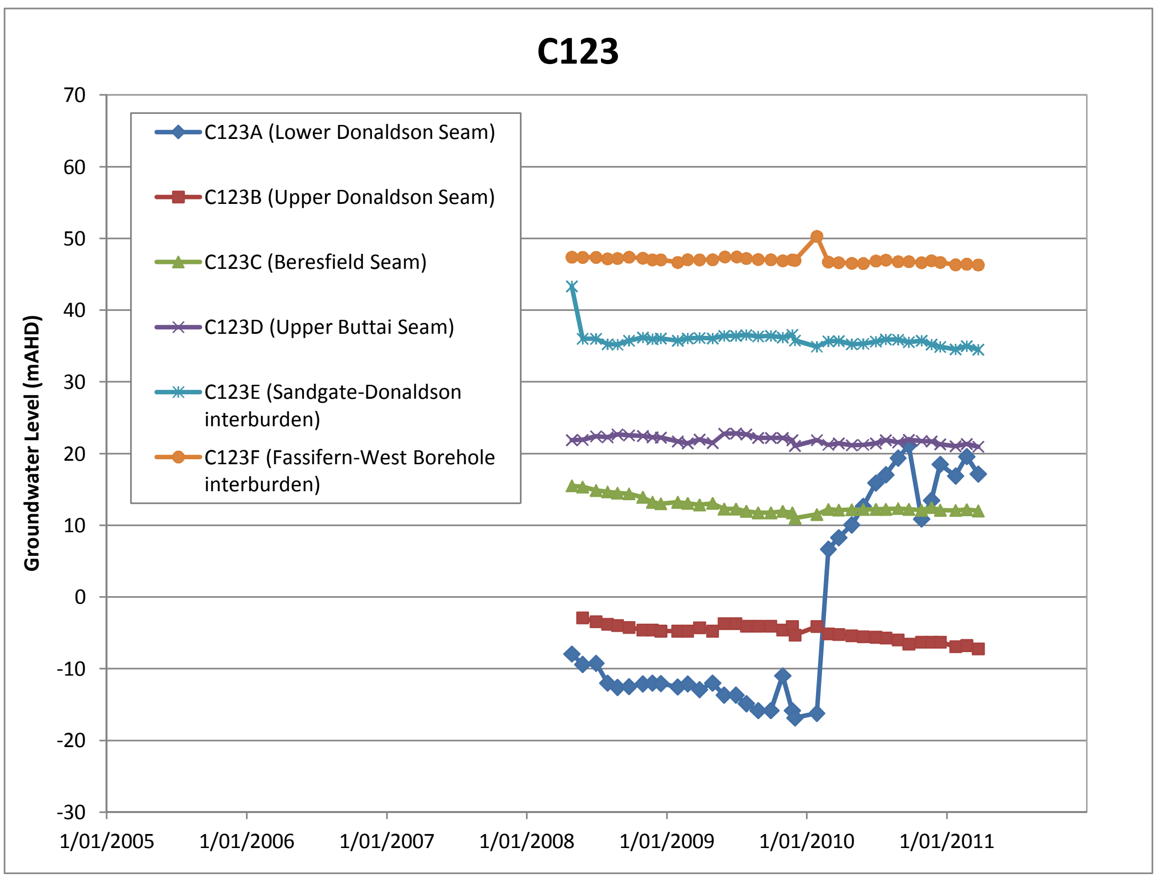


RPS Aquaterra

CO82 AND CO87 HISTORICAL HYDROGRAPHS FIGURE B13

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB13

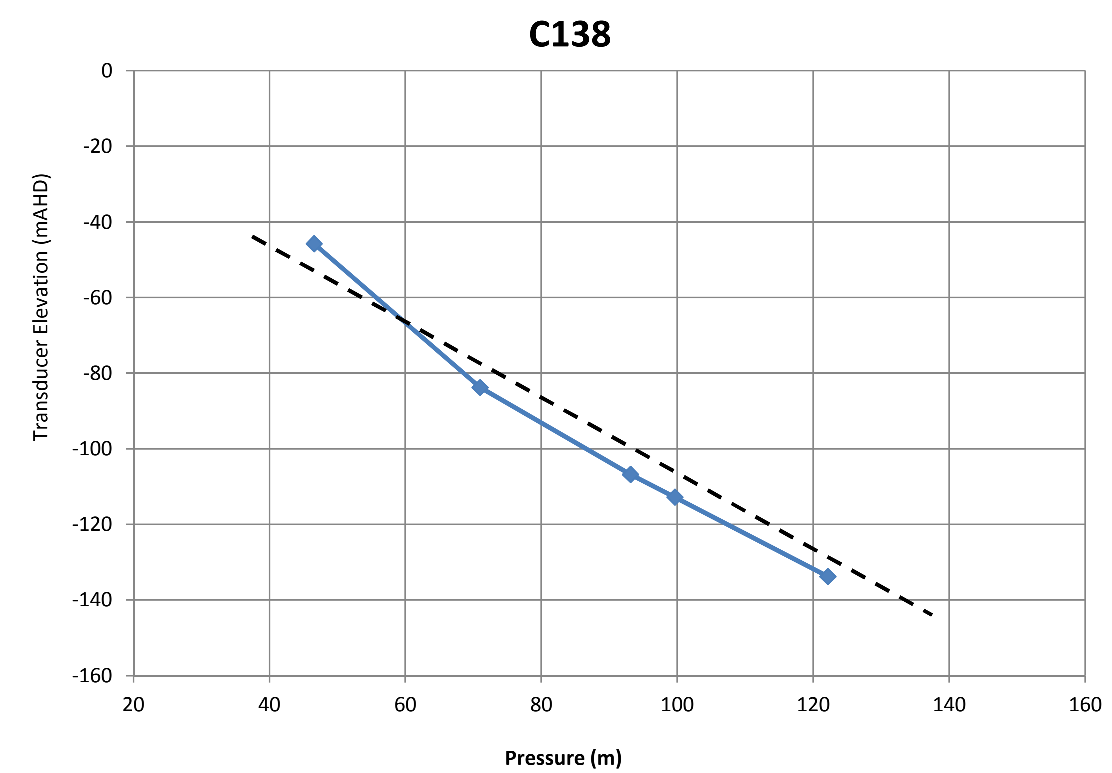


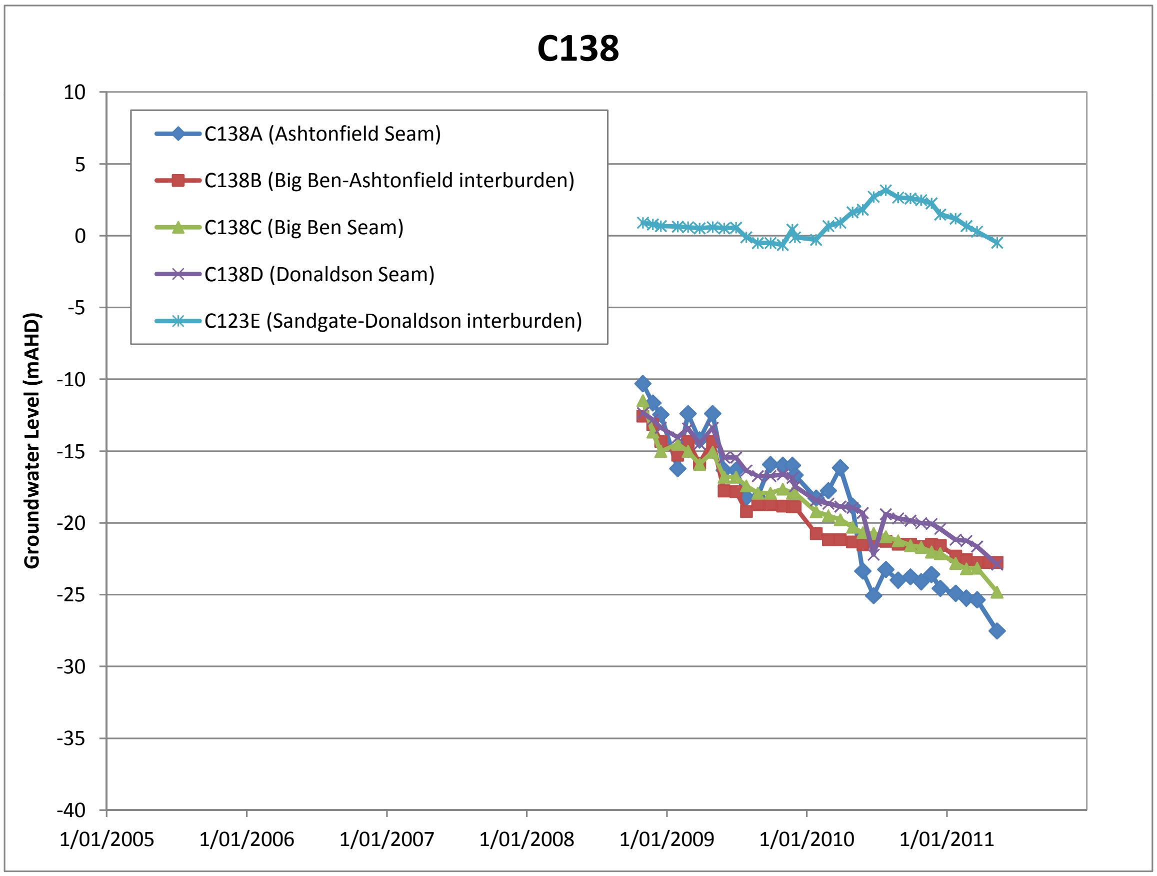


RPS Aquaterra

C123 PIEZOMETER HYDROSTATIC PROFILE AND HYDROGRAPHS FIGURE B14

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB14

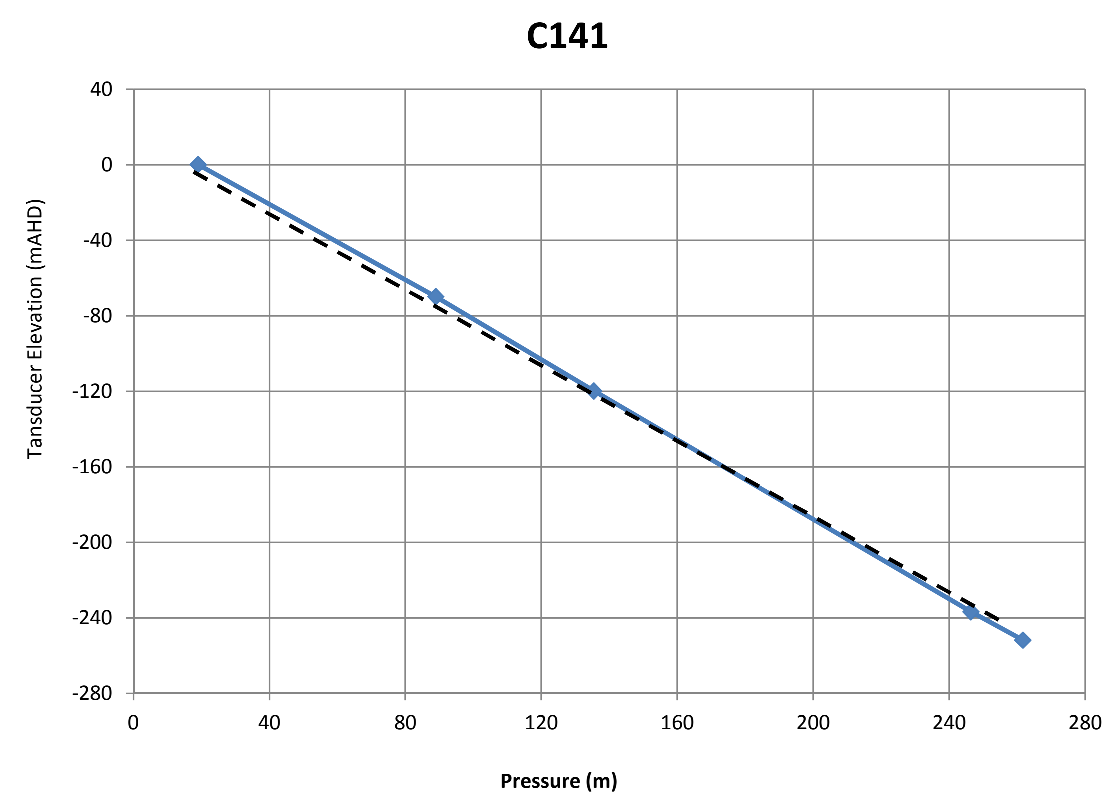


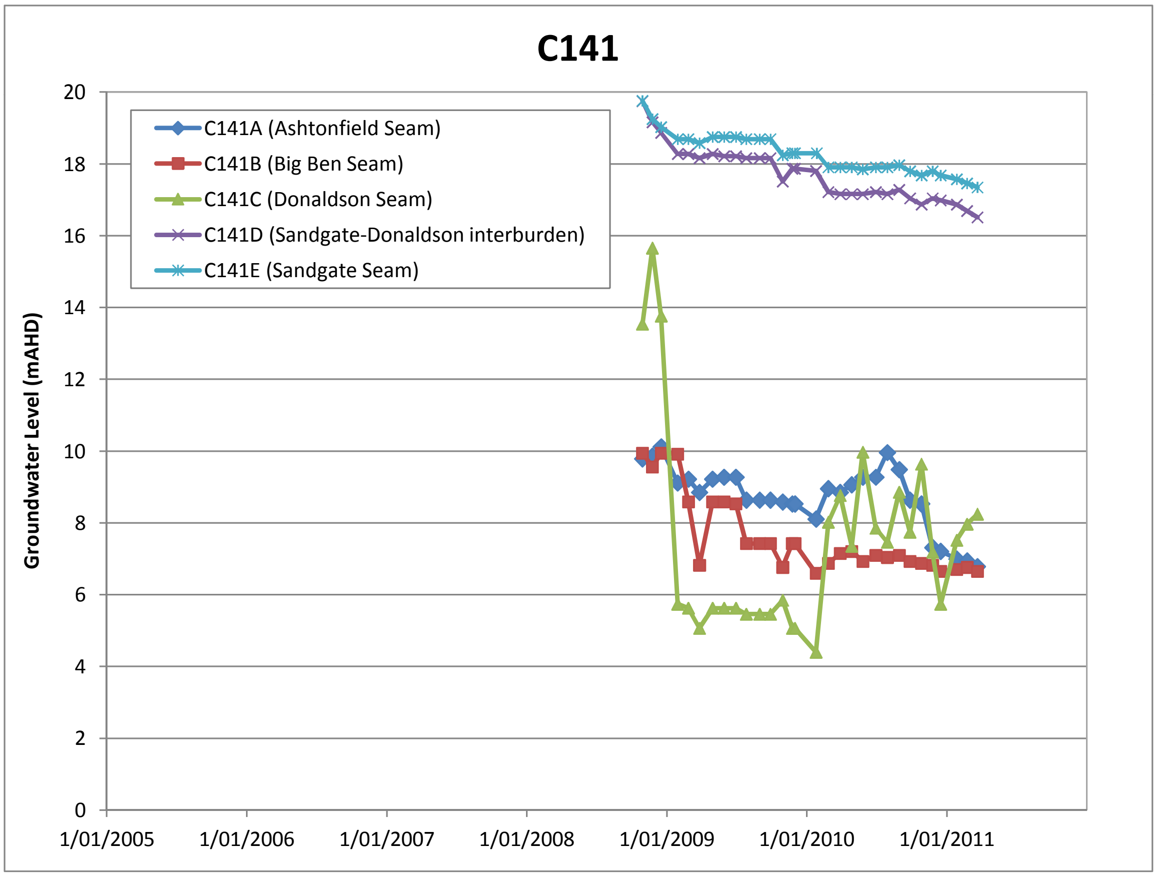


RPS Aquaterra

C138 PIEZOMETER HYDROSTATIC PROFILE AND HYDROGRAPHS FIGURE B15

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB15

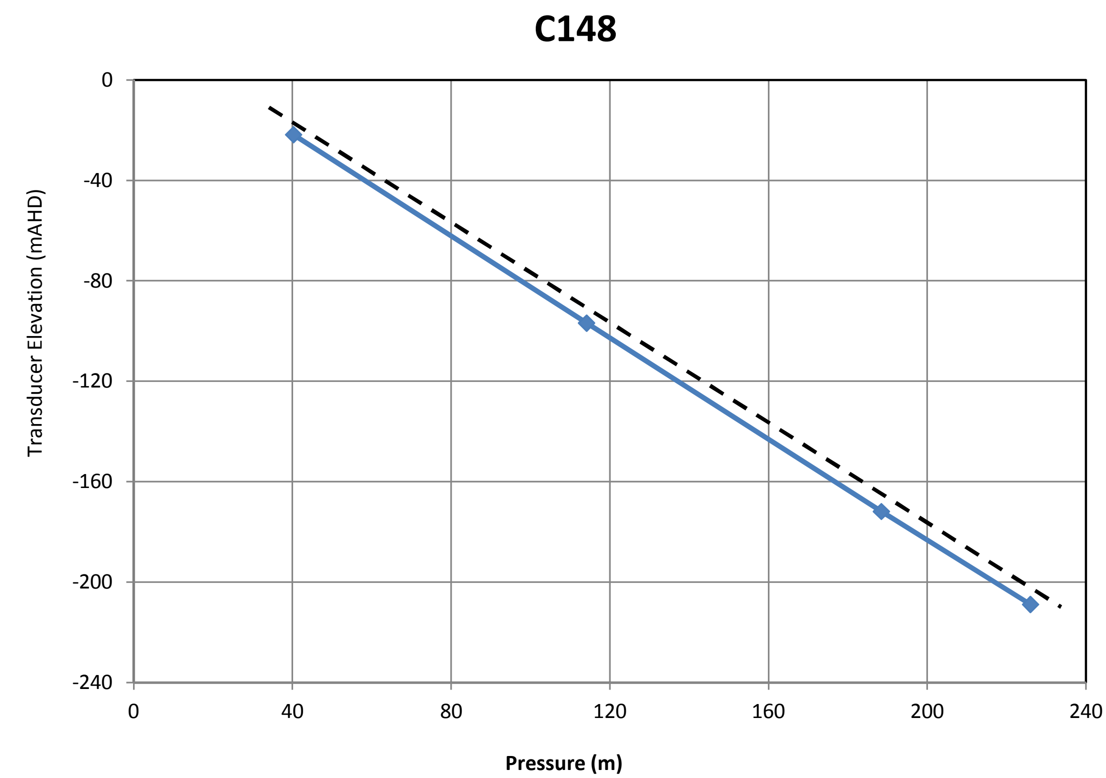


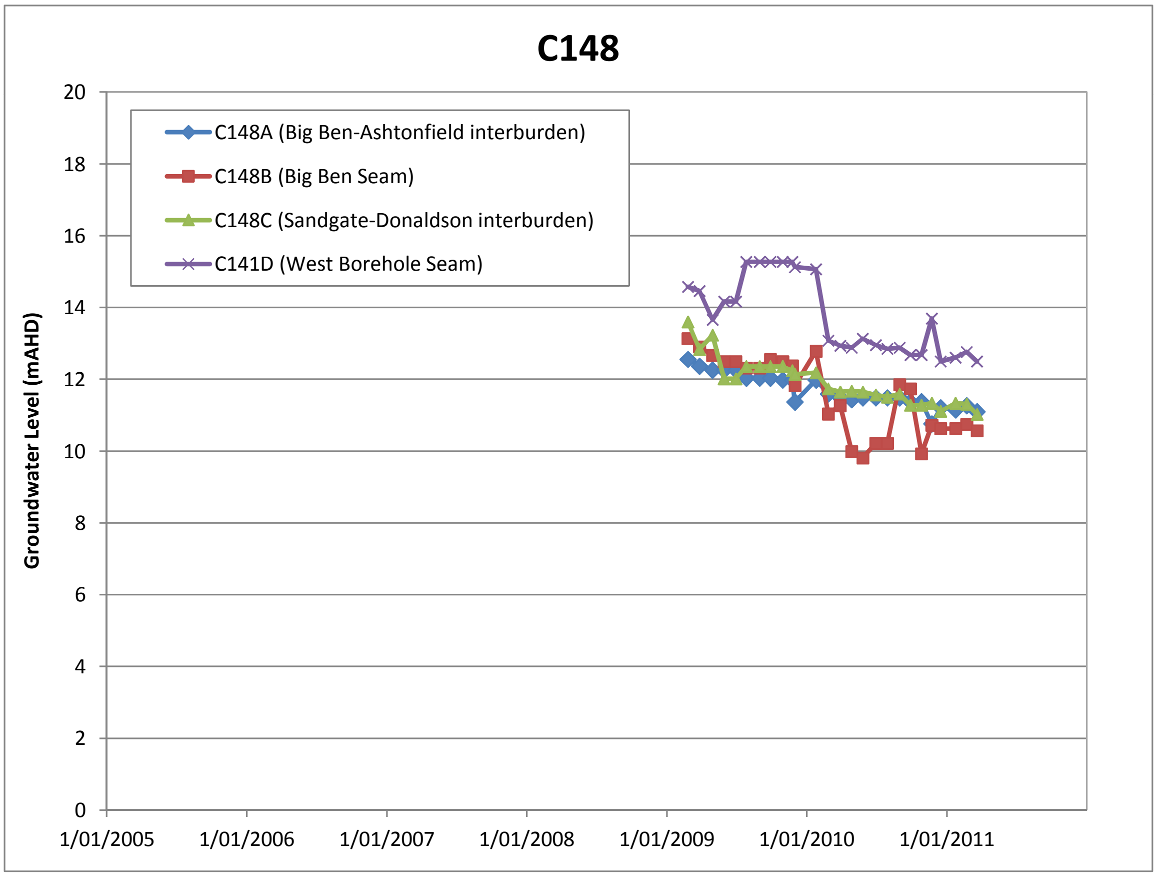


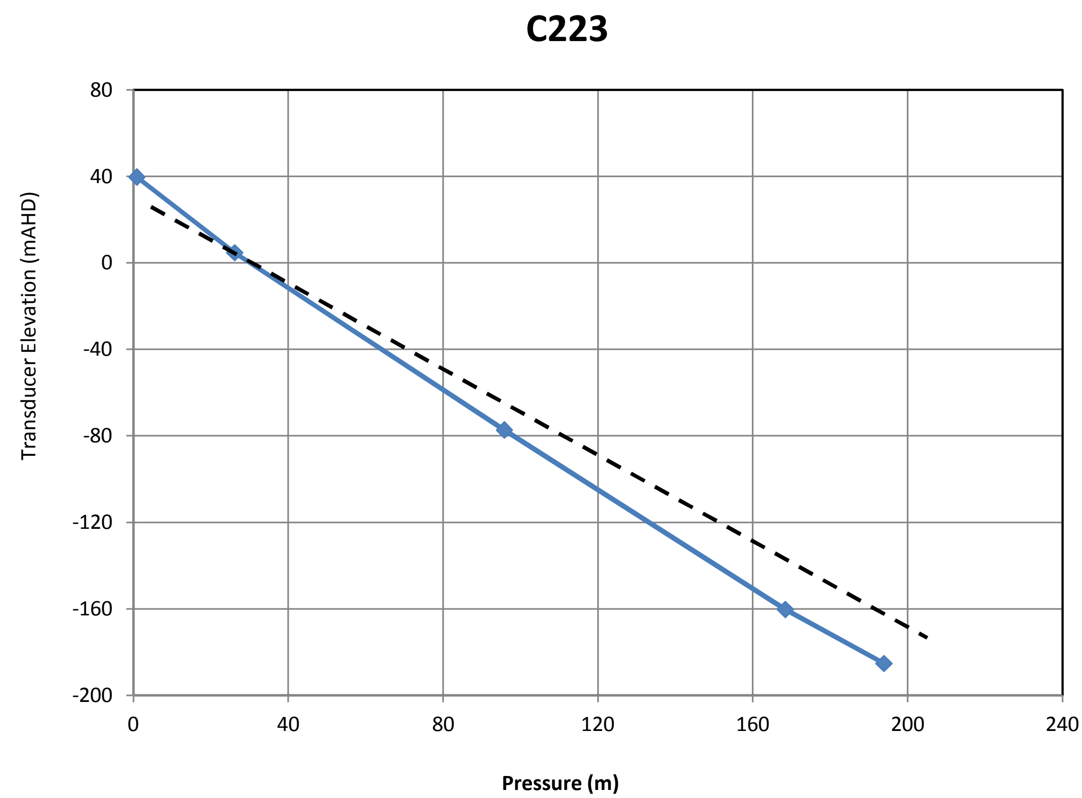
RPS Aquaterra

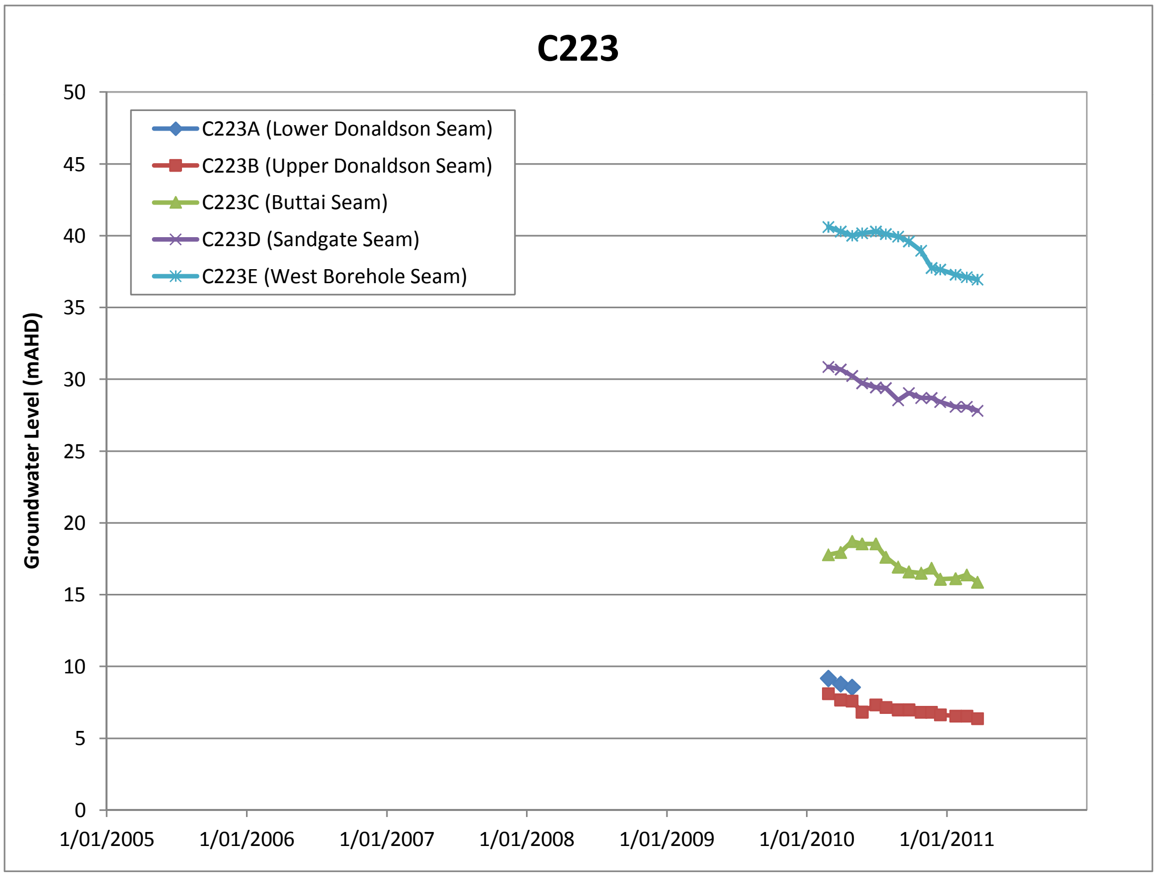
C141 PIEZOMETER HYDROSTATIC PROFILE AND HYDROGRAPHS FIGURE B16

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB16


C148
Transducer Elevation (mAHD)
Pressure (m)
0
-40
-80
-120
-160
-200
-240
0
40
80
120
160
200
240


C148
C148A (Big Ben-Ashtonfield interburden)
C148B (Big Ben Seam)
C148C (Sandgate-Donaldson interburden)
C141D (West Borehole Seam)
Groundwater Level (mAHD)
20
18
16
14
12
10
8
6
4
2
0
1/01/2005
1/01/2006
1/01/2007
1/01/2008
1/01/2009
1/01/2010
1/01/2011

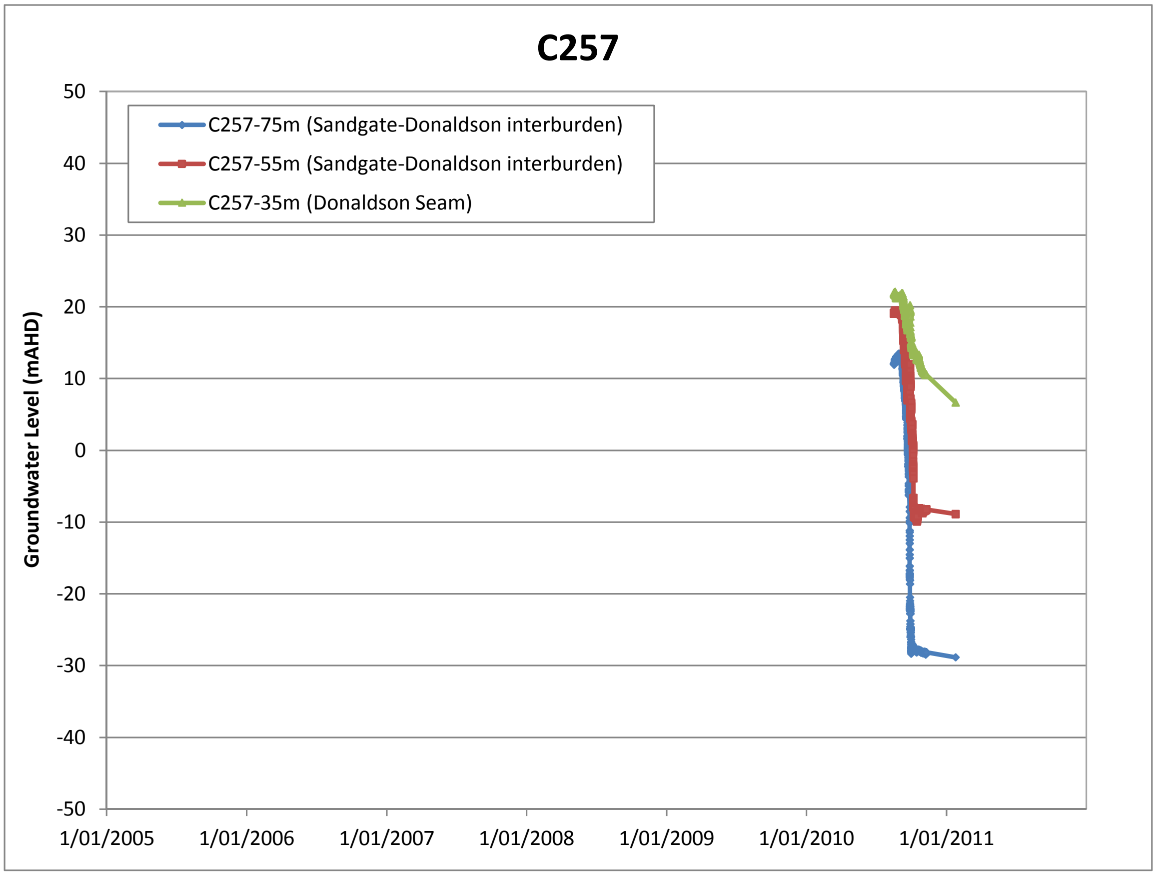


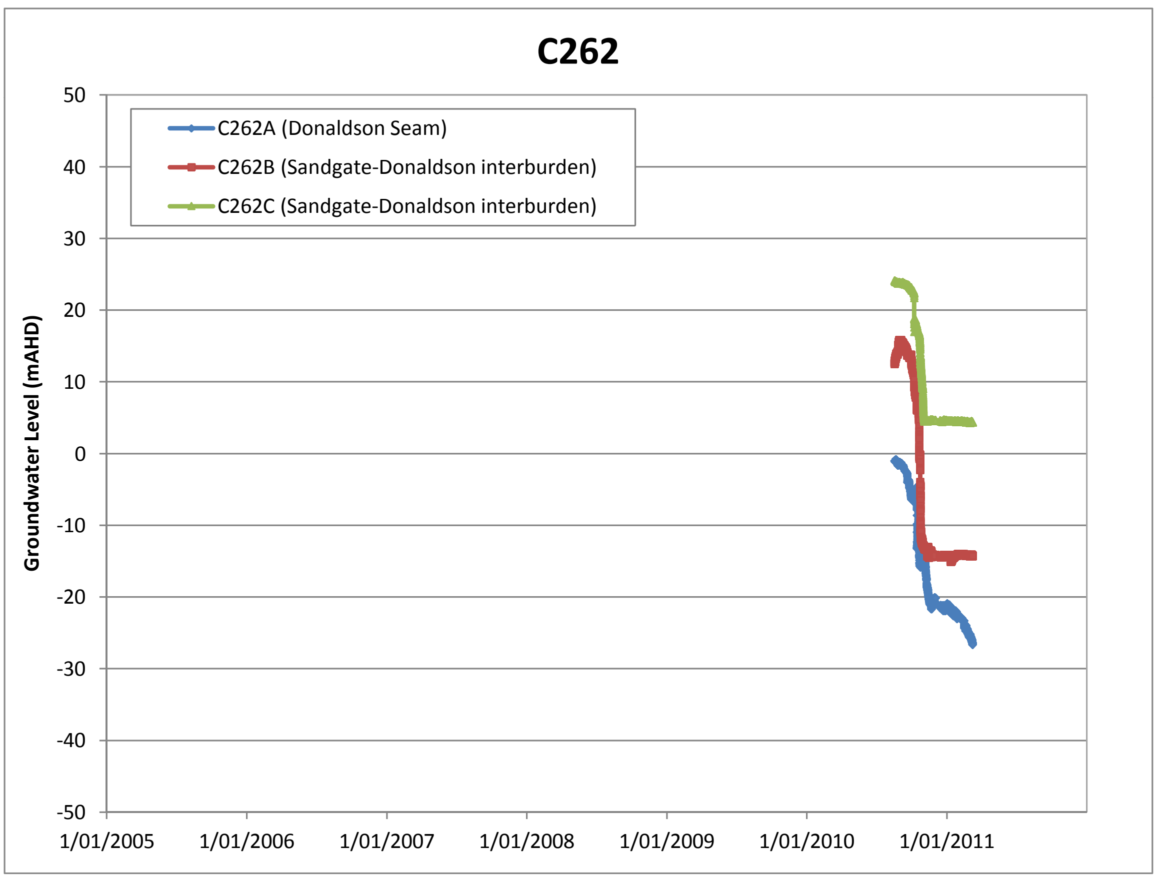


RPS Aquaterra

C223 PIEZOMETER HYDROSTATIC PROFILE AND HYDROGRAPHS FIGURE B18

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB18

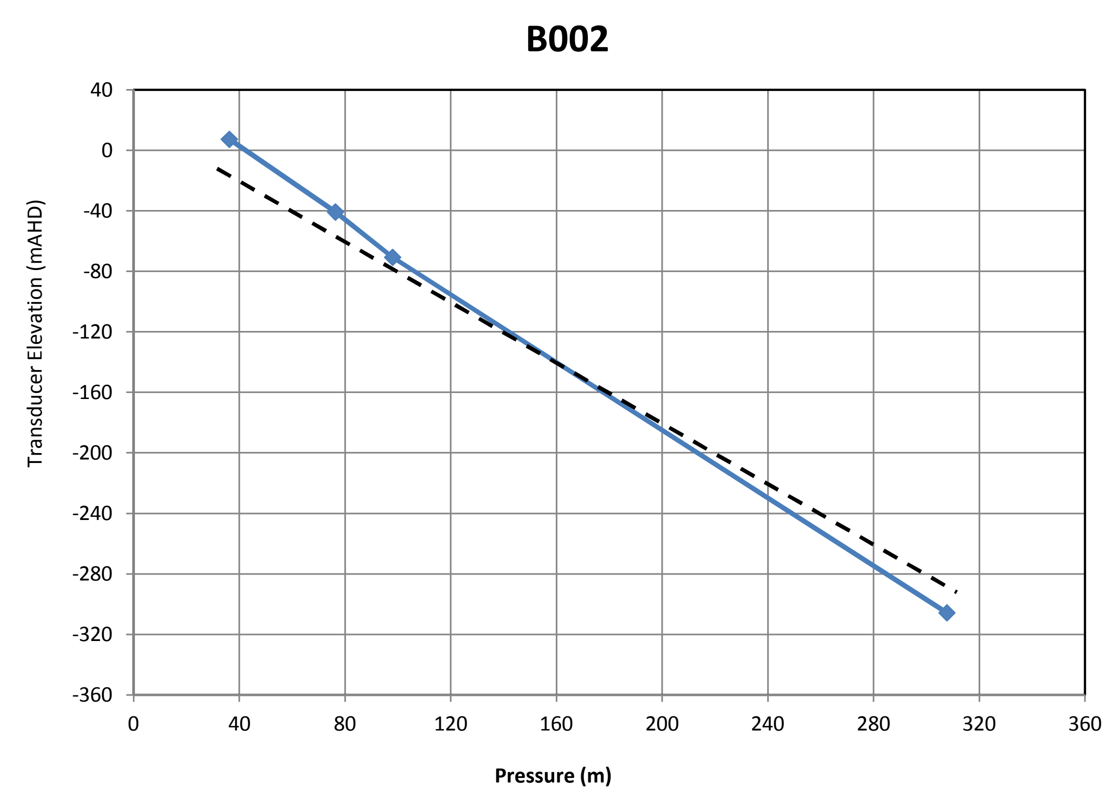


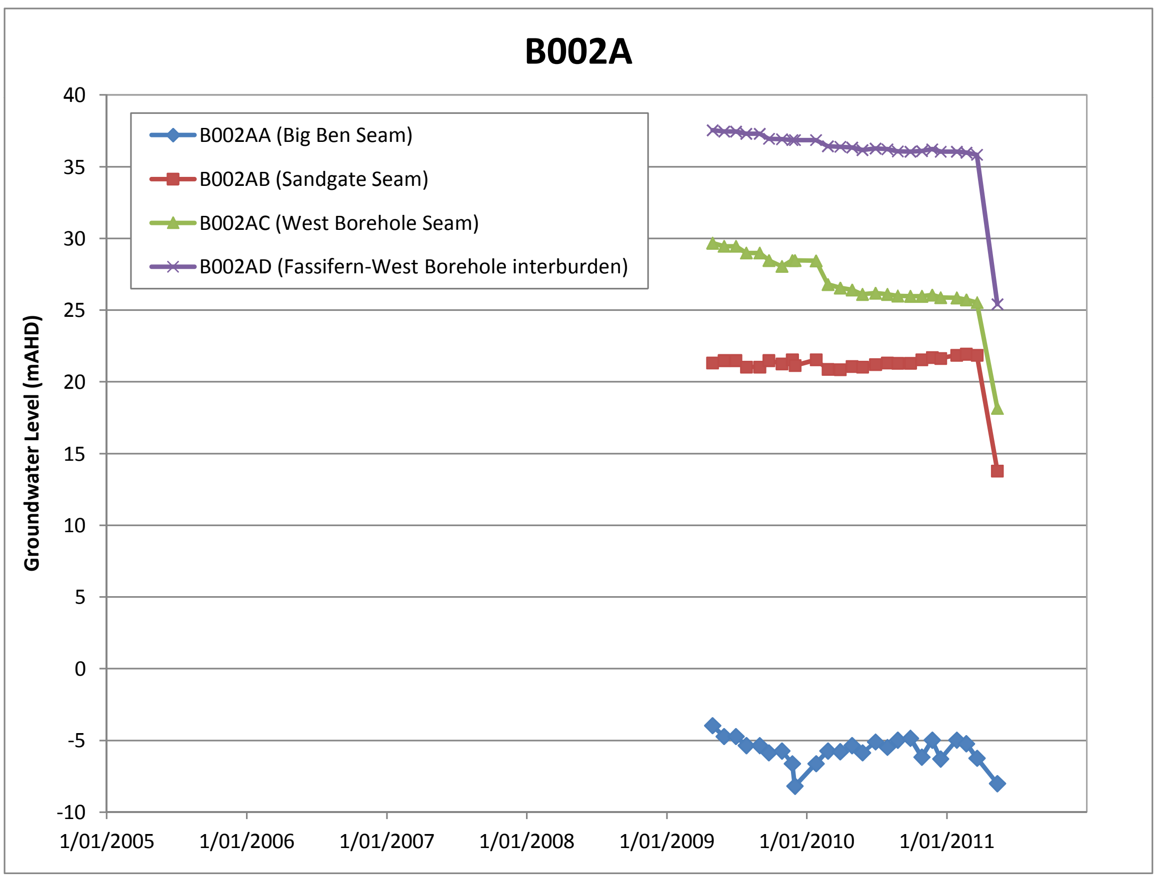


RPS Aquaterra

C257 AND C262 HISTORICAL HYDROGRAPHS FIGURE B19

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB19

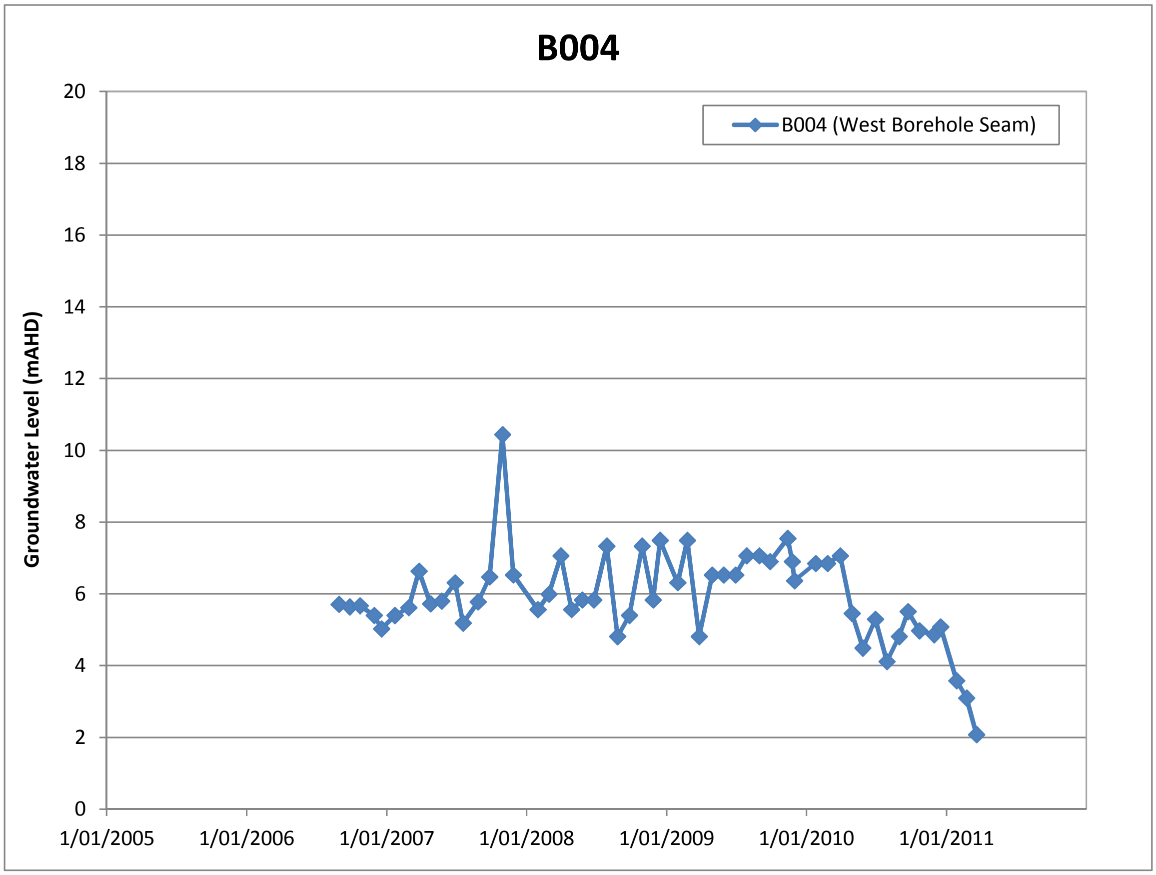


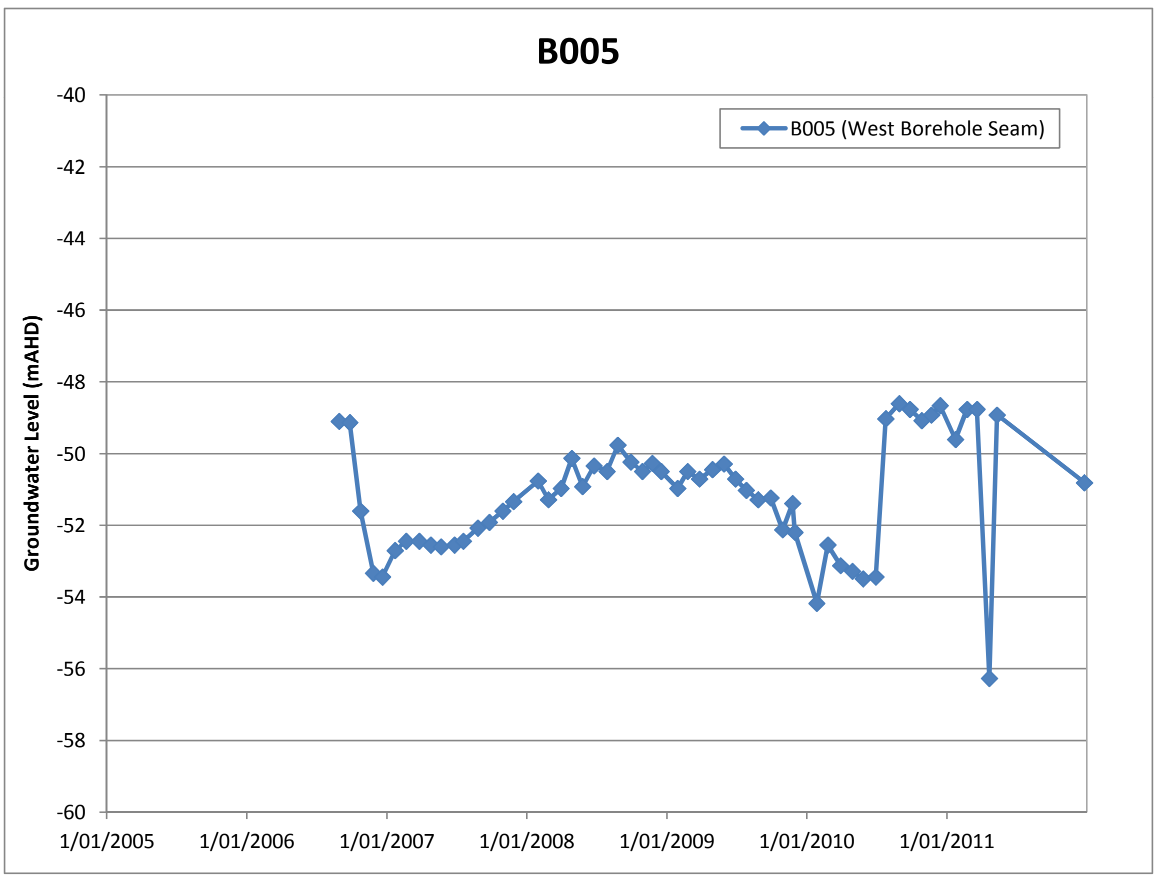


RPS Aquaterra

B002A PIEZOMETER HYDROSTATIC PROFILE AND HYDROGRAPHS FIGURE B20

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB20

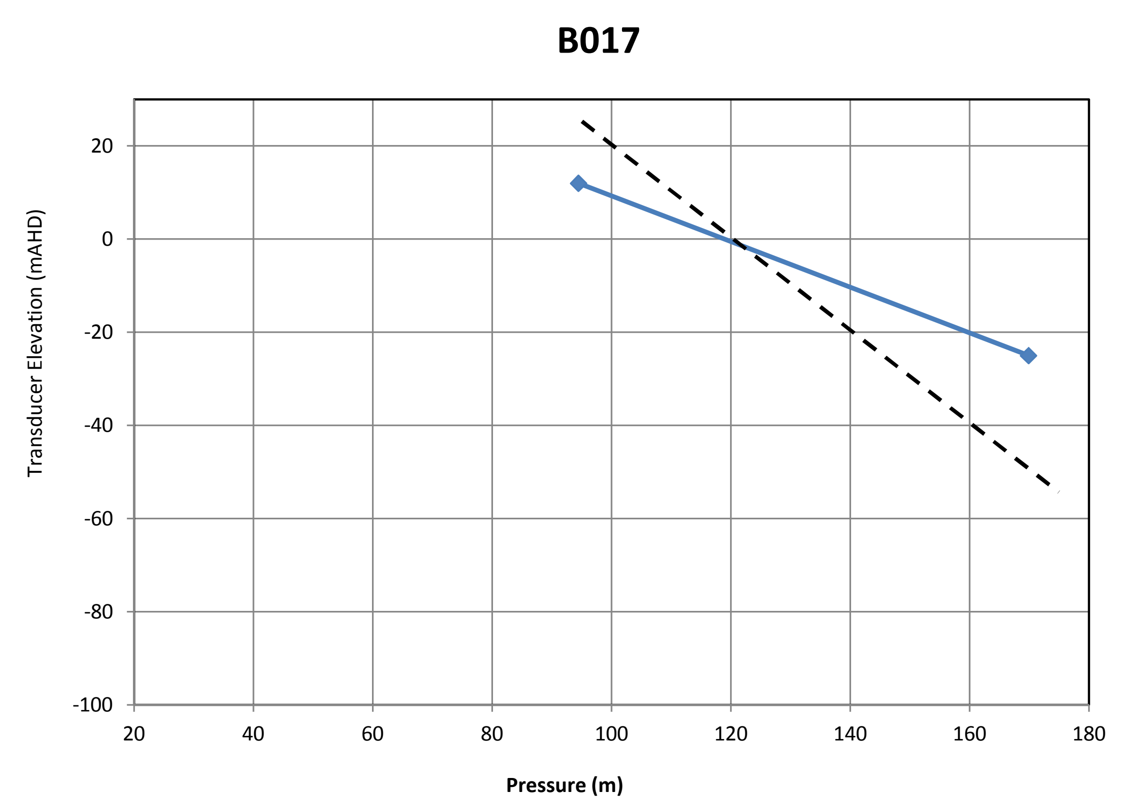


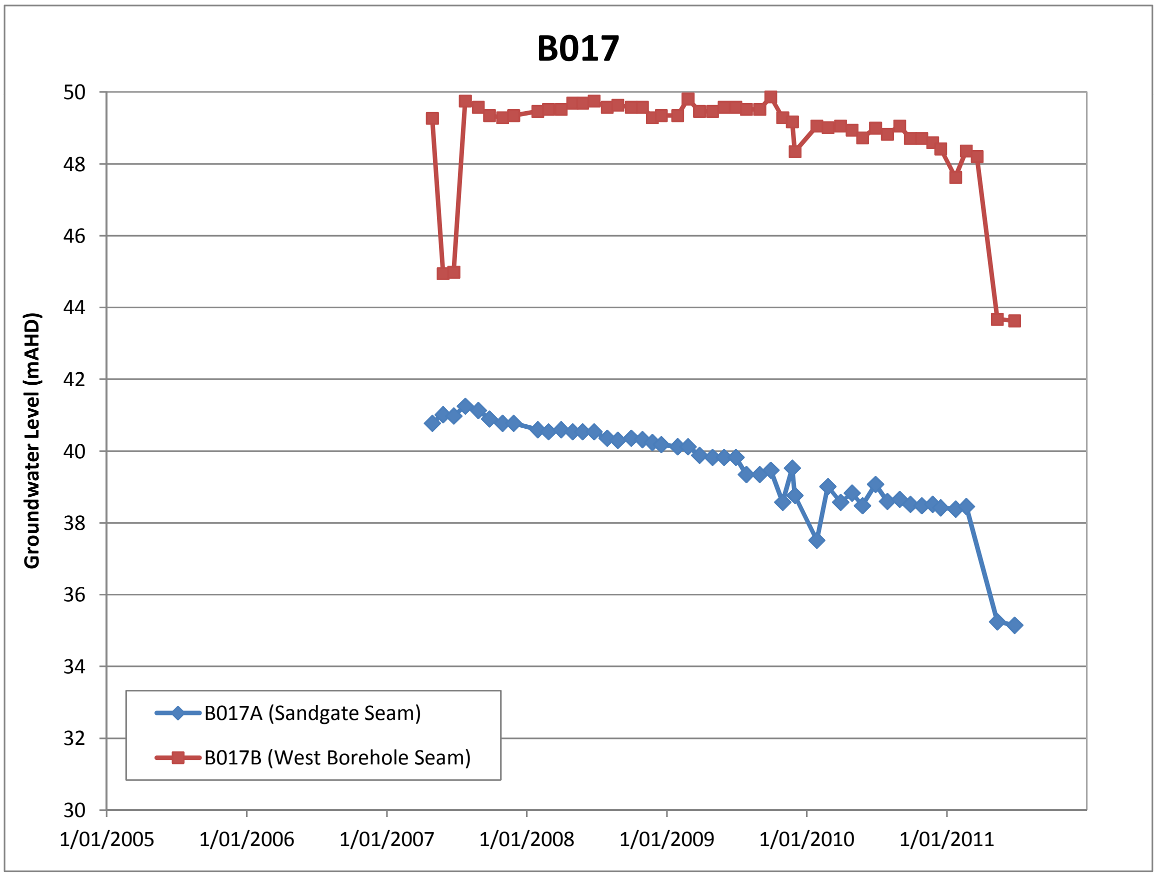


RPS Aquaterra

B004 AND B005 HISTORICAL HYDROGRAPHS FIGURE B21

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB21

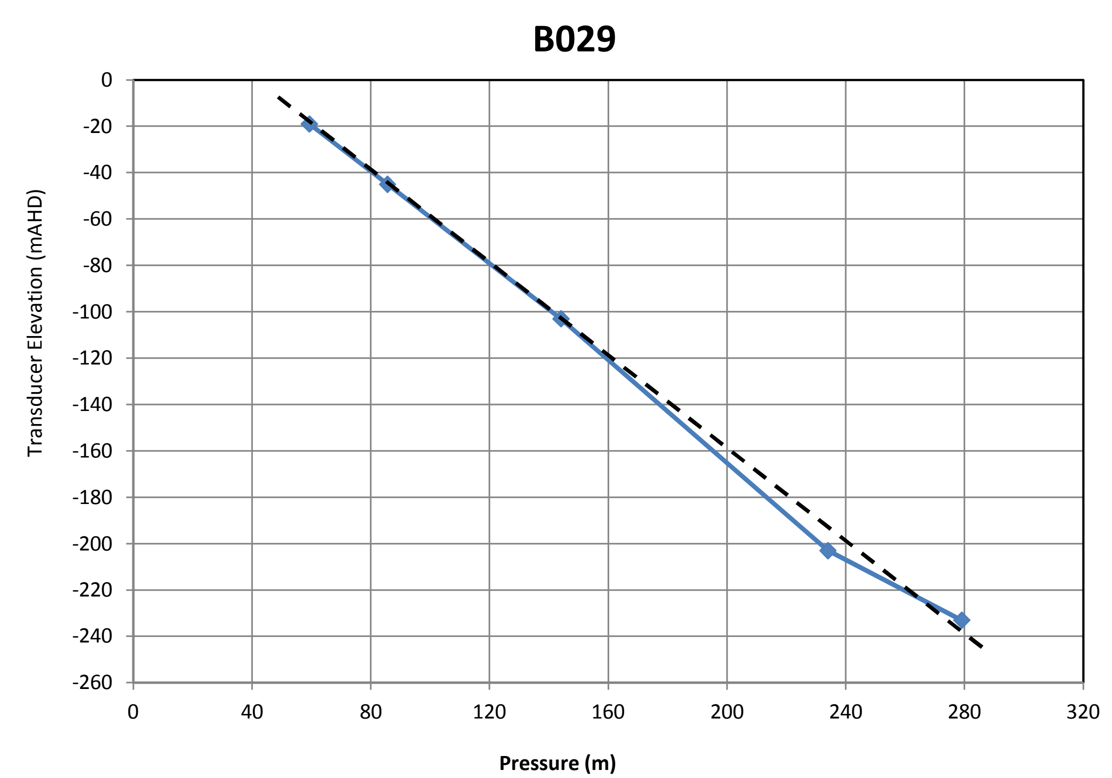


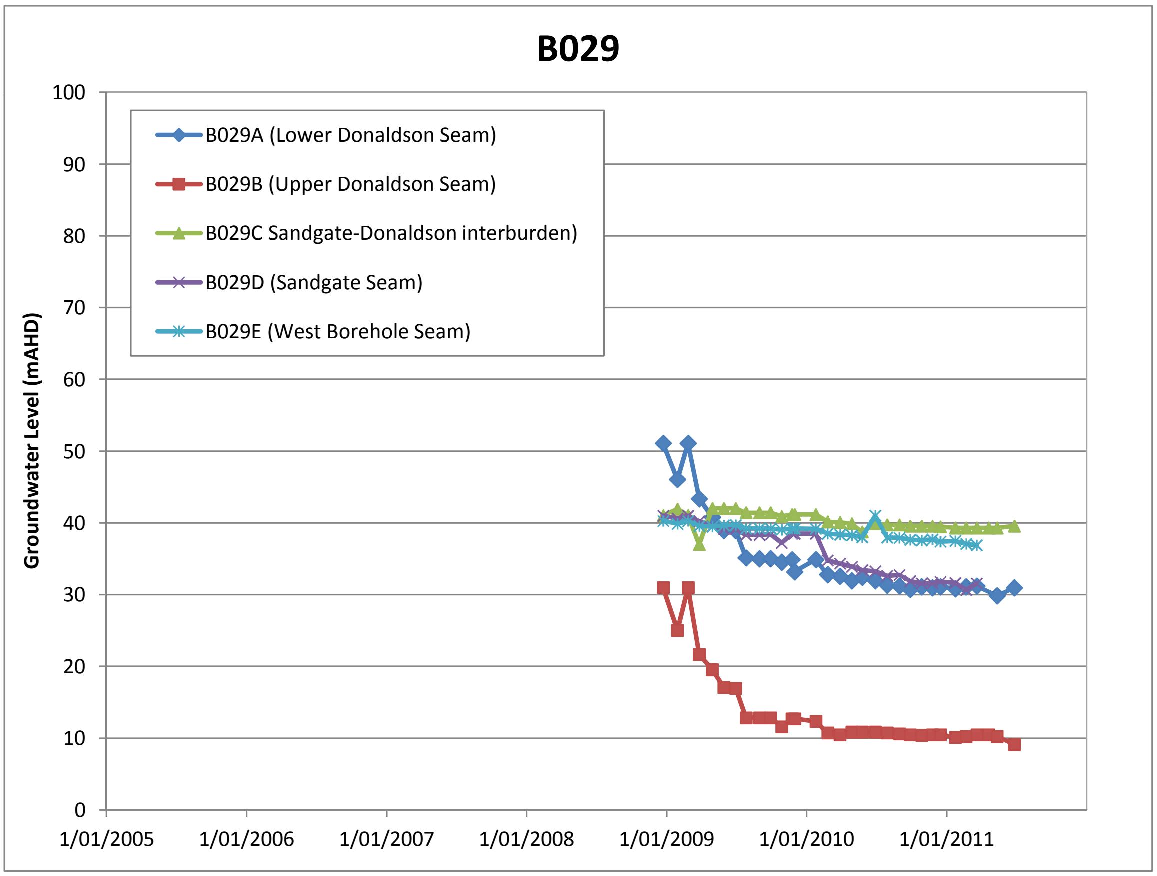


RPS Aquaterra

B017 PIEZOMETER HYDROSTATIC PROFILE AND HYDROGRAPHS FIGURE B22

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB22

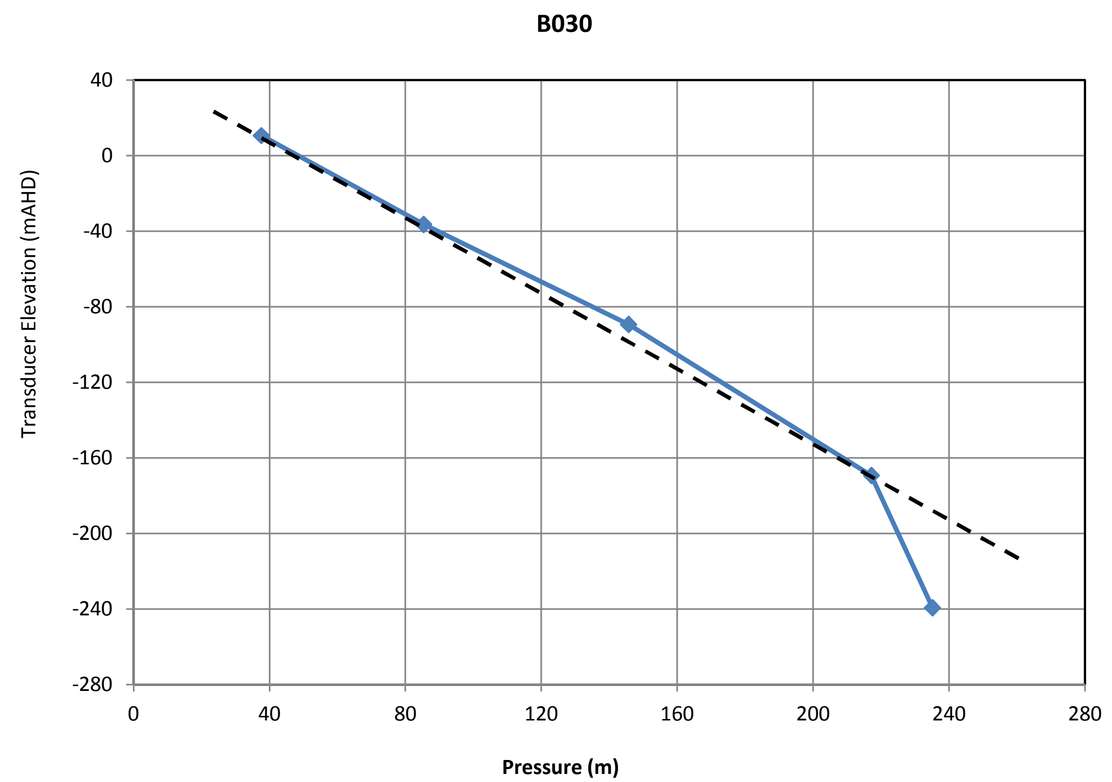


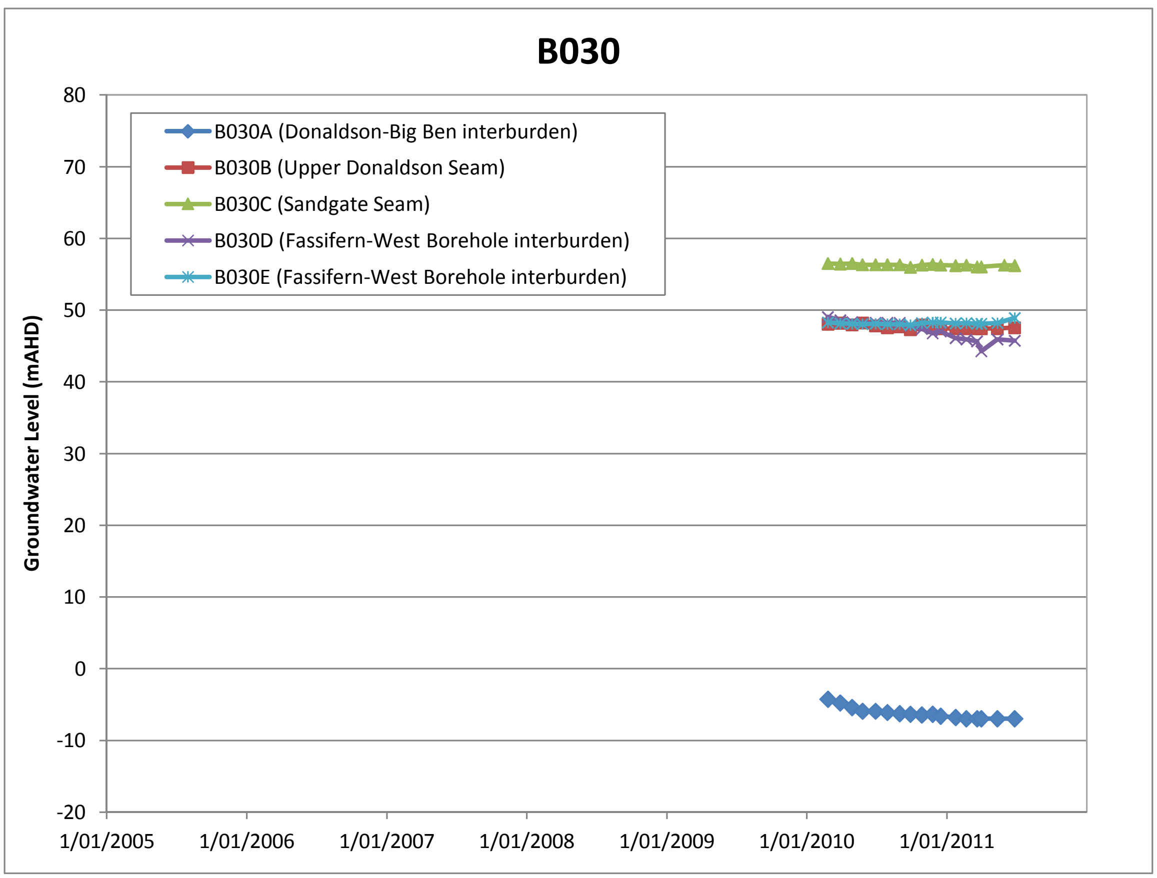


RPS Aquaterra

B029 PIEZOMETER HYDROSTATIC PROFILE AND HYDROGRAPHS FIGURE B23

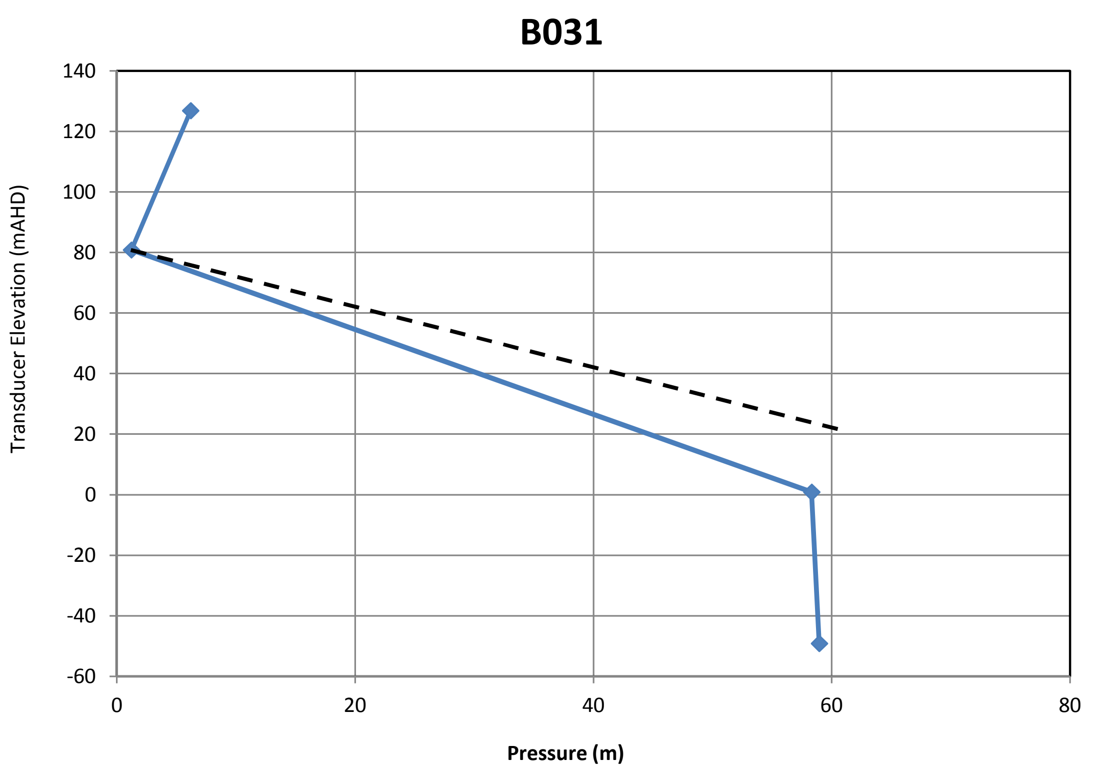
F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB23

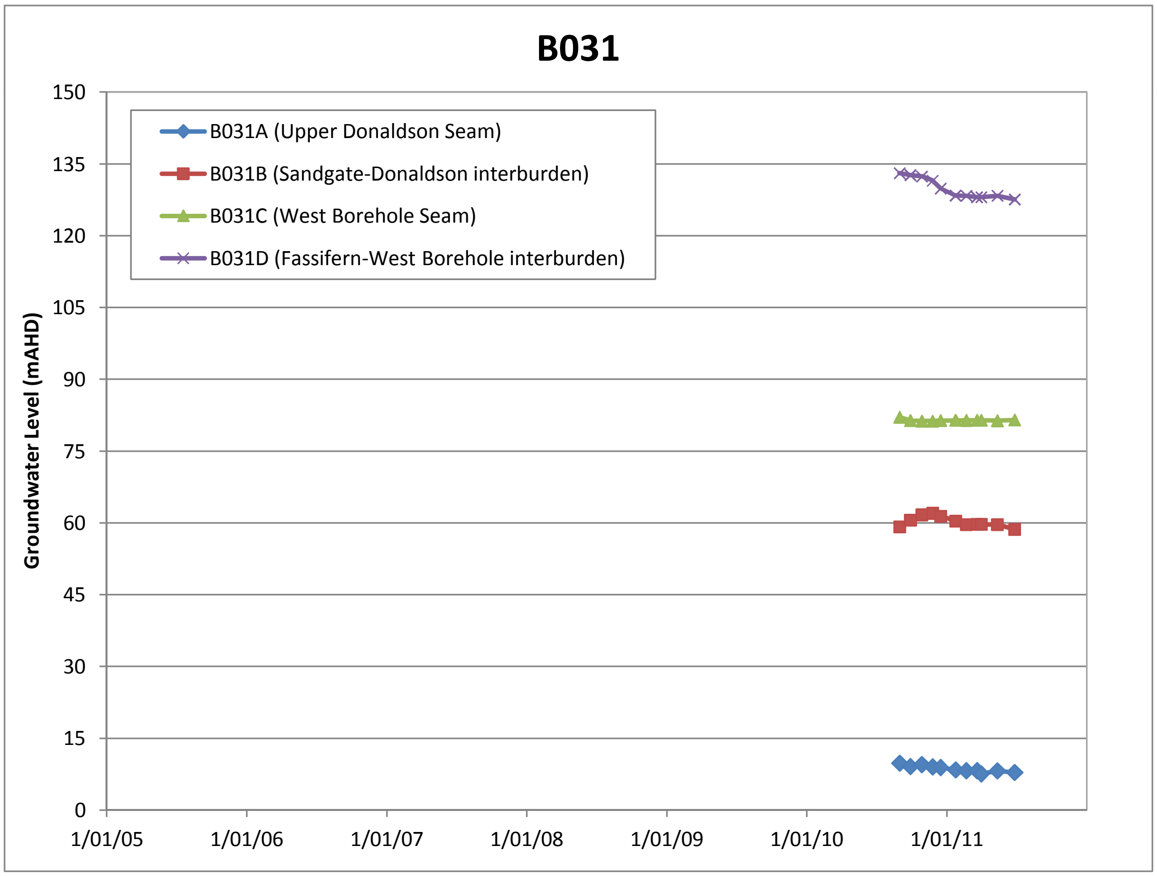




B030 PIEZOMETER HYDROSTATIC PROFILE AND HYDROGRAPHS FIGURE B24

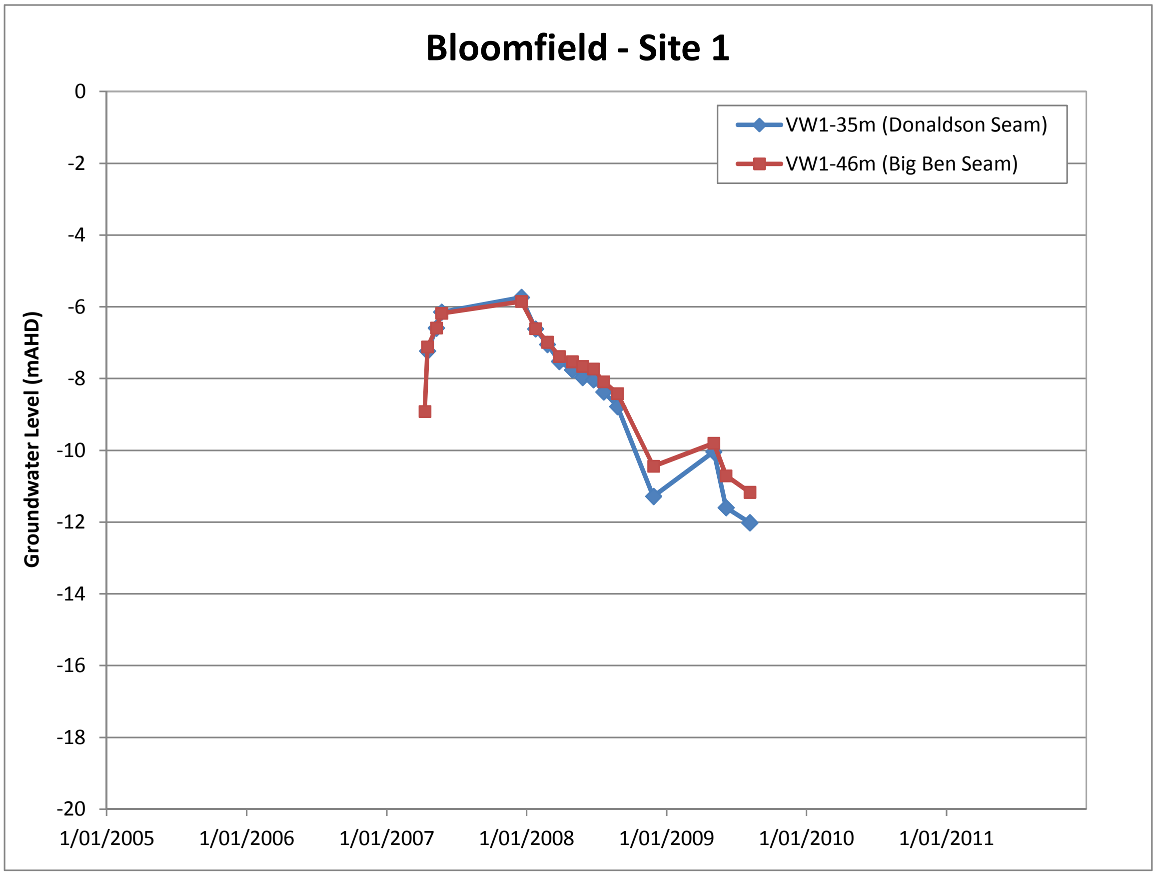
F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB24

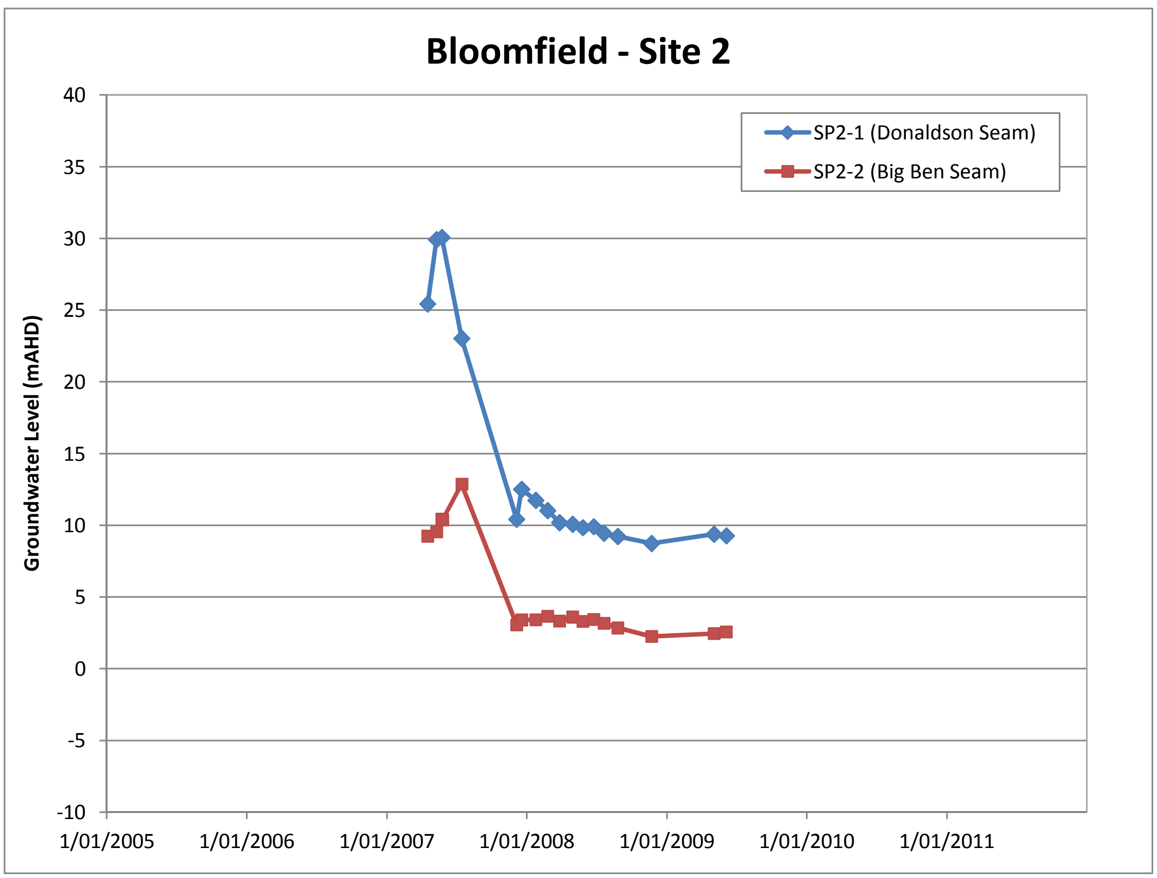




B031 PIEZOMETER HYDROSTATIC PROFILE AND HYDROGRAPHS FIGURE B25

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB25

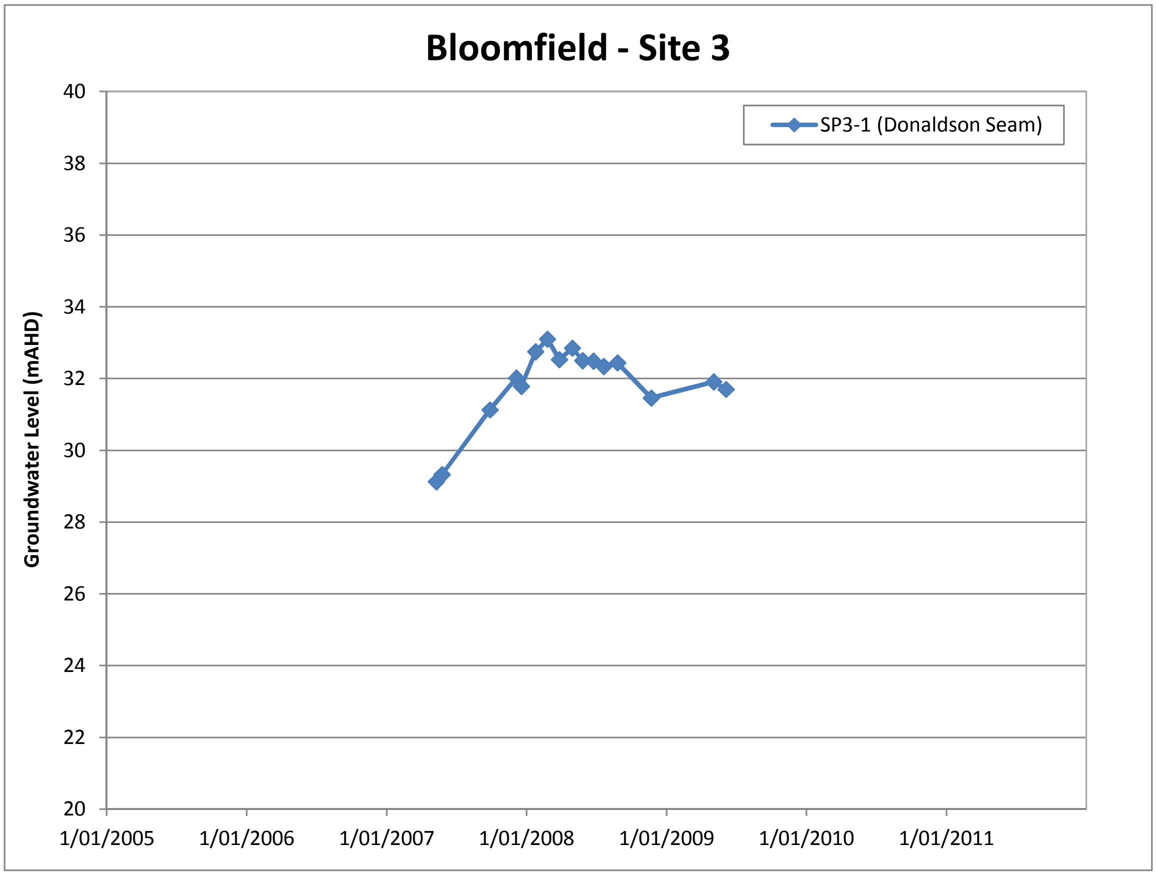


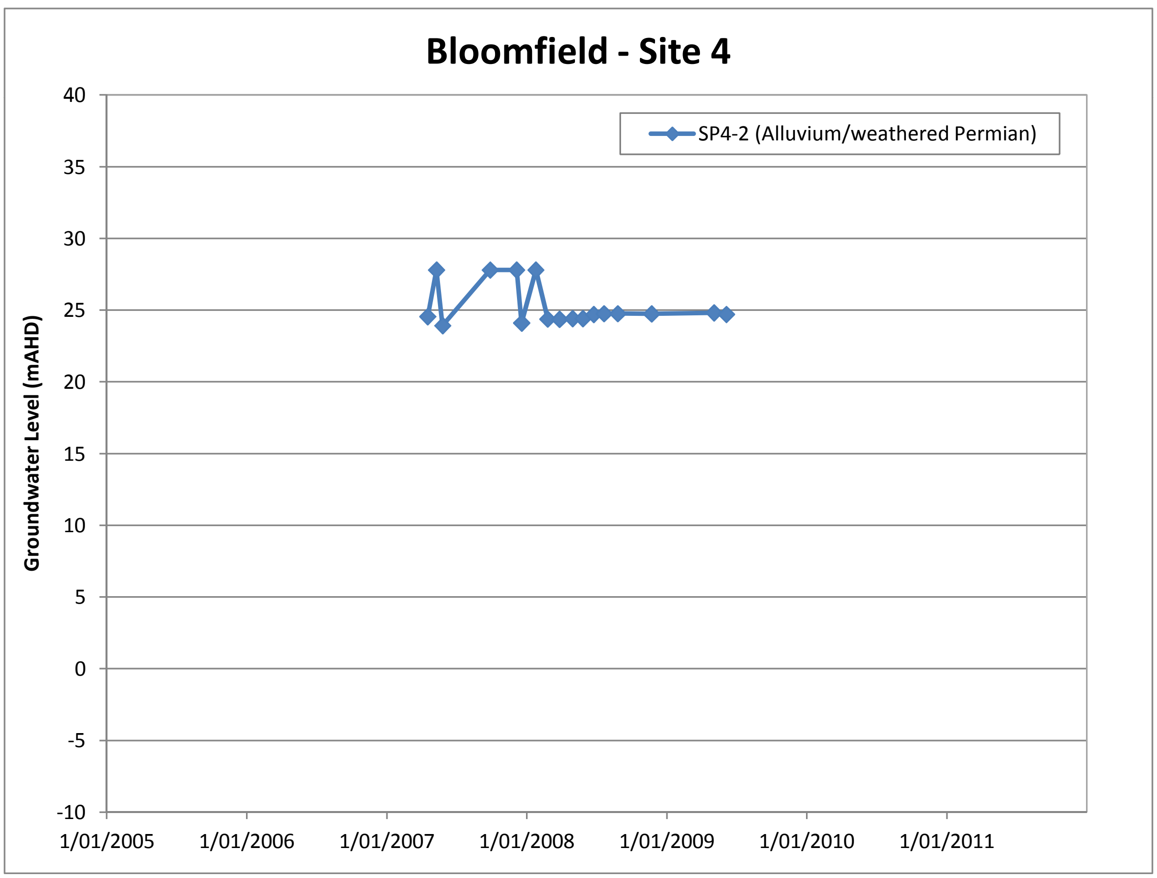


RPS Aquaterra

BLOOMFIELD SITES 1 AND 2 HISTORICAL HYDROGRAPHS FIGURE B26

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB26

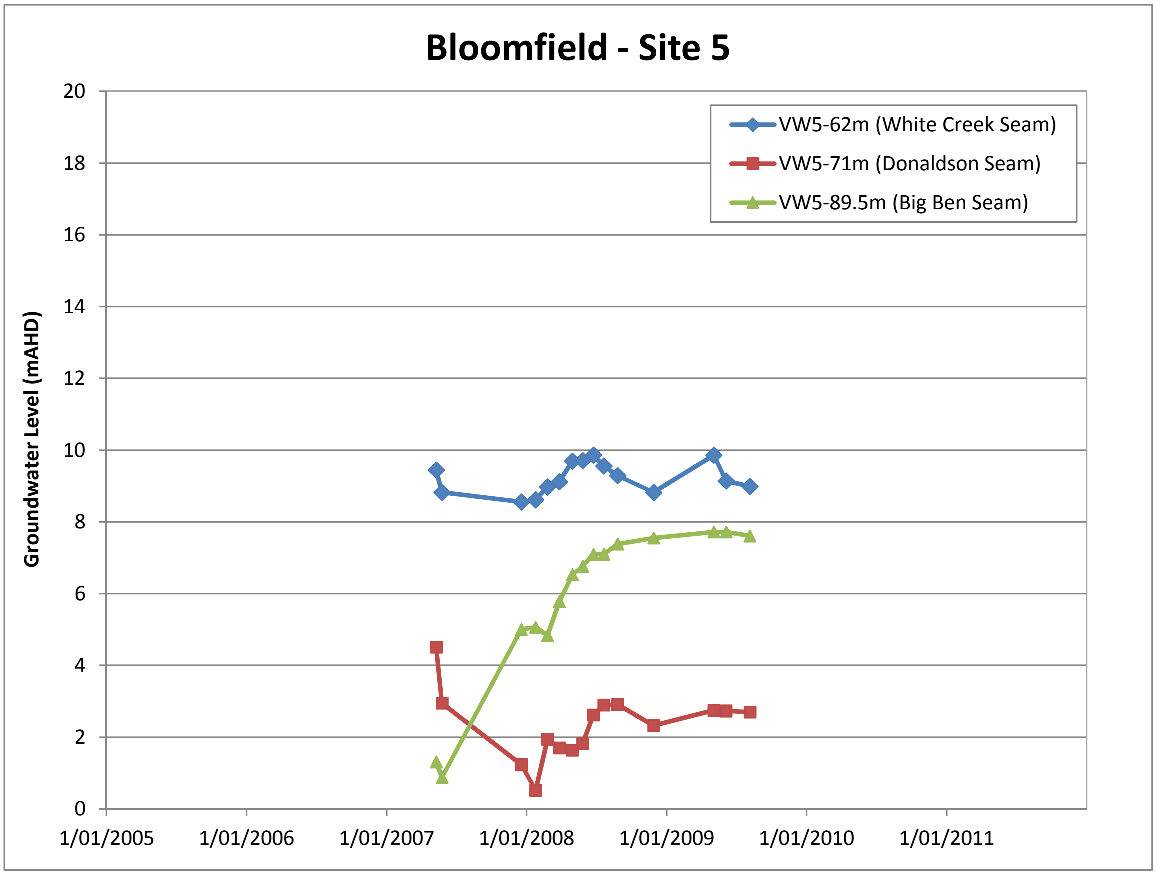


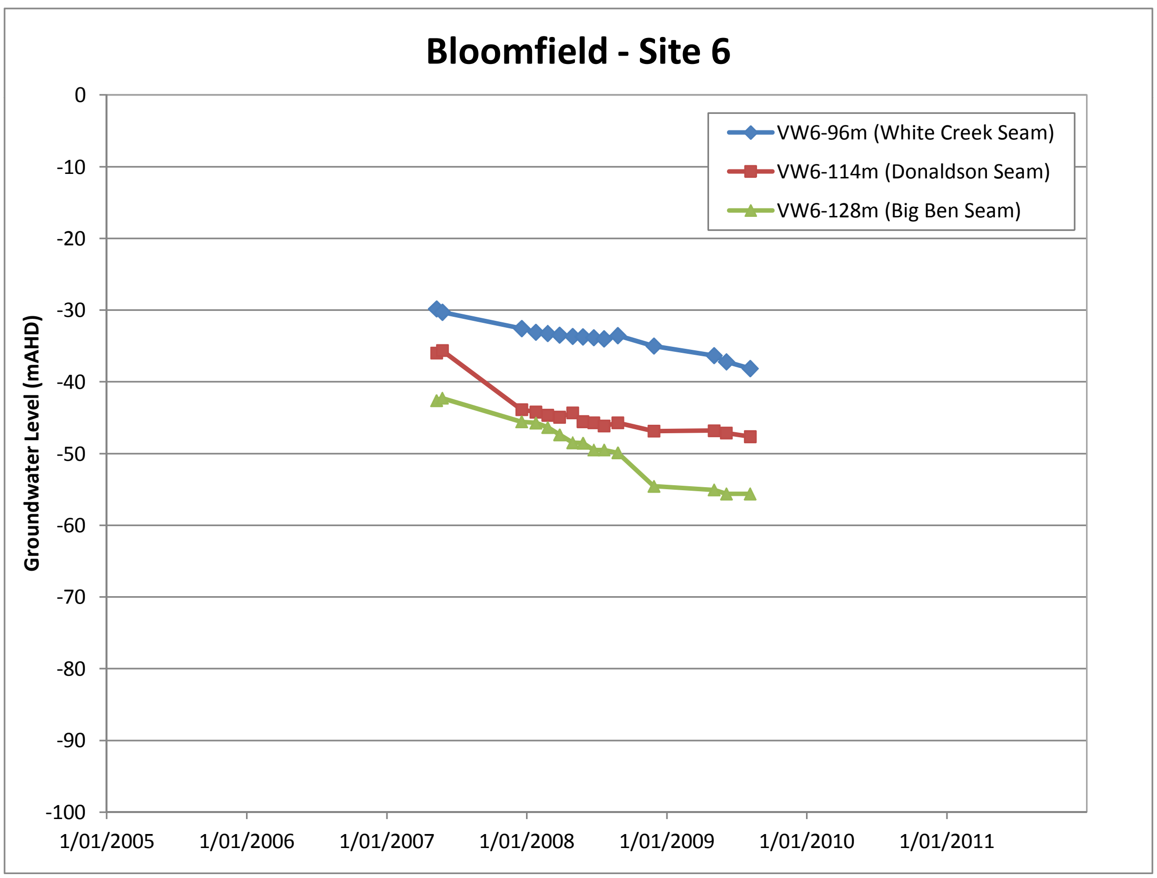


RPS Aquaterra

BLOOMFIELD SITES 3 AND 4 HISTORICAL HYDROGRAPHS FIGURE B27

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB27

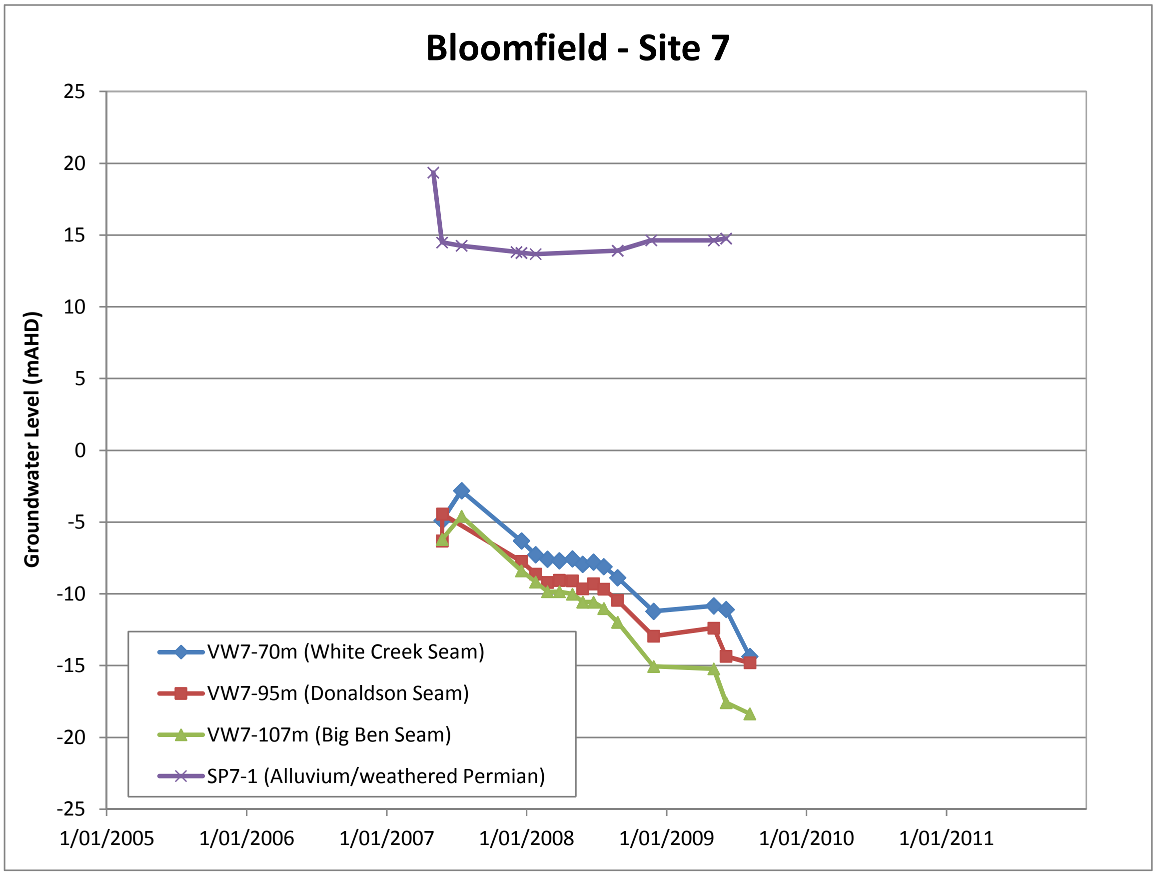


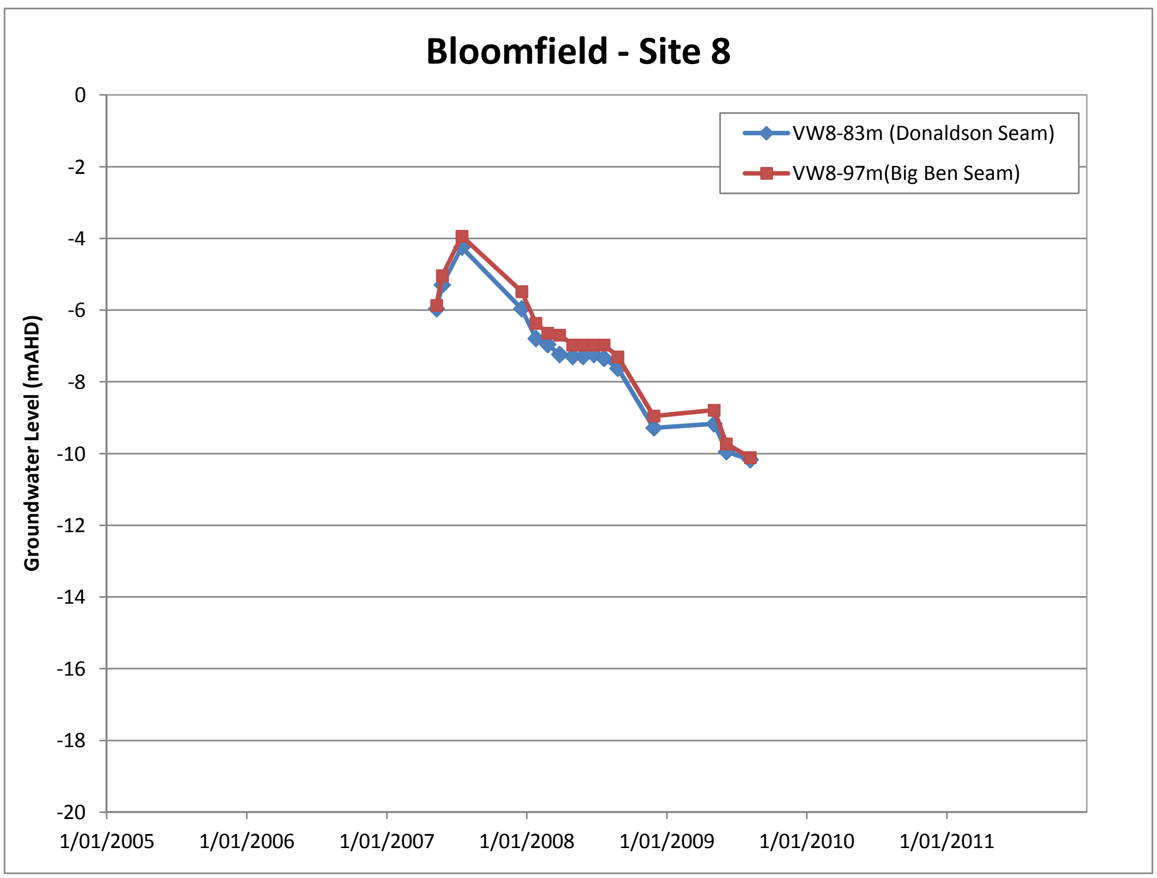


RPS Aquaterra

BLOOMFIELD SITES 5 AND 6 HISTORICAL HYDROGRAPHS FIGURE B28

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB28

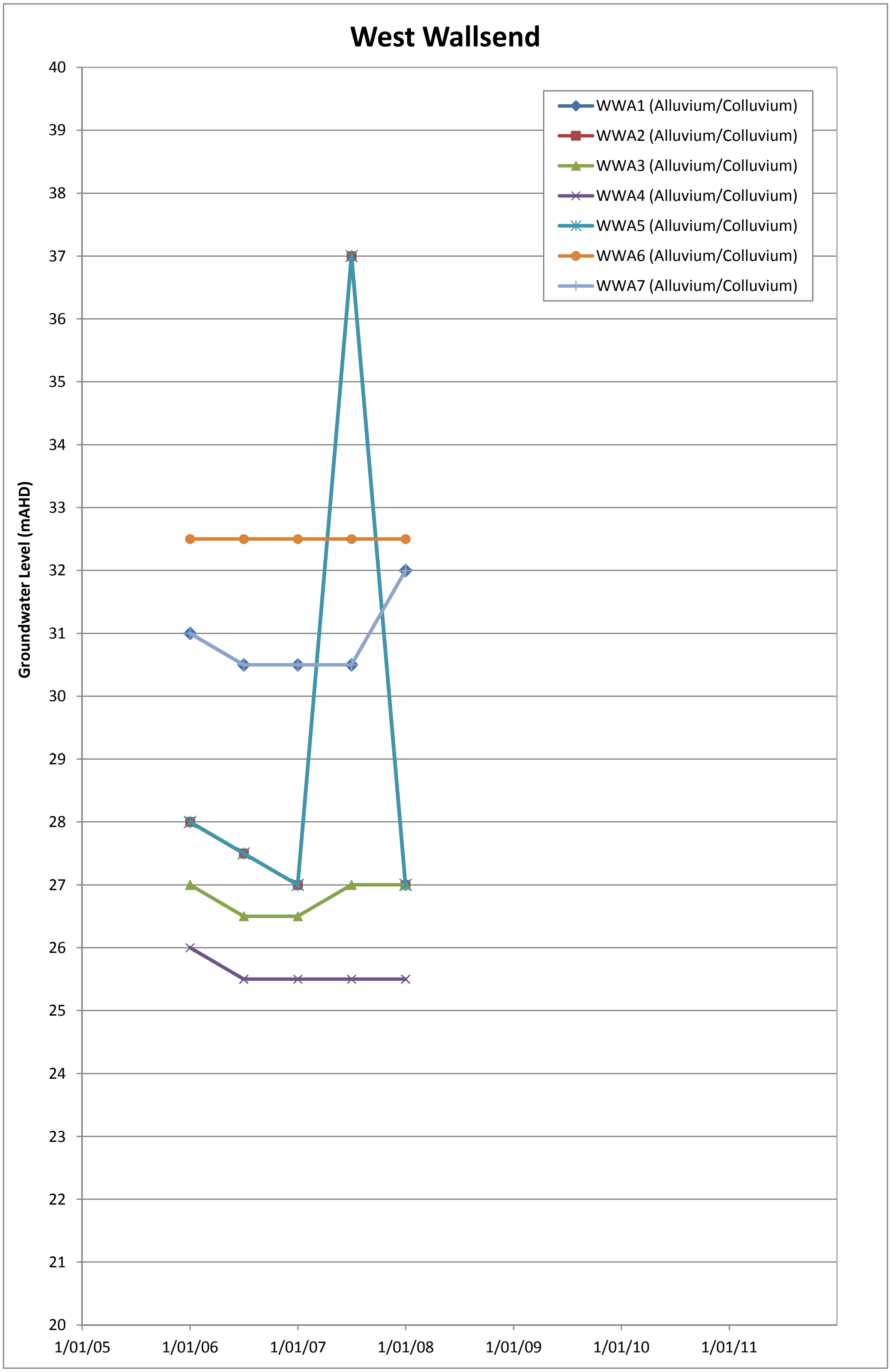




RPS Aquaterra

BLOOMFIELD SITES 7 AND 8 HISTORICAL HYDROGRAPHS FIGURE B29

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB29



RPS Aquaterra

WEST WALLSEND HISTORICAL HYDROGRAPHS FIGURE B30

F:\Jobs\S35\300 Technical\360_Water Levels_Flows_Logs\Groundwater Level Database\[050_Donaldson_borehole_inventory.xlsx]FigB30

APPENDIX C: REGISTERED GROUNDWATER BORES

Registered Bores within 5km of the Tasman Extension Project

WORK NO	LICENSE	EASTING	NORTHING	WORK TYPE	OWNER TYPE	FINAL DEPTH (m)	COMPLETION	SALINITY (ppm)	YIELD (L/S)	Depth to STANDING WATER LEVEL (m)
GW051353	20BL114994	366090.2	6365986.78	Bore open thru rock	Private	49.7	1/11/1980	3001-7000	0	0
GW053411	20BL120966	361319	6366875.88	Bore open thru rock	Private	20	1/03/1981	0-500	0	0
GW053412	20BL121021	361344.5	6366907.04	Bore open thru rock	Private	7.9	1/03/1981	0-500	0	0
GW078578	20BL167496	363965.5	6358232.28	Bore		99	6/11/1997		0	55
GW078600	20BL167000	357470.4	6359643.6	Bore		4.2			0.75	0
GW078814	20BL167109	363599.7	6360284.46	Bore		256.5	30/04/1998		0	210.7
GW078815	20BL167110	364817.9	6359762.38	Bore		131.1	6/11/1998		0	103
GW078816	20BL167111	363595.2	6360253.74	Bore		310.5	13/05/1998		0	109.5
GW080369	20BL168615	357900	6354510.36	Bore		10	15/01/2003		0	0

APPENDIX D: MODEL CALIBRATION TARGET BORES

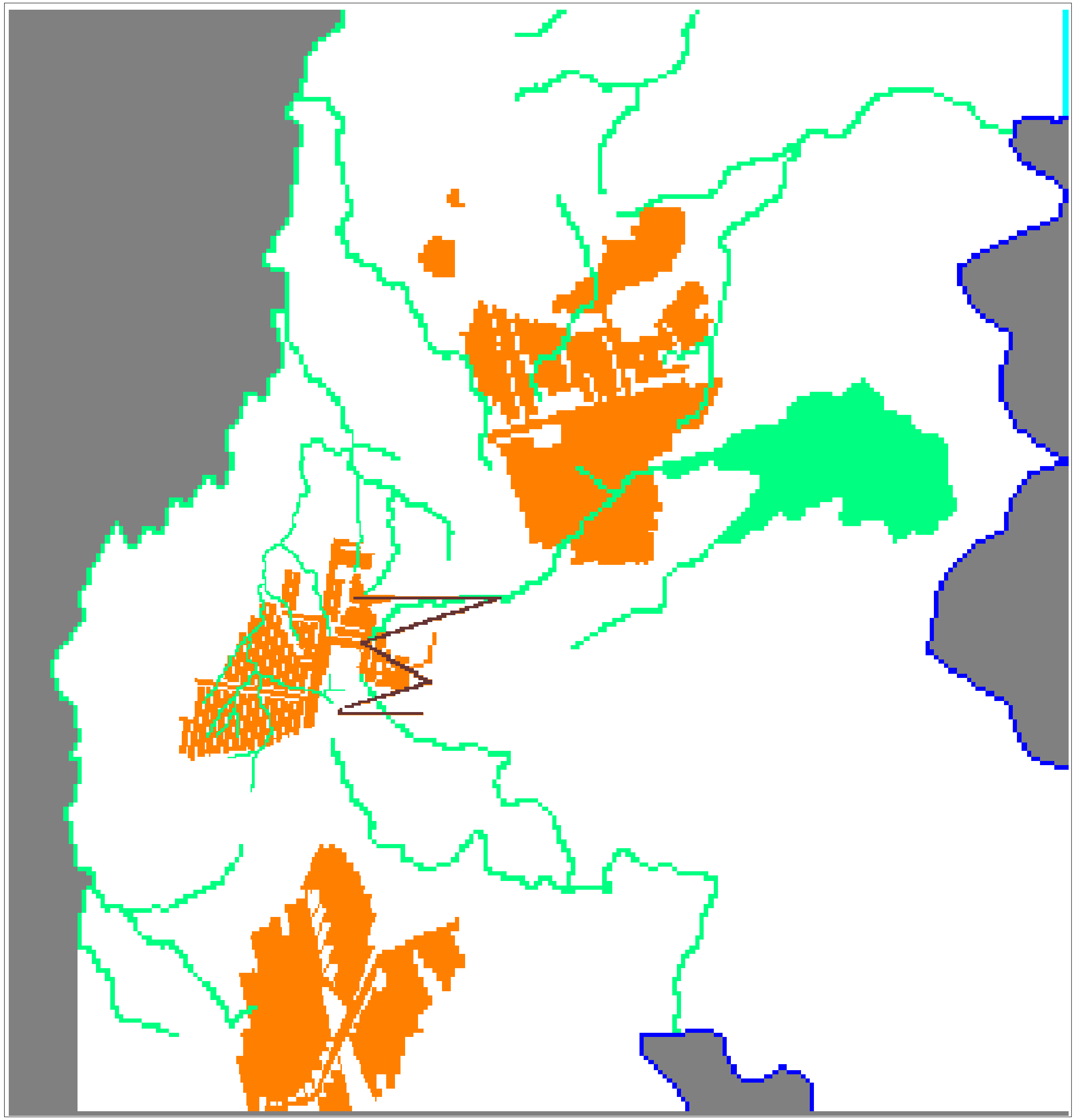
Model Calibration Target Bores

Name	Easting	Northing	Formation	Layer
C072B	369927	6362562	Weathered Permian	1
C081B	370011	6364016.95	Alluvium / colluvium	1
C082	370328	6364650	Weathered Permian	1
SP4-2	367612	6370989	Alluvium	1
SP7-1	364619	6368701	Alluvium	1
WWA1	364299	6353855	Alluvium / colluvium	1
WWA2	364199	6353895	Alluvium / colluvium	1
WWA3	364299	6354055	Alluvium / colluvium	1
WWA4	364299	6353955	Alluvium / colluvium	1
WWA5	364199	6354255	Alluvium / colluvium	1
WWA6	364299	6354355	Alluvium / colluvium	1
WWA7	364370	6354420	Alluvium / colluvium	1
TA23	360597	6357695	Fassifern Overburden	2
TA24	364947	6359793	Fassifern Seam	3
B002AD	361942	6360970.96	Fassifern - West Borehole Interburden	4
B030E	361400	6359400.29	Fassifern - West Borehole Interburden	4
TA41C	361231	6354125.71	Fassifern - West Borehole Interburden	4
B030D	361400	6359400.29	Fassifern - West Borehole Interburden	5
B029E	361362	6360638.75	Fassifern - West Borehole Interburden	6
C123F	366288	6364702.571	Fassifern - West Borehole Interburden	6
TA41B	361231	6354125.71	Fassifern - West Borehole Interburden	6
B002AC	361942	6360970.96	West Borehole Seam	7
B004	363048	6362107	West Borehole Seam	7
B005	363760	6362001	West Borehole Seam	7
B017B	360800	6359938	West Borehole Seam	7
B031C	360086	6358946.09	West Borehole Seam	7
C078B	367140	6367054	West Borehole Seam	7
C148D	362443	6364501.02	West Borehole Seam	7
C223E	365530	6364593.9	West Borehole Seam	7
B002AB	361942	6360970.96	Sandgate Seam	9
B017A	360800	6359938	Sandgate Seam	9
B029D	361362	6360638.75	Sandgate Seam	9
B030C	361400	6359400.29	Sandgate Seam	9
C123E	366288	6364702.571	Sandgate Seam	9
C141E	363873	6364369.65	Sandgate Seam	9
C223D	365530	6364593.9	Sandgate Seam	9
TA41A	361231	6354125.71	Sandgate Seam	9
C082	370319	6364647.4	Sandgate - Donaldson Interburden	10
C123D	366288	6364702.571	Upper Buttai	10
B029C	361362	6360638.75	Sandgate - Donaldson Interburden	11
C072	369927	6362562	Donaldson Seam	11
C087	367417	6366585	Weathered Permian	11
C123C	366288	6364702.571	Donaldson Seam	11
C141D	363873	6364369.65	Sandgate - Donaldson Interburden	11
C148C	362443	6364501.02	Sandgate - Donaldson Interburden	11
C257	370030	6366642.01	Sandgate - Donaldson Interburden	11
C262C	370215	6367252	Sandgate - Donaldson Interburden	11
DPZ10	371001	6368463.04	Sandgate - Donaldson Interburden	11

Model Calibration Target Bores

DPZ12	369114	6366413.5	Sandgate - Donaldson Interburden	11
DPZ3	368774	6368609	Sandgate - Donaldson Interburden	11
B030B	361400	6359400.29	Sandgate - Donaldson Interburden	12
B031B	360086	6358946.09	Sandgate - Donaldson Interburden	12
C063B	372107	6366189	Sandgate - Donaldson Interburden	12
C078A	367140	6367054	Sandgate - Donaldson Interburden	12
C138A	364964	6367033.74	Sandgate - Donaldson Interburden	12
C223C	365530	6364593.9	Sandgate - Donaldson Interburden	12
C257	370030	6366642.01	Sandgate - Donaldson Interburden	12
C262B	370215	6367252	Sandgate - Donaldson Interburden	12
DPZ13	371249	6367556.91	Sandgate - Donaldson Interburden	12
B029A	361362	6360638.75	Donaldson Seam	13
C138A	364964	6367033.74	Donaldson Seam	13
C141C	363873	6364369.65	Donaldson Seam	13
C223B	365530	6364593.9	Donaldson Seam	13
C257	370030	6366642.01	Donaldson Seam	13
C262	370215	6367252	Donaldson Seam	13
DPZ6	368614	6367357.11	Donaldson Seam	13
DPZ7@50	368847	63676419	Donaldson Seam	13
DPZ9	369374	6368073.04	Upper /Lower Donaldson Seam	13
TA28	364167	6361241	Donaldson Seam	13
C063A	372107	6366189	Big Ben Seam	15
C080	368011	6365175	Donaldson Seam	15
C081A	370011	6364016.95	Donaldson Seam	15
C141B	363873	6364369.65	Big Ben Seam	15
C148B	362443	6364501.02	Big Ben Seam	15
C148A	362443	6364501.02	Big Ben - Ashtonfield Interburden	16
B002AA	361942	6360970.96	Donaldson Seam	17
C138C	364964	6367033.74	Big Ben Seam	17
C141A	363873	6364369.65	Ashtonfield Seam	17
DPZ20A	370540	6368439	Big Ben Seam	17
DPZ8	369374	6368073.04	Big Ben Seam	17
SP2-1	365112	6371264	Big Ben Seam	17
SP3-1	366732	6371893	Big Ben Seams	17
C138B	364964	6367033.74	Big Ben - Ashtonfield Interburden	18
C138A	364964	6367033.74	Ashtonfield Seam	19

APPENDIX E:
DRAIN CELL MODEL SET-UP



Rivers or Creeks
No Flow
General Head Boundary
Drain Cells

Date	17/04/2012	Scale	As Shown
Initials	HZ	Project	S35
Drawing Number	S35-028	Revision	A

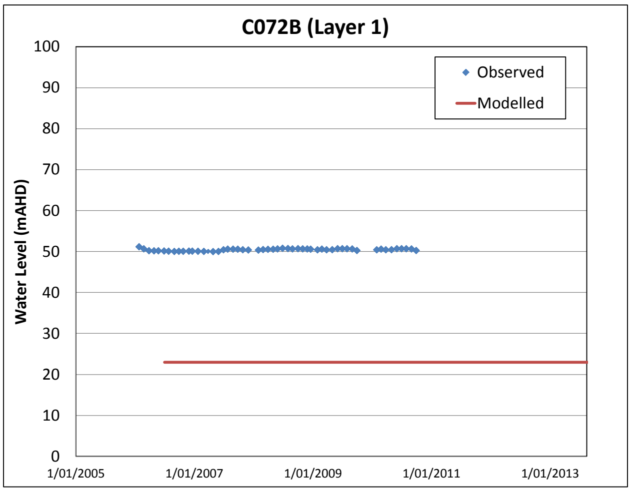
RPS Aquaterra

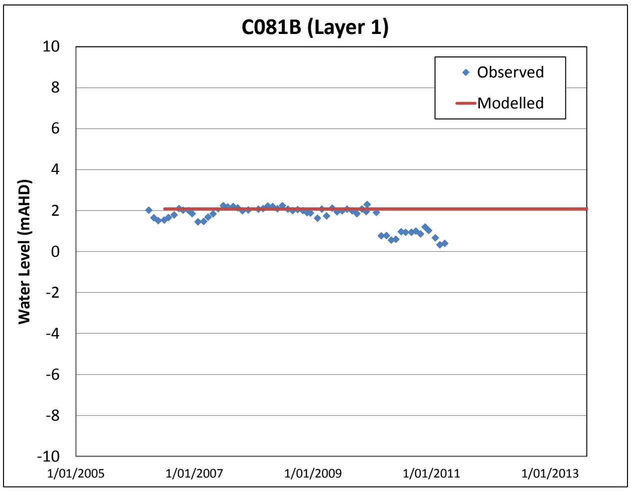
Donaldson Coal Pty Ltd

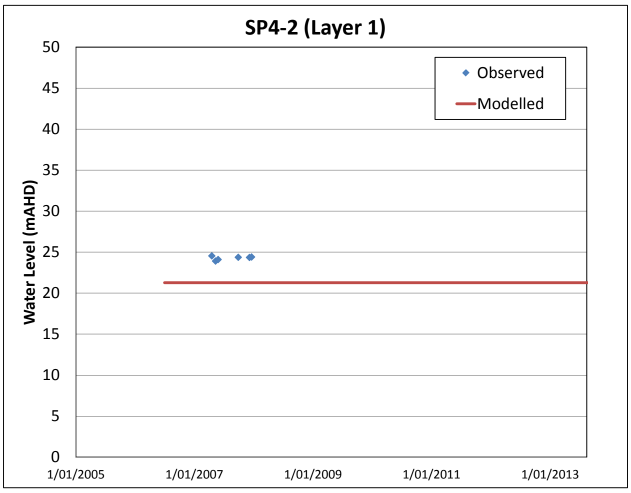
Model Drain Cells

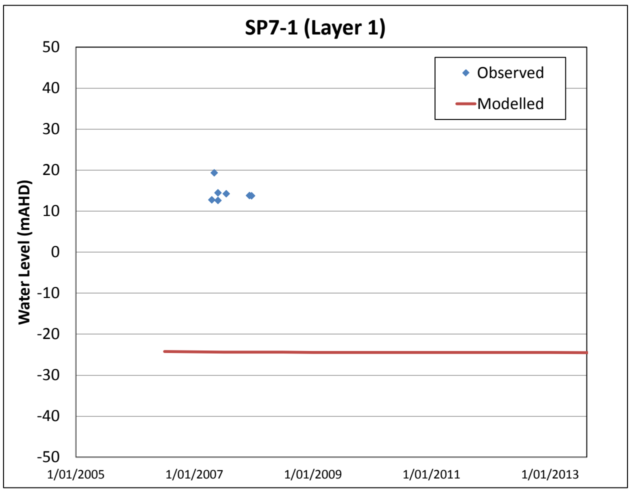
Figure E1

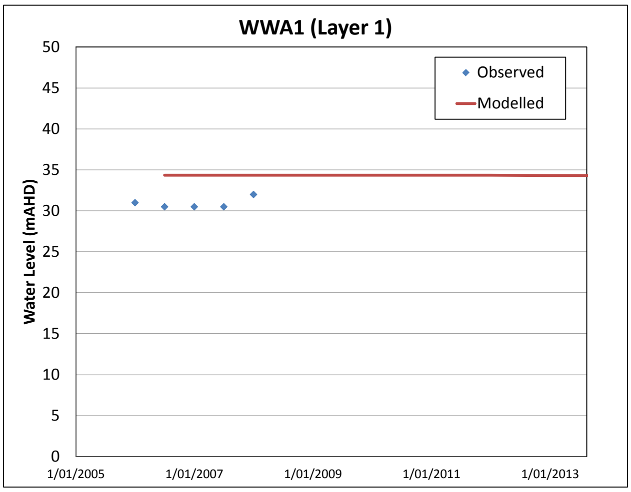
APPENDIX F: TRANSIENT CALIBRATION HYDROGRAPHS

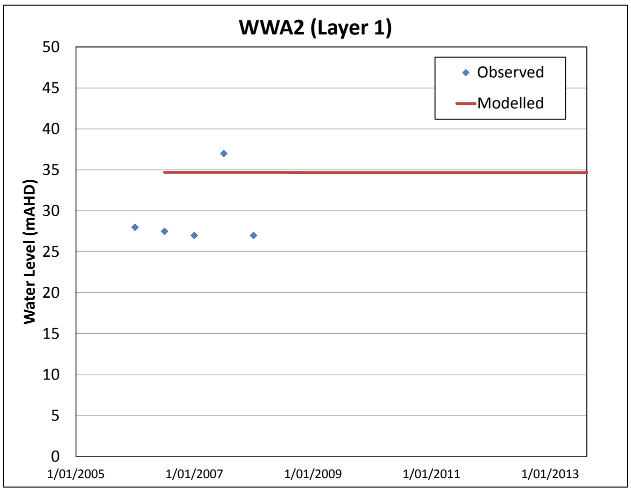

C072B (Layer 1)
Observed
Modelled
Water Level (mAHD)
100
90
80
70
60
50
40
30
20
10
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

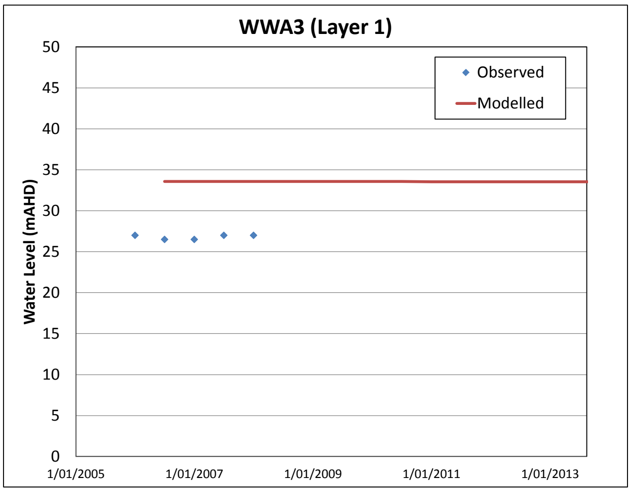

C081B (Layer 1)
Observed
Modelled
Water Level (mAHD)
10
8
6
4
2
0
-2
-4
-6
-8
-10
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

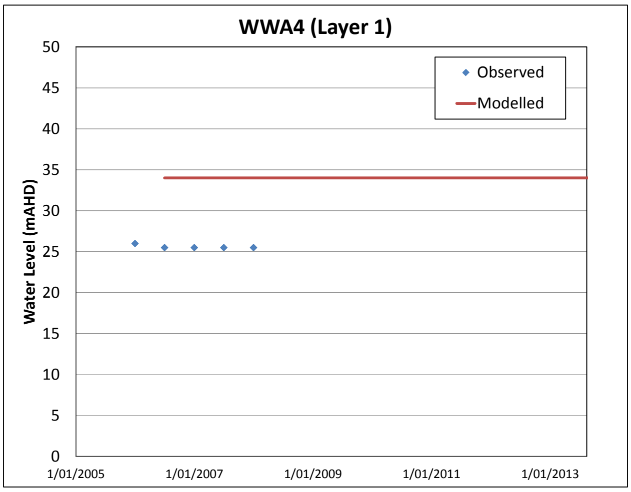

SP4-2 (Layer 1)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

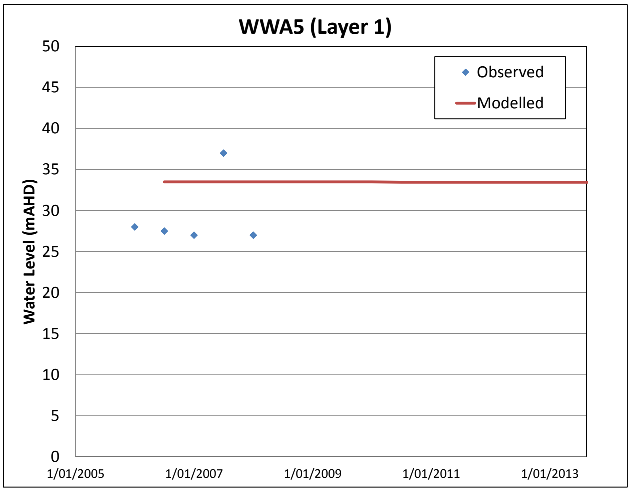

SP7-1 (Layer 1)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

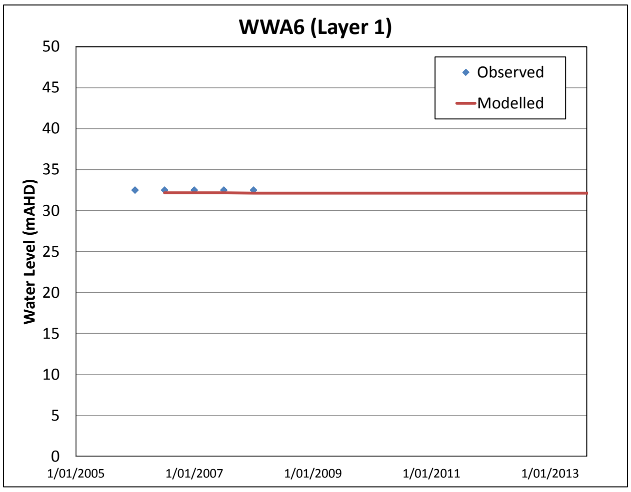

WWA1 (Layer 1)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

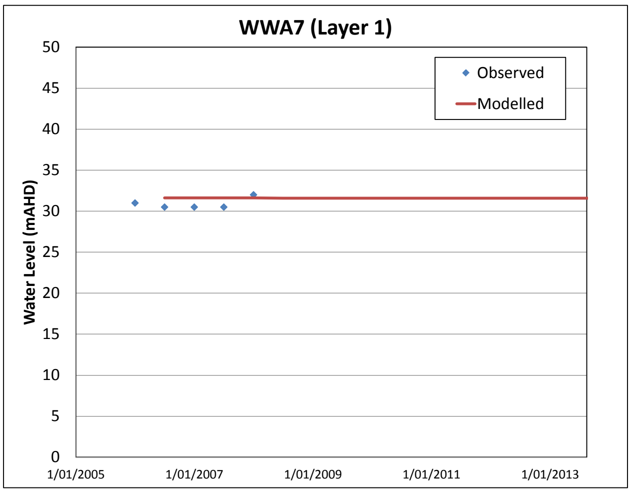

WWA2 (Layer 1)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

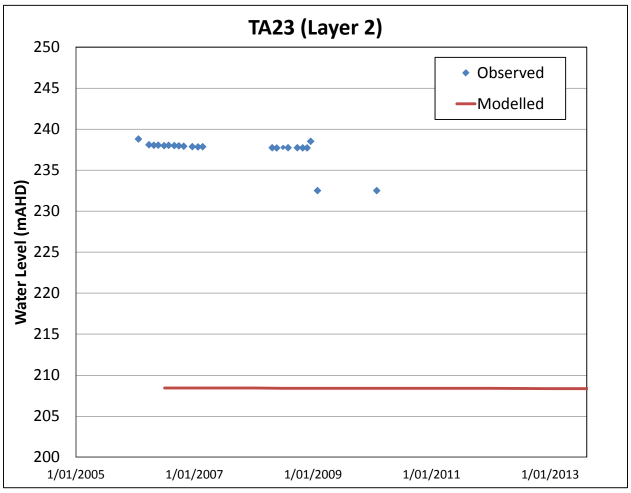

WWA3 (Layer 1)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

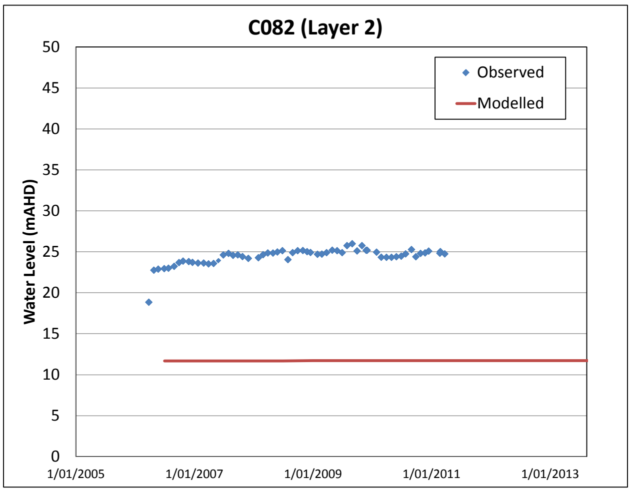

WWA4 (Layer 1)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

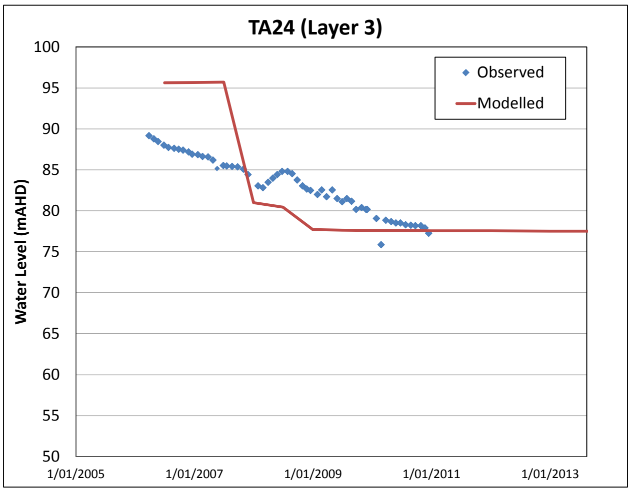

WWA5 (Layer 1)
Water Level (mAHD)
0
5
10
15
20
25
30
35
40
45
50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

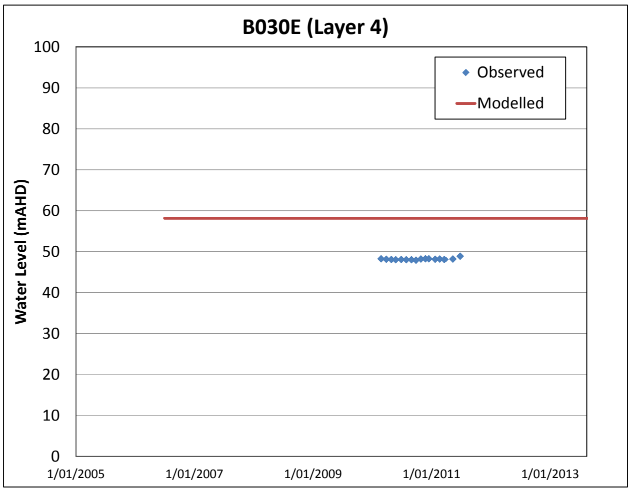

WWA6 (Layer 1)
Water Level (mAHD)
0
5
10
15
20
25
30
35
40
45
50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

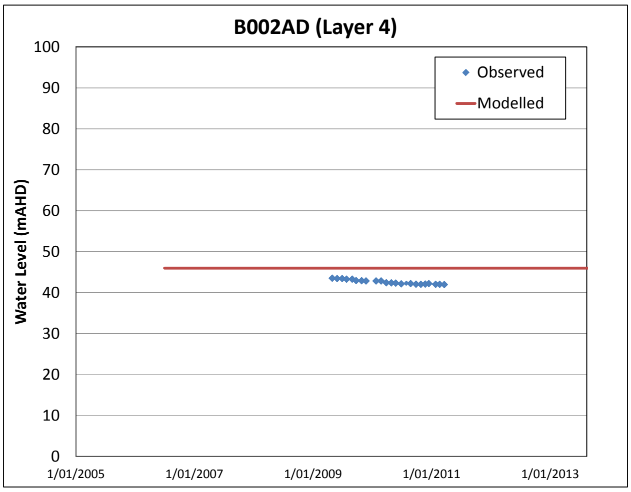

WWA7 (Layer 1)
Water Level (mAHD)
0
5
10
15
20
25
30
35
40
45
50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

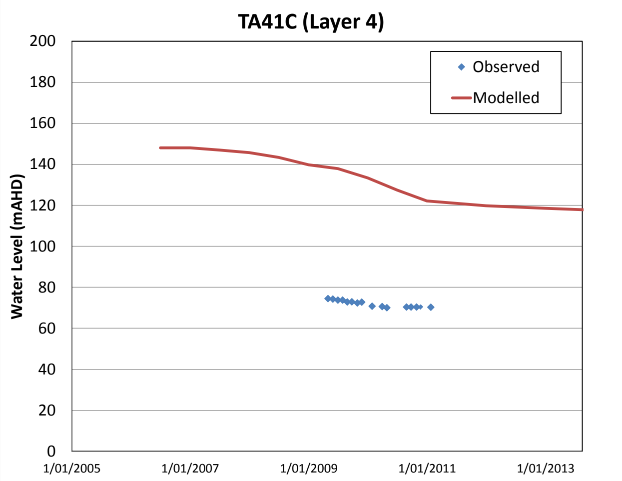

TA23 (Layer 2)
Water Level (mAHD)
200
205
210
215
220
225
230
235
240
245
250
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

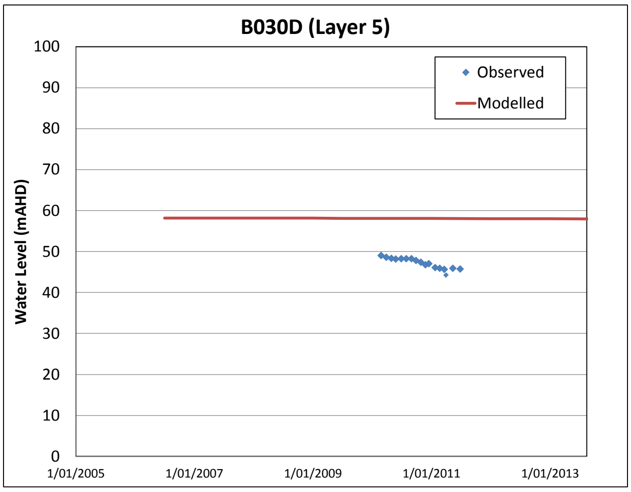

C082 (Layer 2)
Water Level (mAHD)
0
5
10
15
20
25
30
35
40
45
50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

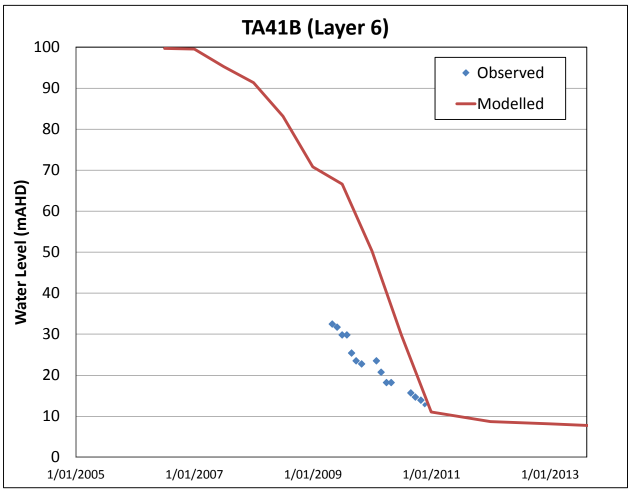

TA24 (Layer 3)
Water Level (mAHD)
50
55
60
65
70
75
80
85
90
95
100
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

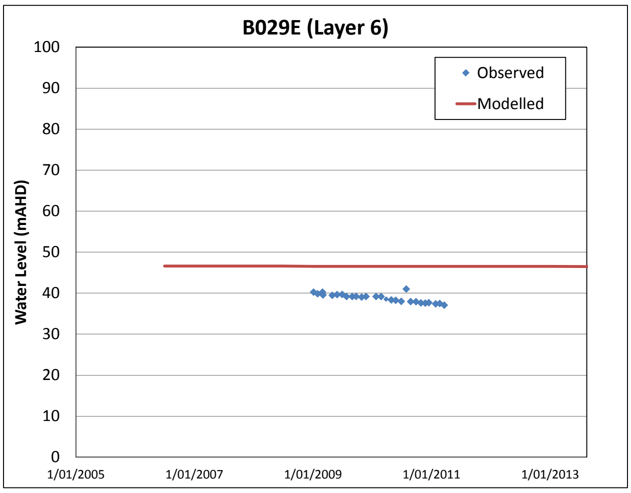

B030E (Layer 4)
Water Level (mAHD)
0
10
20
30
40
50
60
70
80
90
100
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

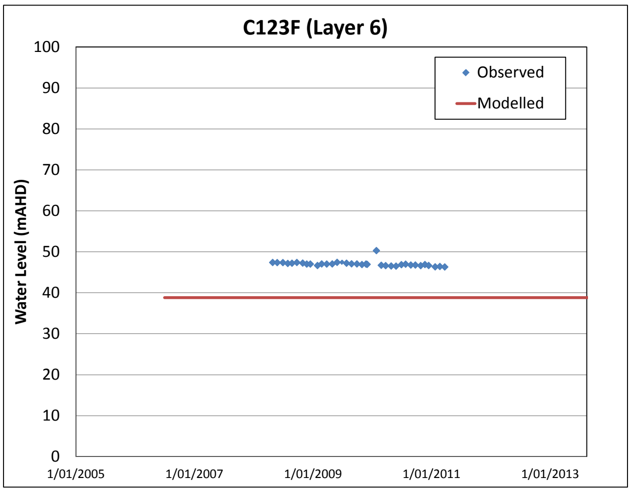

B002AD (Layer 4)
Water Level (mAHD)
0
10
20
30
40
50
60
70
80
90
100
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

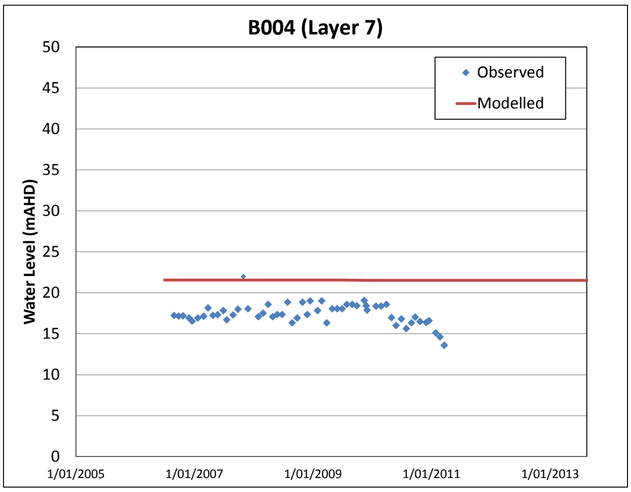

TA41C (Layer 4)
Water Level (mAHD)
200
180
160
140
120
100
80
60
40
20
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

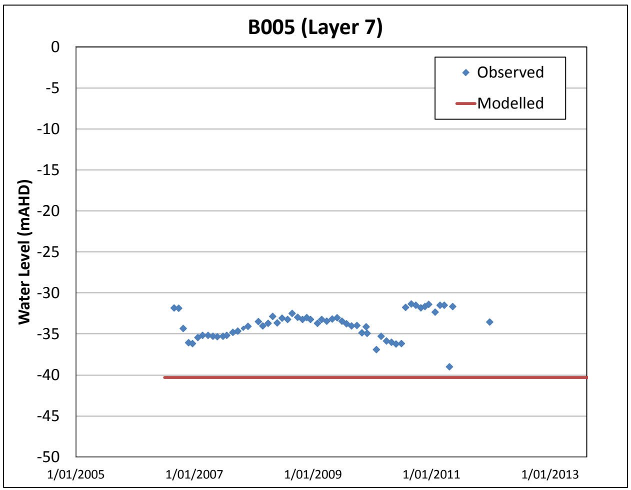

B030D (Layer 5)
Water Level (mAHD)
100
90
80
70
60
50
40
30
20
10
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

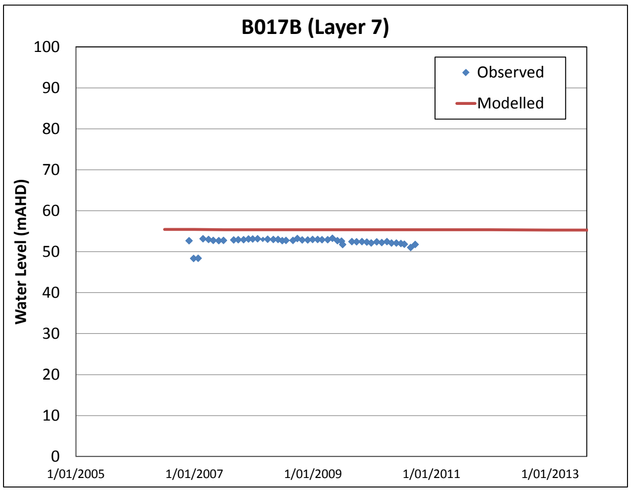

TA41B (Layer 6)
Water Level (mAHD)
100
90
80
70
60
50
40
30
20
10
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

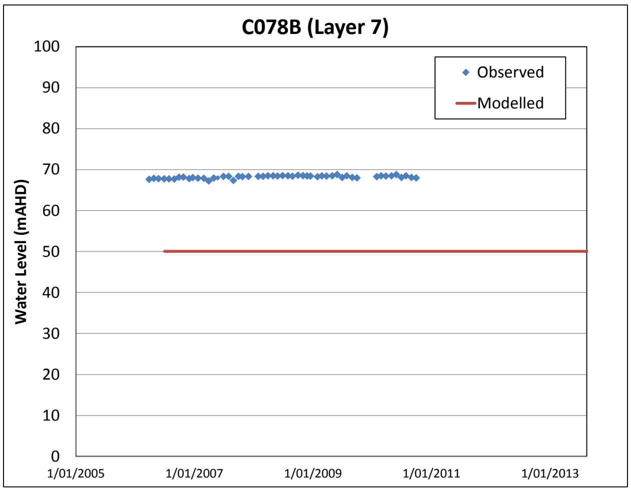

B029E (Layer 6)
Water Level (mAHD)
100
90
80
70
60
50
40
30
20
10
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

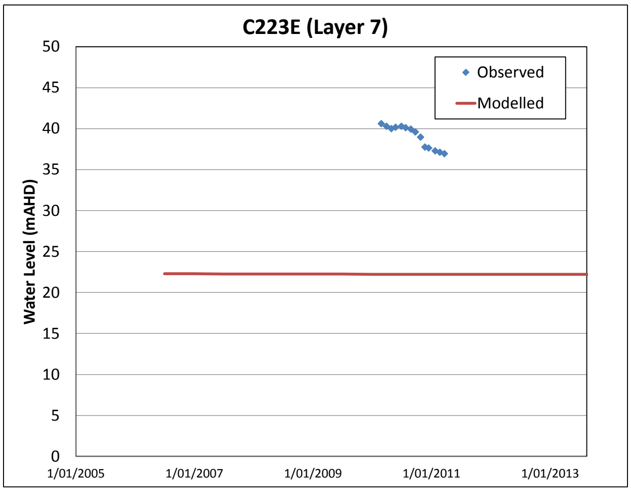

C123F (Layer 6)
Water Level (mAHD)
100
90
80
70
60
50
40
30
20
10
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

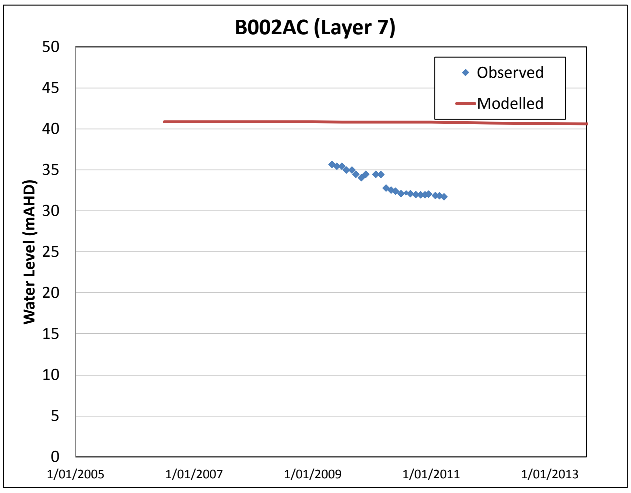

B004 (Layer 7)
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

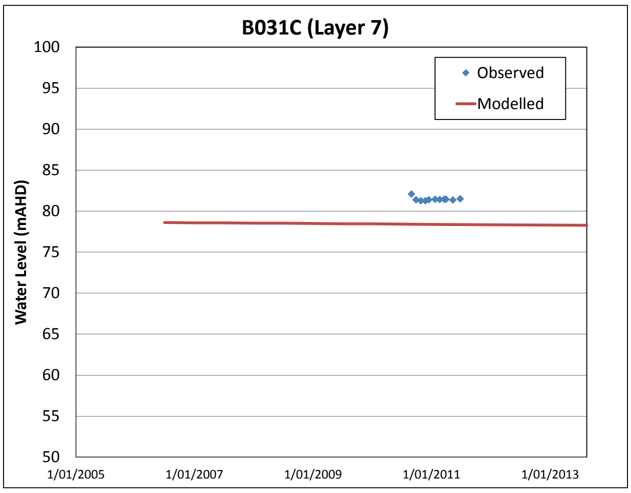

B005 (Layer 7)
Water Level (mAHD)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

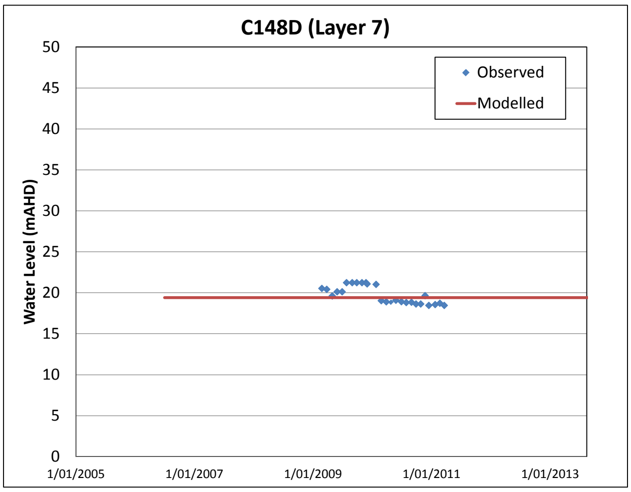

B017B (Layer 7)
Water Level (mAHD)
100
90
80
70
60
50
40
30
20
10
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013
Observed
Modelled

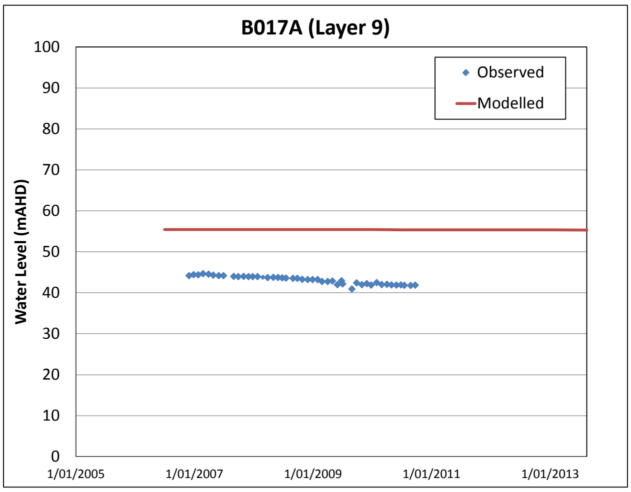

C078B (Layer 7)
Water Level (mAHD)
Observed
Modelled
0
10
20
30
40
50
60
70
80
90
100
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

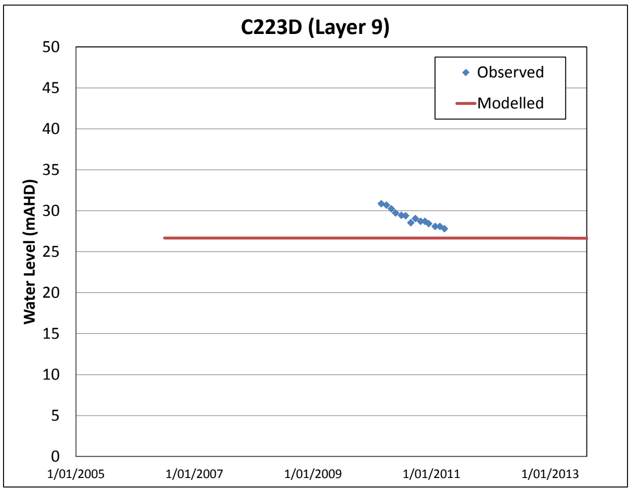

C223E (Layer 7)
Water Level (mAHD)
Observed
Modelled
0
5
10
15
20
25
30
35
40
45
50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

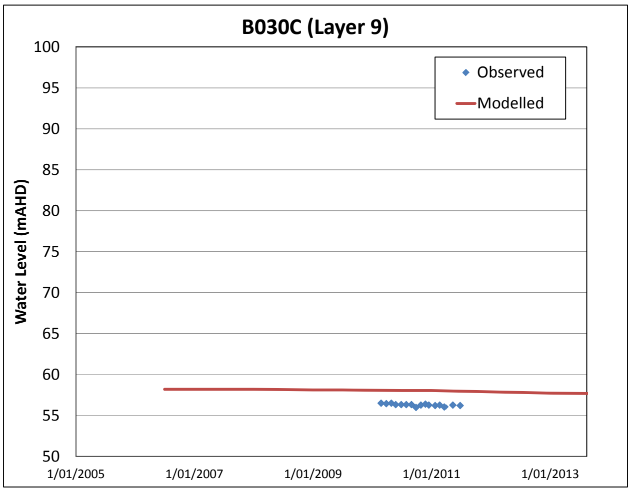

B002AC (Layer 7)
Water Level (mAHD)
Observed
Modelled
0
5
10
15
20
25
30
35
40
45
50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

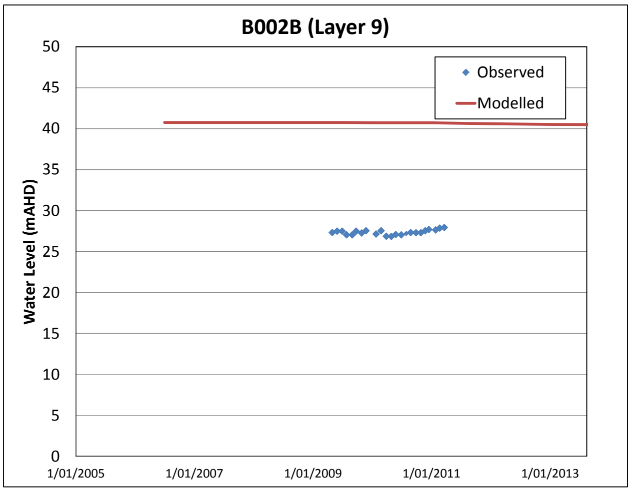

B031C (Layer 7)
Water Level (mAHD)
Observed
Modelled
50
55
60
65
70
75
80
85
90
95
100
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

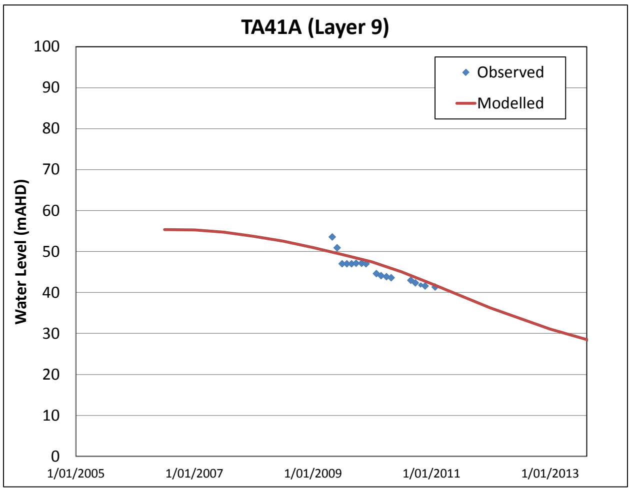

C148D (Layer 7)
Water Level (mAHD)
Observed
Modelled
0
5
10
15
20
25
30
35
40
45
50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

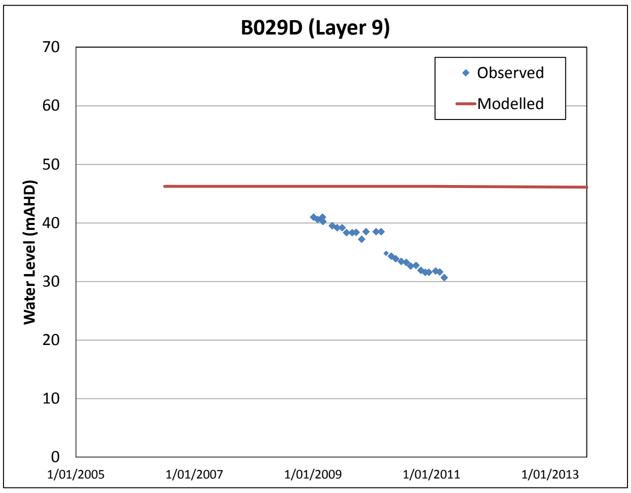

B017A (Layer 9)
Water Level (mAHD)
Observed
Modelled
0
10
20
30
40
50
60
70
80
90
100
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

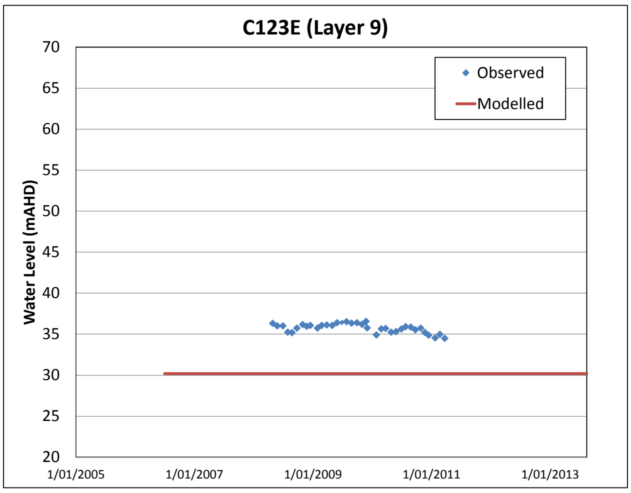

C223D (Layer 9)
Water Level (mAHD)
Observed
Modelled
0
5
10
15
20
25
30
35
40
45
50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

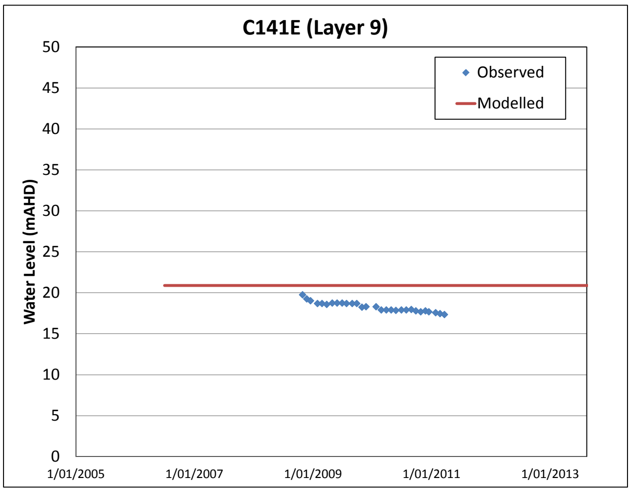

B030C (Layer 9)
Water Level (mAHD)
Observed
Modelled
50
55
60
65
70
75
80
85
90
95
100
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

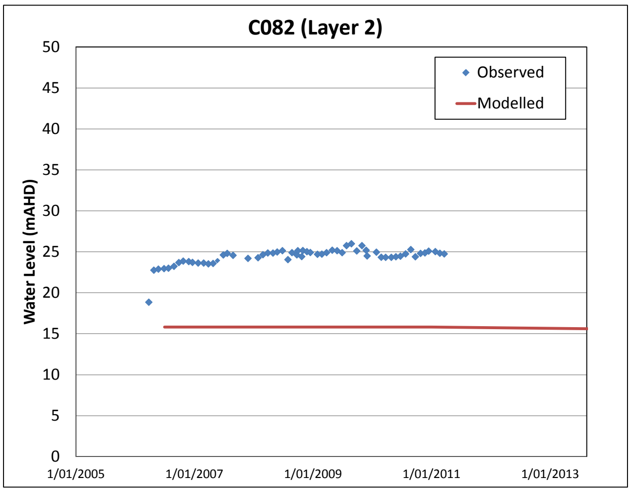

B002B (Layer 9)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

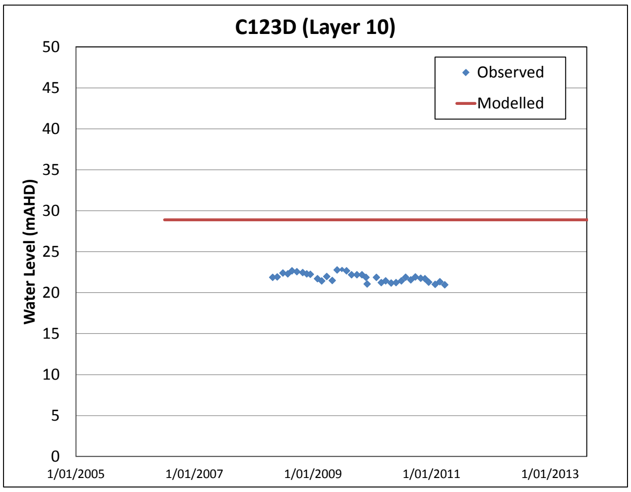

TA41A (Layer 9)
Observed
Modelled
Water Level (mAHD)
100
90
80
70
60
50
40
30
20
10
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

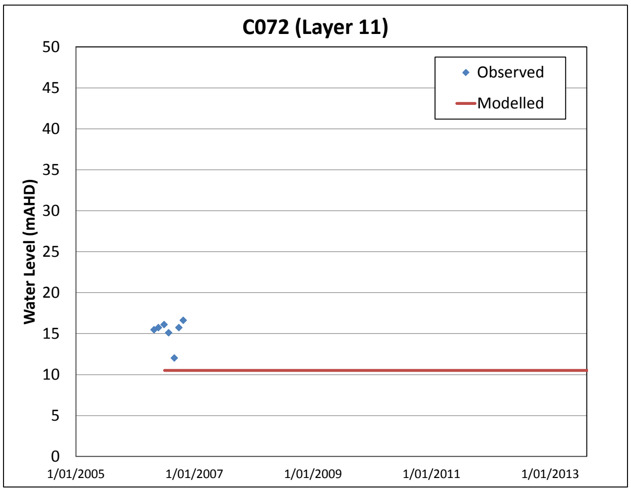

B029D (Layer 9)
Observed
Modelled
Water Level (mAHD)
70
60
50
40
30
20
10
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

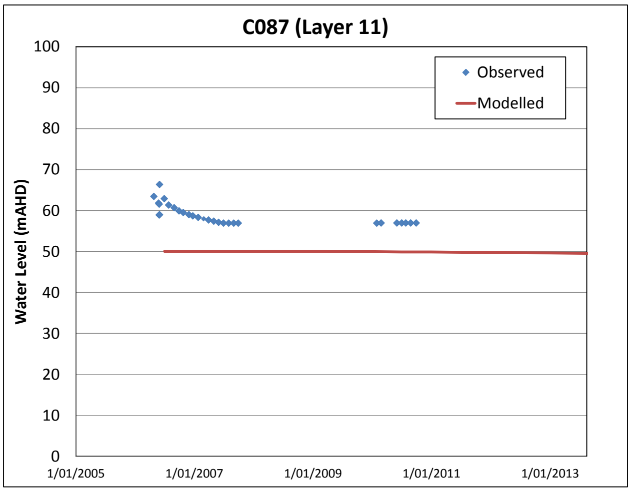

C123E (Layer 9)
Observed
Modelled
Water Level (mAHD)
70
65
60
55
50
45
40
35
30
25
20
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

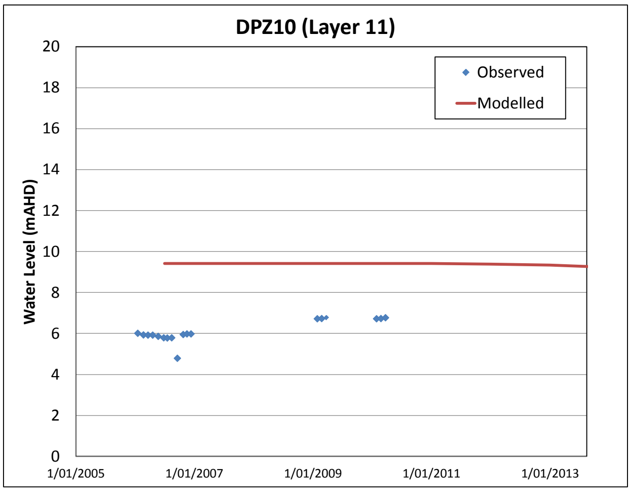

C141E (Layer 9)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

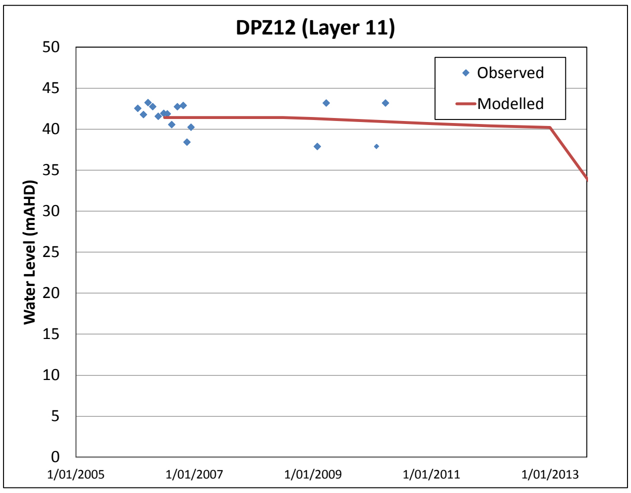

C082 (Layer 2)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

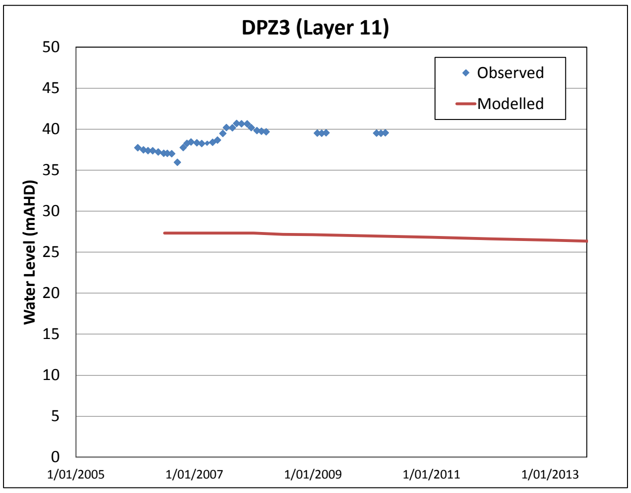

C123D (Layer 10)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

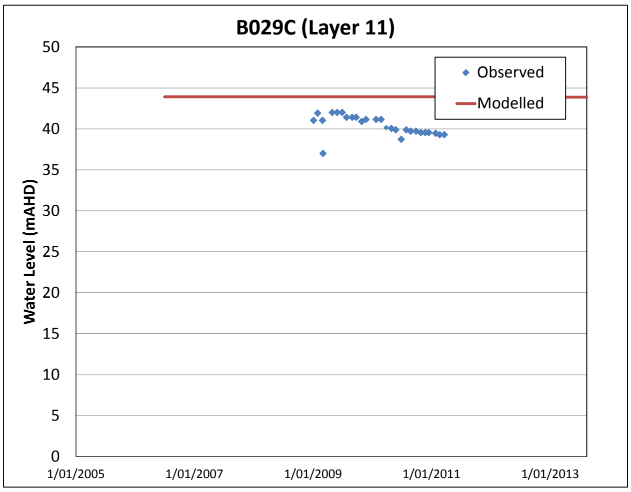

C072 (Layer 11)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

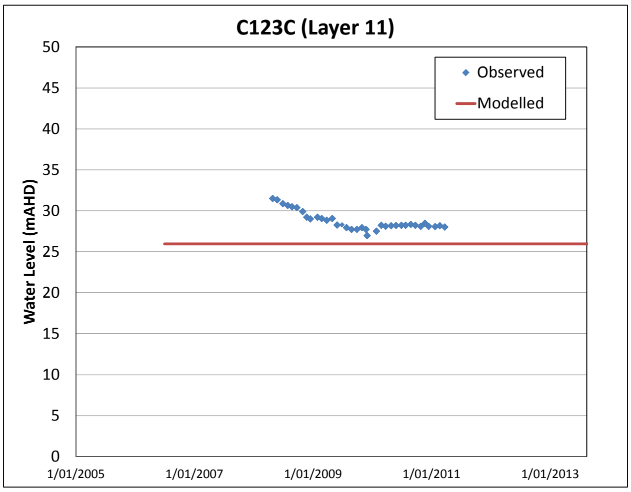

C087 (Layer 11)
Observed
Modelled
Water Level (mAHD)
100
90
80
70
60
50
40
30
20
10
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

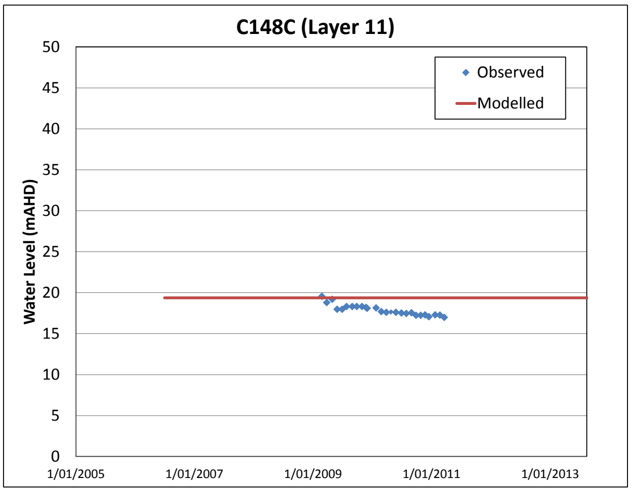

DPZ10 (Layer 11)
Observed
Modelled
Water Level (mAHD)
20
18
16
14
12
10
8
6
4
2
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

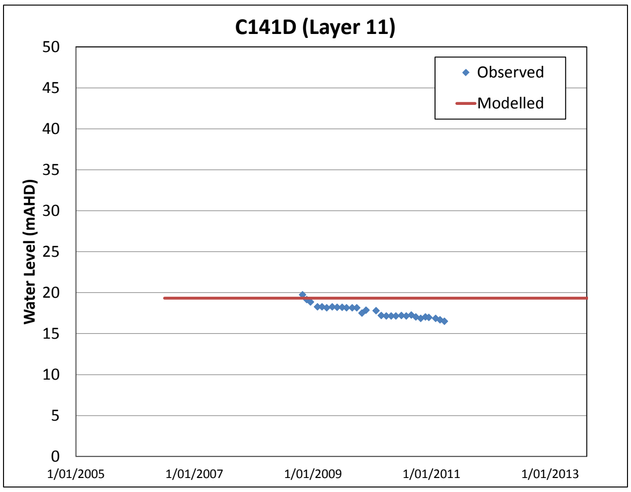

DPZ12 (Layer 11)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

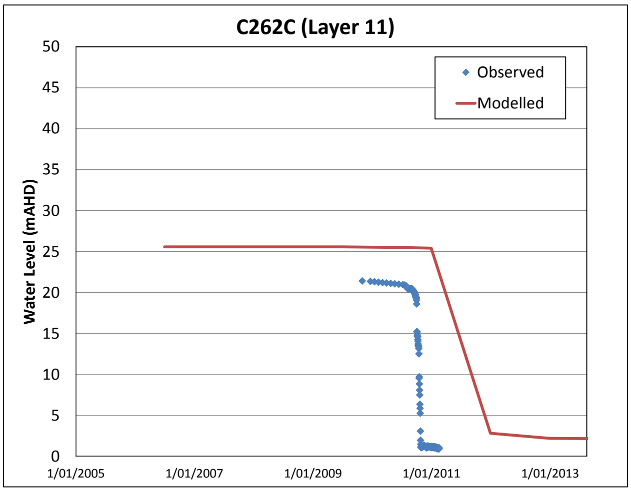

DPZ3 (Layer 11)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

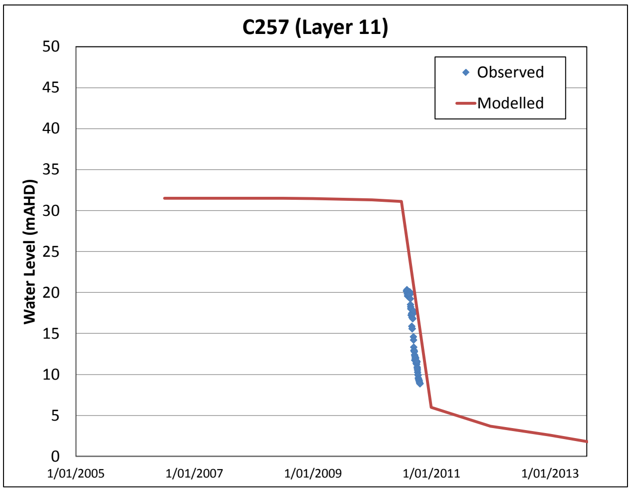

B029C (Layer 11)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

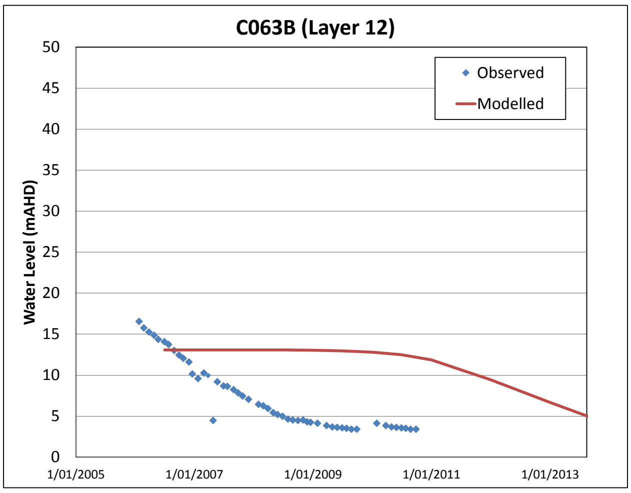

C123C (Layer 11)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

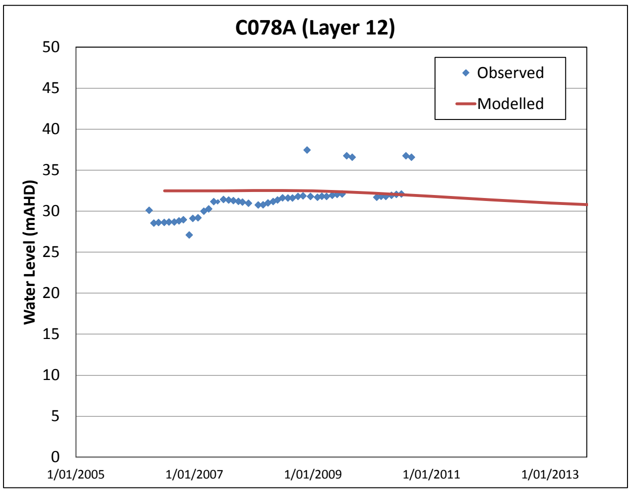

C148C (Layer 11)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

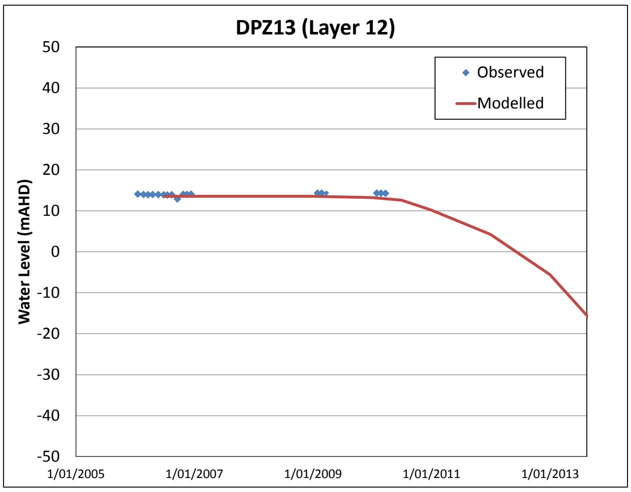

C141D (Layer 11)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

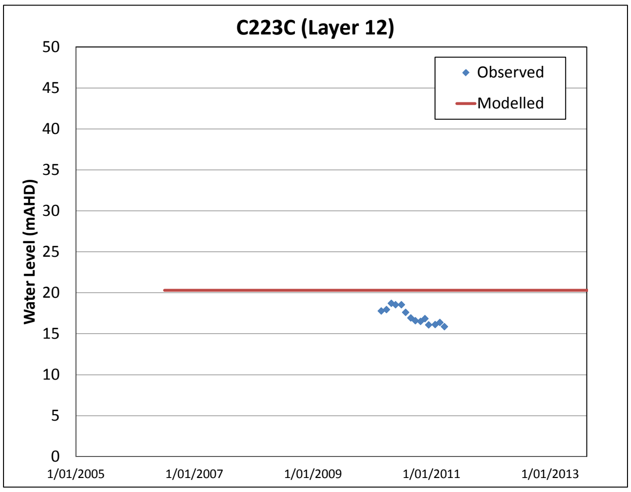

C262C (Layer 11)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

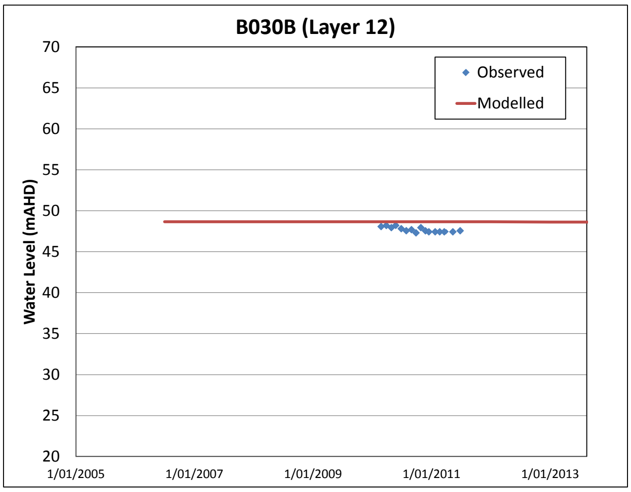

C257 (Layer 11)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

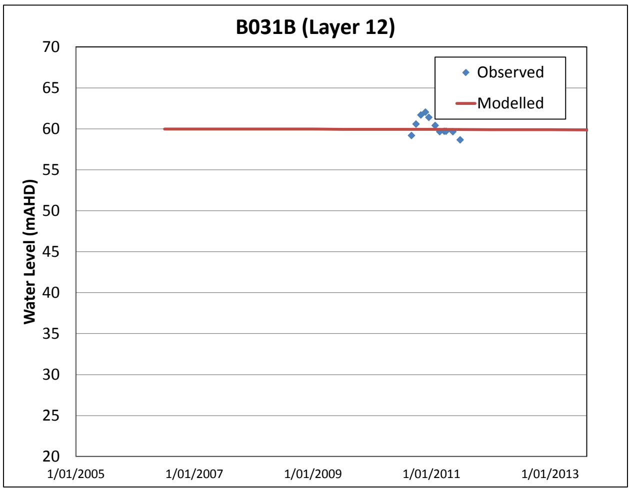

C063B (Layer 12)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

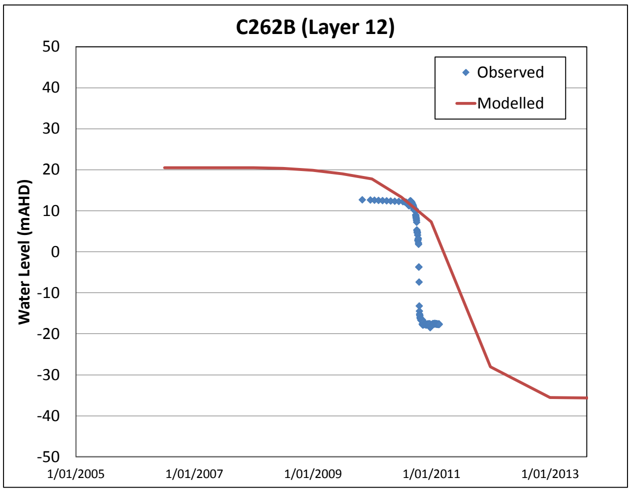

C078A (Layer 12)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

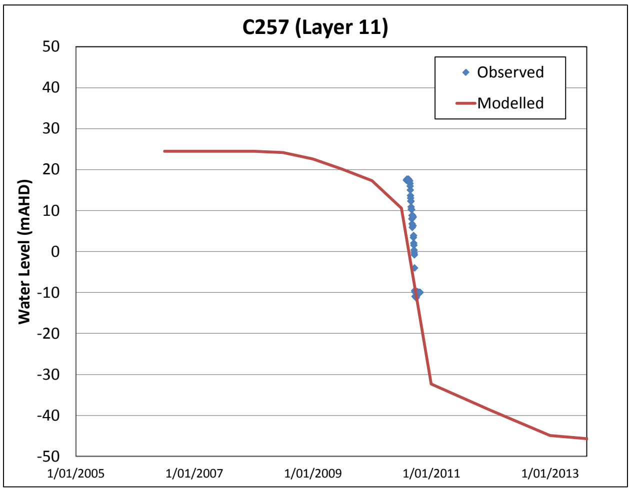

DPZ13 (Layer 12)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

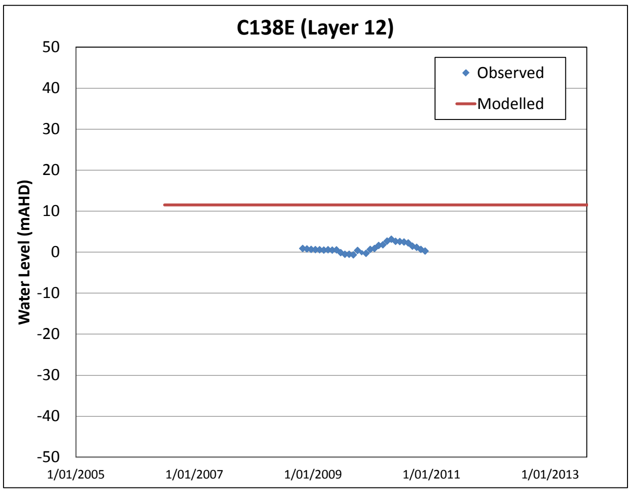

C223C (Layer 12)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

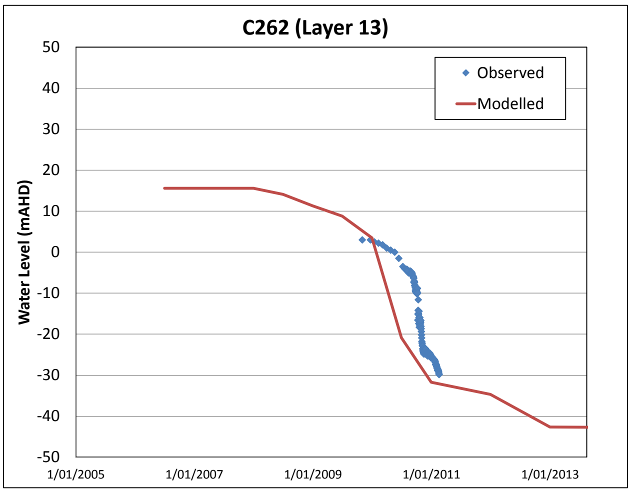

B030B (Layer 12)
Observed
Modelled
Water Level (mAHD)
70
65
60
55
50
45
40
35
30
25
20
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

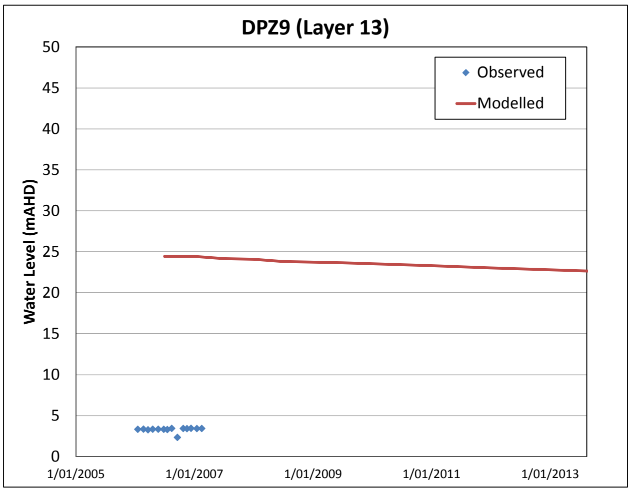

B031B (Layer 12)
Observed
Modelled
Water Level (mAHD)
70
65
60
55
50
45
40
35
30
25
20
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

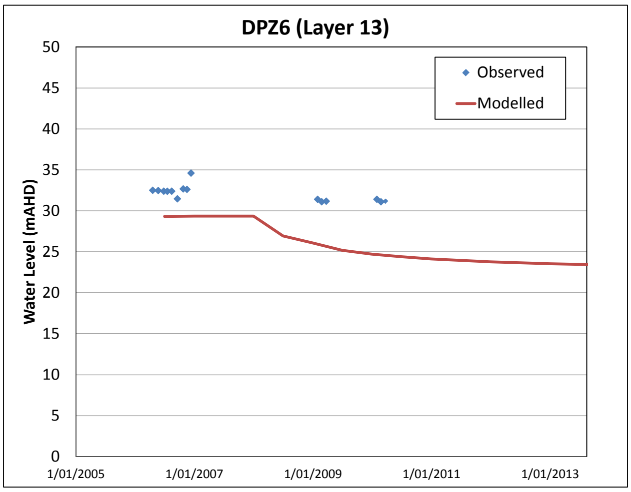

C262B (Layer 12)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

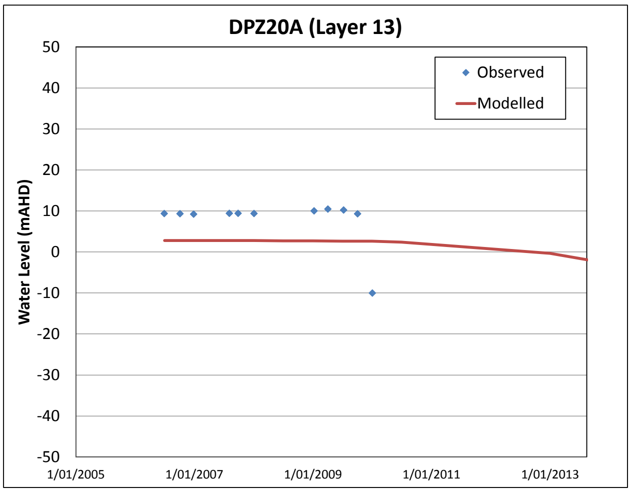

C257 (Layer 11)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

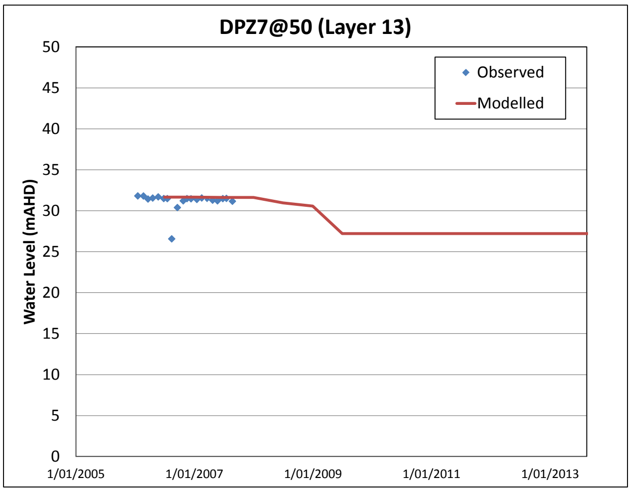

C138E (Layer 12)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

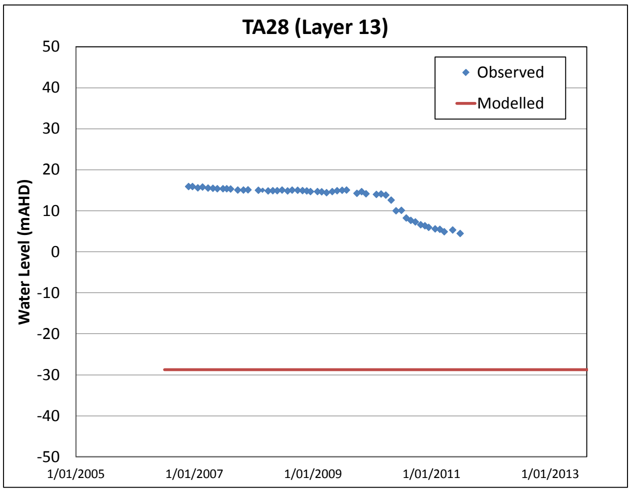

C262 (Layer 13)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


DPZ9 (Layer 13)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


DPZ6 (Layer 13)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


DPZ20A (Layer 13)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


DPZ7@50 (Layer 13)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


TA28 (Layer 13)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
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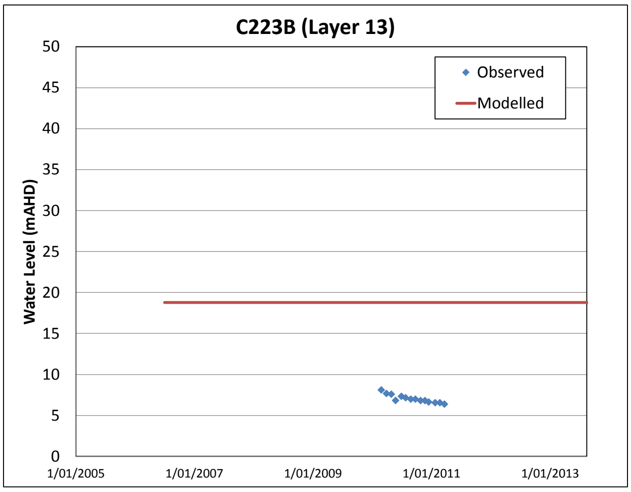
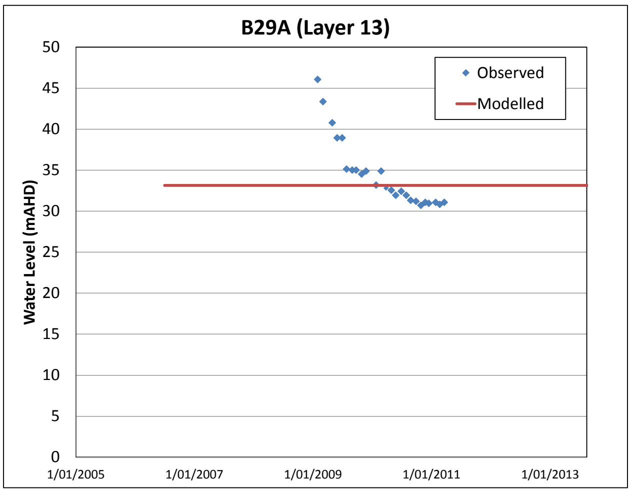
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


C223B (Layer 13)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


B29A (Layer 13)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
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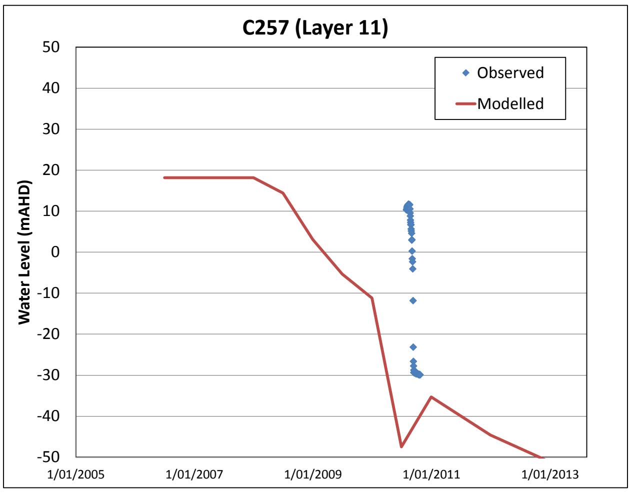
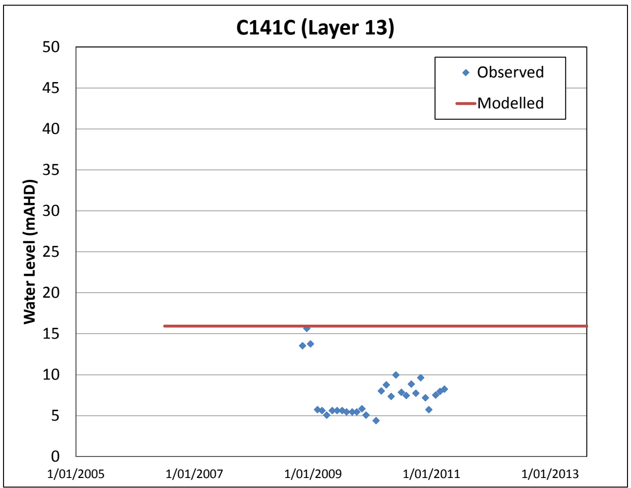
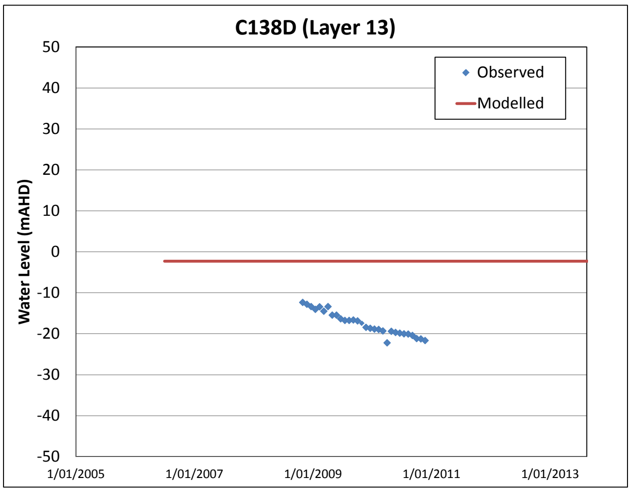
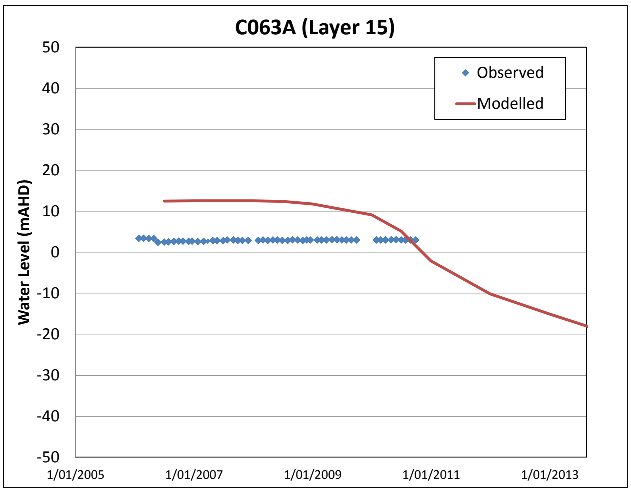
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


C257 (Layer 11)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


C141C (Layer 13)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


C138D (Layer 13)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


C063A (Layer 15)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
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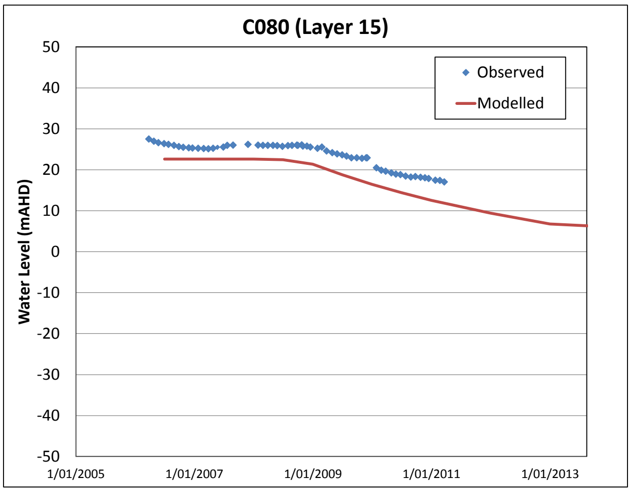
1/01/2009
1/01/2011
1/01/2013


C080 (Layer 15)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
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1/01/2005
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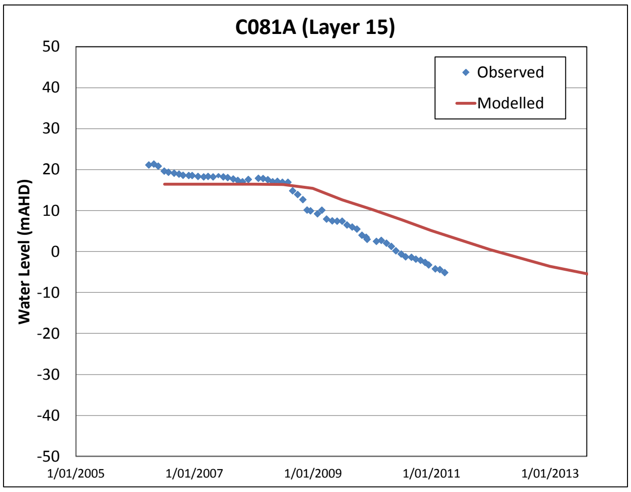
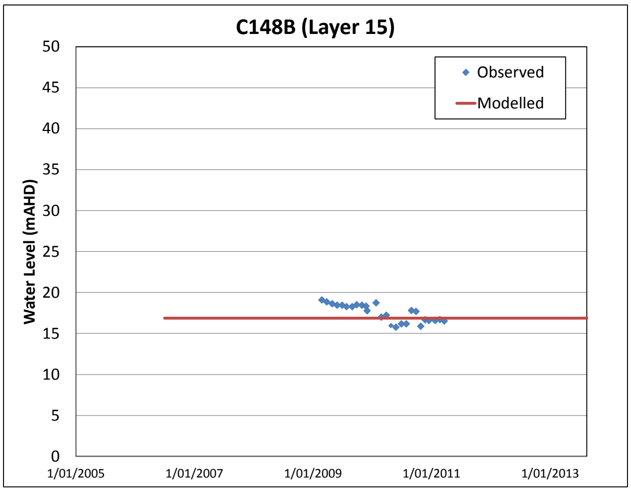
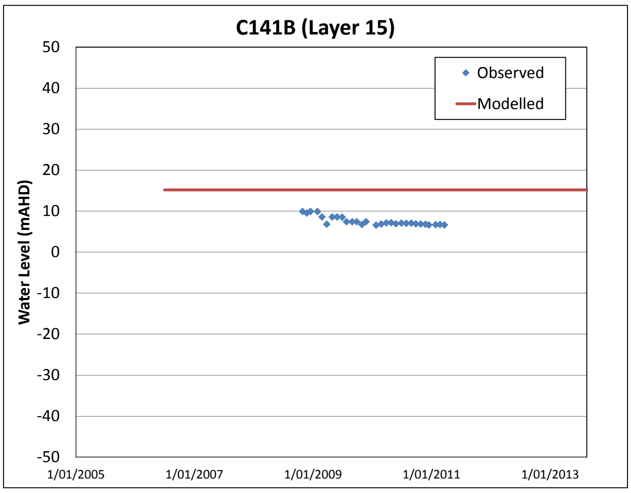
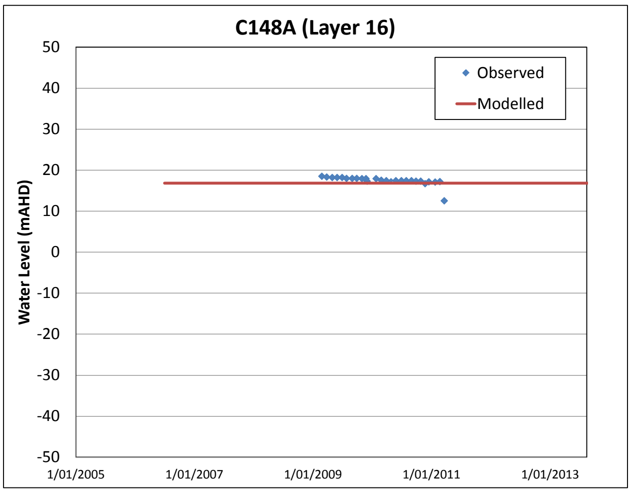
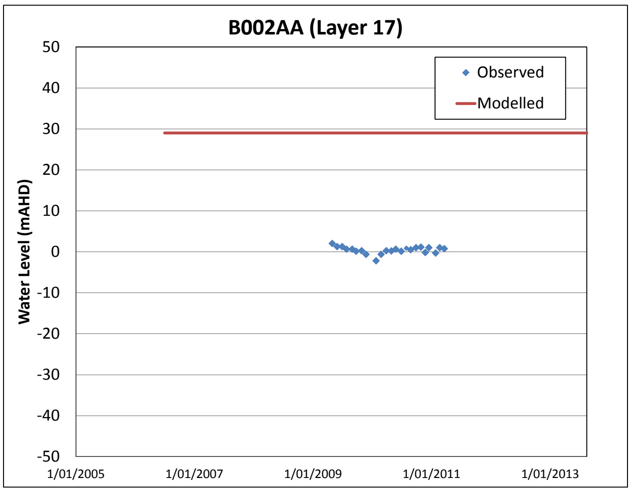
1/01/2011
1/01/2013

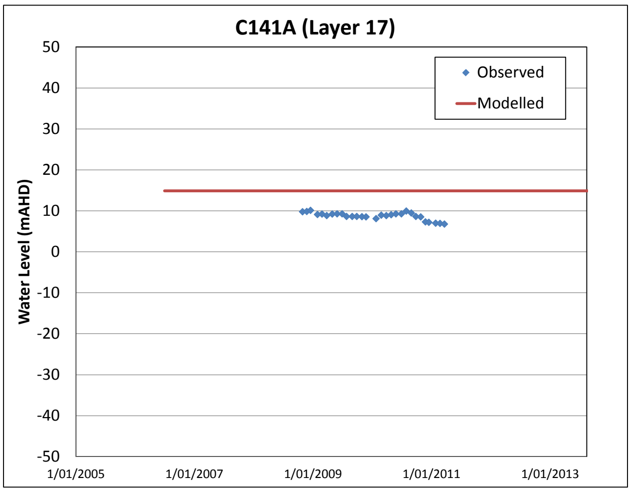

C081A (Layer 15)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

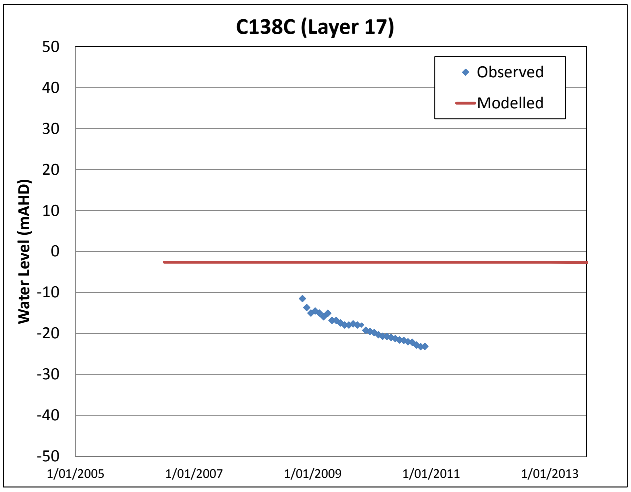

C148B (Layer 15)
Observed
Modelled
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

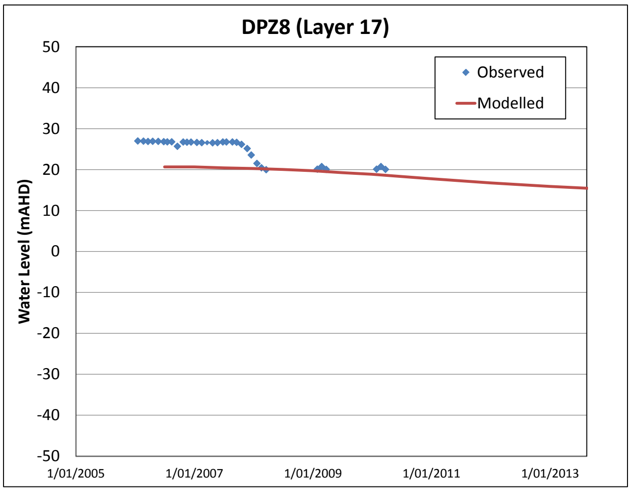

C141B (Layer 15)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

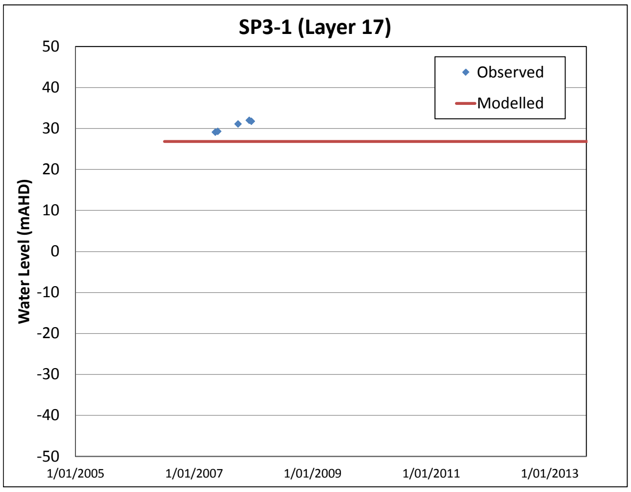

C148A (Layer 16)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

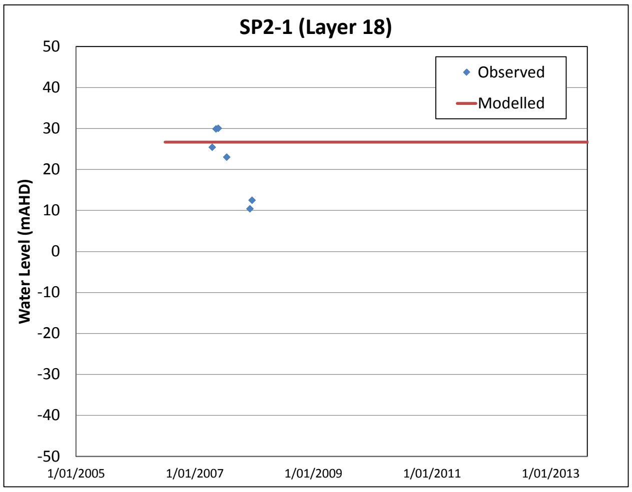

B002AA (Layer 17)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

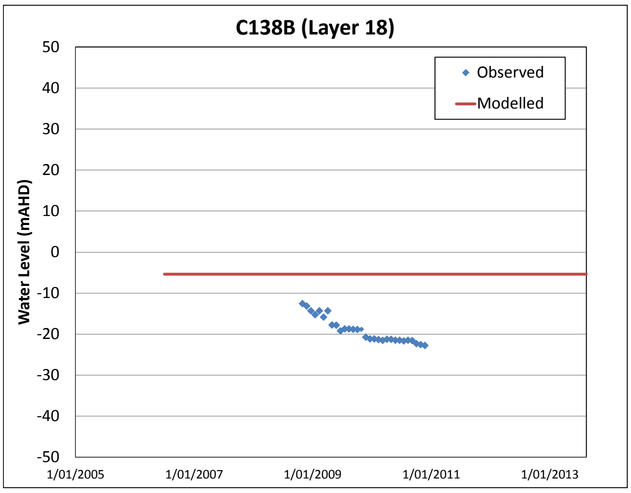

C141A (Layer 17)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

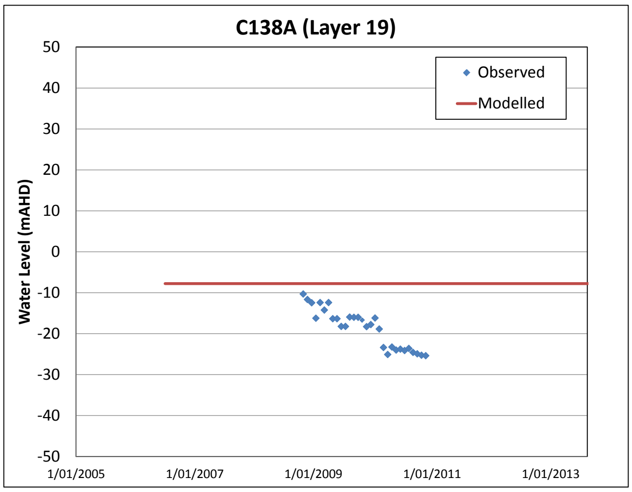

C138C (Layer 17)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


DPZ8 (Layer 17)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


SP3-1 (Layer 17)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

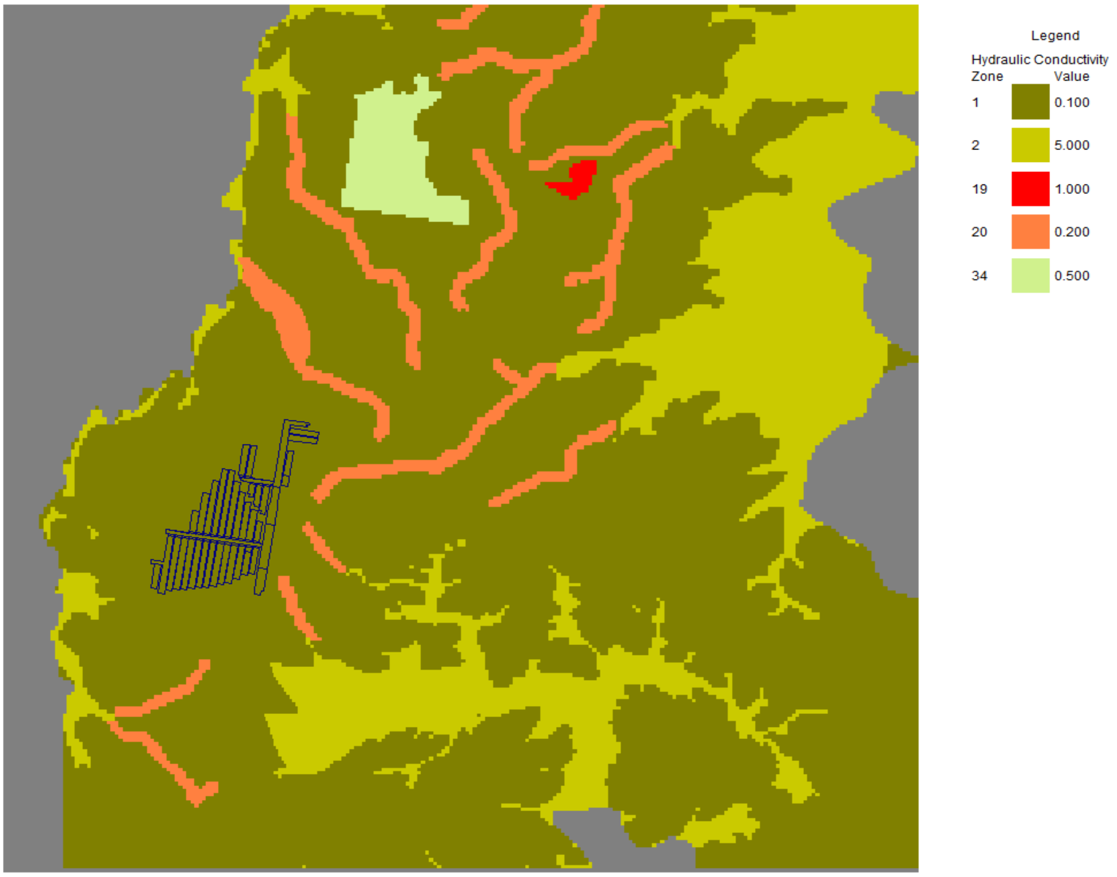

SP2-1 (Layer 18)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013


C138B (Layer 18)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

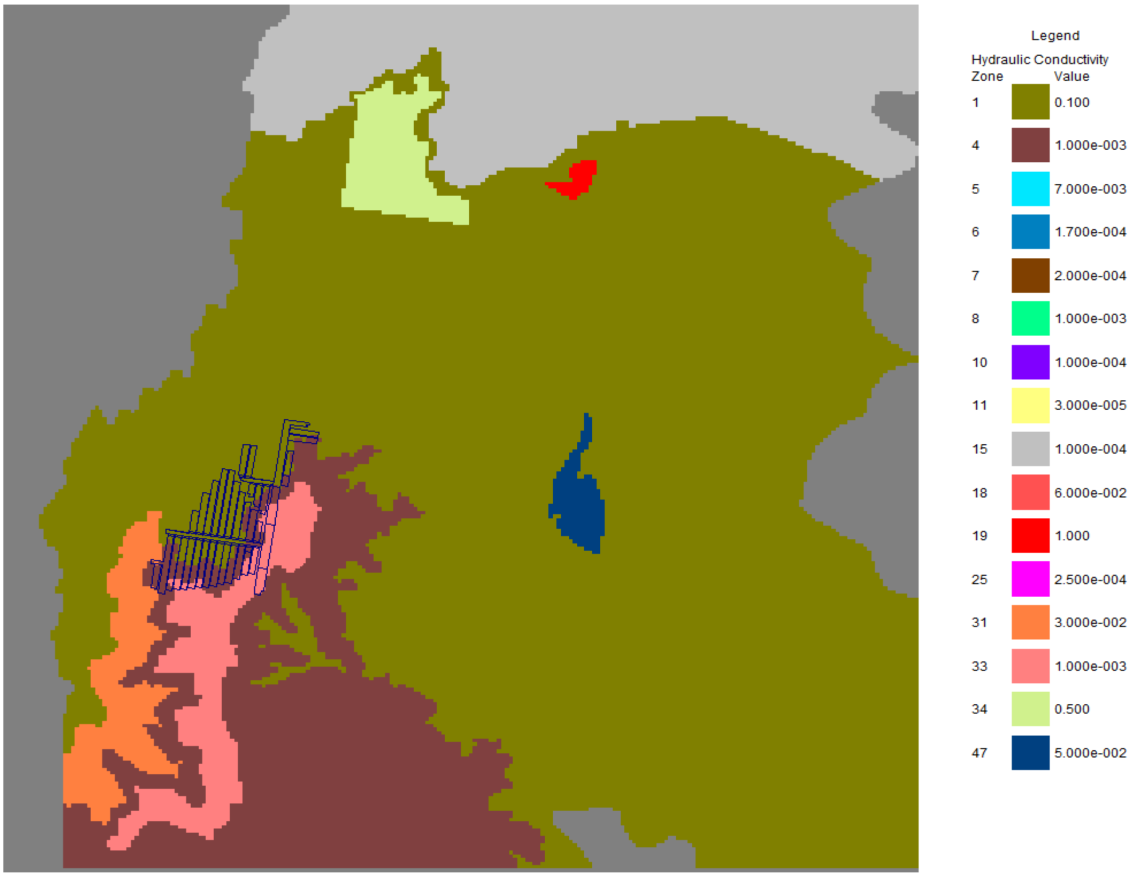

C138A (Layer 19)
Observed
Modelled
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2007
1/01/2009
1/01/2011
1/01/2013

APPENDIX G:
MODEL LAYER HYDRAULIC CONDUCTIVITY

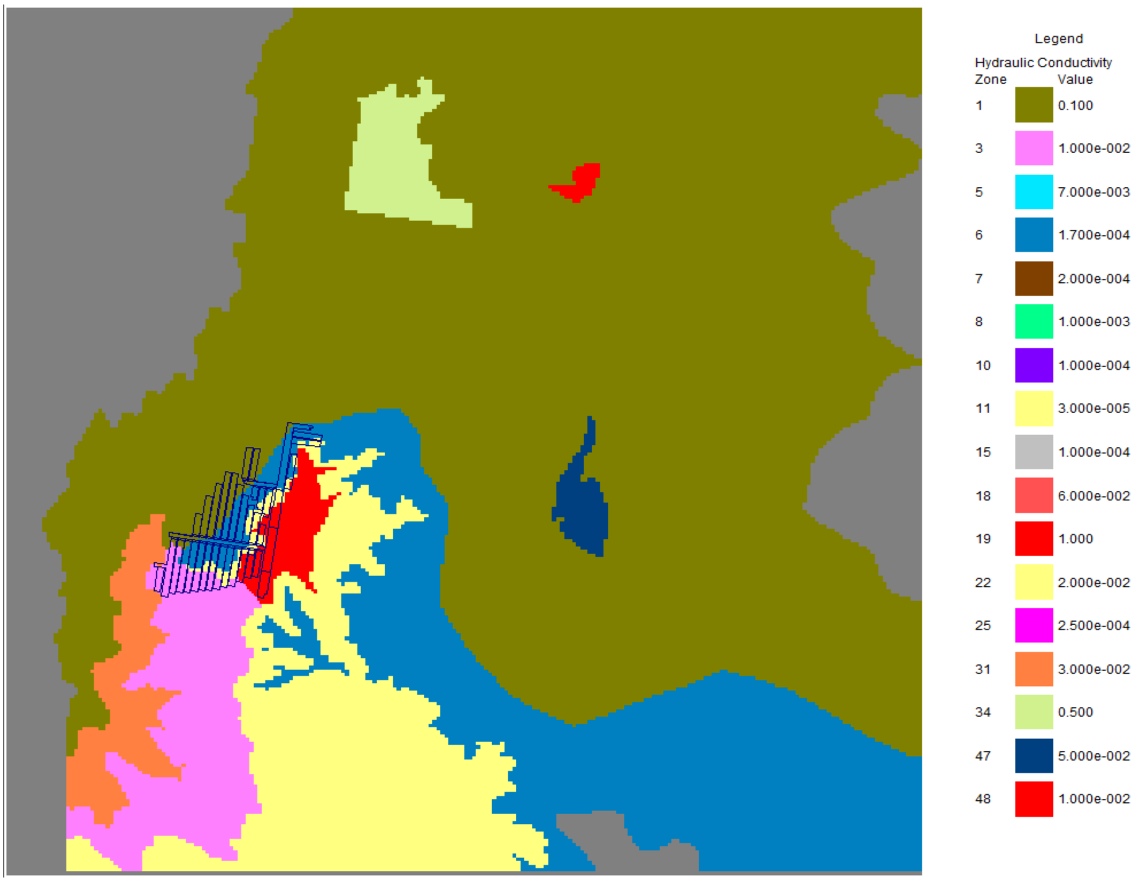
Hydraulic Conductivity for Model Layer 1



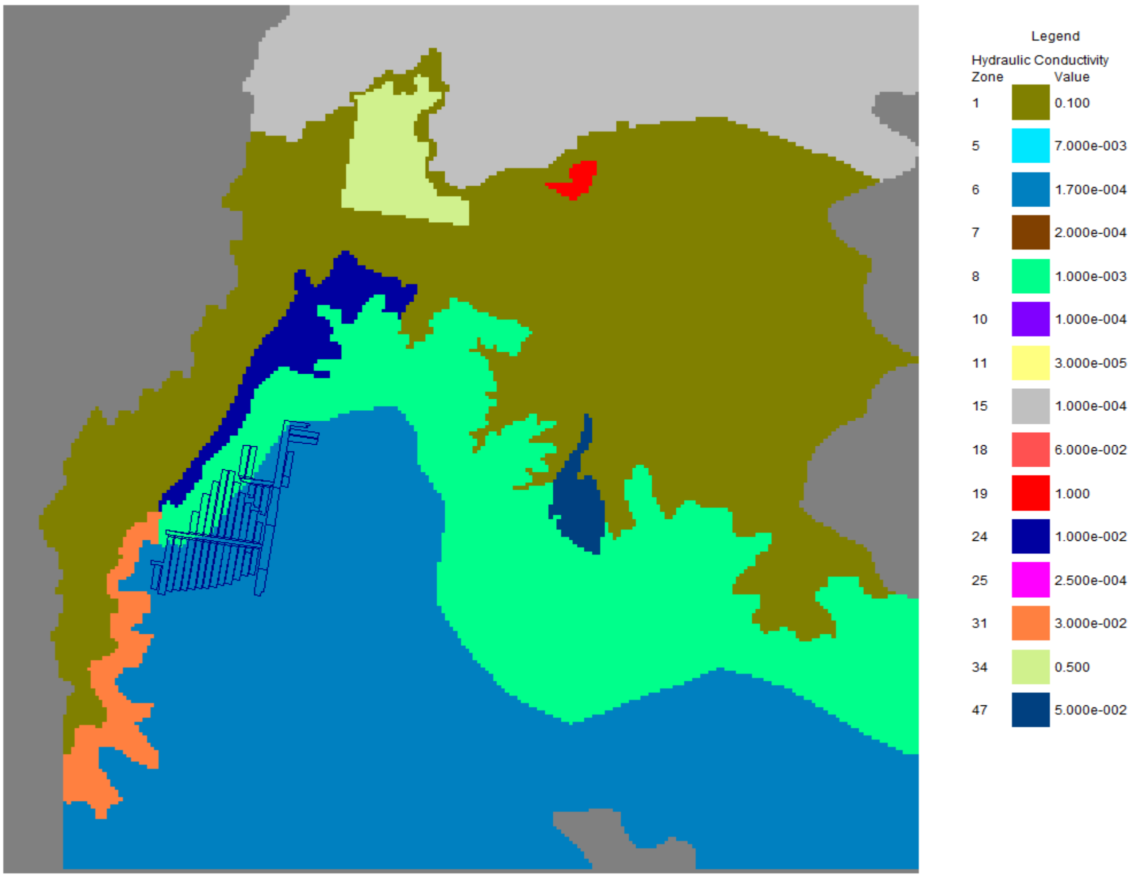
Hydraulic Conductivity for Model Layer 2



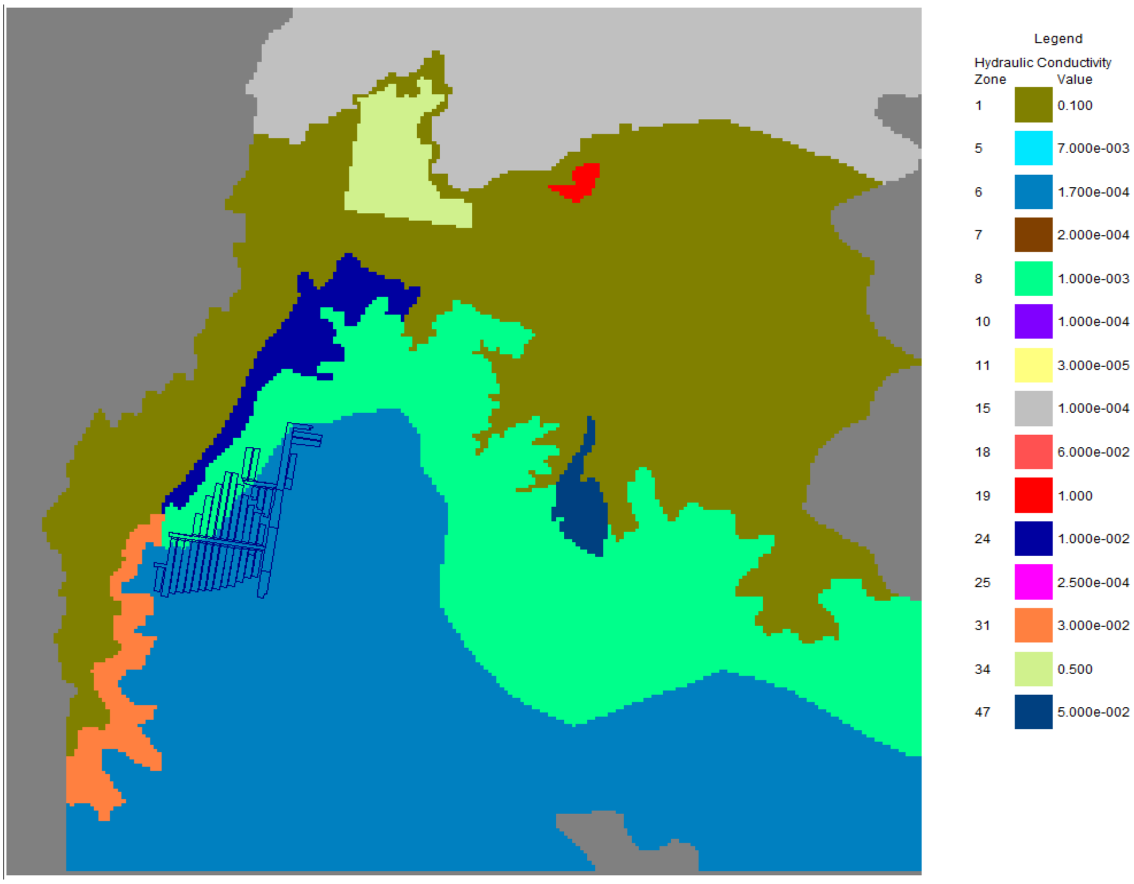
Hydraulic Conductivity for Model Layer 3



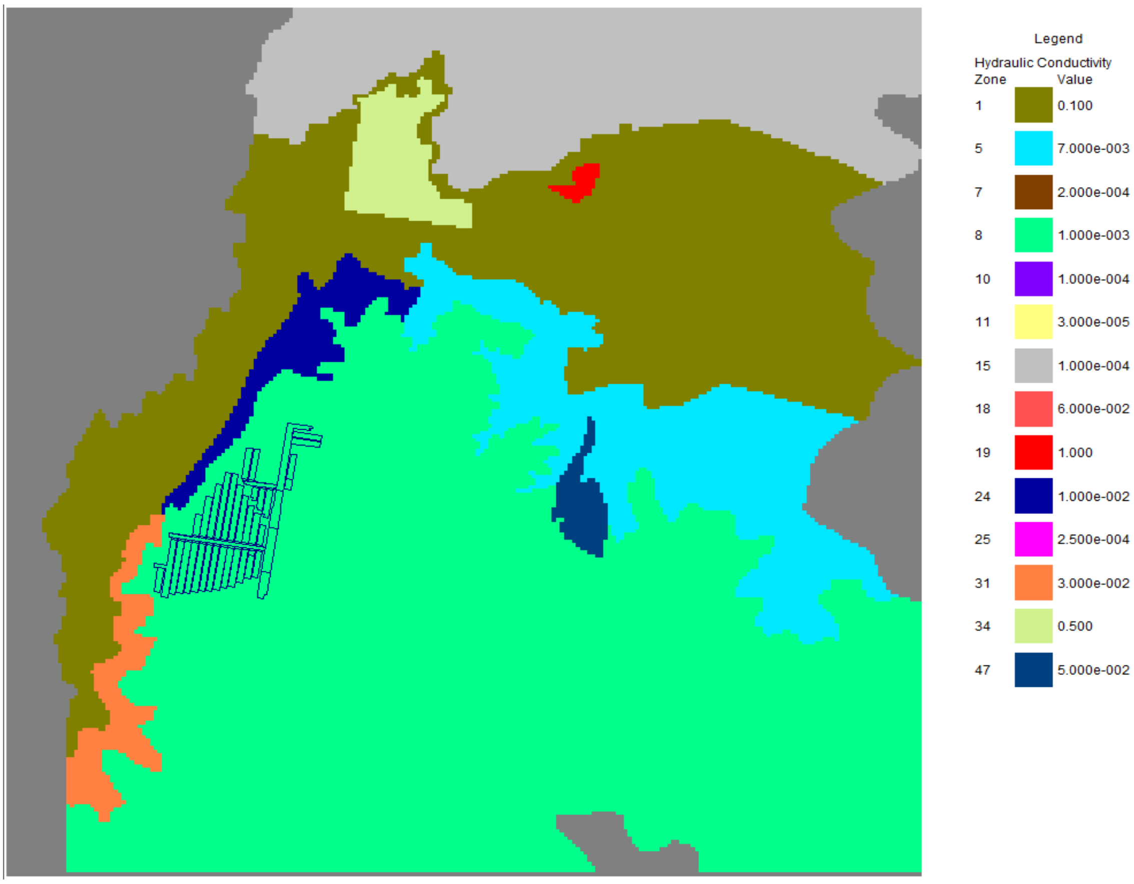
Hydraulic Conductivity for Model Layer 4



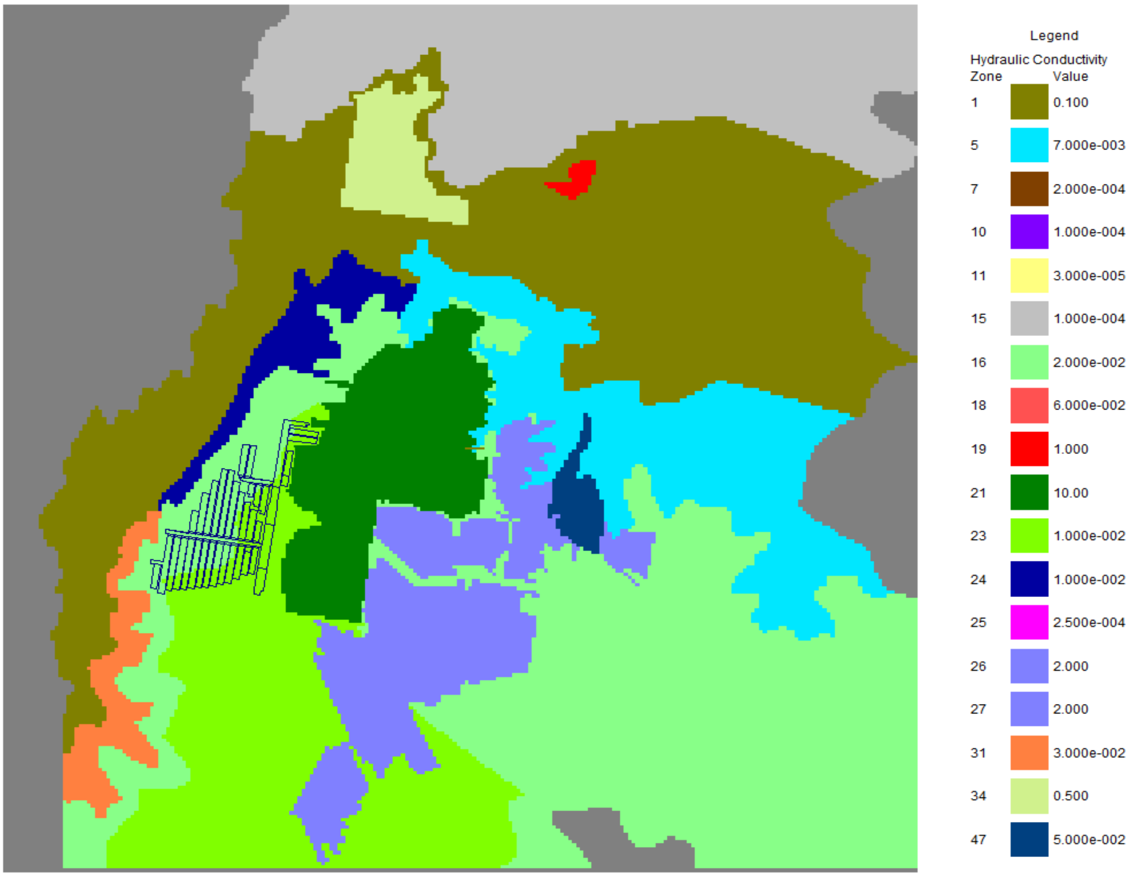
Hydraulic Conductivity for Model Layer 5



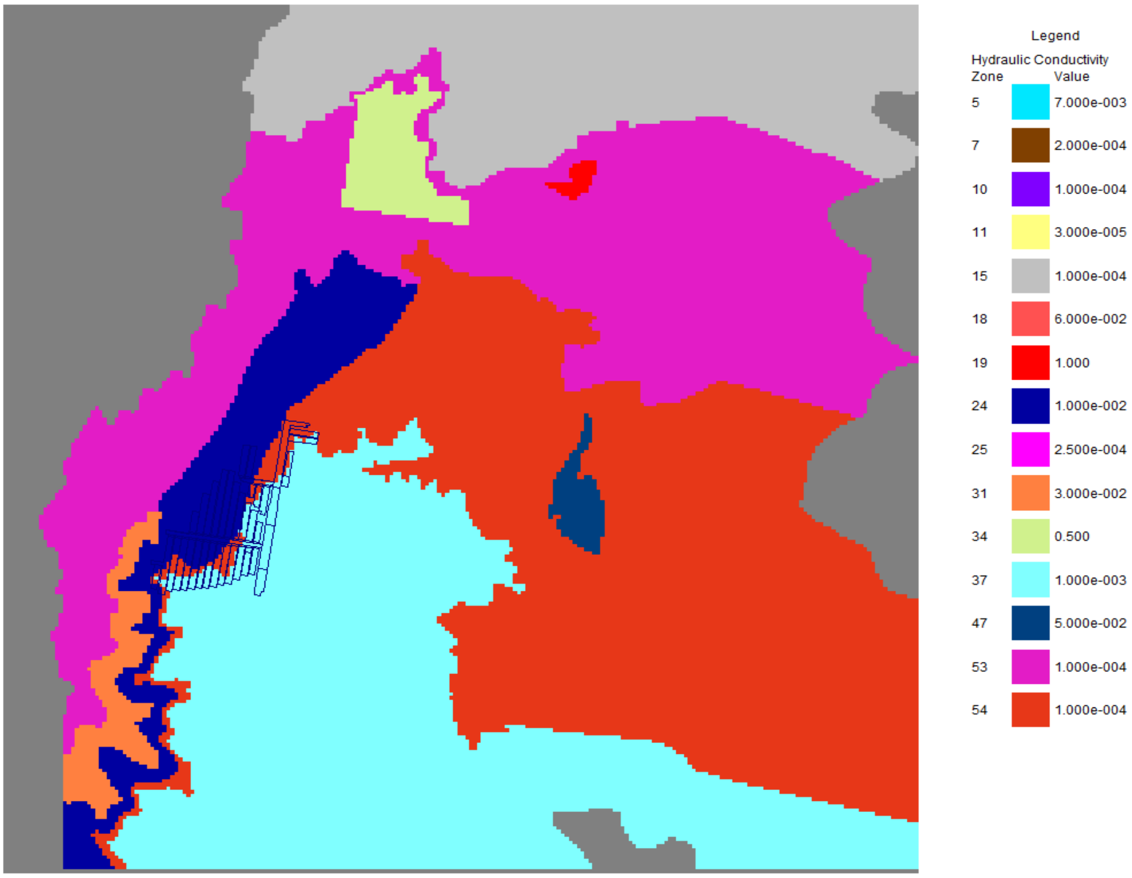
Hydraulic Conductivity for Model Layer 6



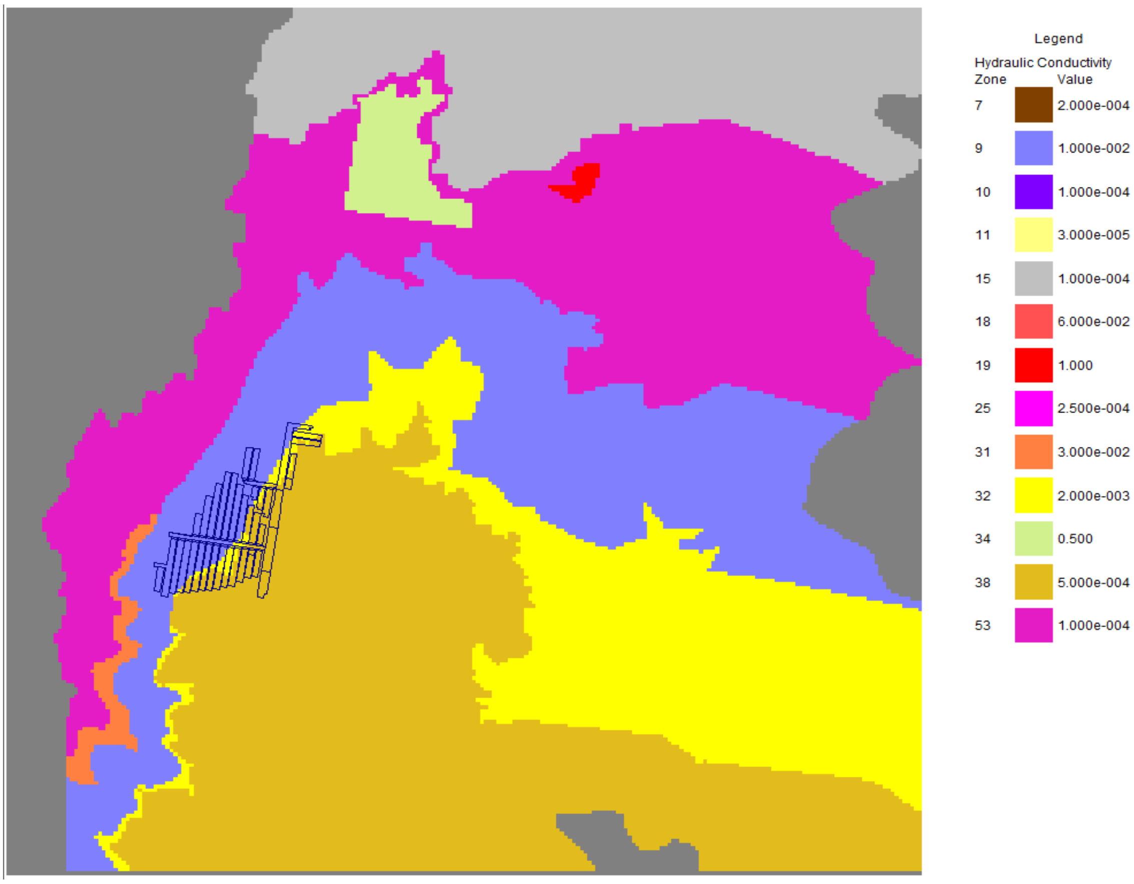
Hydraulic Conductivity for Model Layer 7



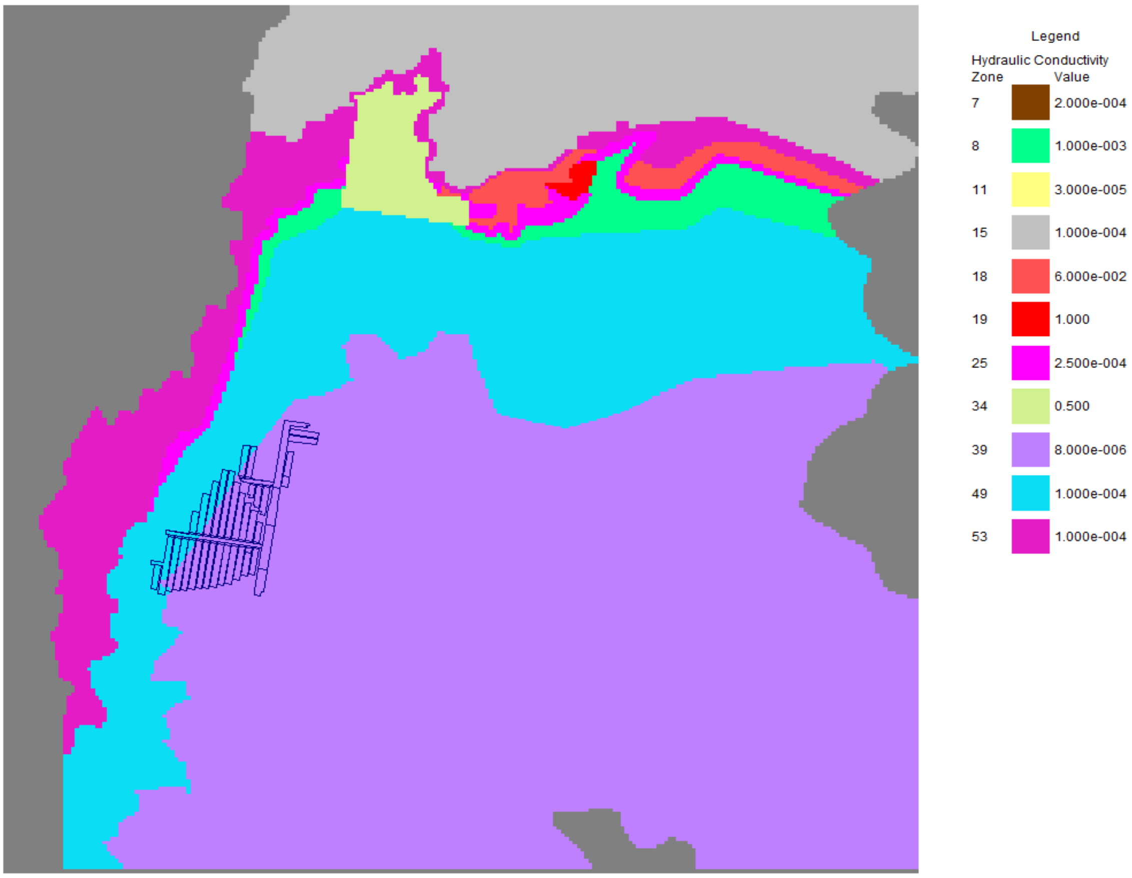
Hydraulic Conductivity for Model Layer 8



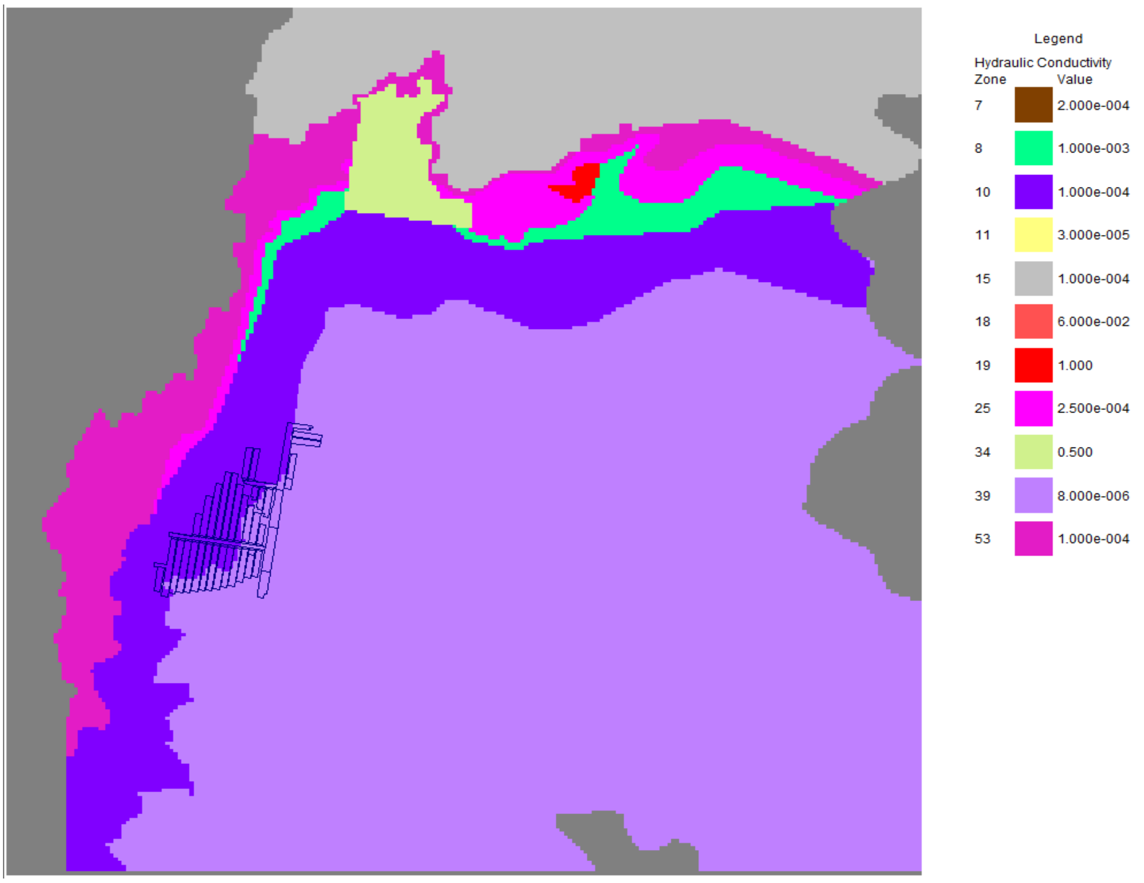
Hydraulic Conductivity for Model Layer 9



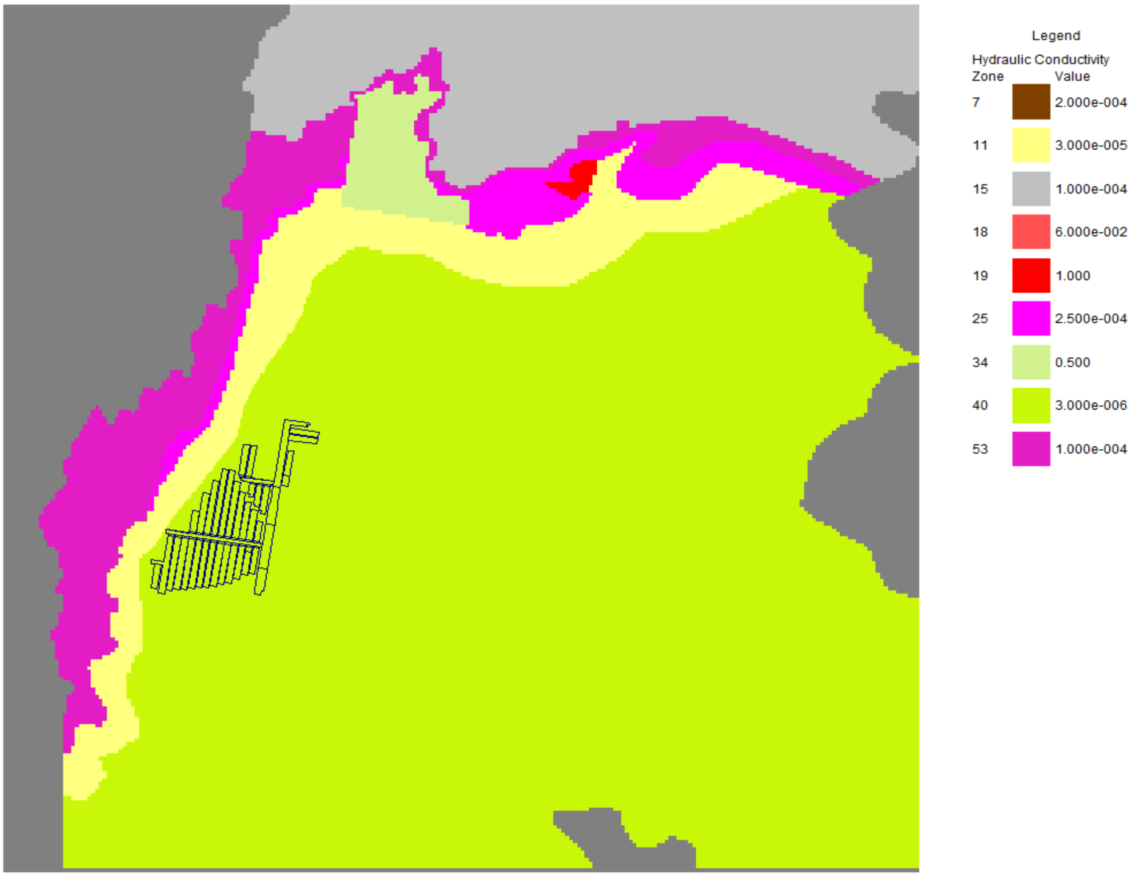
Hydraulic Conductivity for Model Layer 10



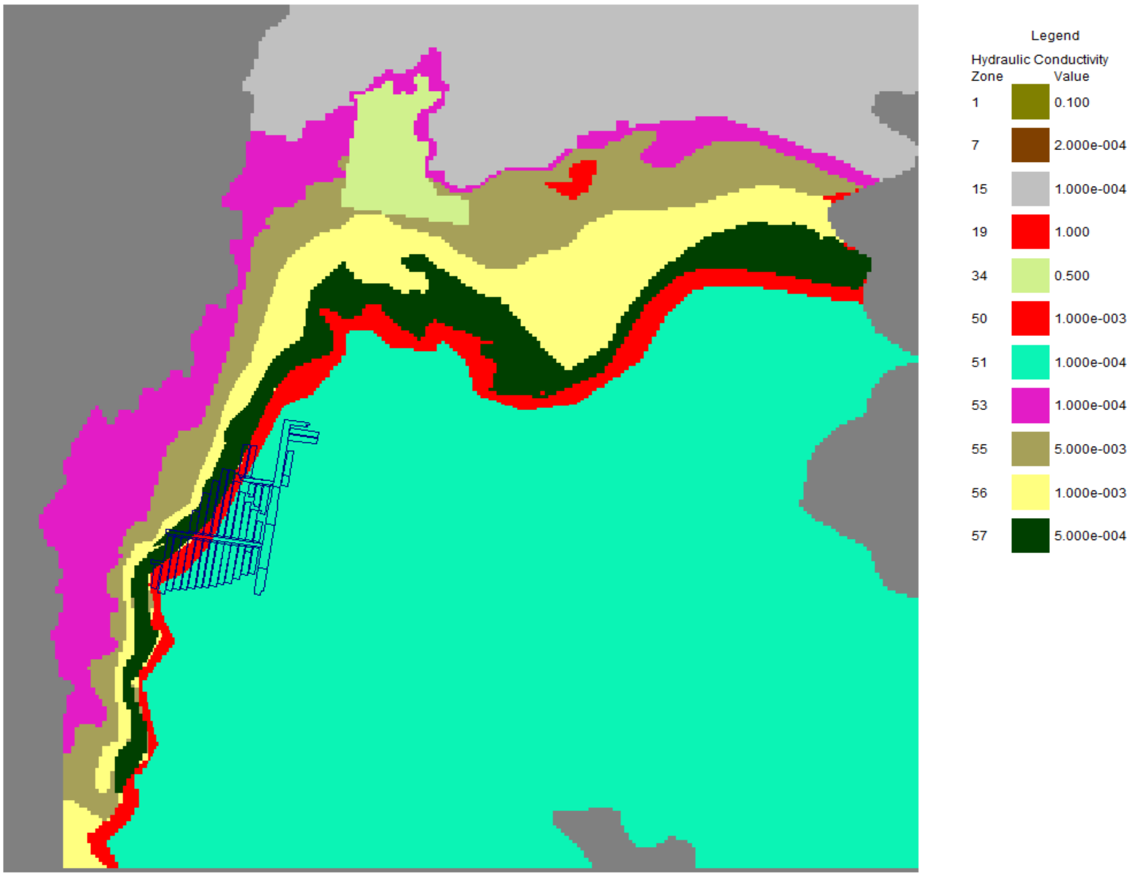
Hydraulic Conductivity for Model Layer 11



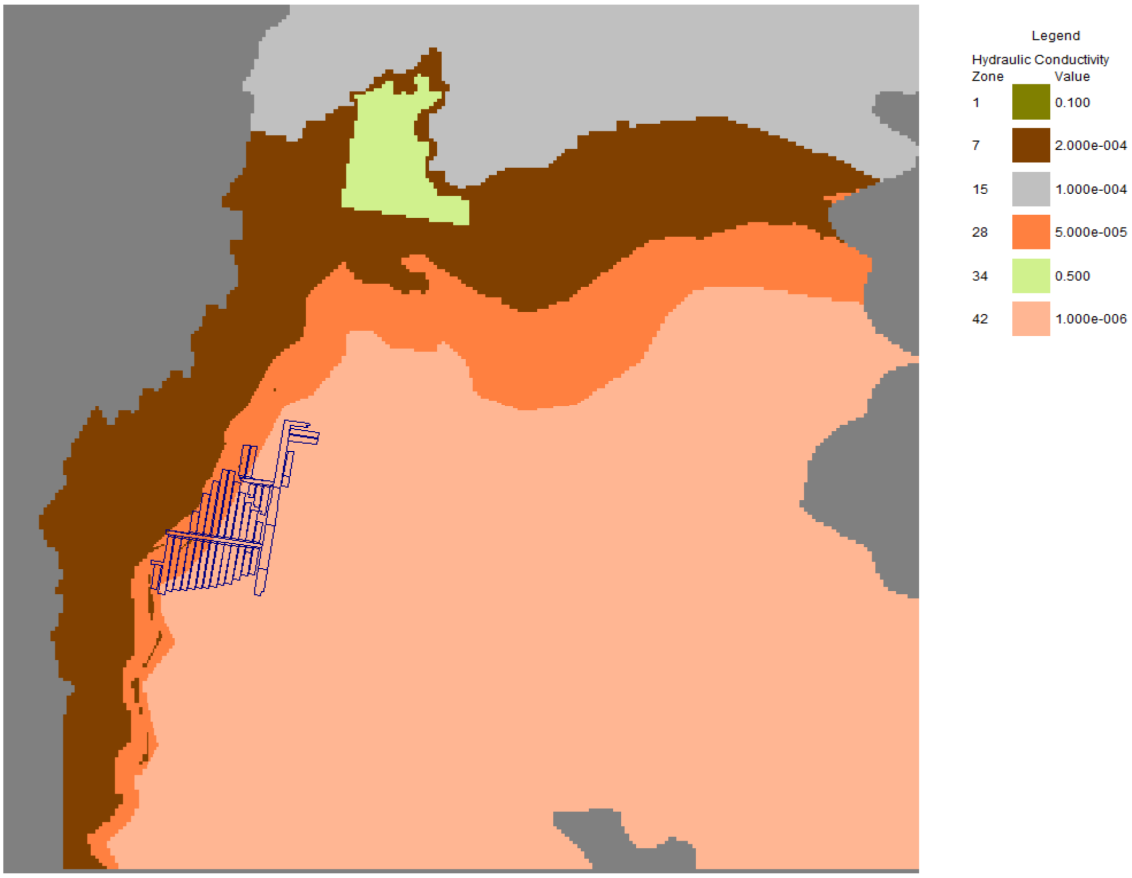
Hydraulic Conductivity for Model Layer 12



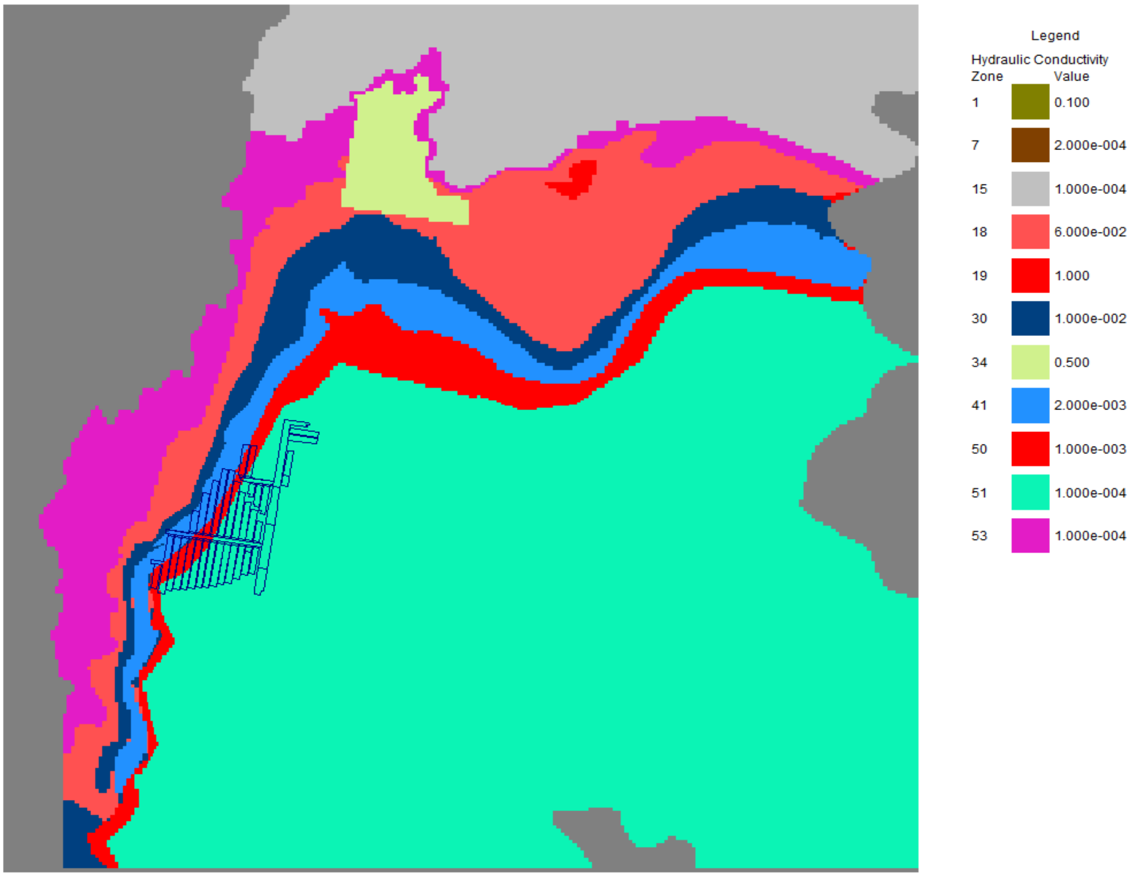
Hydraulic Conductivity for Model Layer 13



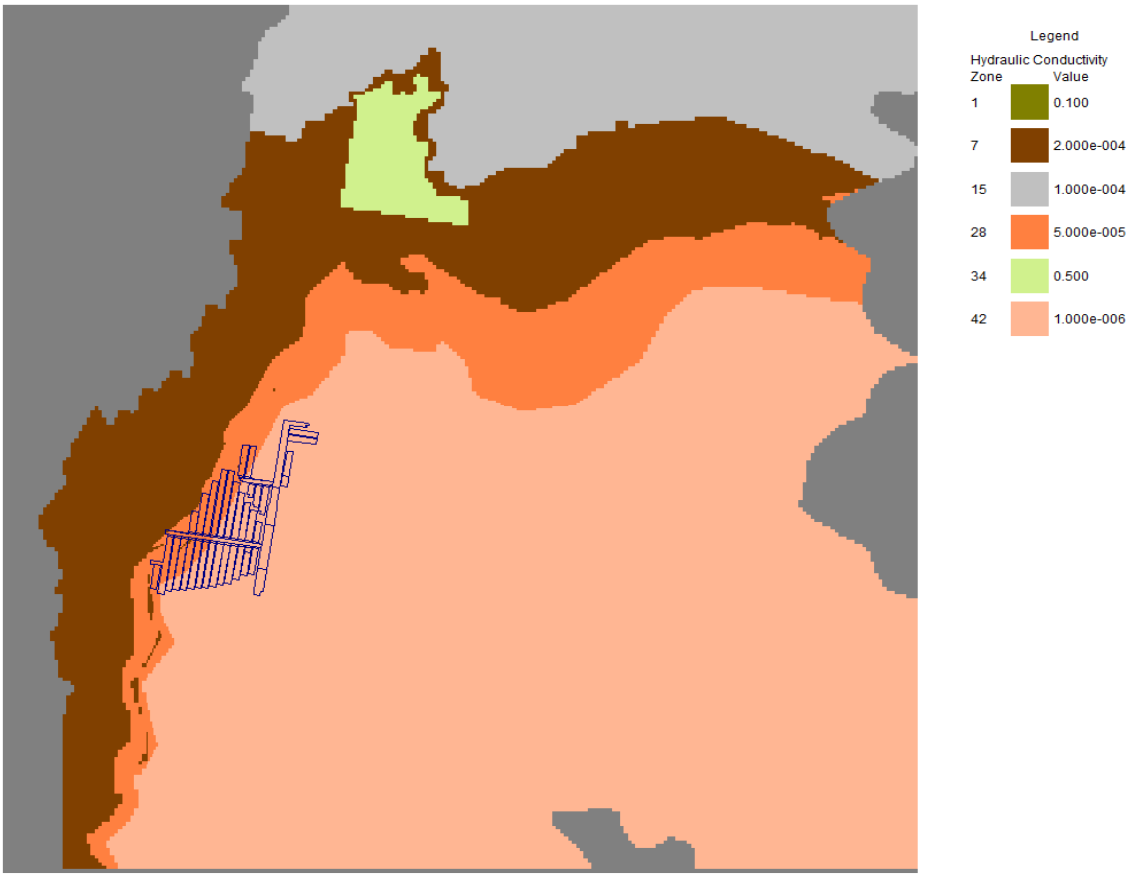
Hydraulic Conductivity for Model Layer 14



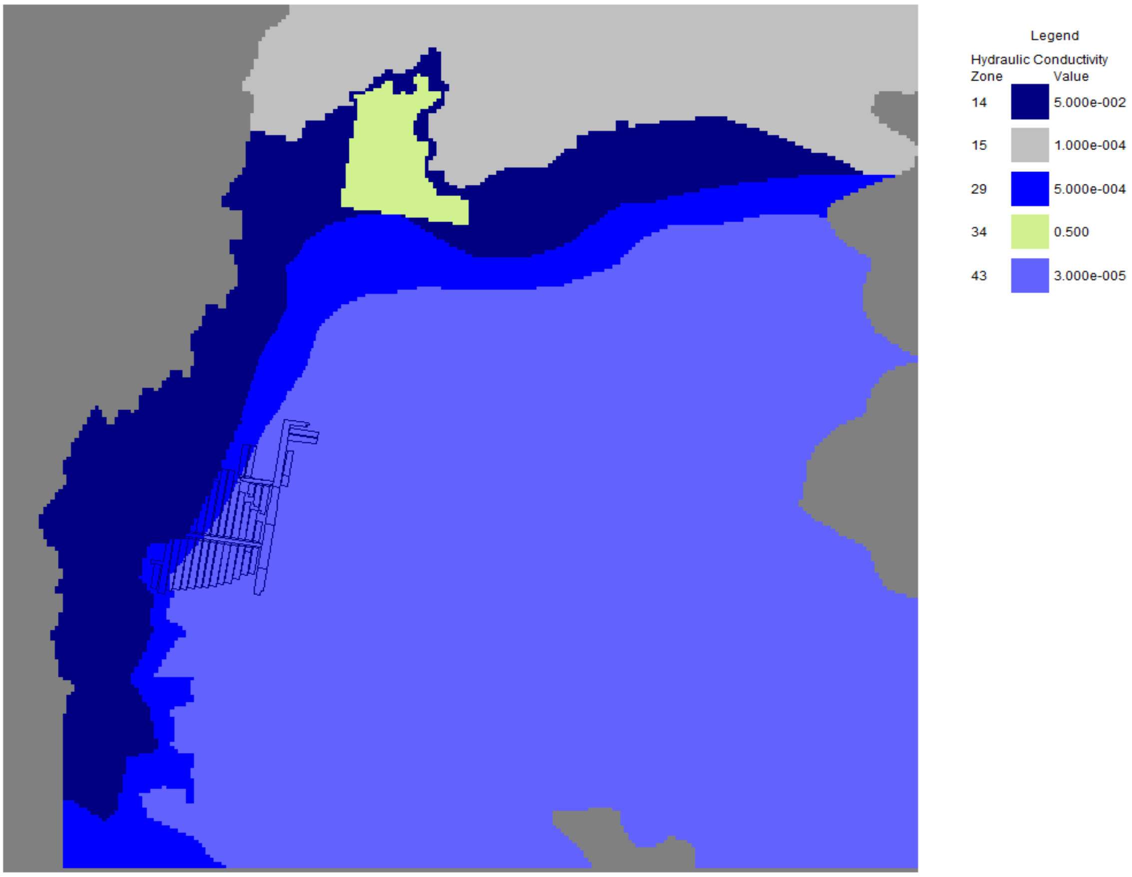
Hydraulic Conductivity for Model Layer 15



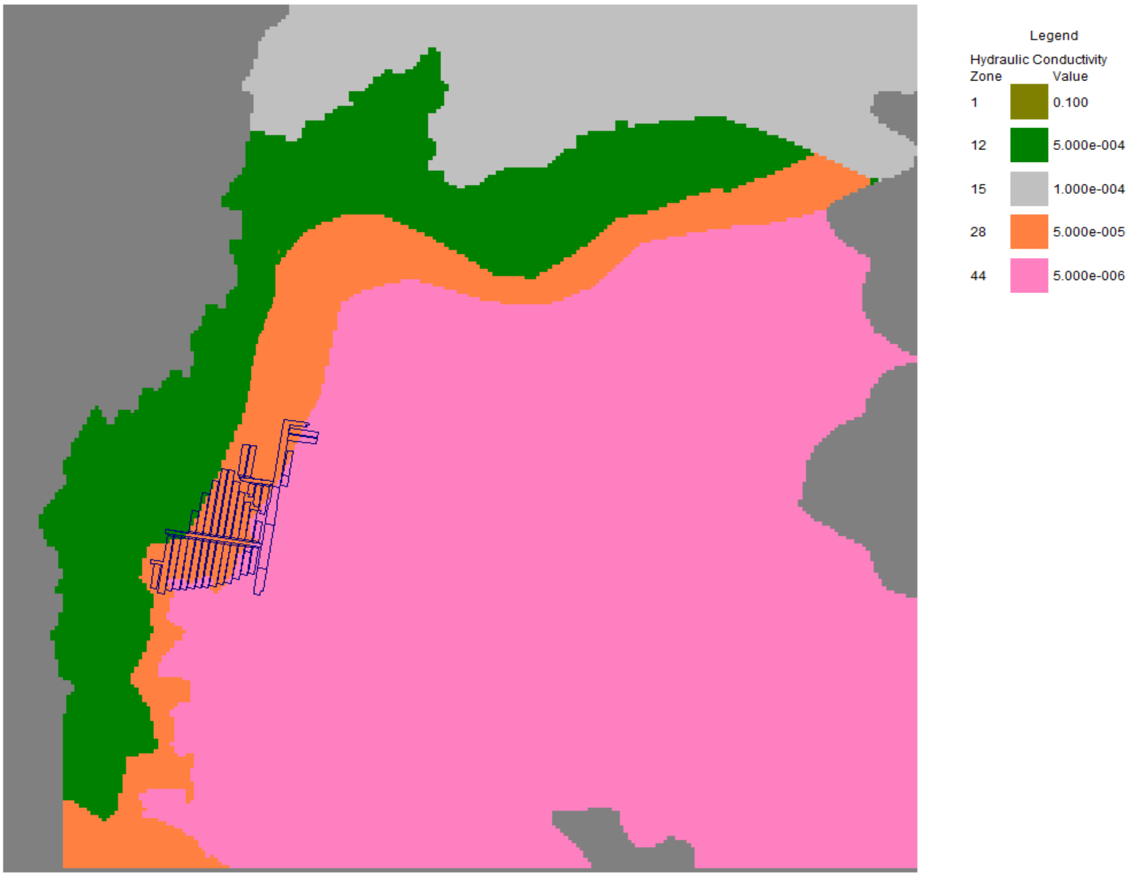
Hydraulic Conductivity for Model Layer 16



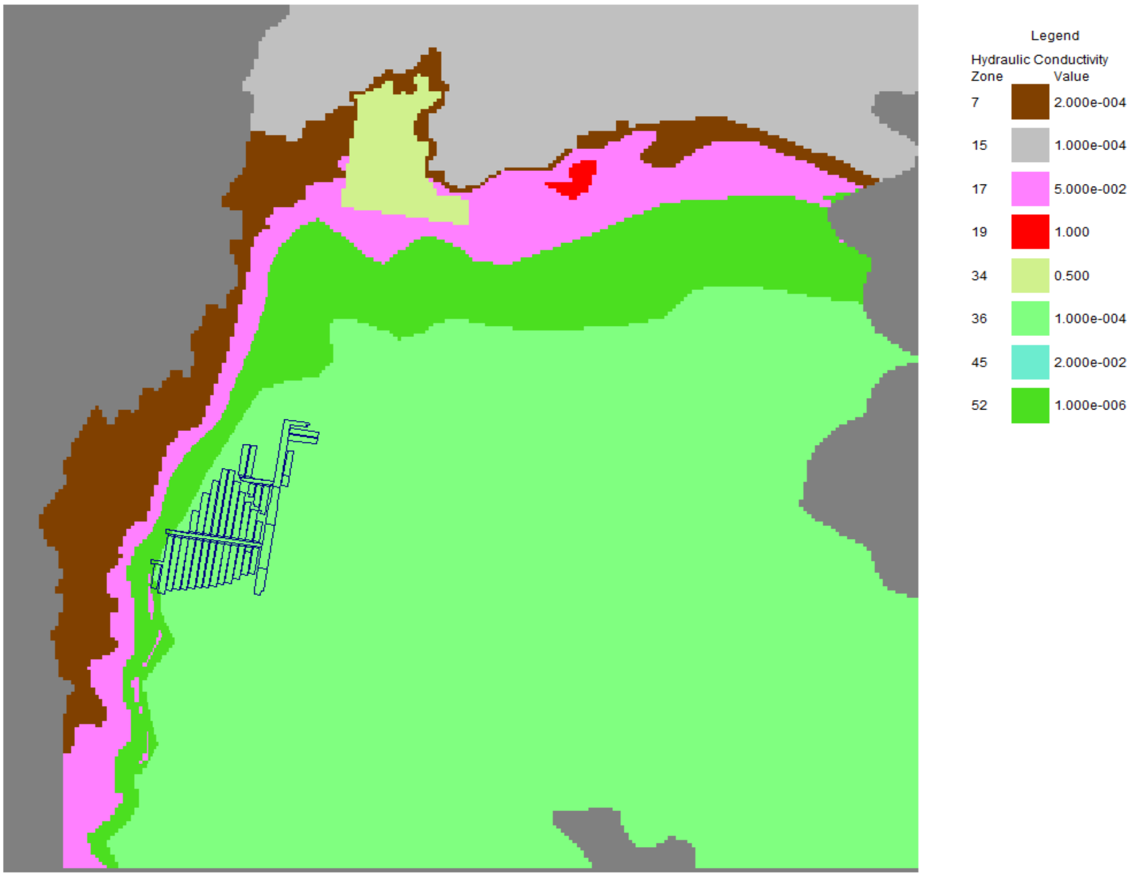
Hydraulic Conductivity for Model Layer 17



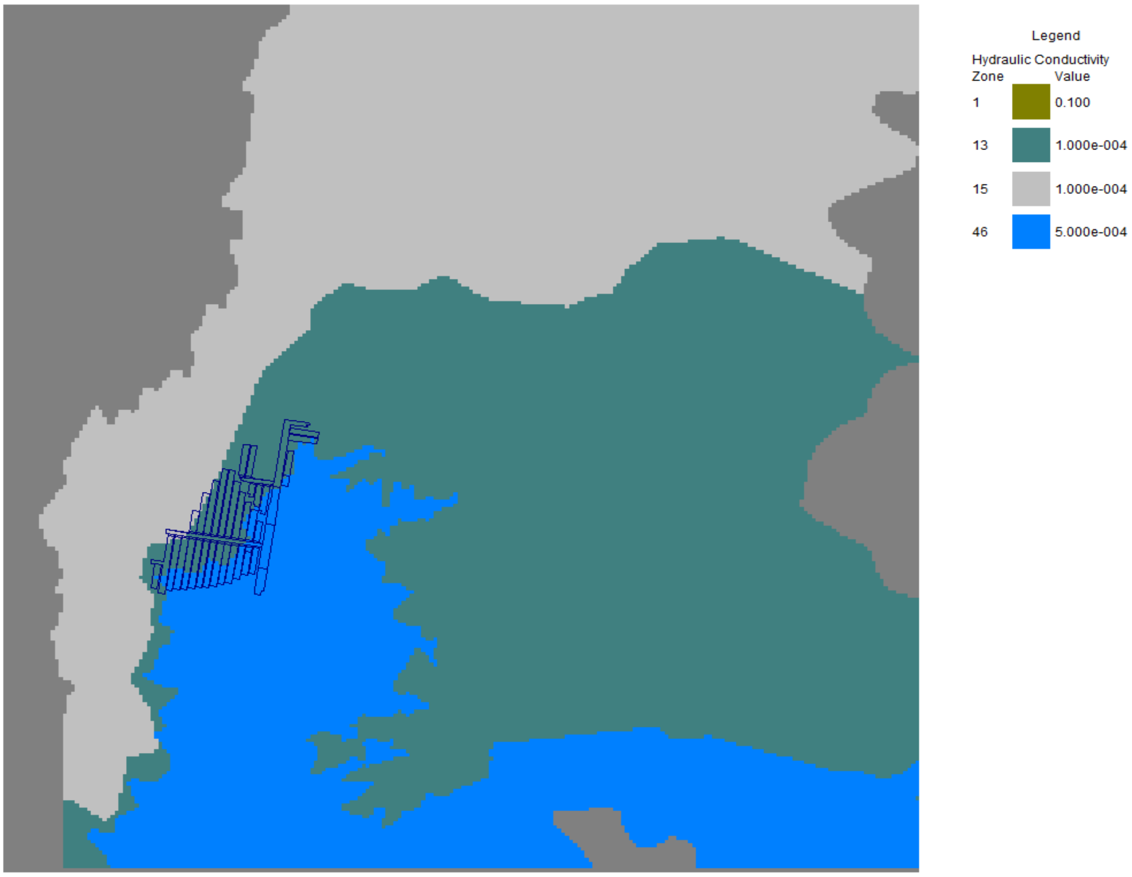
Hydraulic Conductivity for Model Layer 18



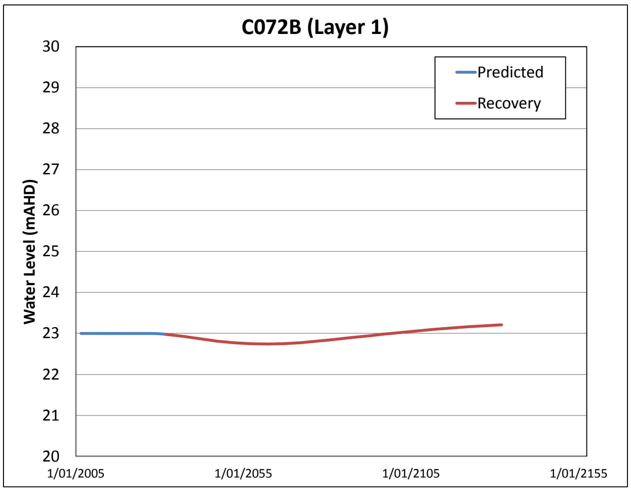
Hydraulic Conductivity for Model Layer 19

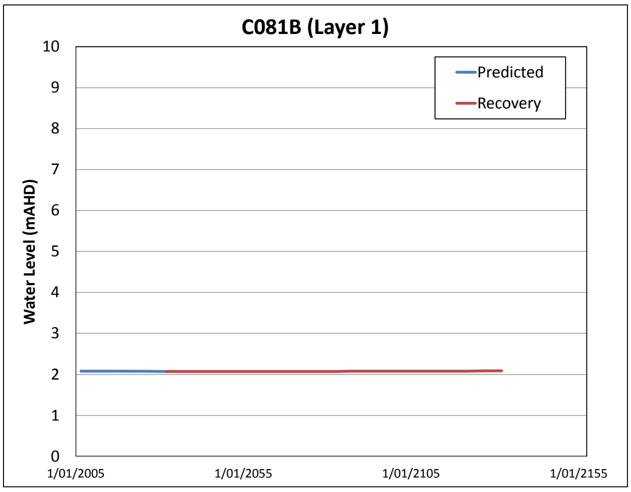


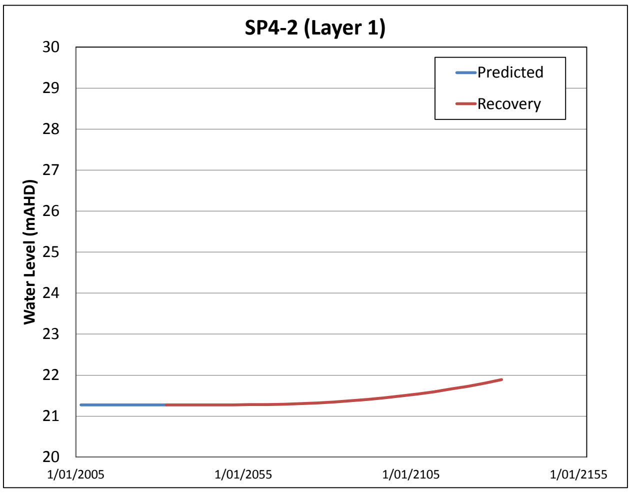
Hydraulic Conductivity for Model Layer 20

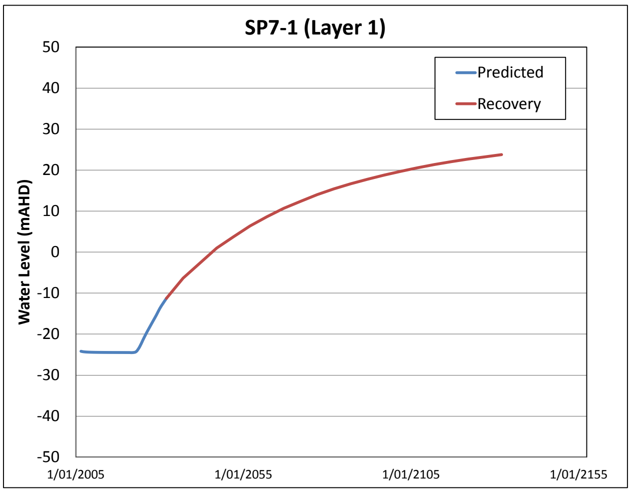


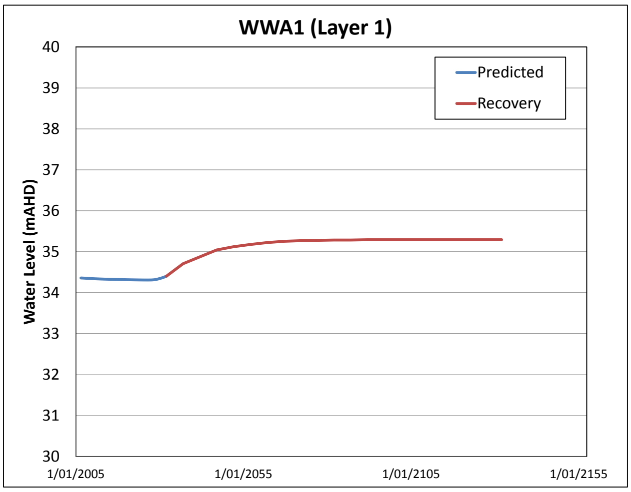
APPENDIX H:
RECOVERY HYDROGRAPHS

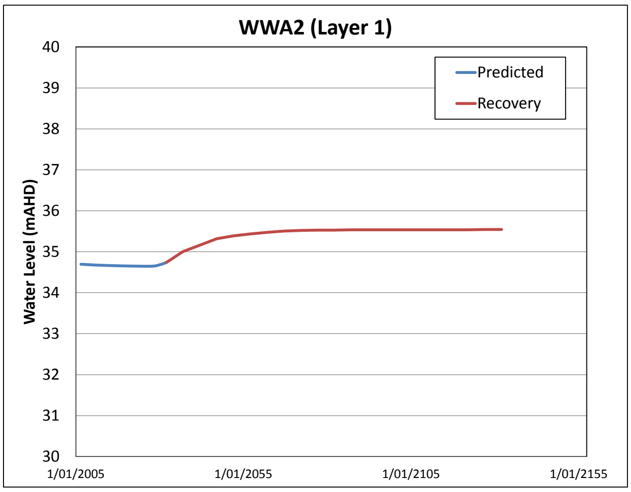

C072B (Layer 1)
Predicted
Recovery
Water Level (mAHD)
30
29
28
27
26
25
24
23
22
21
20
1/01/2005
1/01/2055
1/01/2105
1/01/2155

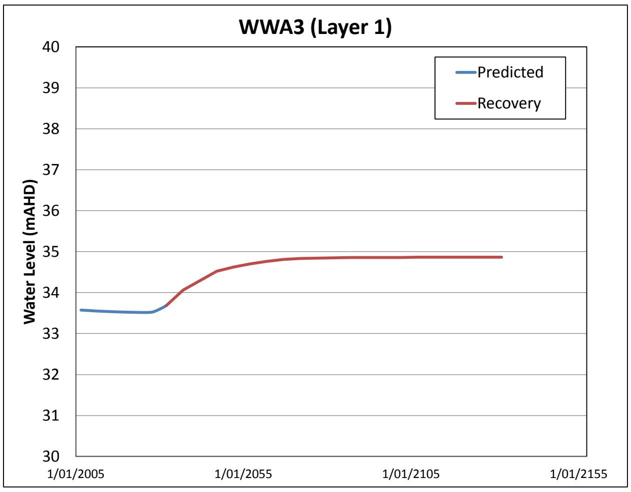

C081B (Layer 1)
Predicted
Recovery
Water Level (mAHD)
10
9
8
7
6
5
4
3
2
1
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155

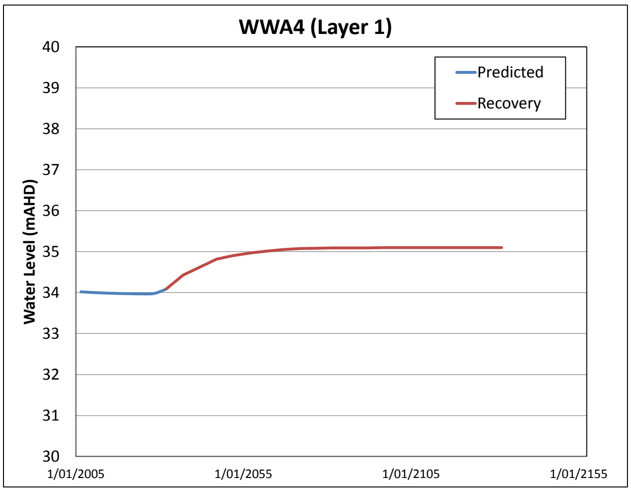

SP4-2 (Layer 1)
Predicted
Recovery
Water Level (mAHD)
30
29
28
27
26
25
24
23
22
21
20
1/01/2005
1/01/2055
1/01/2105
1/01/2155

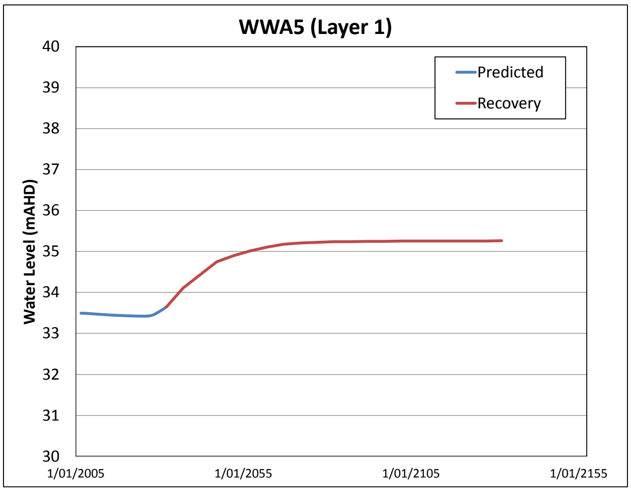

SP7-1 (Layer 1)
Predicted
Recovery
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155

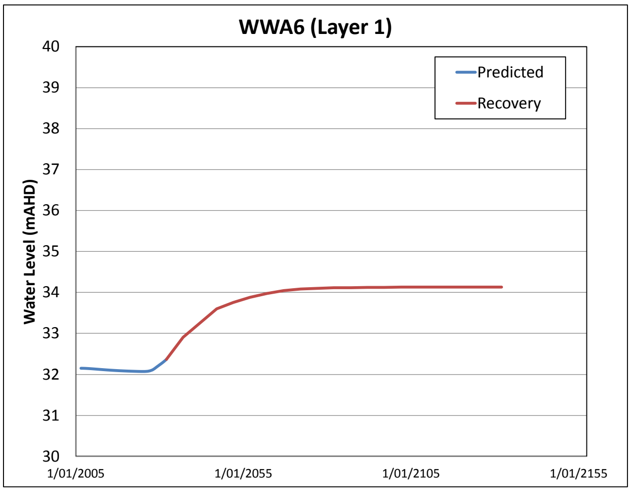

WWA1 (Layer 1)
Predicted
Recovery
Water Level (mAHD)
40
39
38
37
36
35
34
33
32
31
30
1/01/2005
1/01/2055
1/01/2105
1/01/2155

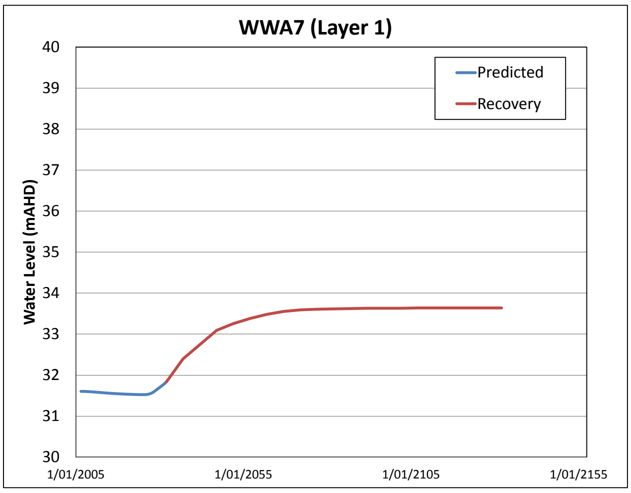

WWA2 (Layer 1)
Predicted
Recovery
Water Level (mAHD)
40
39
38
37
36
35
34
33
32
31
30
1/01/2005
1/01/2055
1/01/2105
1/01/2155

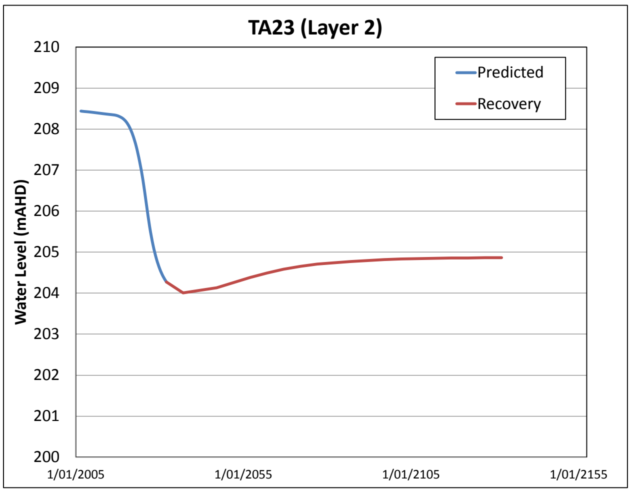

WWA3 (Layer 1)
Predicted
Recovery
Water Level (mAHD)
40
39
38
37
36
35
34
33
32
31
30
1/01/2005
1/01/2055
1/01/2105
1/01/2155

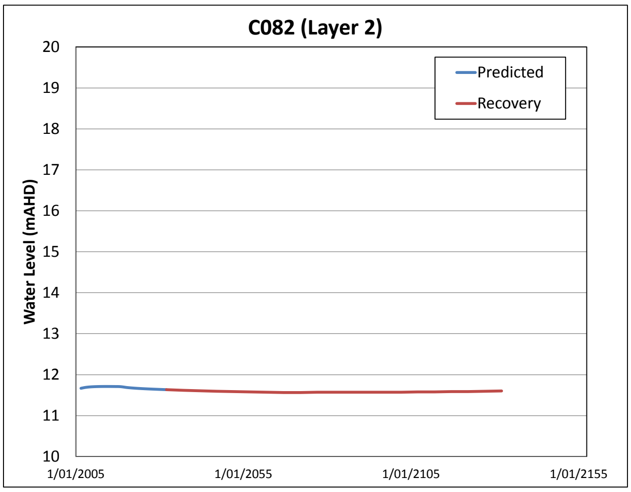

WWA4 (Layer 1)
Predicted
Recovery
Water Level (mAHD)
40
39
38
37
36
35
34
33
32
31
30
1/01/2005
1/01/2055
1/01/2105
1/01/2155

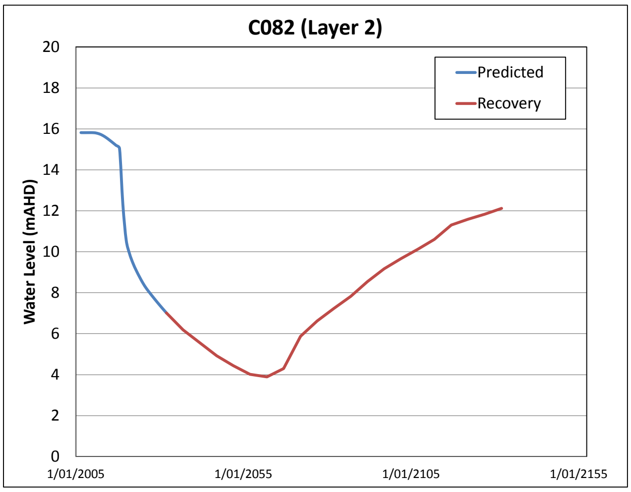

WWA5 (Layer 1)
Water Level (mAHD)
40
39
38
37
36
35
34
33
32
31
30
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

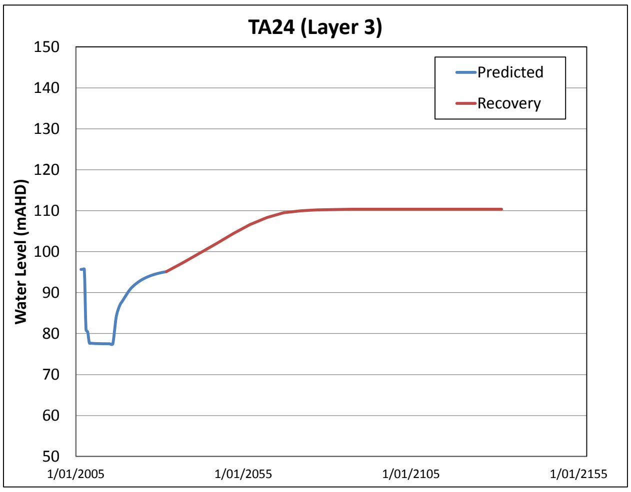

WWA6 (Layer 1)
Water Level (mAHD)
40
39
38
37
36
35
34
33
32
31
30
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

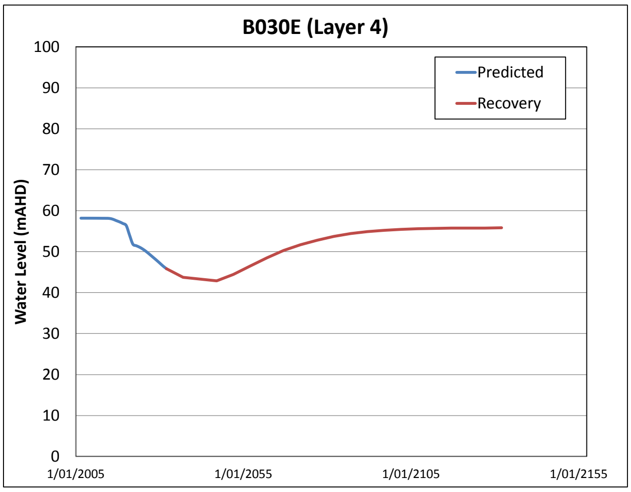

WWA7 (Layer 1)
Water Level (mAHD)
40
39
38
37
36
35
34
33
32
31
30
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

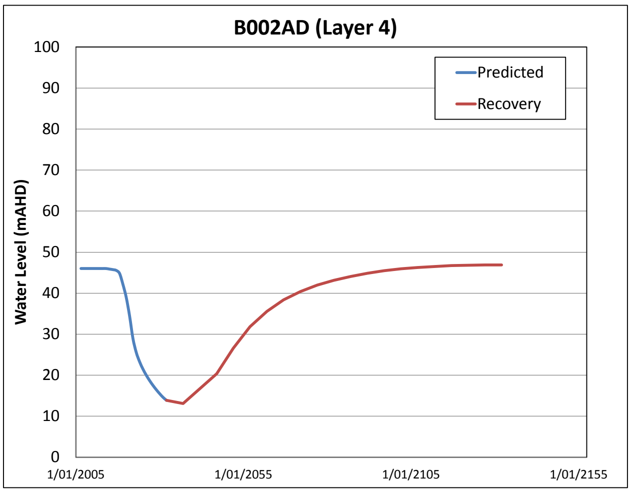

TA23 (Layer 2)
Water Level (mAHD)
210
209
208
207
206
205
204
203
202
201
200
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

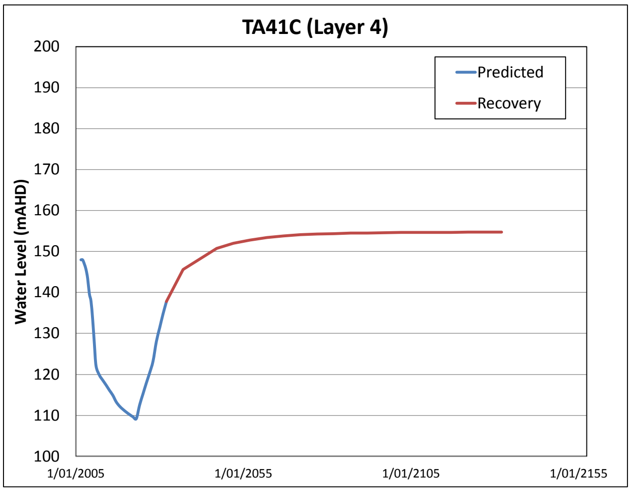

C082 (Layer 2)
Water Level (mAHD)
20
19
18
17
16
15
14
13
12
11
10
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

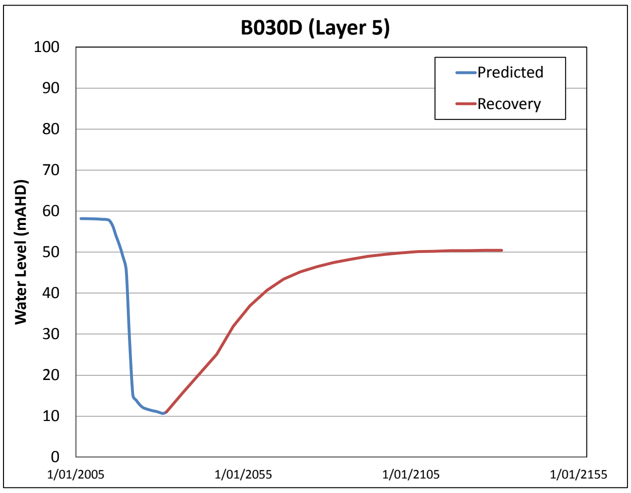

C082 (Layer 2)
Water Level (mAHD)
20
18
16
14
12
10
8
6
4
2
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

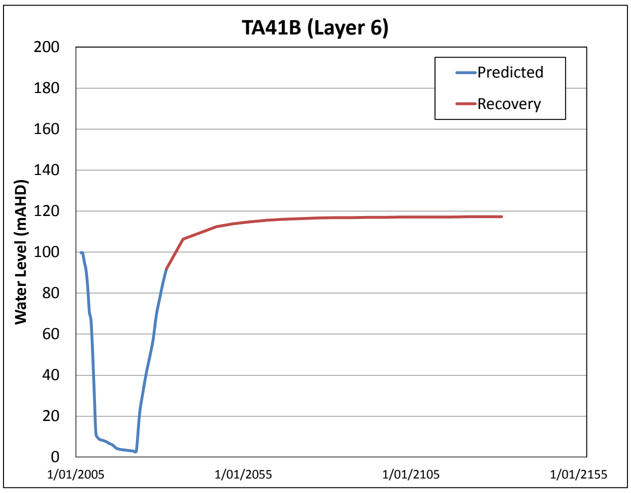

TA24 (Layer 3)
Water Level (mAHD)
150
140
130
120
110
100
90
80
70
60
50
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

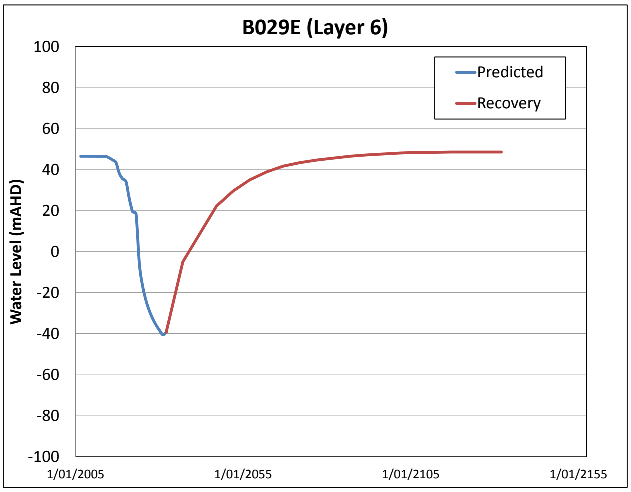

B030E (Layer 4)
Water Level (mAHD)
100
90
80
70
60
50
40
30
20
10
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

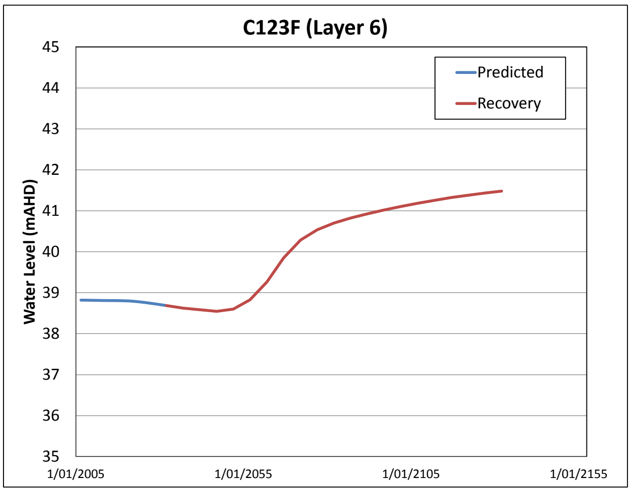

B002AD (Layer 4)
Water Level (mAHD)
100
90
80
70
60
50
40
30
20
10
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

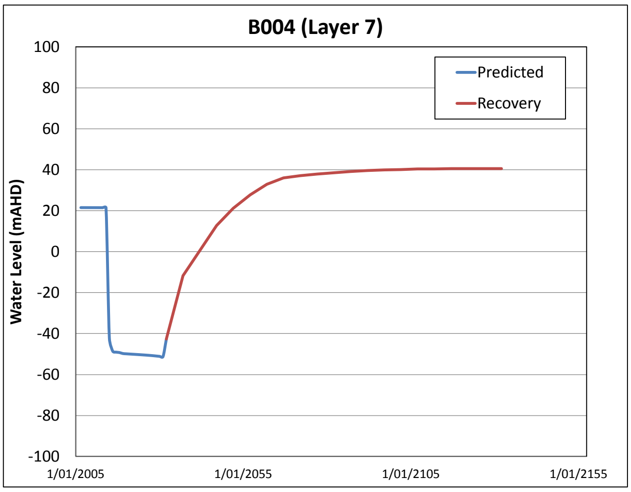

TA41C (Layer 4)
Water Level (mAHD)
200
190
180
170
160
150
140
130
120
110
100
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

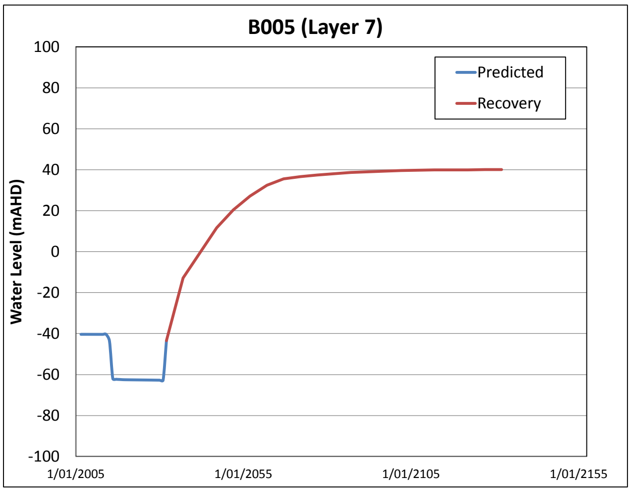

B030D (Layer 5)
Water Level (mAHD)
100
90
80
70
60
50
40
30
20
10
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

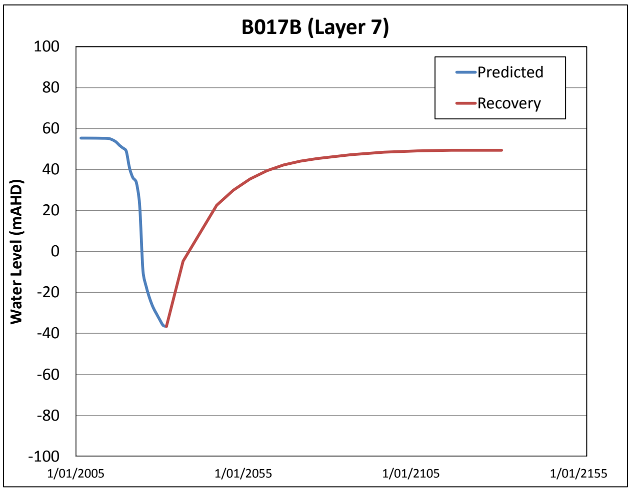

TA41B (Layer 6)
Water Level (mAHD)
200
180
160
140
120
100
80
60
40
20
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

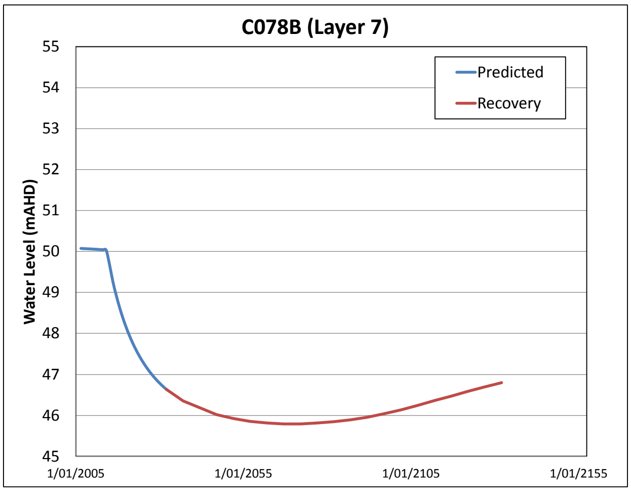

B029E (Layer 6)
Water Level (mAHD)
100
80
60
40
20
0
-20
-40
-60
-80
-100
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

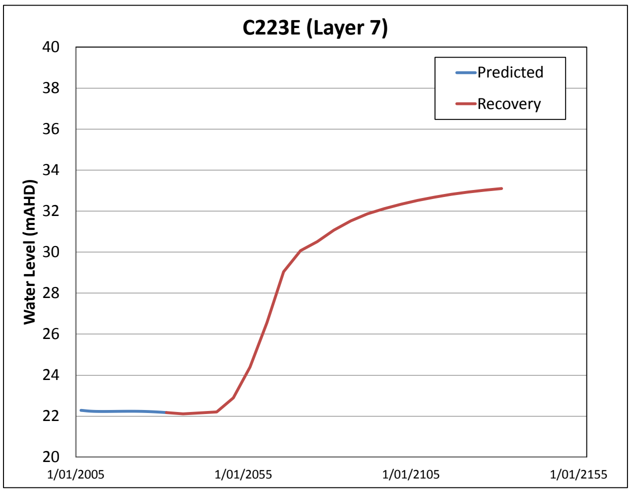

C123F (Layer 6)
Water Level (mAHD)
45
44
43
42
41
40
39
38
37
36
35
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

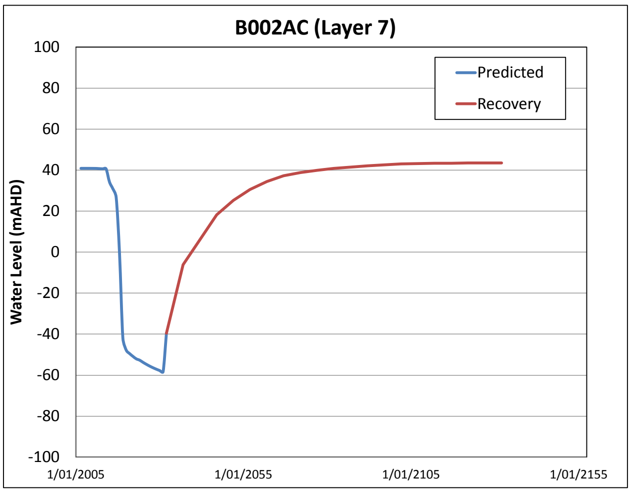

B004 (Layer 7)
Water Level (mAHD)
100
80
60
40
20
0
-20
-40
-60
-80
-100
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

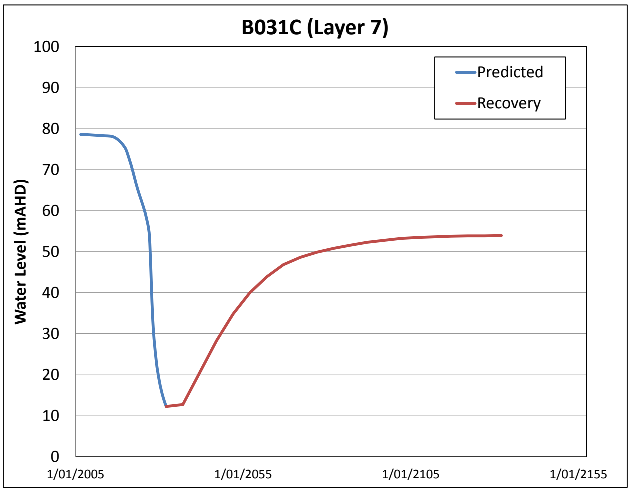

B005 (Layer 7)
Water Level (mAHD)
100
80
60
40
20
0
-20
-40
-60
-80
-100
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

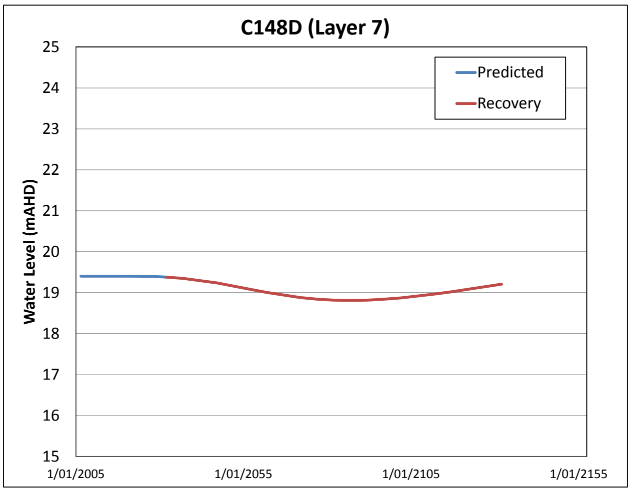

B017B (Layer 7)
Water Level (mAHD)
Predicted
Recovery
1/01/2005
1/01/2055
1/01/2105
1/01/2155

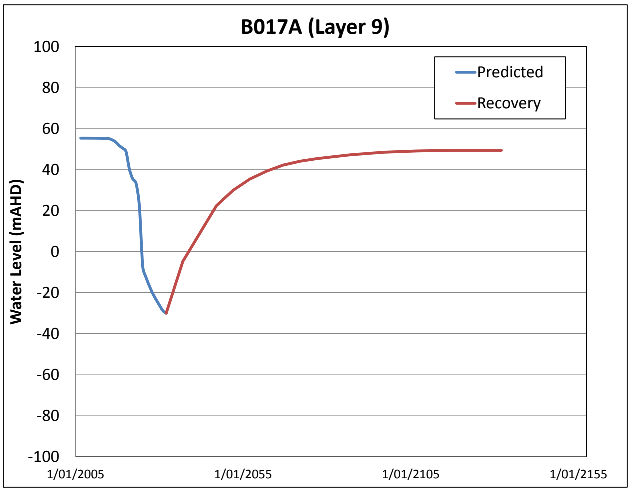

C078B (Layer 7)
Water Level (mAHD)
Predicted
Recovery
1/01/2005
1/01/2055
1/01/2105
1/01/2155

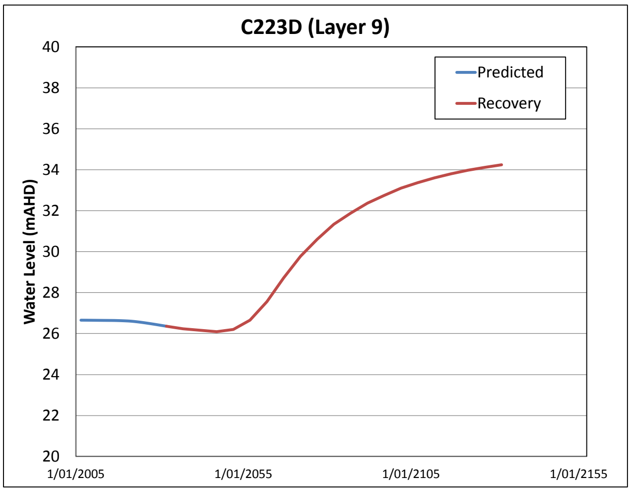

C223E (Layer 7)
Water Level (mAHD)
Predicted
Recovery
1/01/2005
1/01/2055
1/01/2105
1/01/2155

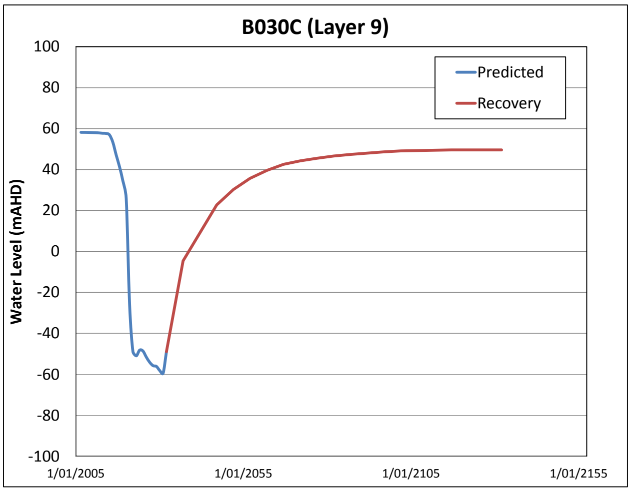

B002AC (Layer 7)
Water Level (mAHD)
Predicted
Recovery
1/01/2005
1/01/2055
1/01/2105
1/01/2155

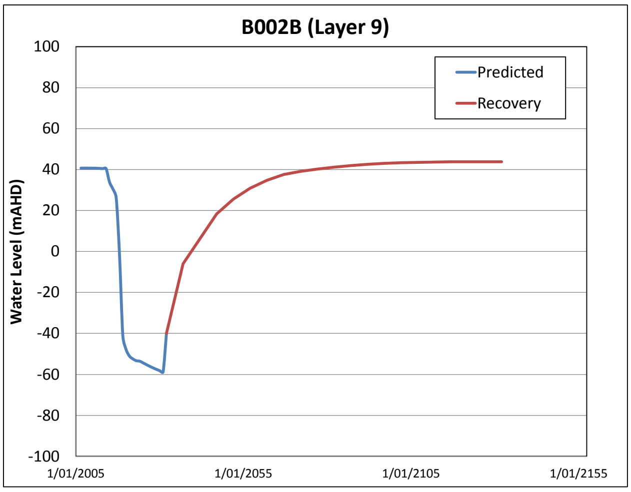

B031C (Layer 7)
Water Level (mAHD)
Predicted
Recovery
1/01/2005
1/01/2055
1/01/2105
1/01/2155

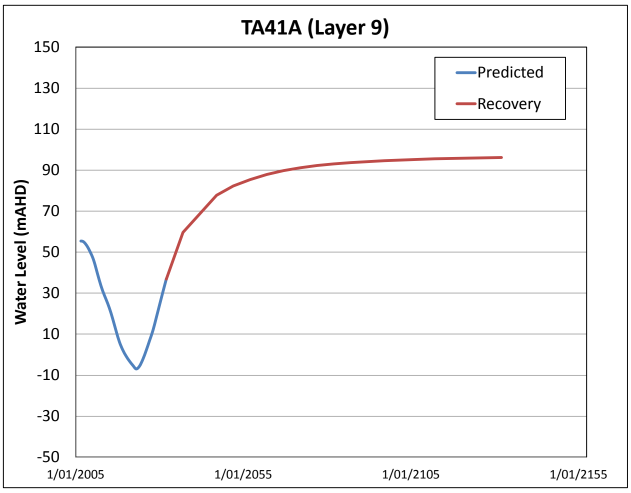

C148D (Layer 7)
Water Level (mAHD)
Predicted
Recovery
1/01/2005
1/01/2055
1/01/2105
1/01/2155

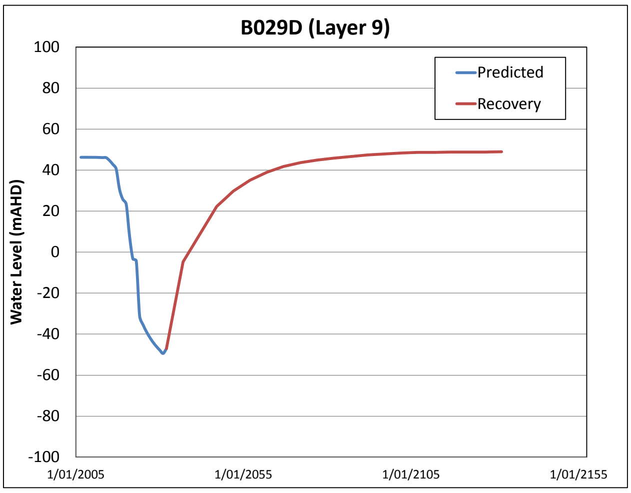

B017A (Layer 9)
Water Level (mAHD)
Predicted
Recovery
1/01/2005
1/01/2055
1/01/2105
1/01/2155

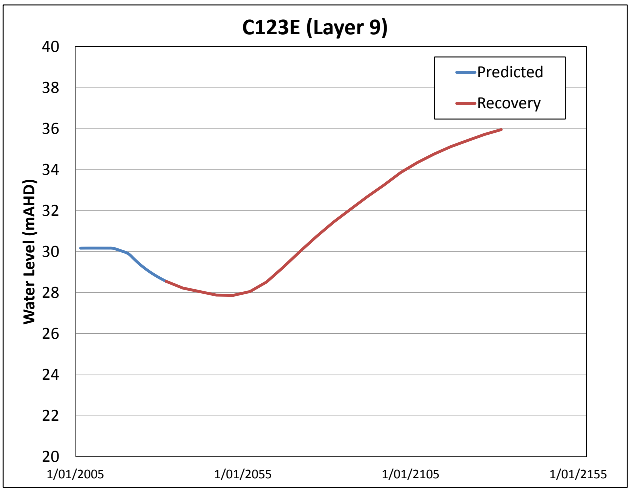

C223D (Layer 9)
Water Level (mAHD)
Predicted
Recovery
1/01/2005
1/01/2055
1/01/2105
1/01/2155

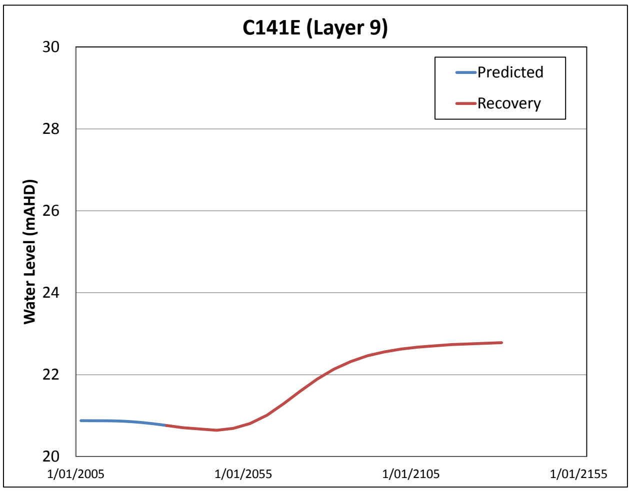

B030C (Layer 9)
Water Level (mAHD)
100
80
60
40
20
0
-20
-40
-60
-80
-100
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

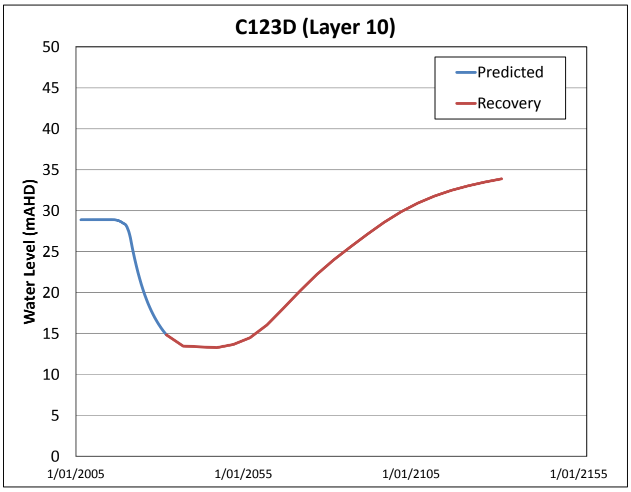

B002B (Layer 9)
Water Level (mAHD)
100
80
60
40
20
0
-20
-40
-60
-80
-100
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

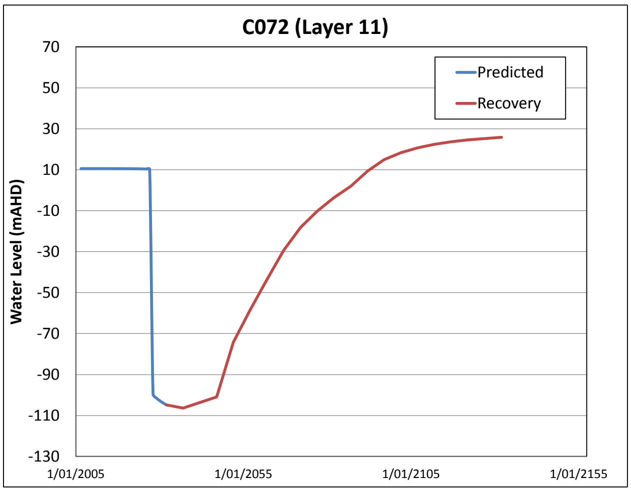

TA41A (Layer 9)
Water Level (mAHD)
150
130
110
90
70
50
30
10
-10
-30
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

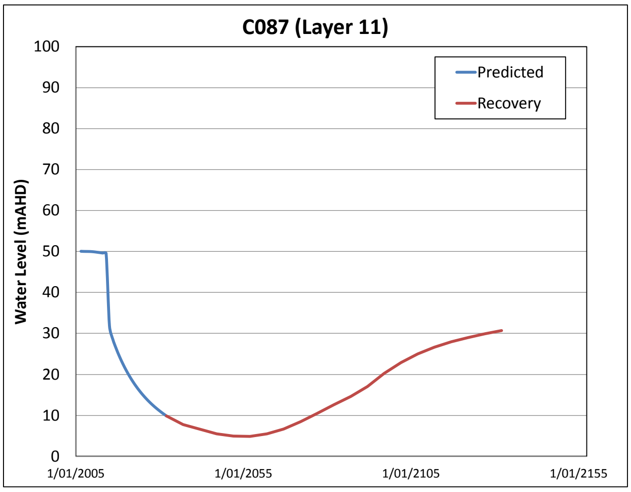

B029D (Layer 9)
Water Level (mAHD)
100
80
60
40
20
0
-20
-40
-60
-80
-100
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

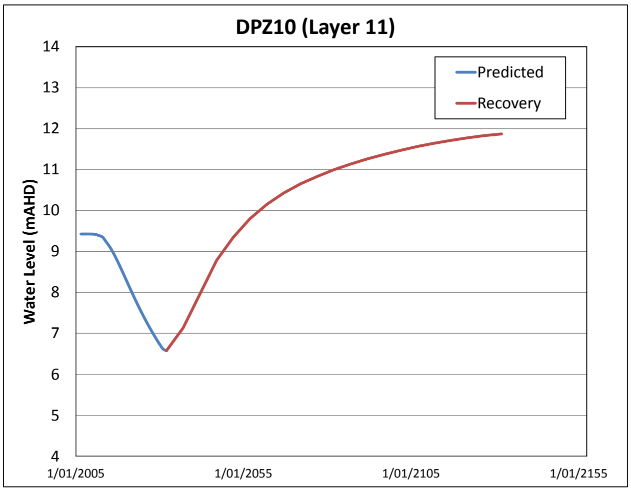

C123E (Layer 9)
Water Level (mAHD)
40
38
36
34
32
30
28
26
24
22
20
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

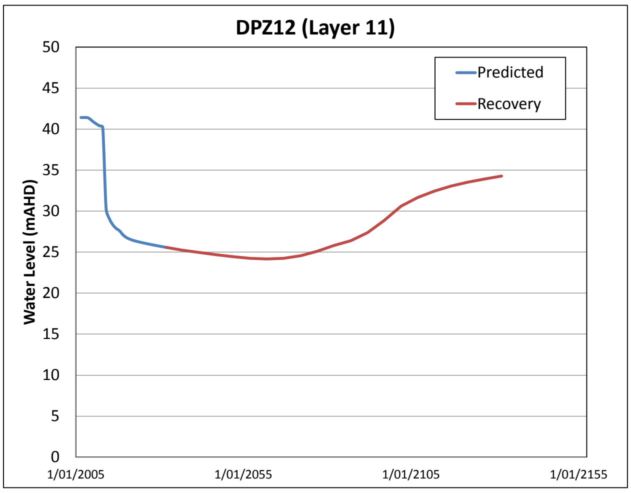

C141E (Layer 9)
Water Level (mAHD)
30
28
26
24
22
20
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

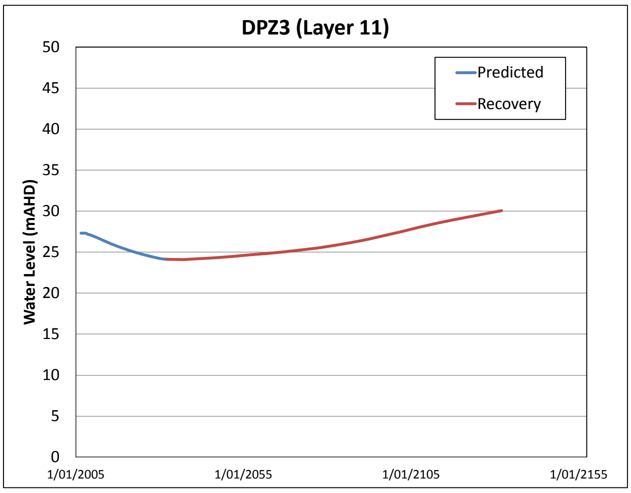

C123D (Layer 10)
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

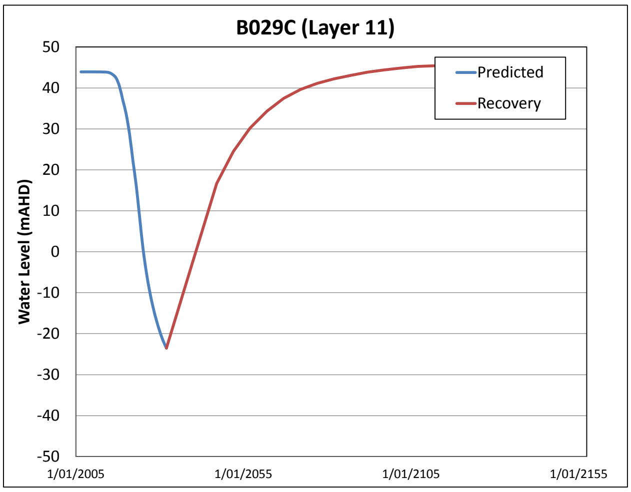

C072 (Layer 11)
Water Level (mAHD)
70
50
30
10
-10
-30
-50
-70
-90
-110
-130
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

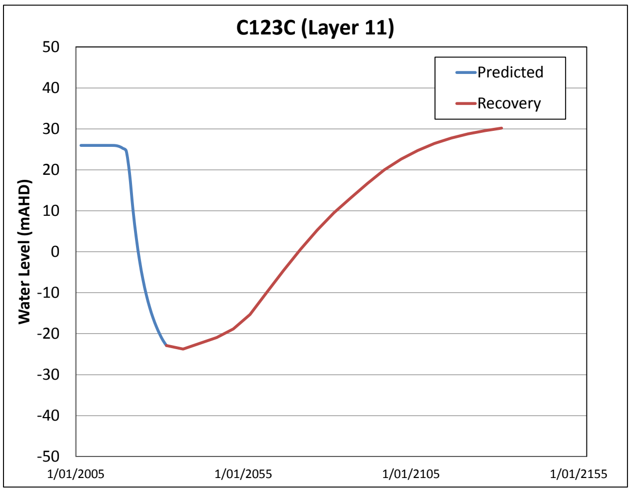

C087 (Layer 11)
Water Level (mAHD)
100
90
80
70
60
50
40
30
20
10
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

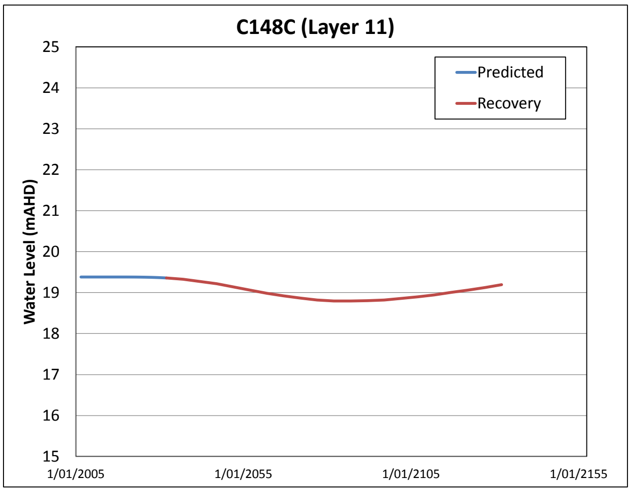

DPZ10 (Layer 11)
Water Level (mAHD)
14
13
12
11
10
9
8
7
6
5
4
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

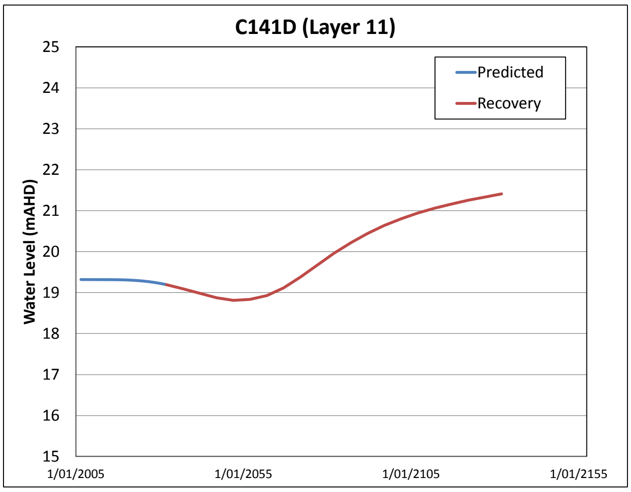

DPZ12 (Layer 11)
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

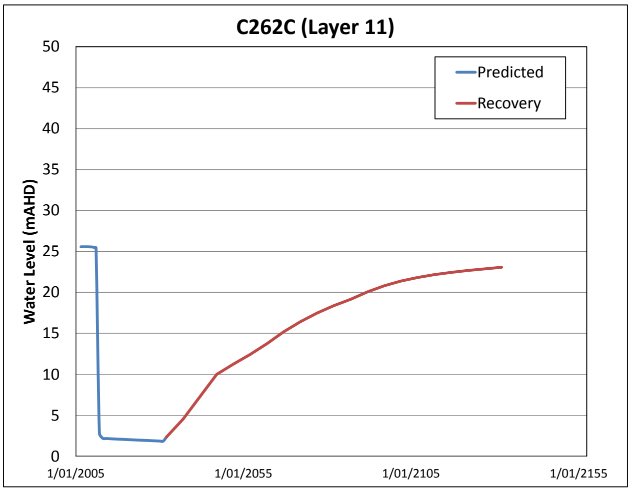

DPZ3 (Layer 11)
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

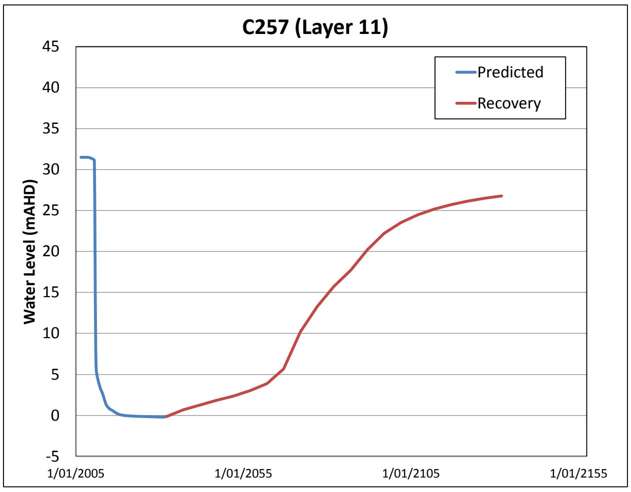

B029C (Layer 11)
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

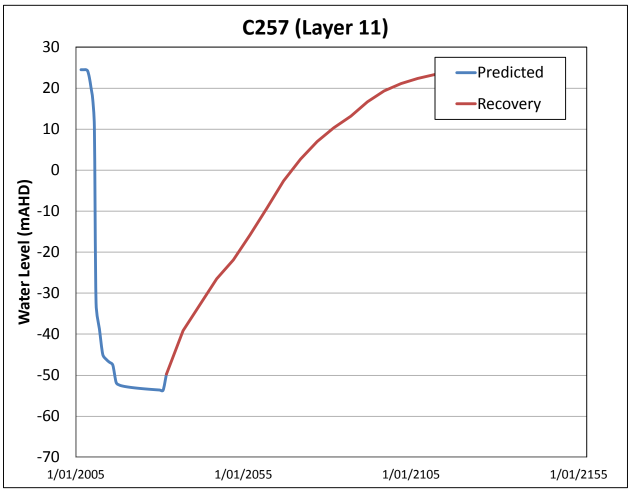

C123C (Layer 11)
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

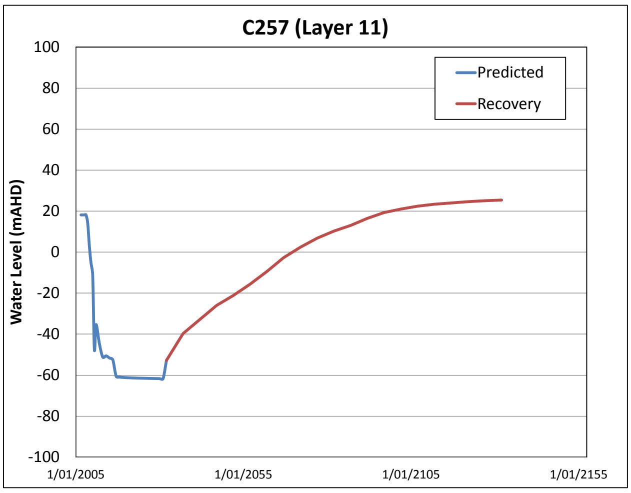

C148C (Layer 11)
Water Level (mAHD)
25
24
23
22
21
20
19
18
17
16
15
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

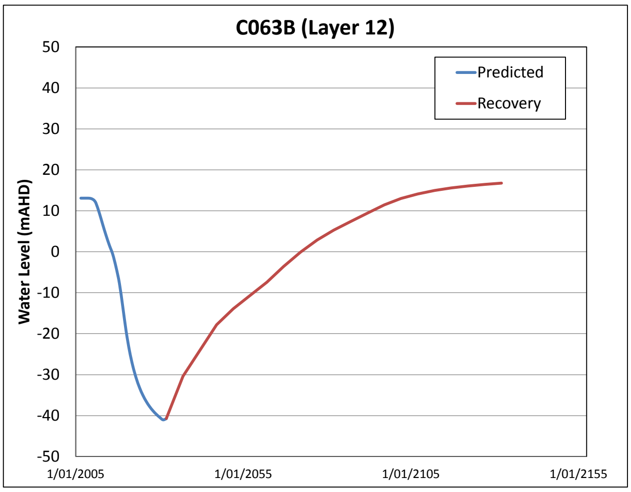

C141D (Layer 11)
Water Level (mAHD)
25
24
23
22
21
20
19
18
17
16
15
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

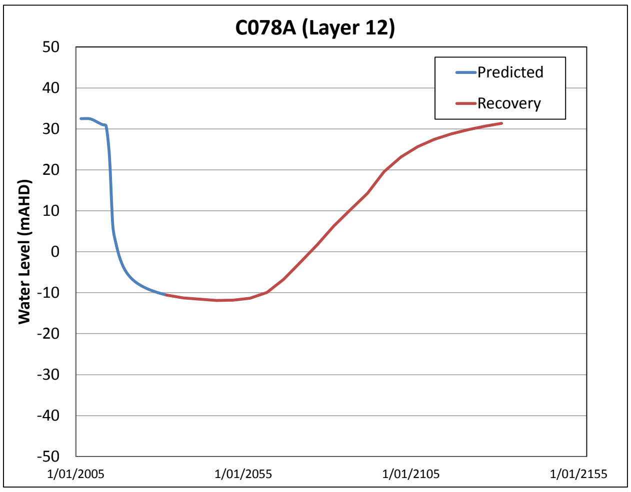

C262C (Layer 11)
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

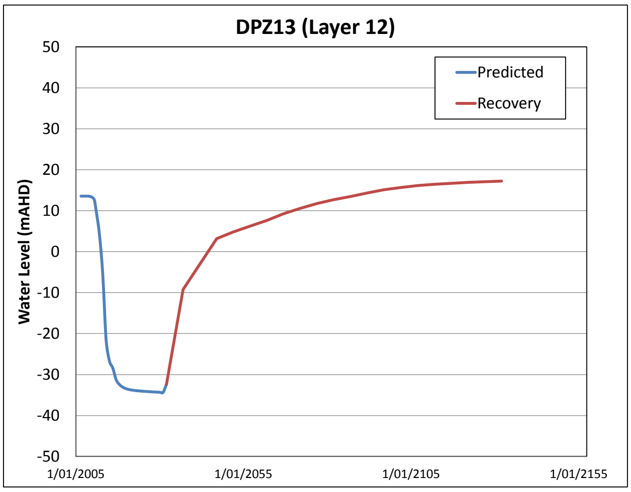

C257 (Layer 11)
Water Level (mAHD)
45
40
35
30
25
20
15
10
5
0
-5
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

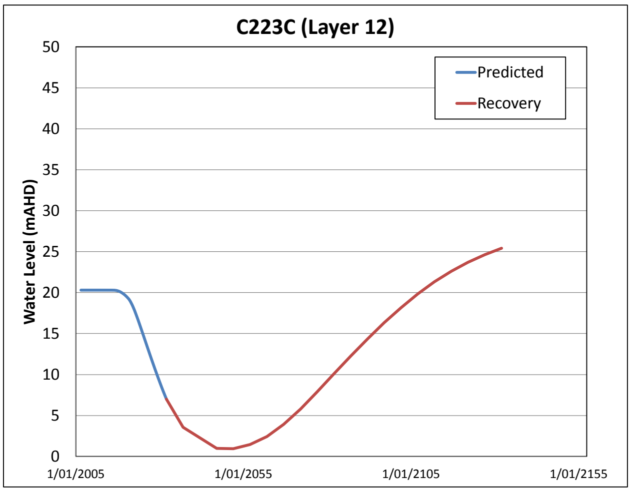

C257 (Layer 11)
Water Level (mAHD)
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

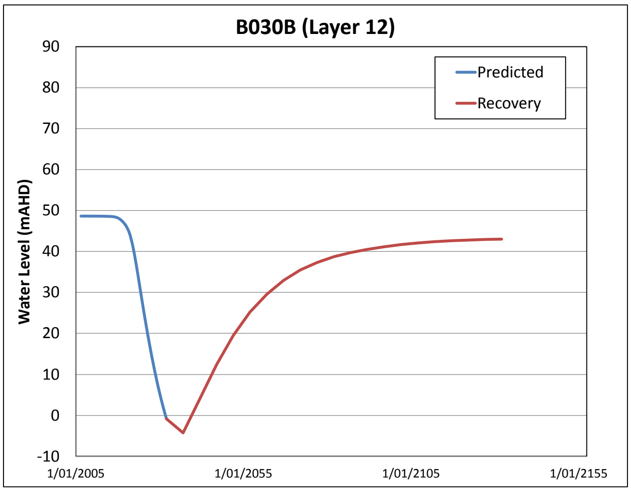

C257 (Layer 11)
Water Level (mAHD)
100
80
60
40
20
0
-20
-40
-60
-80
-100
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

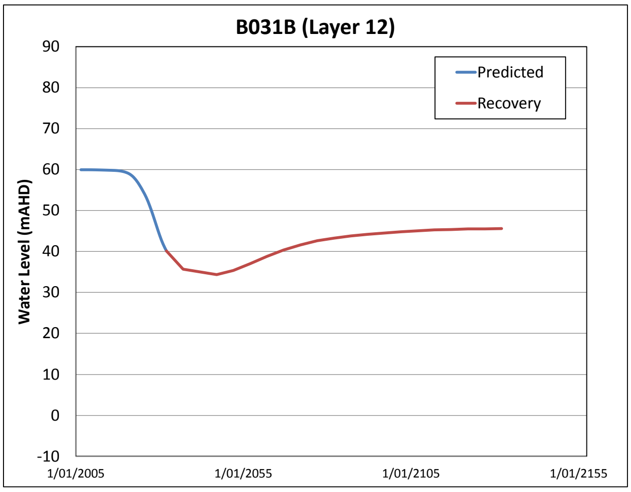

C063B (Layer 12)
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

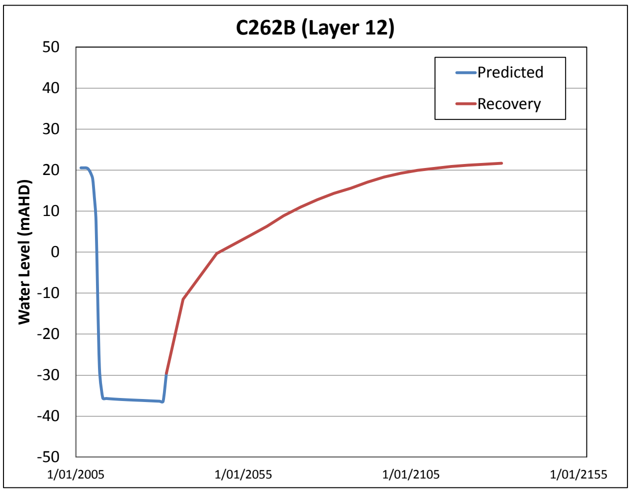

C078A (Layer 12)
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

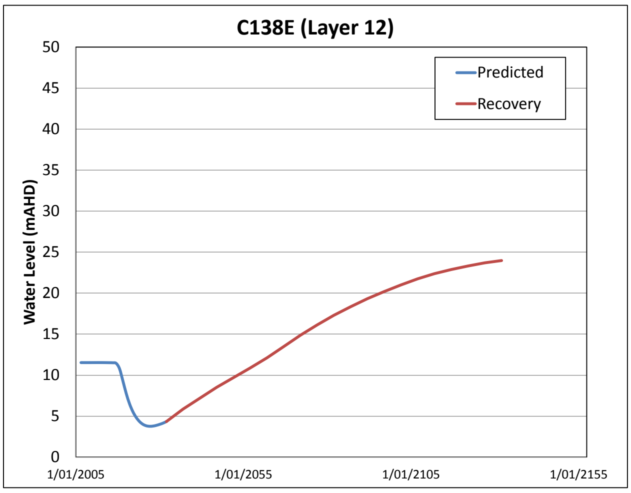

DPZ13 (Layer 12)
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

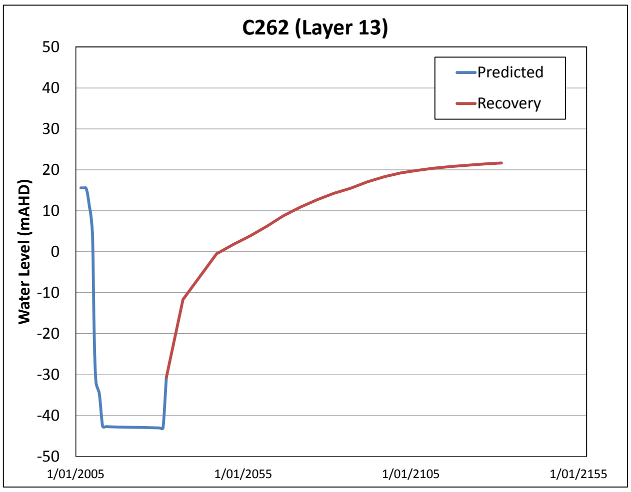

C223C (Layer 12)
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

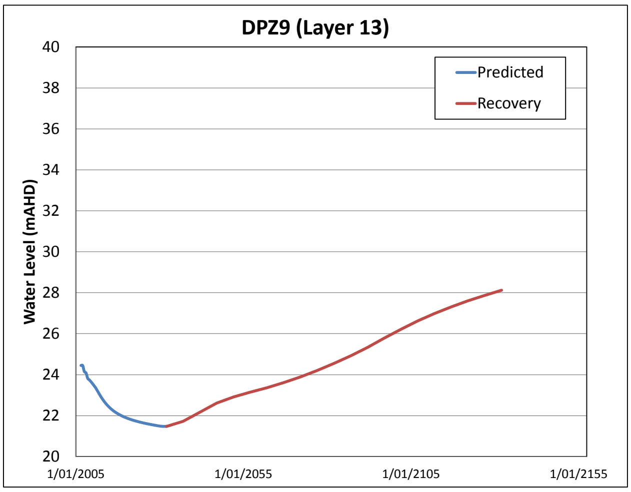

B030B (Layer 12)
Water Level (mAHD)
Predicted
Recovery
90
80
70
60
50
40
30
20
10
0
-10
1/01/2005
1/01/2055
1/01/2105
1/01/2155

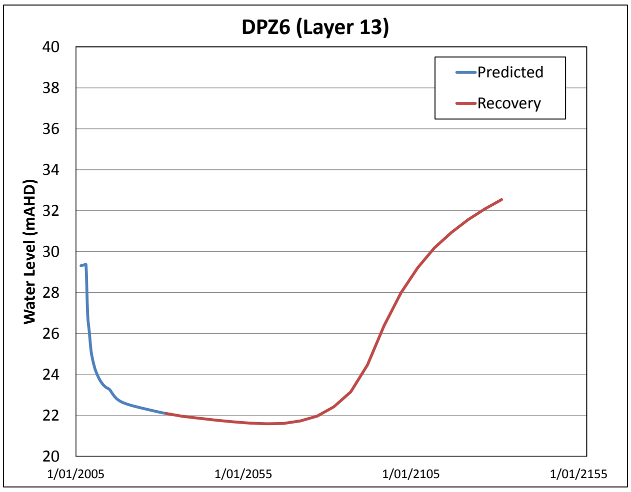

B031B (Layer 12)
Water Level (mAHD)
Predicted
Recovery
90
80
70
60
50
40
30
20
10
0
-10
1/01/2005
1/01/2055
1/01/2105
1/01/2155

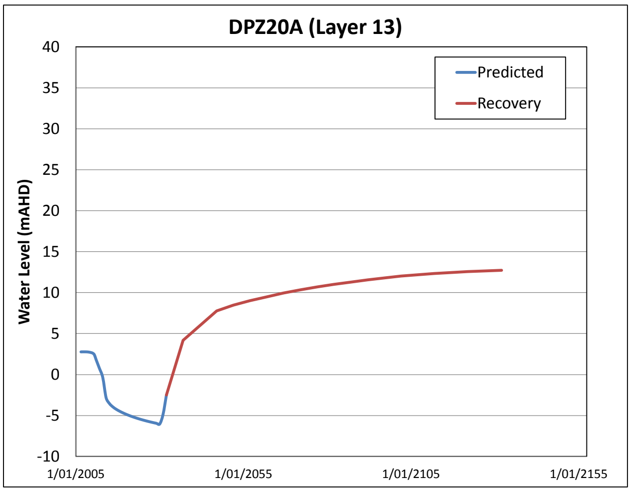

C262B (Layer 12)
Water Level (mAHD)
Predicted
Recovery
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155

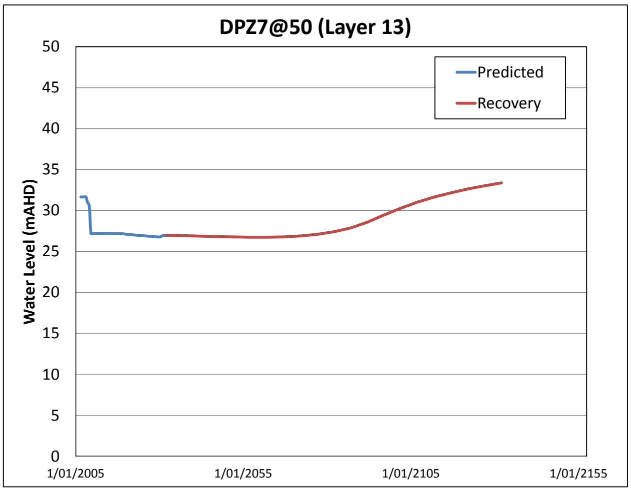

C138E (Layer 12)
Water Level (mAHD)
Predicted
Recovery
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155

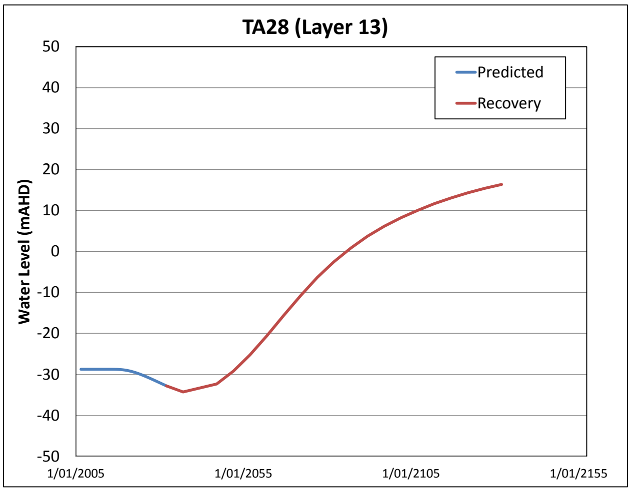

C262 (Layer 13)
Water Level (mAHD)
Predicted
Recovery
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155

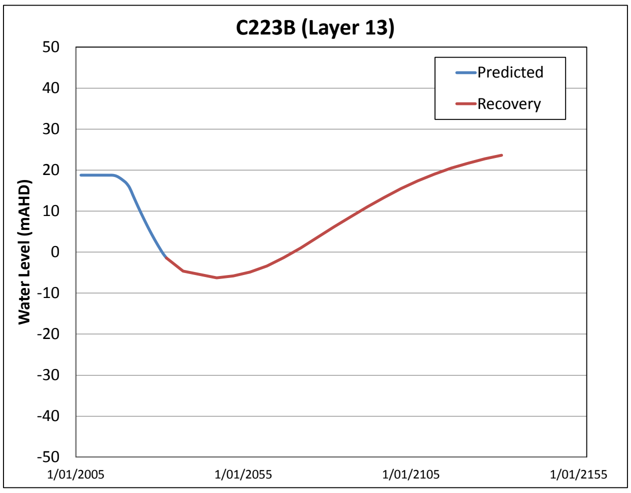

DPZ9 (Layer 13)
Water Level (mAHD)
Predicted
Recovery
40
38
36
34
32
30
28
26
24
22
20
1/01/2005
1/01/2055
1/01/2105
1/01/2155

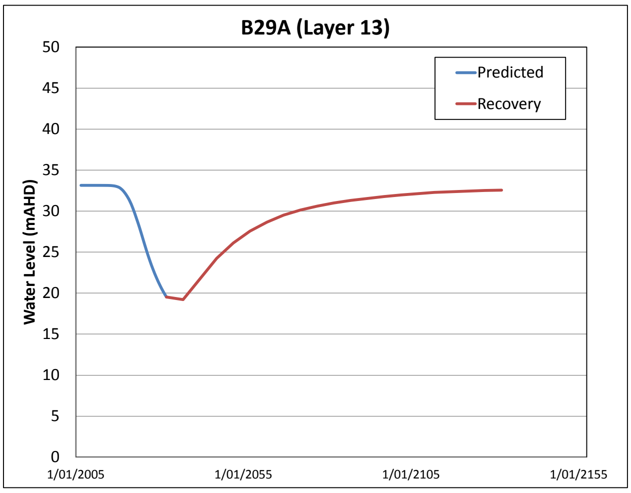

DPZ6 (Layer 13)
Water Level (mAHD)
Predicted
Recovery
40
38
36
34
32
30
28
26
24
22
20
1/01/2005
1/01/2055
1/01/2105
1/01/2155

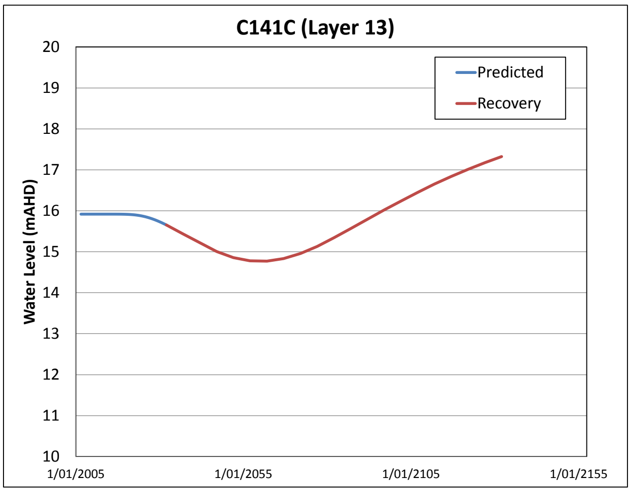

DPZ20A (Layer 13)
Water Level (mAHD)
Predicted
Recovery
40
35
30
25
20
15
10
5
0
-5
-10
1/01/2005
1/01/2055
1/01/2105
1/01/2155

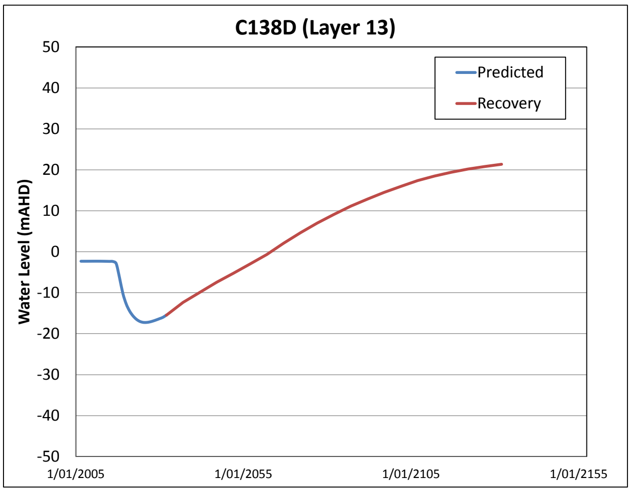

DPZ7@50 (Layer 13)
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

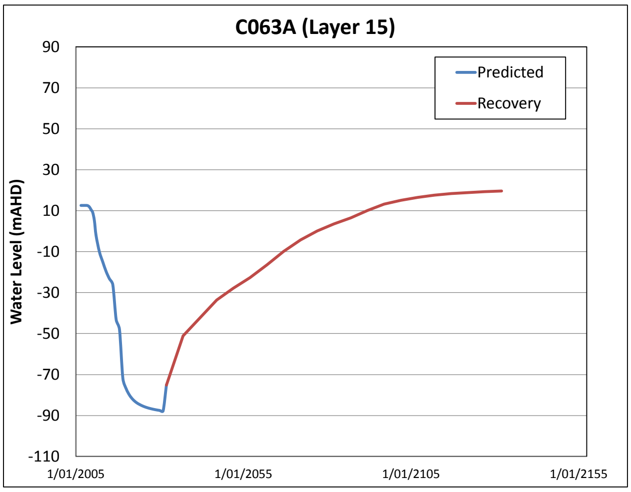

TA28 (Layer 13)
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

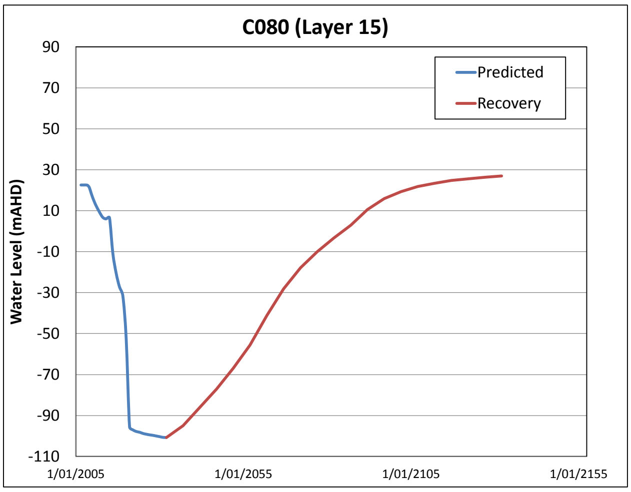

C223B (Layer 13)
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

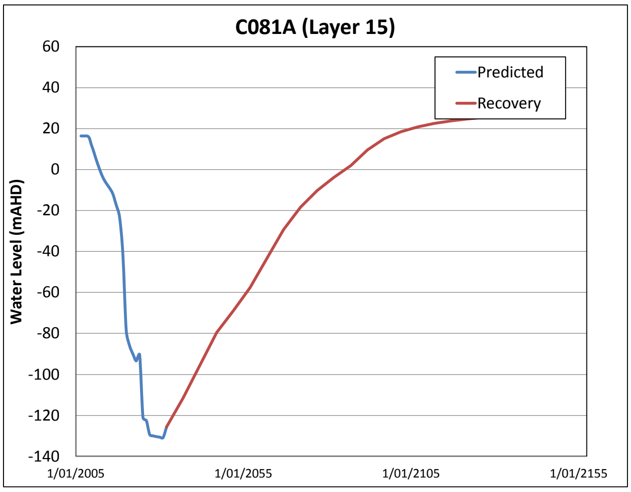

B29A (Layer 13)
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

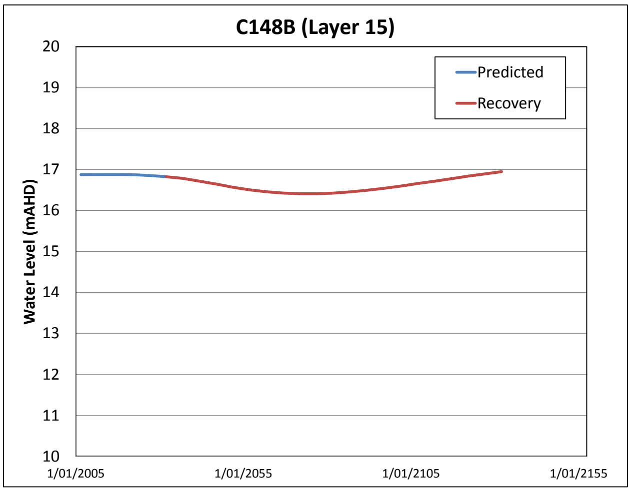

C141C (Layer 13)
Water Level (mAHD)
20
19
18
17
16
15
14
13
12
11
10
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

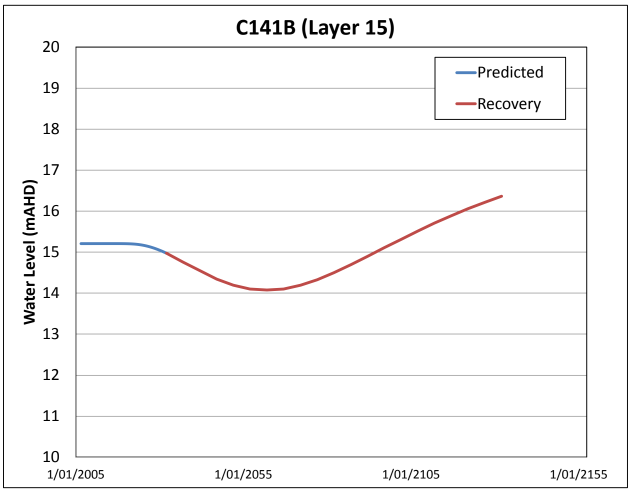

C138D (Layer 13)
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

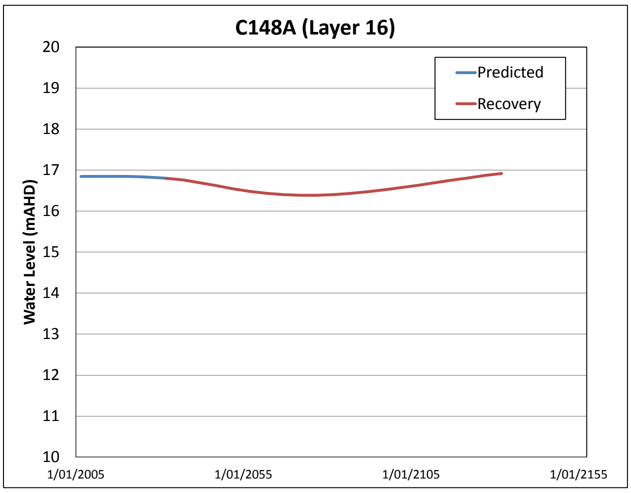

C063A (Layer 15)
Water Level (mAHD)
90
70
50
30
10
-10
-30
-50
-70
-90
-110
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

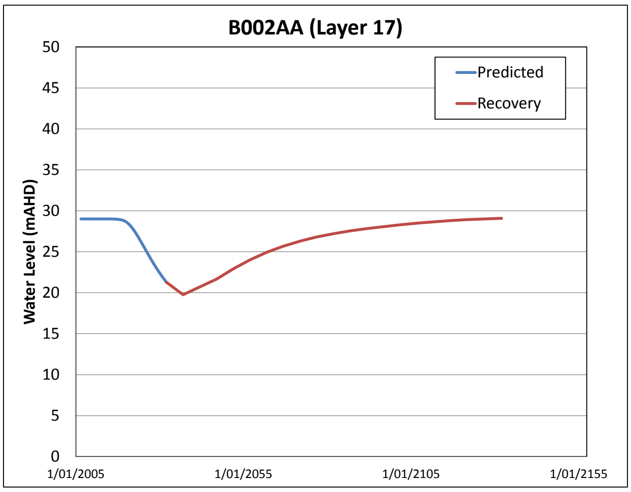

C080 (Layer 15)
Water Level (mAHD)
90
70
50
30
10
-10
-30
-50
-70
-90
-110
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

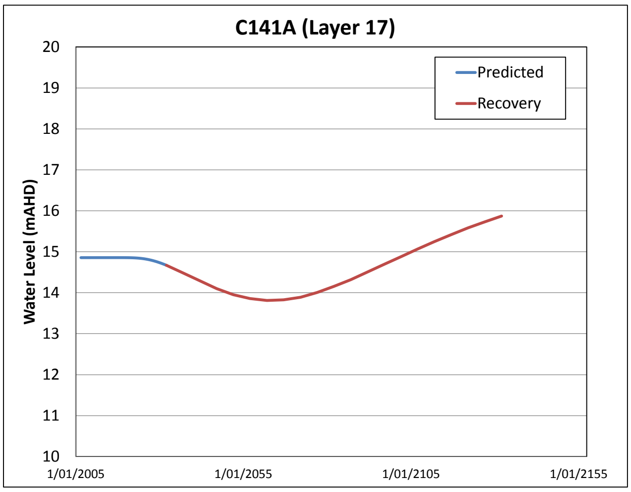

C081A (Layer 15)
Water Level (mAHD)
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

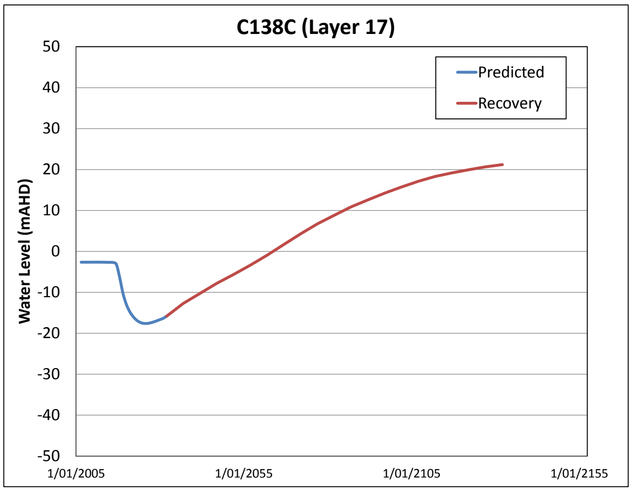

C148B (Layer 15)
Water Level (mAHD)
20
19
18
17
16
15
14
13
12
11
10
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

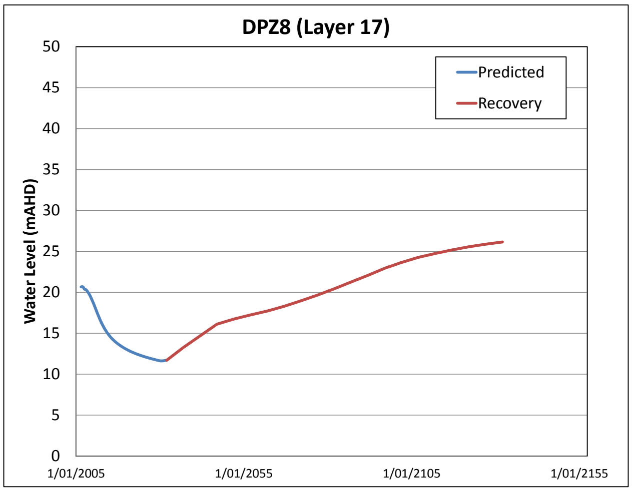

C141B (Layer 15)
Water Level (mAHD)
20
19
18
17
16
15
14
13
12
11
10
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

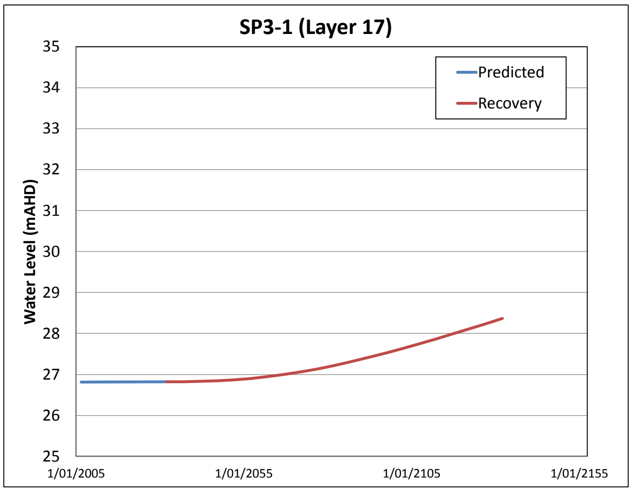

C148A (Layer 16)
Water Level (mAHD)
20
19
18
17
16
15
14
13
12
11
10
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

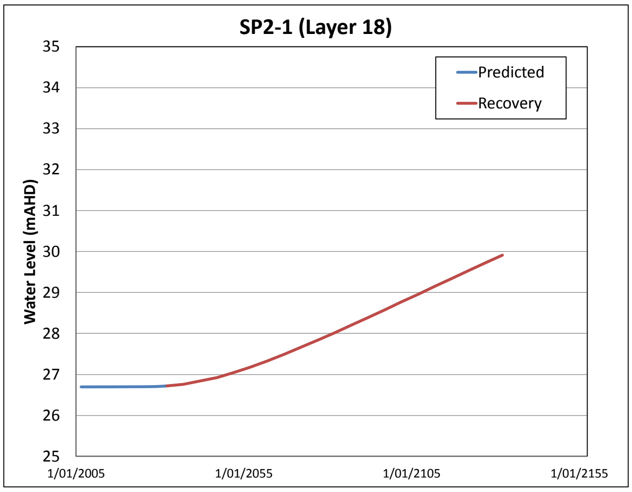

B002AA (Layer 17)
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

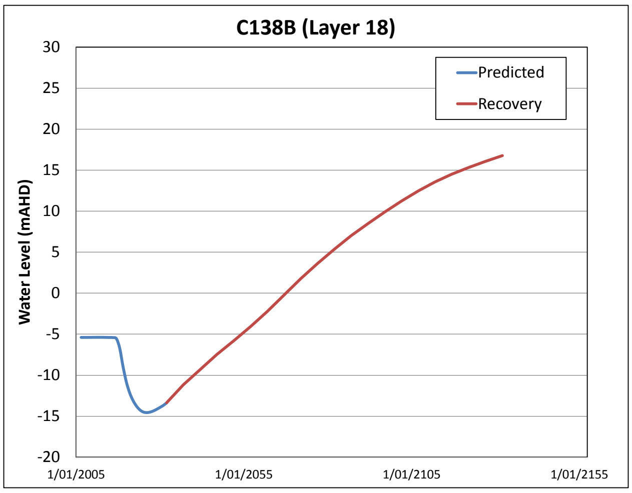

C141A (Layer 17)
Water Level (mAHD)
20
19
18
17
16
15
14
13
12
11
10
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery

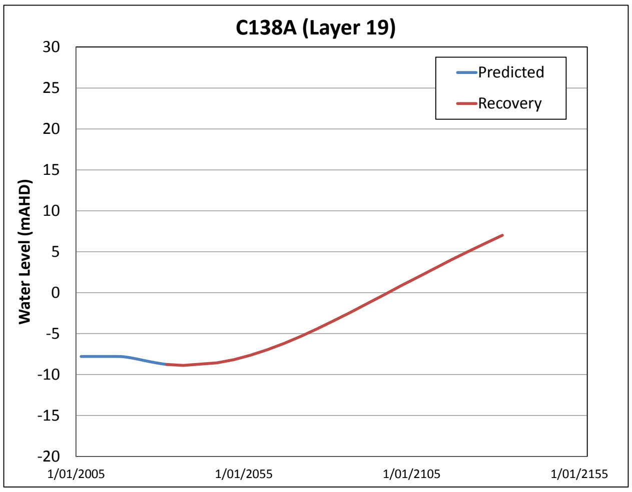

C138C (Layer 17)
Water Level (mAHD)
50
40
30
20
10
0
-10
-20
-30
-40
-50
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery


DPZ8 (Layer 17)
Water Level (mAHD)
50
45
40
35
30
25
20
15
10
5
0
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery


SP3-1 (Layer 17)
Water Level (mAHD)
35
34
33
32
31
30
29
28
27
26
25
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery


SP2-1 (Layer 18)
Water Level (mAHD)
35
34
33
32
31
30
29
28
27
26
25
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery


C138B (Layer 18)
Water Level (mAHD)
30
25
20
15
10
5
0
-5
-10
-15
-20
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery


C138A (Layer 19)
Water Level (mAHD)
30
25
20
15
10
5
0
-5
-10
-15
-20
1/01/2005
1/01/2055
1/01/2105
1/01/2155
Predicted
Recovery