

**RIX'S CREEK
CONTINUATION OF MINING PROJECT
GROUNDWATER IMPACT ASSESSMENT**





RIX'S CREEK CONTINUATION OF MINING PROJECT GROUNDWATER IMPACT ASSESSMENT

Prepared by:

RPS

Level 9, 17 York Street, Sydney NSW 2007
GPO Box 4401 Sydney NSW 2001

T: 61 2 8270 8388

F: 61 2 8270 8399

E: water@rpsgroup.com.au

W: rpsgroup.com.au

Our ref: S66D/015d

Date: 30 September 2014

Prepared for:

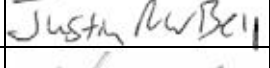
Bloomfield Collieries Pty Ltd

PO Box 4

EAST MAITLAND NSW 2323

Document Status

	Issue Date	Purpose of Document
Revision A	16 July 2014	First draft for client review
Revision B	22 July 2014	Second draft incorporating comments from The Bloomfield Group
Revision C	25 September 2014	Final report for adequacy assessment
Revision D	30 September 2014	Final Report for Adequacy Assessment

	Name	Position	Signature	Date
Author	Sam Cook	Senior Hydrogeologist		30/09/2014
Author	Dr Justin Bell	Principal Modeller		30/09/2014
Reviewer	Greg Sheppard	Principal Hydrogeologist		30/09/2014

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EXECUTIVE SUMMARY

Rix's Creek Mine (the mine) of Rix's Creek Pty Limited, is owned and operated by Bloomfield Collieries Pty Limited (Bloomfield). The mine is an open cut coal mine approximately 5 km north-west of Singleton in the Hunter Valley Coalfields of NSW. The mine currently produces approximately 1.5 million tonnes per annum (Mtpa) of product coal from its existing operations.

Bloomfield is seeking approval for the Rix's Creek Continuation of Mining Project (the Project), which relates to the continued operation of the existing open cut coal mine. The Project would allow the mine to continue to operate as an open cut mine, accessed via its existing infrastructure facilities.

The Project seeks to extend the life of the existing open cut mining operation at Rix's Creek until approximately 2037. The continuation of mining operations will extend in a north-westerly direction and require a modification to Mine Lease 1432 for an out of pit dump. The continuation of operations will utilise the existing mine access, Coal Handling and Preparation Plant (CHPP), coal stockpiling and rail facilities.

This report has been compiled in order to address groundwater related hazards and risks that may arise as a result of proposed Project activities and will support and form part of the Environmental Impact Statement for the Project. The report has also been developed and structured to address key issues specific to groundwater resources as prescribed Director General Requirements for the Project.

The groundwater impact assessment for the mine has been completed using a detailed hydrogeological understanding of the site together with an updated groundwater model. The model has been used to predict both the cumulative impacts of the Project with other existing and proposed mining operations, as well as the incremental impacts that are directly attributable to the Project.

Existing Environment

The Project is situated within a geological basin-like north-south trending syncline and it hosts the Permian coal reserves that are part of the Whittingham Coal Measures. The syncline is approximately 8 km long by 3 km wide and is bounded by the Camberwell and Darlington Anticlines. The syncline is asymmetrical with the western limb generally dipping at a steeper angle than the eastern limb.

With the exception of licensed bore GW052121, all registered water bores or wells are located more than 4.5 km from the centre of the mine lease.

The proximity of groundwater dependent ecosystem to the Project area has been assessed by reviewing the WSP and the Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology, 2012) and consulting with the ecological specialist involved in this impact assessment process. The findings have confirmed that there are no identified GDEs in the vicinity of the Project.

Predicted Impacts (during Mining)

Mine Inflows

- The total mine inflows are predicted to peak at around 960 m³/day (350 ML/a) in 2017, declining to around 344 m³/d (125 ML/a) by the end of mining.

Groundwater Drawdown

- Taking into account all mining influences (cumulative impacts) no drawdown impacts within the regolith/alluvium (Layer 1) are predicted outside of the coal lease boundary.
- Groundwater impacts (drawdown of up to 10 m) are predicted outside of the lease boundary to the north of the Project. In this area the regolith/alluvium (Layer 1) is shown to be dry in the absence of mining influences as shown in the cumulative impact null case. The predicted drawdown impact is therefore within the underlying Permian hardrock.

- Drawdown impact within the underlying Hebden coal seam propagates to the north as mining progresses. The drawdown within the Hebden Seam to the north is exacerbated in the cumulative impact scenario.

Baseflow

- Impacts from approved mining operations at the mine can be seen in a comparison of the null case and the cumulative null case. In the null case the regolith (Layer 1) in areas adjacent to Rix's Creek is predicted to recover resulting in an increased baseflow contribution (<0.01 L/sec). Impacts from the proposed Project are shown to negate this recovery with the regolith adjacent to Rix's Creek remains dry throughout the life of the Project.

Residual Impacts (100 Years after Mining)

Groundwater Drawdown

- The predicted water level in the backfilled void is approximately 55 m AHD with a pit lake level of approximately 50 m AHD.
- Predicted residual drawdown levels in excess of 50 m are constrained to the backfill zones, the Pit 1 portal and the final void.
- Predicted residual drawdown levels between 20 and 50 m are constrained within the syncline formation and do not extend outside of the mine lease boundary.
- The predicted residual drawdown within the regolith/alluvium (Layer 1) outside of the mine lease boundary is less than 2 m.

Baseflow

- The modelling indicates that there will be no significant baseflow contribution to the creek following 100 years of recovery and therefore water quality impacts (based on the current simulations) are considered negligible.

Groundwater Quality

- The modelling indicates that the inflows to the pit void will exceed outflows and the evaporative losses will exceed rainfall. On this basis the pit void will act as a groundwater sink with evaporative salinification predicted to increase the salinity from 7,454 mg/L (11,125 μ S/cm), at the end of mining, to in excess of 20,000 mg/L ($\sim$ 30,000 μ S/cm) by 2,000 years after mining. This prediction is conservative with current pit water showing lower salinity levels.
- Due to the low outflows from the pit void and hence the marginal contribution the void water will make to the surrounding groundwater system the risk of adverse impacts to water quality is considered to be negligible.
- As such, the potential impacts on the Hunter River Alluvium are also considered to be negligible.

Potential Impacts on Existing Groundwater Users

There are no identified groundwater users within the mine lease boundary.

The mine to the north (Integra Mine) forms the only identified groundwater users within the predicted extent of groundwater drawdown. Modelling indicates a peak reduction to inflows at the Integra Mine of <2 m³/d at which forms <1 ML per water year.

Potential Impacts on Groundwater Dependent Ecosystems

There are no identified groundwater dependent ecosystems within the mine lease boundary or the predicted extent of groundwater drawdown.

Groundwater Licence Requirement

The peak licensing requirement is predicted to occur in the 2020–2021 water year, with a total modelled inflow of 305 ML/a ($840 \text{ m}^3/\text{d}$) in that water year.

The predicted annual inflow diminishes to 126 ML/a ($345 \text{ m}^3/\text{d}$) during the final full water licensing year. During recovery, modelling shows that the rate of inflow is less than during mining.

The total groundwater licence currently held is 100 ML/a, therefore it is anticipated that additional groundwater licences will need to be obtained prior to the first year of mining.

Surface Water Licence Requirement

The peak licensing requirement is predicted to occur around 2015 to 2016 and persist throughout the life of mine, with a total modelled alluvial water take of 2 ML/a ($5.5 \text{ m}^3/\text{d}$). During recovery, modelling shows that the rate of inflow is less than during mining.

The surface water licences currently held total 555 ML/a. Of this total, 300 ML/a pertains to Rix's Creek so the modelled alluvial water take can be accommodated by the currently held licences.

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1. INTRODUCTION

1.1 Rix's Creek Continuation of Mining Project

This section provides an introduction to Rix's Creek Mine, the proposed Rix's Creek Continuation of Mining Project (the Project), and the purpose and content of this report.

1.1.1 Overview

Rix's Creek Mine (the mine) of Rix's Creek Pty Limited, is owned and operated by Bloomfield Collieries Pty Limited (Bloomfield). The mine is an open cut coal mine approximately 5 km north-west of Singleton in the Hunter Valley Coalfields of NSW. The mine currently produces approximately 1.5 million tonnes per annum (Mtpa) of product coal from its existing operations. The mine location is shown in Figure 1.1 and a detailed map of the current operation is provided in Figure 1.2.

Bloomfield is seeking approval for the Rix's Creek Continuation of Mining Project (the Project), which relates to the continued operation of the existing open cut coal mine. The Project would allow the mine to continue to operate as an open cut mine, accessed via its existing infrastructure facilities.

The Project seeks to extend the life of the existing open cut mining operation at Rix's Creek until approximately 2037. The continuation of mining operations will extend in a north-westerly direction and require a modification to Mine Lease 1432 for an out of pit dump. The continuation of operations will utilise the existing mine access, Coal Handling and Preparation Plant (CHPP), coal stockpiling and rail facilities. The proposed final landform is shown in Figure 1.3.

1.1.2 Proposed Development

The Project seeks to continue the existing mining operation at the mine and to mine up to 4.5 Mtpa ROM coal per year. Mining methods will be the same as those currently employed at the mine, being multi-seam bench open cut techniques. Run of mine (ROM) coal will continue to be processed on site at the existing CHPP which has capacity to accept the proposed increase in throughput. Product coal will then be transported by rail to the Port of Newcastle. It is estimated that the mine could yield a total of 32 million saleable tonnes of coal at an overburden ratio of approximately 10.5:1 before coal seams are exhausted.

The components of the proposed development comprise:

- The ongoing use of, and future additions to, the existing mine fleet.
- Use of the existing mine infrastructure facilities including the CHPP.
- Continuation of operating hours - 24 hours a day seven days a week.
- Use of existing and new rejects and tailings emplacements. Plus tailings dewatering technology to decrease the area of tailings emplacement required.
- Rail transport of product coal to the Port of Newcastle.
- Mine closure and rehabilitation.
- Environmental management.

1.2 Proposed Operations Relevant to this Groundwater Impact Assessment

The proposed continuation of mining at the Project has been identified as having the potential to impact on the groundwater resource in the area. The following project components are highlighted as they directly relate to this groundwater impact assessment (GIA):

- The extraction of material from beneath the regional groundwater table. Mining operations employ a multi-seam bench open cut technique which will involve the removal of the overburden, up to nine coal seams and the coal seams interburden.
- The construction of an additional New England Highway underpass (tunnel) to be located to the north of the existing tunnel crossing.

- Fine rejects. The fine rejects at the mine consist of a slurry of clay, silt and composite mineral and coal particles less than 1.5 mm in size, with mixed water to a pulp density of around 28 per cent. This slurry will be pumped from the underflow of the tailings thickener through a pipeline to the Tailings Emplacement Dam No. 4. Dewatered tailings will be co-disposed with coarse rejects.
- Tailings emplacement. The tailings emplacement area within Pit 2 (Tailings Emplacement No. 3) covers 19 ha and is scheduled to reach capacity during 2014. This tailings emplacement area will continue to be dewatered, capped and eventually rehabilitated by 2019. Tailings Emplacement No. 4, located in a section of the Pit 1 void received approval in 2012. Placement of tailings in Tailings Emplacement No. 4 will commence when Pit 2 (Tailings Emplacement No. 3) reaches tailings capacity and will accept tailings during the continuation of operations at the mine.
- Post-mining land surface. The rehabilitation of the Project will be influenced by waste rock dumps and the proposed final pit void.

1.3 Purpose of the Report

This report has been compiled in order to address groundwater related hazards and risks that may arise as a result of proposed Project activities and will support and form part of the Environmental Impact Statement (EIS) for the Project.

The report has also been developed and structured to address key issues specific to groundwater resources as prescribed DGRs for the Project.

The report is designed to provide sufficient information on the existing groundwater environment within the Project area and its immediate surrounds to enable assessment of the potential impacts of the Project on groundwater system; and any subsequent impacts on surface water, groundwater dependent ecosystems (GDEs) and existing groundwater users.

The assessment has been used to develop appropriate management and mitigation strategies that are based on the predicted impacts.

1.3.1 Director General's Requirements

The Rix's Creek Continuation of Mining Project Environmental Impact Statement has been prepared in accordance with Division 4.1, Part 4 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) which ensures that the potential environmental effects of a proposal are properly assessed and considered in the decision-making process.

In preparing this GIA, the Director-General's Requirements (DGRs) issued for the Rix's Creek Continuation of Mining Project (SSD 13_6300) on 3 March 2014 have been addressed as required by Clause 75F of the EP&A Act. The key matters raised by the Director-General for consideration in the GIA are outlined in Table 1 along with a reference to where the requirements are addressed in the report.

Table 1.1: Director General's Requirements

Director General's Requirements	Section Addressed
Detailed assessment of potential impacts (including cumulative impacts) on the quality and quantity of existing surface and ground water resources, including:	
• Detailed modelling of potential groundwater impacts, including any potential impacts on alluvial aquifers	8
• Impacts on affected licensed water users and basic landholder rights	9.4
• Impacts on riparian, ecological, geo-morphological and hydrological values of watercourses, including environmental flows	9
• A flood assessment including identification of any necessary flood impact mitigation measures.	See Surface Water Impact Assessment
A detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume, salinity and frequency of any water discharges), water supply infrastructure and water storage structures	7

Director General's Requirements	Section Addressed
An assessment of proposed water discharge quantities and quality against receiving water quality and flow objectives	8.8 to 8.11, 9
Assessment of impacts of salinity from mining operations, including disposal and management of coal rejects and modified hydrogeology, a salinity budget and the evaluation of salt migration to surface and groundwater sources	8.11, 9
An assessment of groundwater impacts against the minimal impact considerations in the NSW Aquifer Interference Policy	9.6
Identification of any licensing requirements or other approvals under the <i>Water Act 1912</i> and/or <i>Water Management Act 2000</i>	10
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)	See Surface Water Impact Assessment
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	10, 11
A detailed description of the proposed water management system (including sewage), water monitoring program and measures to mitigate surface and groundwater impacts	5, 11
Compliance with the Hunter River Salinity Trading Scheme (as required)	7.3

1.4 Report Structure

This report is written such that it provides the reader with clear and concise information on the state of the groundwater environment within the Project and its immediate surrounds (study area). It aims to assess the potential impacts on groundwater levels and quality, environmental receptors and local groundwater users from the proposed Project. It also addresses all of the relevant licensing requirements, and puts forward monitoring and management methodologies to ensure that all relevant stakeholders in the Project have been considered.

This report is structured as follows:

- **Section 2** presents the methodology by which the Impact Assessment has been undertaken including data sources and a brief outline of the modelling method.
- **Section 3** presents the statutory requirements and relevant legislation which is applicable to the Project in relation to groundwater. This includes the Director Generals Requirements (DGRs) the NSW Office of Water requirements and the Office of Environment and Heritage requirements which are specific to groundwater resources. It also addresses the relevant state policies and *Water Management Act 2000* along with the licensing and the NSW Aquifer Interference Policy.
- **Section 4** reports on the existing environment within the study area. It presents the existing climatic information, catchment description, the geological setting, and the hydrogeological setting.
- **Section 5** provides detail on the current monitoring network which is installed across the site and describes how this monitoring network is designed to obtain groundwater data from the separate hydrogeological systems which are present in the study area. It also presents data on the existing groundwater users in the Project Application Area. The groundwater data obtained from the monitoring network is discussed and analysed in terms of groundwater flow paths, vertical gradients, and recharge and discharge points.
- **Section 6** presents the relevant hydrogeological investigations that are relevant to this report and have been used to inform the Impact Assessment.
- **Section 7** Presents a site water balance, including a description of site water demands, water disposal methods, and water supply infrastructure and water storage structures.
- **Section 8** presents the groundwater numerical modelling which was undertaken to predict potential mining induced impacts on the groundwater system and environmental receptors. The objectives of the modelling exercise are described along with the calibration, prediction and sensitivity / uncertainty analysis phases.

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- **Section 9** presents the impact assessment from the Project on the surrounding groundwater environment, surface water, GDEs and regional groundwater users.
 - **Section 10** presents the relevant groundwater accounting and water sharing plan relevant to the Project Application Area. The licensing rules are discussed along with the relevance of the aquifer interference approval.
 - **Section 11** presents the groundwater monitoring, management and contingency response plans. The impacts of the Project are assessed in relation to the existing monitoring network and any potential changes or additions to this monitoring network are also discussed.
 - **Section 12** presents the published and non-published literature which was used to inform various sections of this report.

2. METHODOLOGY

2.1 Study Area

The study area is situated in the northern section of the Hunter Valley Region. The mine is confined within a geological basin-like north–south trending syncline. The syncline is approximately 8 km long by 3 km wide and is bounded to the east and west by the Camberwell and Darlington Anticlines. The syncline is asymmetrical with the western limb generally dipping at a steeper angle than the eastern limb (Aquaterra 2010a).

For the purpose of this GIA, a study area has been adopted encompassing the entire syncline bounded by the Hunter River to the west and south, the Mulbring Siltstone outcrop to the east and Glennies Creek and the Hunter thrust fault to the north (Figure 2.1). The study area is 173.6km² in size.

2.2 Background Information Review

The following sources of data and information were utilised to ensure the GIA builds on the work and investigations undertaken to date.

2.2.1 Database Searches

A search of the NSW Office of Water database of registered groundwater works (PINNEENA, version 4.1) was completed using a 10 kilometre (km) radius around the centre of the mine lease. The PINNEENA database is maintained and update by the NSW Office of Waters and stores available information on the location and details of registered groundwater works in the state.

2.2.2 Review of Surrounding Developments

Surrounding developments with potential to impact on the hydrogeological system within the study area are depicted in Figure 1.1, and include:

- Integra South Pit and its Western Extension. This development is located immediately to the north of Pit 1. The Integra Pit accesses coal from the Pikes Gully to Upper Hebden Seams.
- The Ashton Coal Underground Mine. Located to the north-west of the mine and on the eastern side of Glennies Creek. Ashton access coal from the Pikes Gully to Lower Barrett Seam.

2.2.3 Review of Previous Studies

The following pertinent investigations were reviewed as part of the GIA:

- Bowmans Creek Diversion, Groundwater Impact Assessment (Aquaterra 2009)
- Glennies Creek Open Cut Coal Mine Groundwater Assessment (AGE 2007)
- Rix's Creek Gap Study (Aquaterra 2010a)
- Monitoring Piezometer Installations at Rix's Creek (Aquaterra 2010b)
- Rix's Creek Final Void Management Plan (RPS Aquaterra 2012)
- Rix's Creek Coal Mine: Environmental Impact Statement (Croft and Associates 1988)
- Rix's Creek Mine Water Management Plan (Bloomfield 2014).

2.2.4 Review of Baseline Data

Baseline groundwater data has been collected on site since 2010. This data has been provided by the proponent, reviewed and incorporated into the groundwater model update.

2.2.5 Preliminary Field Work

A drilling program was conducted in May 2010 to install a groundwater monitoring network (Aquaterra 2010). Five standpipe piezometers (BH1 to BH5) were installed the locations are presented on Figure 2.1.

The two shallow piezometers (BH3 and BH4) target shallow regolith / coal measures overburden and three deep piezometers (BH1, BH2 and BH5) target the Arties or Lower Barrett coal seams.

Deep piezometer BH2 has since been decommissioned; this piezometer was damaged during mining operations.

2.3 Method of Impact Assessment

A groundwater impact assessment for the mine has been completed using a conceptual understanding of the site together with an updated groundwater model. The model has been used to predict both the cumulative impacts of the Project with other existing and proposed mining operations, as well as the incremental impacts that are directly attributable to the Project.

3. LEGISLATION, POLICY AND GUIDELINES

The policies that pertain to the GIA are detailed within this section. The impact assessment has been structured accordingly to address the legislative requirements of the Project.

3.1 Commonwealth Legislation

3.1.1 *Environment Protection and Biodiversity Conservation Act 1999*

Pursuant to the *Environmental Protection and Biodiversity Conservation Act 1999* (the EPBC Act), an action that has, will have, or is likely to have a significant impact upon matters of national environmental significance (MNES) is declared a controlled action. A controlled action requires the approval of the Department of Environment (DoE) in addition to requirements under NSW State legislation.

The proponent intends to refer the project to the DoE for a decision on whether the action is likely to have a significant impact on the MNES. This GIA is intended to be provided as a supporting document for the referral.

The EPBC Act lists nine MNES to be addressed when assessing the impacts of a proposal. The MNES for water resources (water trigger) is applicable to this GIA. The water trigger came into effect on 22 June 2013 when an amendment was passed to provide that water resources are a matter of national environmental significance.

Under the EPBC Act, an expansion or modification to existing facilities may be within the definition “large coal mining development” if the expansion or modification involves extractive coal mining activities which are likely to have a significant impact on a water resource.

DoE has provided significant impact criteria to assist in determining whether the impacts on a water resource from a large coal mining development are likely to be significant. The key criteria raised by the EPBC Act for consideration in the GIA are outlined in Table 3.1 along with a reference to where the assessment criteria have been addressed in the report.

Table 3.1: Significant Impact on Water Resources Guidelines under the EPBC Act

Assessment Criteria	Section(s) Addressed
Valuation of the water resource	4.6 and 4.7
Changes in water quantity, including the timing of variations in water quantity	9.2.2, 9.3.1 and 9.6
Changes in the integrity of hydrological or hydrogeological connections, including substantial structural damage (e.g. large scale subsidence)	9.1
Changes in the area or extent of a water resource	9.6
The risk that the ability to achieve relevant local or regional water quality objectives would be materially compromised	9.3.3
A significant worsening of local water quality (where current local water quality is superior to local or regional water quality objectives)	9.3.3
Risk of high quality water being released into an ecosystem which is adapted to a lower quality of water.	9.3.2 and 9.3.3
Cumulative impacts	9.6

3.1.2 *Environment Planning and Assessment Act 1979*

The Project is a “Major Development” as defined in State Environmental Planning Policy (SEPP) Major Development 2005, and in accordance with the *Environmental Planning and Assessment Act, 1979* (EP&A Act) requires approval of the NSW Minister for Planning to proceed under Part 4 of the EP&A Act.

The Director General's Requirements (DGRs) stipulate that the impact assessment must meet the form and content requirements in Clauses 6 and 7 of Schedule 2 of the Environmental Planning and Assessment Regulations 2000.

The DGRs relating to groundwater for the EIS are outlined in Table 1.1.

3.1.3 Strategic Regional Land Use Policy

The Strategic Regional Land Use Policy has been implemented to identify, map and protect residential and agricultural land across the state from the impacts of mining and Coal Seam Gas (CSG) activity (New South Wales Government 2012).

The Project falls within the Upper Hunter Strategic Regional Land Use Plan and, discussed in the PEA (AECOM 2013), the project area is not mapped as biophysical strategic agricultural land nor is it identified as either viticulture or equine industry strategic land.

Furthermore, Figure 3.1 shows that the project area is situated on land that has been classified as moderate to low capability land in accordance with the Land and Soil Capability (LSC) assessment developed for NSW by the Office of Environment and Heritage (OEH 2012).

3.1.4 Water Management Act 2000

Following the introduction of the *Water Management Act 2000* (WM Act 2000) the NSW Office of Water are progressively developing Water Sharing Plans (WSPs) for rivers and groundwater systems across New South Wales.

Water licensing is administered under the *Water Management Act 2000* and *Water Act 1912*.

Access to surface water and alluvial licences at the mine is governed by the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources* 2009 (HUAWS 2009).

Access to hard-rock licences at the mine is governed by the *Water Act 1912* as the draft *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources* is yet to commence.

Water Sharing Plans

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).

The Project is situated within the Singleton Water Source of the Hunter Unregulated and Alluvial Water Sources WSP as shown on Figure 3.2.

The hard rock is governed by the *Water Act 1912* as the draft *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources* is yet to commence.

Aquifer Interference Policy

The Aquifer Interference Policy (AIP) explains the water licensing and approval processes and requirements for aquifer interference activities. It assists proponents of aquifer interference activities in preparing the necessary information and studies to be used in the assessment of the proposed activity. The AIP also forms the basis of the assessment and subsequent advice provided by the NSW Office of Water for the assessment of the proposed activity under the *Environmental Planning and Assessment Act 1979* (NSW Office of Water 2012).

It is important to note that the AIP defines an aquifer as any type of saturated geological formation irrespective of permeability or water quality. This differs to the "traditional" definition of an aquifer as being a groundwater system of sufficient permeability such that it can yield productive volumes of water.

The AIP adopts the following definition of an aquifer interference activity from the WM Act 2000:

- 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.
- The disposal of water taken from an aquifer in the course of carrying out mining or any other activity prescribed by the regulations.
- The Policy specifies that the volume of water taken from a water source(s) as a result of an activity is required to be predicted prior to project approval and that approval will not be granted unless adequate arrangements are in force to ensure that no more than minimal harm will be done to an aquifer or its dependent ecosystems.

Minimal harm criteria are specified in the Policy for highly productive and less productive groundwater sources.

In terms of the NSW Aquifer Interference Policy, the Sydney Basin Richmond is classified as a Highly Productive Groundwater Source (NSW Office of Water 2013). The water source is a Porous Rock Water Source, due to being predominantly of sedimentary origin (sandstone, siltstone and claystone).

Aquifer Interference Approval

Under the AIP, an aquifer interference activity requires:

- The necessary volumetric WALs.
- 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.

Under section 91F of the WMA, it is an offence to carry out an aquifer interference activity without an aquifer interference approval. An aquifer interference activity includes the penetration, interference or obstruction of flows within an aquifer, or to take, or dispose of waters from an aquifer.

However, section 91F of the WMA does not currently apply. Section 88A provides that Part 3 of Chapter 3 (including section 91F) applies to each part of the state or each water source and each type or kind of approval that relates to that part of the state or that water source that is declared by proclamation. In essence, the AIP applies, however the approvals framework has not been finalised.

A framework for the implementation of the AIP has been produced by NSW Office of Water (October 2013) and this report addresses the key issues in this draft document (Section 7.3.12).

Under the Aquifer Interference Policy (AIP) a water licence is required for any activity that penetrates, interferes, obstructs flow in aquifer or takes and disposes of water from aquifer during mining activity. Where the activity causes the movement of water from one part of the aquifer to another or to and from a surface water body, a licence is also required.

Drilling licences under the *Water Act 1912* will be required for installation of monitoring piezometers for the purposes of water level, groundwater quality monitoring and hydraulic testing in any aquifer underlying the study area. Compliance with this licensing is ongoing at Rix's Creek Mine.

The *Water Management Act 2000* includes the concept of ensuring "no more than minimal harm" for both the granting of water access licences and the granting of licences and approvals. Water Access Licences will not be granted unless the Minister is satisfied that adequate arrangements are in force to ensure that no more than minimal harm will be done to any water source as a consequence of water being taken under the licence. In order to address minimal harm criteria, groundwater sources have been divided into "highly productive" and "less productive" based on certain criteria that are detailed in the AIP.

4. EXISTING ENVIRONMENT

4.1 Topographical Setting

The natural topography surrounding the mine exhibits gentle undulations to low hilly country. Natural surface drainage is directed towards Rix's Creek an ephemeral stream that runs to the south-west through the mine and discharges to the Hunter River (Figure 4.1).

Land elevation ranges from 160 m AHD (Australian Height Datum) in the north-west and north-east, to topographical lows in the centre of the mine lease (60 m AHD), where the existing open cut pits are situated (Figure 4.1).

4.2 Historical and Current Mining

Mining operations in the vicinity of the mine first began in the late 1800s; with underground coal-mining activities to the east of Pit 2 and in the area where Pit 1 is now situated (refer to Figure 1.2).

Development Consent for mining operations in their current form at the mine was first issued on 19 October 1989. The 1989 Development Consent allowed production of up to 0.3 Mtpa of raw coal for the first five years, increasing to 1.5 Mtpa in year six following the commissioning of a coal preparation plant.

The 1989 Development Consent for Rix's Creek mine was issued under CL352, which allowed mining operations for a period of 21 years from the date of approval. CL 352 included surface mining exclusions required by the then landowners, which prevented the operation of open cut mining activities. Following agreement being reached with the landholder's, preparation of an Environmental Impact Statement began in order to allow surface mining to take place. This development application was approved on 16 October 1995 and ML 1432 issued on 24 June 1998 allowing open cut mining to occur over the entire area. The mine continues to operate under this approval.

The 1995 EIS undertook a full assessment of environmental impacts across ML 1432 with current day operations largely reflecting the operations assessed and approved in 1995. The proposed project, as described below, would see a new EIS prepared across predominantly the same study area (ML 1432) as the 1995 EIS taking into consideration new environmental legislation, guidelines, regulations and constraints.

Open cut mining at Rix's Creek began in 1990. Extraction has occurred via a multi seam bench open cut operation, which mines up to nine coal seams and associated splits. In 1992, the mining operation was focused to the north of the underground workings in Pit 1 (North Pit) into the Liddell and Arties seams and to the south of the highway in Pit 2 (now the tailings emplacement area) into the Barrett and Hebden Seams, as part of Stage 2.

The Camberwell open cut mine is located immediately north of Pit 1 and is mining down to the Barrett seam.

Mine progression into Stage 3 and Stage 4 allowed for continued operation in Pit 1 (North Pit) and Pit 2 (Tailings Dam), with the beginning of mining in Pit 3 (West Pit) into the Liddell seams. Pits 1 and 3 are planned to be mined down to the Liddell and Barrett seams respectively. The mining of Pit 1 is scheduled to finish in 2015. Pit 2 has been fully mined out and developed into an approved tailings emplacement area and is anticipated to be at full capacity by 2014 and then subsequently drained, capped and rehabilitated by 2019.

Pits 1 and 3 are being mined down to the bottom of the Liddell and Barrett seams, respectively. The elevations of the Upper Liddell and Barrett coal seams along with the geological cross-sections are presented in Figures 4.2 and 4.3.

4.3 Climate

The Hunter Valley region has a moderate climate, comparable to a Mediterranean climate with hot summers and mild winters. The RCCP area has a summer dominated rainfall pattern with the majority of rainfall occurring over the November to March period. The mean annual rainfall recorded at Singleton is 659 mm/year (Bureau of Meteorology station number 061397) based on

data from 2003 to 2013. Evaporation data is not available at this meteorological station; however, the *Climatic Atlas of Australia – Evaporation* (BOM 2001) suggests that the annual average potential evaporation is around 1300 mm/yr for the region.

4.4 Catchment Description and Local Hydrology

Run-off from undisturbed areas is directed away from mining operations through diversion banks, which direct run-off into natural watercourses or into a number clean water dams. Clean water dams overflow into the natural drainage system.

In the project area Rix's Creek is a losing (influent) stream. The elevation of the bottom of the Creek is above groundwater level and therefore the creek does not receive a base flow (Aquaterra 2010a).

4.5 Geology

4.5.1 Regional Geology

The Project is located within the Hunter Coalfields of the Sydney Basin. The coal reserves occur within the Permian age Foybrook Formation of the Vane Sub-group, which comprises the Lemington to Hebden coal seams.

The target coal seams are separated by interburden sediments, which comprise sandstone, siltstone, conglomerate, mudstone, and shale, as well as occasional minor coal seams.

The main regional geological structures in the area are two approximately parallel thrust faults, these being the continental scale Hunter Thrust Fault to the north of the Project and the Hebden Thrust Fault to the south.

There are a number of anticlines and synclines that are significant to the Project. The axes of the anticlines and synclines are orientated approximately north–south. No major faults or other significant structures or igneous intrusions (dykes or sills) are known to occur in the mining area.

4.5.2 Local Geology

The Project is confined within a geological basin-like north–south trending syncline (Figure 2.1), and it hosts the Permian coal reserves that are part of the Whittingham Coal Measures. The syncline is approximately 8 km long by 3 km wide and is bounded by the Camberwell and Darlington Anticlines. The syncline is asymmetrical, the western limb generally dipping at a steeper angle than the eastern limb (RPS Aquaterra 2010).

The major coal seams identified in the Rix's Creek syncline are (in descending stratigraphic order):

- Lemington Seam
- Pikes Gully Seam
- Arties Seam
- Liddell Seam
- Barrett Seam
- Hebden Seam.

The target coal seams are dispersed as several splits, separated by interburden sediments that comprise alternating sandstone, siltstone, conglomerate, mudstone and shale, as well as occasional minor coal seams. Interburden between the Barrett and Upper Hebden seams increases to in excess of 20 m in the northern and western regions, rendering the Upper Hebden seam uneconomical to mine (RPS Aquaterra 2010). Sub-cropping to the east and west of the mine area are the Pikes Gully, Arties, Upper to Lower Liddell, Barrett and Hebden seams.

The unconsolidated regolith in the area comprises clay-bound and silt-bound sands and gravels. Minor alluvium, associated with Rix's Creek, exists to the south of the mine lease (RPS Aquaterra 2010).

4.6 Hydrogeology

4.6.1 Regional Hydrogeology

The hydrogeology of the Upper Hunter Valley is dominated by two aquifer groups; alluvial deposits of quaternary age and consolidated sedimentary rocks of Permian age.

The alluvial deposits have been shown to produce reliable yields of good quality water, which are utilised for domestic and agricultural purposes. These sediments consist mainly of gravel, sand and clay deposits, which can provide increased yields where unconsolidated.

The permeabilities of the unconsolidated sediments are generally 10 to 100 times greater than the coal seams.

Groundwater within the Permian sedimentary rocks is generally of poorer quality and lower yielding than that of the alluvial aquifers. The coal seams are the main aquifers within the Permian strata, and can show a semi-confined behaviour with leakage from overlying and underlying mudstones, sandstones and siltstones. Weathered zones of the Permian strata near surface also form localised aquifers and can form laterally and vertically inconsistent perched aquifer systems.

The permeabilities of the coal seams are in the range 0.001 and 12 m/day with a logarithmic mean value of 0.11 m/day. The permeabilities of the coal seams decrease exponentially with depth (AGE 1984).

The sedimentary rocks that comprise the interburden strata have permeabilities in the range 0.426 and 0.0013 m/day and a log mean of 0.0018 m/day (AGE 1984).

The regional composite potentiometric surface is a subdued replica of the topography. The potentiometric surface is located at a greater depth beneath the elevated areas. Groundwater flows from elevated areas to lower lying areas. Superimposed on the regional flow pattern are local flow systems that are controlled by the shape of the local rather than regional topography. In the valleys, the potentiometric surface is often at ground level, and these areas constitute groundwater discharge points that are brackish or saline.

4.6.2 Local Hydrogeology

Figures 4.2 and 4.3 depict north–south and east–west cross-sections that represent the pre-mining and current hydrogeological conceptualisation of the site.

The main aquifer unit relevant to the Project is a hard rock system hosted in the Permian coal measures. The groundwater flow within the aquifer is predominantly confined to the cleats and fractures in the coal seams. The coal seams themselves form the main aquifer units within the hard rock system. The hydraulic conductivity (permeability) of the coal seams is generally low (0.01 to 0.05 m/d), but are typically elevated in comparison to the non-coal Permian strata.

The unconsolidated regolith comprises clay-bound and silt-bound sands and gravels. Minor alluvium, associated with Rix's Creek exists to the south of the mine lease. Rix's Creek is essentially ephemeral and has minimal groundwater contribution as it flows across the site, and as such, there are no GDE's associated with the creek.

South of the site, the potentiometric surface converges with the bed of Rix's Creek and the creek provides local drainage to the Hunter River for groundwater that flows along the Rix's Creek syncline.

The hydraulic gradient across the site generally trends north to south along the axis of the syncline and from the eastern and western boundaries of the syncline towards the axis. The impact on the regime due to mining activity varies spatially and temporally and discussed further below.

Pit 1

Pit 1 has mined down to the Lower Liddell Seam and, at the time of writing, mining of this pit was almost complete. The south-easterly void is currently being used for water storage. Known as the "Old North Pit Storage", the head of water within this void has been shown to be associated with seepage at ground surface from the underground workings. This seepage is now controlled by maintaining the head of water in the old North Pit Storage to below 78 m AHD, which corresponds to the ground elevation of the seepage.

Whilst Pit 1 and the underground workings have not mined the same seams, hydraulic connectivity of the two mined areas through the interburden has been demonstrated.

Pit 2

Pit 2 is situated south of the New England Highway and was mined down to the Barrett Seam. Mining of this pit ceased in 2003 and the use of the pit as a tailings emplacement area will create a head of water that will permeate into the exposed coal seams of the pit wall in accordance with their relative permeabilities. During mining of Pit 2, connectivity with the underground workings was demonstrated by inflows, which were subsequently managed by dewatering from the workings.

Dewatering of Pit 2 is planned as part of the Project and through doing so, Pit 2 will become a groundwater sink and the hydraulic gradient between this pit and the underground workings may eventually be reversed.

Pit 3

Pit 3 is the focus of the continuation of mining and will increasingly provide a sink for groundwater as the pit expands northwards and extraction approaches the planned maximum depth of the Hebden Seam. Pit 3 has no direct connection with the underground workings.

Underground Workings

The extent of the underground workings is shown on Figure 1.2. Mining was undertaken from these workings up until 1939 and extracted the Lower Barrett seam. There is believed to be some degree of collapse within the underground workings, however the extent of which is not known. Seepage from the workings has been observed at ground surface suggesting there is some form of blockage and some degree of connective cracking.

The seepage has been managed through the maintenance of the head in Pit 1 and during the excavation of Pit 2 seepage was noted from the east wall, which was managed through the maintenance of head within the underground workings.

The seepage observations suggest that there is connectivity between the underground workings and Pits 1 and 2 as well as with the ground surface. Furthermore, the underground workings have been used as water storage and the injection and abstraction may lead to variations in hydraulic gradients and hence variations in the degree of inflows and outflows associated with the workings.

Integra Mine

The Integra Mine comprises the Camberwell open pit, which has mined down to the base of the Hebden Seam and the Glennies Creek underground mine, which extracts from the Middle Liddell Seam.

The Integra Mine is extracting coal measures within the Rix's Creek syncline and represents significant dewatering of the coal measures up hydraulic gradient of the Project. This operation is considered to create a groundwater sink for the majority of the southerly trending groundwater within the coal measures. The small proportion of the groundwater within the syncline that will report to Rix's Creek Mine will be that which enters the syncline as recharge at the coal measure outcrop in the immediate vicinity.

4.7 Environmental Values

The groundwater receptors within the vicinity of the Project, which have the potential to be impacted by mining operations, are discussed below. Impact analysis and details of the predicted impacts are discussed in Section 9.

4.7.1 Groundwater Users

With the exception of licensed bore GW052121, all registered water bores or wells are located more than 4.5 km from the centre of the mine lease. The locations of the known bores and wells are shown on Figure 4.4.

A review of geological data obtained from the DWE groundwater database, shows that licensed bores are generally less than 16 m deep and target alluvial deposits, associated with the Hunter River (Figure 4.4). The alluvial aquifers targeted by existing users do not extend into the mined area and are considered hydraulically isolated to the mined formations (coal seams). Hence, there are no groundwater impacts to existing users from current and future mining. An assessment of the potential impact to the adjacent operations at Integra Mine is presented in Section 9.4.

Bore GW052121 is located 2.38 km to the east of the Project. The bore is 30.5 m deep and is screened from 24.5 to 30.5 m targeting a coal measure within the Darlington Anticline (Maitland Group). Mining activities are not expected to impact this bore as the target formation is hydraulically disconnected from the mined coal seams at the Project. Furthermore, this bore is significantly outside the area of anticipated depressurisation effects as the deepest mined seam within the pit (the Hebden seam) outcrops around 2.2 km to the west of this bore. The outcrop of this seam is expected to represent the limit of the groundwater depressurisation effects due to mining and is discussed further in Section 9.

4.7.2 Groundwater Dependant Ecosystems

The proximity of GDEs to the Project area has been assessed by reviewing the WSP and the Groundwater Dependent Ecosystem Atlas (Bureau of Meteorology, 2012) and consulting with the ecological specialist involved in this EIS process. The findings have confirmed that there are no identified GDEs in the vicinity of the Project.

Most of the existing mine footprint is situated up hydraulic gradient of Rix's Creek and there are no alluvium deposits associated with the creek in the immediate vicinity of the mine. Surface water monitoring data (EC and flow observations) obtained from the creek shows the water to be relatively fresh (EC <200 $\mu\text{S}/\text{cm}$) and flows to be occasional, which suggests that the flow within the Creek is almost entirely derived from surface water run-off.

As there is no alluvium in the mining area and no apparent base flow contributions, the pumping or interception of groundwater from current or future mining activities is unlikely to impact on creek flow. The only risks to the creek therefore relate to water quality impacts associated with backfilling and potentially affected baseflow water quality. This is discussed in more detail in Section 9.

5. GROUNDWATER MONITORING

The Project mining lease (1432) covers an area of 18.46 km². Monitoring locations for potential impacts were selected to facilitate the observation of any significant changes in the groundwater regime across the project area.

The monitoring network was designed to comply with the NSW Office of Water guidelines to:

- Permit the collecting of a sufficient and reliable level of data such that any interpretation based on that data should accurately represent the condition of the natural resource at the time of sampling;
- Provide a mechanism for monitoring the impact of mining developments on the groundwater system and to relate it to the predictions made during the environmental impact assessment process; and
- Initiate any required remediation and restoration program where there is degradation of the groundwater regime beyond the approvals in the development application.

5.1 Monitoring Bores

In May 2010, five monitoring bores were installed BH1 to BH5 (Aquaterra 2010b). The site selection for the five bores was based on:

- An assessment of the local environment.
- The current and proposed mining operations.
- Mine rehabilitation plans.
- The existing groundwater users in the area.

The overall aim of the monitoring program was to develop a baseline set of water level and quality data against which any future perceived, or actual groundwater impacts of the mine can be adequately assessed.

The monitoring network currently includes a combination of five standpipe piezometers (monitoring bores) and one existing production bore as shown in Table 5.1.

Bore logs for the five monitoring bores are provided in Appendix D of this report.

Table 5.1: Rix's Creek Groundwater Monitoring Network

Bore ID	Easting (GDA94)	Northing (GDA94)	Type	Depth (mbgl)	Location	Screened Aquifer
BH1	323190	6400562	Standpipe Piezometer	130	Middle of syncline	Upper and Lower Arteries
BH2	322936	6402272	Standpipe Piezometer	90	West of syncline, close to outcrop	Lower Barrett
BH3	325457	6401923	Standpipe Piezometer	11	East of waste dump / backfill area	Regolith and shallow coal seams
BH4	323982	6398666	Standpipe Piezometer	10	Rix's Creek south of Pit 3	Regolith
BH5	324562	6399924	Standpipe Piezometer	66.5	East of Rix's Creek / tailings emplacement area	Lower Barrett
20BL170864	324633	6400335	Production bore	~70	Above underground workings	All coal seams

Of the groundwater monitoring bores, three are screened in the Permian coal measures (BH1, BH2 and BH5) and two in the overlying regolith (BH3 and BH4). A production bore, which is no longer in operation, (production bore 20BL170864) is also utilised as part the monitoring network. The bore intercepts the old underground workings that previously mined down to the Barrett seam (Figure 2.1).

The groundwater monitoring program currently involves:

- Monthly measurement of groundwater levels in all piezometers and continuous logging of groundwater levels in BH4.
- Monthly sampling of all bores and creeks for analysis of Electrical Conductivity (EC), Total Dissolved Solids (TDS) and pH.
- Quarterly collection of water samples from bores and creeks for comprehensive laboratory analysis of a broader suite of parameters including:
 - Physical properties (EC, TDS and pH)
 - Major cations and anions (Ca, Mg, Na, K, Cl, SO₄, HCO₃ and CO₃)
 - Nutrients
 - Dissolved metals.

5.2 Groundwater Level Monitoring and Interpretation

Groundwater level data collected from the six monitoring bores has been interpreted with respect to mining activity, rainfall and the geological and topographical setting. Hydrographs are displayed in Figures 5.1 to 5.3.

5.2.1 Coal Measures

BH1

The water levels in the Upper and Lower Arties Seam (BH1) have shown a substantial decline in water levels which began in March 2011 and accelerated from October 2011. By January 2013, the decline had reached approximately 17 m, after which, the water level decline continued but at a slower rate until the end of the data set in February 2014 when the decline had reached a total of over 18 m.

The Arties Seam has undergone significant depressurisation due to mining activity and the rate of depressurisation does appear to be impacted by rainfall with a higher rate associated with the lower than average rainfall experienced during much of 2012.

BH2

BH2 was designed to monitor the Lower Barrett Seam and was damaged sometime after the February 2012 monitoring round. This damage was believed to be due to ground movement collapsing the piezometer.

Water levels prior to this occurrence were showed a steadily declining trend that was likely due to advancing operations. A response to variation in rainfall is not evident in this hydrograph.

From the beginning of the data set, BH2 is showing water levels in the Lower Barrett to be approximately 3 m below that measured in BH5, whereas the elevation of the Lower Barrett at BH2 is approximately 35 higher than at BH5. This represents significant depressurisation of the Lower Barrett due mining of the North Pit and the Camberwell Pit.

BH5

BH5 monitors water levels in the Lower Barrett Seam and is located down dip of the underground workings on the eastern flank of the syncline.

BH5 has shown an overall rising trend since data collection began in July 2010. Water levels in this bore are likely to be influenced by the head of water in the underground workings, which is evident from the hydrographs shown on Figure 5.1. The hydrograph for BH5 also indicates a strong relationship with rainfall, however it is not clear if the dominant response is direct rainfall recharge at the Barrett Seam outcrop or indirect via the underground workings.

Production Bore

The production bore is no longer used for abstraction and is used to monitor the water levels in the underground workings, which mined to the Lower Barrett Seam. There is most likely some degree of collapse within the underground workings, however the extent of which and any impacts on groundwater movement is not known.

The production bore hydrograph (Figure 5.1) shows a general rising trend since monitoring began, with responses to rainfall evident.

The persistent rising trend despite depressurisation during mining and below average rainfall during 2012 is likely to be attributable to the proximity of the underground workings to Pit 2, which is now used for tailings emplacement. During the excavation of Pit 2, a connection with the underground working was believed to have been made; therefore, seepage to the underground workings would be expected due to the head of water associated with the tailings emplacement.

5.2.2 Regolith

BH3 monitors the overlying regolith in the north-eastern area of the site. The hydrograph for the bore (Figure 5.2) shows the water level variation to be within a range 1.5 m since data collection began in August 2010.

A response to rainfall is more evident when this hydrograph is plotted alongside Cumulative Rainfall Distribution (CRD), which displays the seasonal variation in rainfall. The regolith demonstrates a response to seasonal rainfall, as opposed to daily events, due its relatively low permeability compared to the coal measures.

The BH3 hydrograph shows no apparent response to mining activity, which highlights the relatively low permeability of the regolith and the confinement of the groundwater depressurisation to within the coal measures of the Rix's Creek syncline.

5.2.3 Colluvium

BH4 is screened in siltstone and it monitors the shallow water table that eventually drains into Rix's Creek. As with the regolith, a response to rainfall is evident when compared to the CRD, demonstrating the relatively low permeability of this formation through its response to seasonal rainfall variation.

For reference, the elevation of Rix's Creek bed (61.80 m AHD) has been plotted on Figure 5.3 and shows that the colluvium water table has remained below the creek bed since data collection began, corroborating the conceptualisation of the creek being influent in the vicinity of the Project.

The colluvium water table at BH4 has shown no apparent response to mining activity since data collection began.

5.3 Groundwater Quality Monitoring and Interpretation

The following section discusses the groundwater chemistry data that has been obtained during the baseline monitoring.

Sampling for hydrochemical analysis has been undertaken at the mine since August 2010. Samples are analysed by ALS Sydney for major ions, nutrients, metals and physical parameters.

The certificate of analysis for the August 2013 monitoring round is presented in Appendix D, including the ionic balance of each sample. The results from all hydrochemical analyses are presented as Piper Trilinear Plots (Figure 5.7).

5.3.1 Sampling Methods

Disposable bailers are used to purge and sample at the monitoring locations. Prior to sampling, the bores are purged in accordance with AS/NZS 5667 (Standards Australia 1998).

Samples are collected in laboratory prepared containers, stored on ice and submitted with a chain of custody to the NATA accredited laboratory ALS Environmental Pty Ltd (ALS).

The depth to water caused difficulties purging monitoring bore BH1. To ensure groundwater samples at this bore are representative of the screened aquifer low-flow sampling was in July 2011. An air-displacement bladder pump has been since used at the bore and the accepted low-flow sampling method.

Low-flow sampling minimises the drawdown from pumping by using low flow rates (<0.5L/min) to initially purge and then sample the screened formations. Throughout pumping the water level is monitored and the pump rate changed accordingly to reduce or eliminate drawdown. Minimising the drawdown effectively reduces the potential for stagnant water (from inside the bore casing) to mix with fresh water by directly drawing water from the screened formation.

The pump intake is situated in the middle of the screened zone. Abstracted groundwater is then pumped through a flow cell containing probes measuring pH, EC, dissolved oxygen (DO) and total dissolved solids (TDS). The probes are monitored and readings recorded at desired intervals. A minimum purge time (20 minutes) plus the demonstrated stabilisation of water quality parameter ensures a representative sample.

5.3.2 Electrical Conductivity

The salinity of the groundwater is measured in the field as electrical conductivity (EC). The EC within the six monitoring bores has been measured generally on a monthly basis since July 2010.

Table 5.2 provides a statistical summary of the field water quality data with time series EC graphs displayed in Figure 5.4.

EC profiling has also been undertaken, which shows the EC variation with depth through the column of standing water within the bore. EC profiles are displayed in Figure 5.5.

Table 5.2: Field Water Quality Parameters

Hole ID	pH				EC (mS/cm)			
	Average	Median	Minimum	Maximum	Average	Median	Minimum	Maximum
BH1	6.80	6.85	5.97	7.21	2.20	0.72	0.25	11.01
BH2	6.90	6.93	6.79	7.15	6.40	6.38	6.17	6.70
BH3	5.24	5.23	4.70	6.35	5.37	5.55	4.20	6.07
BH4	7.18	7.24	6.34	7.75	19.20	19.6	13.88	21.42
BH5	6.73	6.83	4.46	7.23	4.54	4.52	2.82	6.81
20BL170864	7.55	7.68	6.70	8.12	3.08	1.79	1.36	7.30

Coal Measures

The time series EC graph for BH1 (Figure 5.4) shows the majority of the data to have remained between 0.25 and 1.22 mS/cm with three significant data spikes to between 5.86 and 11.81 mS/cm. The spikes in EC are not consistent with rainfall patterns and may be due to variation in the sampling depth. The salinity profile (Figure 5.5) for this bore shows an order of magnitude increase in salinity from between 80 to 90 mbgl. The stratification will likely represent the extent of the vertical mixing as the high EC water from the Artesian seam enters the bore through the screened sections located at 115 to 121 mbgl and 127 to 130 mbgl.

EC monitoring at BH2 has been undertaken from August 2010 to November 2011 and shows a relatively stable trend with values fluctuating from 6.26 to 6.70 mS/cm. Figure 5.4 does appear to show a correlation with rainfall with reduced EC associated with reduced rainfall; however the data set is not extensive enough to discern a significant pattern. EC profiling has not been undertaken.

EC monitoring at BH5 commenced in July 2010. The EC levels are shown to range from 2.82 to 6.81 mS/cm with a median of 4.52 mS/cm (Figure 5.4).

Figure 5.4 appears to show an inverse correlation with rainfall, fresher water is generally associated with higher rainfall. As discussed in Section 5.2.1, the BH5 hydrograph correlates with rainfall so it is likely that the groundwater entering this bore is being diluted by rainfall recharge, possibly via infiltration through the tailing emplacement in Pit 2.

The salinity profile for BH5 (Figure 5.5) shows relative uniformity with only a minor gradient increase from 4.8 to 5.2 mS/cm from the surface to 67 mbgl, which is 1m below the screen. The readings in the final 0.6 m of the bore show an increase, most likely due to sediment at the bottom of the bore.

EC monitoring in the production bore commenced in November 2010 and has a more limited data set compared to the other bores. The data show the EC to have ranged from 1.36 to 7.3 mS/cm with a median of 1.79 mS/cm.

The time series graph (Figure 5.4) shows EC to have ranged from 1.36 to 2.06 mS/cm between November 2010 and February 2012. The EC had increased markedly by the end of 2012 and remained elevated through much of 2013 before dropping slightly towards the end of the data set.

The underground workings have been used for water storage and it has also been established that there is connectivity with the ground surface, which will permit some degree of direct rainfall infiltration. Both of these factors will impact the EC to varying degrees. The increase during 2012 does correlate with a period of decreased rainfall, and hence decreased freshwater dilution. However, the water level within the production bore continued to rise during this time (Figure 5.1), which is likely due to the injection of process water into the workings, which will lead to elevated levels of EC.

The EC profile for the production bore shows the fresher water from rainfall recharge at the top of the column and generally a good degree of vertical mixing with EC values approximately between 4 and 5 mS/cm.

Regolith

EC monitoring of the regolith is undertaken via measurements at BH3, which commenced in August 2010. Values have ranged from 4.2 to 6.07 mS/cm with a median of 5.55 mS/cm. The time series graph (Figure 5.4) does appear to show an inverse correlation with rainfall, particularly when assessed alongside CRD. This corroborates the analysis of the hydrograph discussed in Section 5.2.2 in that this formation receives direct rainfall recharge in the vicinity of the Project.

Colluvium

EC monitoring of the colluvium is undertaken via measurements at BH4, which commenced in August 2010. Manual measurements have ranged from 13.88 to 21.42 mS/cm with a median of 19.6 mS/cm. Measurements recorded by the data logger range from 15.95 to 22.09 mS/cm with a median of 19.64 mS/cm, which is consistent with the manual data as shown in Figure 5.4.

The EC measured at BH4 is typically an order of magnitude higher than measurements from the other bores. The measured EC levels suggest evaporative concentration effects as the limited permeability of this formation will impede groundwater through flow and rainfall recharge. It is likely that the colluvium is acting as a sink for salt as water moves through this formation from the coal measures and /or the underlying Saltwater Creek Formation.

The time series graph (Figure 5.4) also appears to show an inverse correlation with CRD, which again corroborates the analysis of the hydrograph discussed in Section 5.2.3 in that this formation receives direct rainfall recharge in the vicinity of the Project.

Salinity profiling for BH4 (Figure 5.5) shows EC to increase significantly within the screened section of the bore (7 to 10 mbgl) to reach a maximum of 56.7 mS/cm at 9 mbgl. This represents limited vertical mixing within the bore.

5.3.3 pH

The time series pH data for the groundwater monitoring piezometers are shown in Figure 5.6.

Groundwater at piezometer BH3 is slightly acidic with a median pH of 5.23. The remaining piezometers demonstrate mildly acidic and basic medians (Table 5.2). These pH values are typical of groundwater found within coal seams and demonstrate negligible impacts from mining operations.

5.3.4 Dissolved Metals

Comparisons of the results for analyses of dissolved metals against the ANZECC guideline values for the protection of Freshwater Ecosystems (ANZECC 2000) shows a number of exceedances of the guideline values (Table 5.3), as follows:

- Arsenic was detected in BH3 at a concentration of 0.062 mg/L which exceeds the freshwater ecosystem guideline limit of 0.024 mg/L.
- Chromium was detected in BH4 at a concentration of 0.005 mg/L which exceeds the freshwater ecosystem guideline limit of 0.001 mg/L.
- Cadmium was detected at BH4 at a concentration of 0.003 mg/L which exceeds the freshwater ecosystem guideline limit of 0.002 mg/L.
- Copper was detected above the freshwater ecosystem value limit of 0.0014 mg/L in all piezometers at concentrations of 0.002 to 0.288 mg/L.
- Nickel was detected in BH2, BH4, and BH5 and at concentrations of 0.012 to 0.027 mg/L, which exceed the freshwater ecosystem value of 0.011 mg/L.
- Zinc was detected in all piezometers at concentrations of 0.01 to 0.127 mg/L, which exceed the freshwater ecosystem guideline of 0.008 mg/L.

5.3.5 Nutrients

Comparisons of the analyses for nutrients against the ANZECC guideline values for protection of Freshwater Ecosystems (ANZECC 2000) show a number of exceedances of the guideline values (Table 5.3), as follows:

- Total nitrogen concentrations in all piezometers ranged from 0.6 to 8.9 mg/L. These are above the freshwater ecosystem protection guideline limit of 0.35 mg/L (Total N).
- Total kjeldahl nitrate concentration in piezometers BH2, BH3, BH4 and BH5 ranged from 0.6 to 8.8 mg/L. These exceeded the freshwater ecosystem protection guideline limit of 0.25 mg/L.

Total phosphorus concentrations in all piezometers ranged from 0.06 to 0.038 mg/L. These are above the freshwater ecosystem protection guidelines limit of 0.02 mg/L (Total P).

5.3.6 Major Ions

The major ion chemistry can assist with comparing natural waters to identify whether they are derived from the same or different sources, or mixtures of sources. The Piper Trilinear Diagram is useful for this purpose as it is a graphical representation of the chemistry of a number of water samples. The cations and anion percentages as milliequivalents (meq/L) are shown by separate ternary plots. The location of each sample is related to the water "type" or "hydrochemical facies", which can be used to determine water source. Mixing between two "types" of water can also be evident. The Piper diagram for the samples analysed is presented on Figure 5.7.

A Piper trilinear plot of the groundwater samples from the colluvium and Permian coal measures, together with one sample from Rix's surface flow is shown in Figure 5.7. This figure shows that differences can be seen between the colluvium groundwaters, Permian coal measures and surface water flows in Rix's Creek. The fact that EC and chemical differences exist indicates that there is poor mixing of groundwater between the colluvium, coal measures and the occasional surface water flows, confirming that there is a lack of hydraulic continuity between the each.

Groundwater samples collected from the piezometers plot further to the right hand side of the cation and anion plot (Figure 5.7), this shows dominance in chloride and sodium ions with corresponding minimal levels of bicarbonate and calcium. This is indicative of groundwaters with a

high residence time which are not readily recharged and/or are remote from recharge zones. This is particularly the case for BH4, which is screened in the shallow regolith near Rix's Creek. The high groundwater salinity levels observed (>20 mS/cm) suggests limited hydraulically connected with Rix's Creek.

Table 5.3: Groundwater Chemistry

Parameter	Unit	Guideline limit	BH1	BH2	BH3	BH4	BH5	20BL170864
pH Value	pH Unit	6.5–8.0	7.23	6.92–7.92	4.99–5.51	7.31–7.61	4.56–7.37	6.53–8.06
Total Dissolved Solids at 180 °C	mg/L		6710	320–4060	3110–3550	12300–16300	2810–2950	836–2860
Carbonate Alkalinity as CaCO ₃	mg/L		<1 ^a	<1 ^b	<1 ^a	<1 ^a	1 ^a	1 ^a
Bicarbonate Alkalinity as CaCO ₃	mg/L		1000 ^a	873 ^b	84 ^a	859 ^a	476 ^a	199 ^a
Sulfate as SO ₄	mg/L		816 ^a	390 ^b	478 ^a	1900 ^a	653 ^a	80 ^a
Chloride	mg/L		3240 ^a	1540 ^b	1530 ^a	6520 ^a	817 ^a	352 ^a
Calcium	mg/L		110 ^a	160 ^b	28 ^a	175 ^a	62 ^a	31 ^a
Magnesium	mg/L		464 ^a	297 ^b	109 ^a	577 ^a	113 ^a	39 ^a
Sodium	mg/L		1690 ^a	903 ^b	1070 ^a	3930 ^a	831 ^a	251 ^a
Potassium	mg/L		16 ^a	14 ^b	22 ^a	24 ^a	8 ^a	4 ^a
Arsenic	mg/L	0.024	<0.001	0.001–0.004	0.004–0.062	<0.001–0.006	<0.001	0.002
Cadmium	mg/L	0.0002	<0.0001	<0.0001	<0.0001	<0.0001–0.003	<0.0001	<0.0001–0.0002
Chromium	mg/L	0.001	0.001	<0.005	<0.005	<0.001–0.005	<0.001–0.005	<0.001–0.001
Copper	mg/L	0.0014	0.002	<0.001–0.004	<0.005–0.009	0.003–0.008	0.002–0.288	0.002–0.004
Lead	mg/L	0.0034	0.001	<0.001	<0.001–0.003	<0.001	0.001–0.002	<0.001
Nickel	mg/L	0.011	0.001	0.013–0.017	0.01–0.012	0.012–0.02	0.001–0.027	0.002–0.004
Zinc	mg/L	0.008	0.01	0.006–0.032	0.04–0.058	0.011–0.018	0.006–0.127	0.079–0.099
Mercury	mg/L	0.06	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Nitrite as N	mg/L	0.7	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nitrate as N	mg/L	0.7	0.01	0.01	0.01–0.1	0.01–1.16	0.01–0.1	2.44–2.99
Nitrite + Nitrate as N	mg/L	0.15	0.1	0.01–0.05	0.01–0.1	0.01–1.16	0.01–0.1	2.44–2.99
Total Kjeldahl Nitrogen as N	mg/L	0.25	0.1	0.6–0.8	2.7–8.8	0.9–2.7	0.7–1.9	0.2
Total Phosphorus as P	mg/L	0.02	0.01	0.01–0.19	0.11–0.81	0.1–0.73	0.01–0.15	0.03–0.2

Notes: Shaded cells indicate an exceedance of ANZECC (2000) guideline values for freshwater ecosystem protection.

a. Results from July 2011 monitoring

b. Results from May 2011 monitoring

6. HYDROGEOLOGICAL INVESTIGATIONS

6.1 Hydraulic Testing

Hydraulic testing was carried out by RPS (formerly RPS Aquaterra) on BH1, BH2 and BH5 in June 2010 to establish the hydraulic conductivity of the coal seams. The hydraulic conductivity of the coal seams was found to range from 0.014 to 0.08 metres per day (m/d) (Aquaterra 2010b). The hydraulic testing analyses hydrographs are presented in Figure 6.1.

6.2 Final Void Management Plan

RPS undertook a Final Void Management Plan (FVMP) for the Project to fulfil development consent condition 16C for the currently approved mine. The main requirements of which were as follows:

- i) Incorporate design criteria and specifications for the final void based on verified groundwater modelling predictions and a re-assessment of post-mining groundwater equilibration;
- ii) Assess the potential interactions between creeks on the site and the final void; and
- iii) Describe what actions and measures would be implemented to;
 - minimise any potential adverse impacts associated with the final void; and
 - manage and monitor the potential impacts of the final void.

Predictive groundwater modelling was undertaken to forecast the long-term impacts to local and regional groundwater flows, residual pit voids, spoil dump storage and long-term salinity levels. The modelling was based on groundwater data obtained from a groundwater monitoring program developed in 2010, with data used from May 2010 to April 2011. The monitoring program is ongoing.

This FVMP is designed to present a detailed summary of the potential groundwater-related impacts resulting from the current operations as at 2016 (Mine Lease (ML) 352 for coal extraction expires in 2019).

7. GROUNDWATER MANAGEMENT

The following section details the current groundwater management strategy employed at Rix's Creek Colliery.

7.1 Site Water Balance Overview

The site water balance presented here is as documented in the latest version (version 3a) of the Rix's Creek Mine Water Management Plan (WMP) (Bloomfield Group 2014). A schematic diagram is provided in Figure 7.1.

The water balance has been developed using OPSIM, which is an operational simulation package used for modelling water management systems.

Tables 7.1 and 7.2 show the 2012 water balance figures alongside the 2009 figures for comparison.

Table 7.1: 2009 and 2012 Water Balance Input Volumes

Inputs	2009 (ML/a)	2012 (ML/a)
Groundwater Inflows	22	22
Rainfall Run-off	1,728	945
Recycled (tails decant + run-off + seepage + groundwater)	587	859
Imported (Poor and Fresh)	0	0
Water from ROM Coal	117	202
Recycled to CPP (Tails + run-off + seepage – not included in total)	587	859
Total Inputs	1,867	1,169

Table 7.2: 2009 and 2012 Water Balance Output Volumes

Outputs	2009 (ML/a)	2012 (ML/a)
Dust Suppression	208	482
Evaporation – Mine Water Dams	378	396
Evaporation – Tailings Dams	204	-
Entrained in Process Waste	85	430
Water in Product Coal	125	130
Discharged	0	0
Water in Tailings (not included in total)	382	556
Water in Coarse Reject (not included in total)	197	376
Total Outputs	1,867	1,439
Water consumed from on-site storages to balance demand		269

As can be seen from Tables 7.1 and 7.2, Rix's Creek Colliery is a no discharge site as all input water is consumed on site and wastewater from the CPP is recycled back into the CPP for further use.

It should be noted that contaminated water is preferentially used in the CPP and for dust suppression before water from clean water dams is utilised.

Various operating strategies are also employed to cover different climatic conditions to optimise the reuse of water on site.

7.1.1 Operating Strategies

The movement of water throughout the site has been optimised for three different climatic scenarios, average, wet and dry. The operating strategies under those scenarios are detailed below:

Average

- Store surplus water in dedicated in-pit storage areas.
- Optimise water transfers between sites.
- Maximise dewatering capacity at the operating pits.
- Minimise importation of water.
- Maximise diversion of clean run-off waters away from the mine water system.

Wet

- Store surplus water in dedicated in-pit storage areas.
- Manage water transfers between sites to maximise available storage at the nearest point to the operating pits.
- Maximise dewatering capacity at the operating pits.
- Minimise importation of water from external sources, e.g. Rix's Creek.
- Maximise diversion of clean run-off waters away from the mine water system.

Dry

- Maximise dewatering of all in-pit voids.
- Maximise consumption from storage dams. As required, supplement supplies from licensed extraction points.
- Maximise interception of allowable quota for clean run-off waters.

7.2 Groundwater Management Plan

Groundwater management on site comprises monitoring of levels, quality and inflows for reconciliation against the ANZECC guidelines (ANZECC 2000) with plans to establish a Trigger Action Response Plan (TARP). The key aspects of the monitoring and assessment are as follows:

- Groundwater levels in near surface aquifers such as Rix's Creek alluvium.
- Groundwater levels in the coal seams.
- Groundwater quality.
- Mine inflow rates.
- Mine inflow quality.

The TARP identifies the magnitude changes (trigger values) for each parameter that warrant further investigation. In the event that monitoring identifies a breach in trigger values, a staged response plan will be put into place by RCCP to investigate the cause of the breach, the severity of potential impacts of the breach, measures by which any impacts can be mitigated and management measures to minimise the risk of future breaches.

The adopted trigger values must be derived through a trigger value assessment, where baseline conditions are established from monitoring data. Once the background variation in the monitored parameters is understood, the magnitude of a variation that may lead to adverse impacts can be determined.

The response actions detailed in the WMP are as follows:

- Once an exceedance is detected the circumstances of the event will be immediately investigated including a review of relevant monitoring data, meteorological conditions, etc.

- An assessment will be made to determine the reason for the exceedance, the potential magnitude of the impact and the level of future risk.
- If assessed as being caused by the mining operation, and it is further assessed to be likely to cause an adverse impact on an existing use of surface water, then an appropriate preventative and/or remedial strategy will be prepared for discussion with relevant authorities including the NSW Primary Industries – Minerals & Petroleum and Office of Water, the NSW Office of Environment and Heritage, and NSW Planning and Infrastructure, which may comprise:
 - Additional monitoring including assessment of ecological aspects.
 - Modification of mine water management procedures.
 - Modification to mine water management facilities.
 - (If appropriate) change to operations.
- A response/mitigation plan will be implemented to the satisfaction of the relevant authorities such as NSW Office of Water, OEH and NSW P&I.
- If it is found that downstream water users have been adversely impacted the landholder(s) will be consulted regarding the provision of an alternative water supply or some other appropriate agreement negotiated between the parties.

7.2.1 Underground Workings

The underground workings are known to be saturated and have a shallow depth of cover which would allow connective cracking to the ground surface. The degree of further collapse within the underground workings since mining ceased in the 1930s is not well understood and in May 2012 it was deemed that a blockage within the underground workings had led to an increase in the water level in the northern section resulting in seepage at the surface.

This situation was managed through implementation of the following measures, as detailed in the WMP:

- The level of water in the Old North Pit water storage is to be maintained below a maximum level of 78 m AHD, which corresponds to the elevation of the seepage.
- Continue weekly water level monitoring program at the following sites, providing safe access exists:
 - Old North Pit
 - South Pit
 - Borehole into old underground workings
 - Shaft into old underground workings
 - Piezometer 5
 - Old working borehole 1
 - Old working borehole 2.

7.3 Saline Water

Groundwater hosted within coal seams is typically saline due to the geochemistry of coal and the long residence times of the water. Rix's Creek Colliery operates as a nil discharge facility in accordance with the Hunter River Salinity Trading Scheme (HRSTS), which does permit opportunistic discharges. The Department of the Environment and Climate Change stipulate the requirement for water storage facilities have a capacity to contain direct rainfall from the 100 year ARI 24 hour duration storm. The relevant details of the HRSTS are discussed in Section 7.3.4.

There are three main streams of saline water currently being managed at Rix's Creek Colliery:

- Mine water
- CHPP water supply
- Tailings water.

7.3.1 Mine Water

Mine water comprises rainfall run-off, ground water seepage, spoils seepage and tailings dam seepage. Mine water is primarily pumped into Dirty Water Dam 1 (DWD1); before either overflowing into Dirty Water Dam (DWD4), for use at the CHPP, or being transferred to Dirty Water Dam 2 (DWD2), where it is available for dust suppression.

Mine water can also be transferred directly to the Old North Pit Storage Dam when the primary (out of pit) storage facilities are full.

7.3.2 CHPP Water Supply

The CHPP water supply typically comprises mine water and water recycled from the tailing dam. The recycled water is typically of poorer quality than the mine water as the recycling process enhances salt concentration.

7.3.3 Tailings Water

The tailings dam is located in Pit 2 and receives fine reject from the CHPP, which is pumped as slurry. Water from the tailings dam is either decanted off the surface and recycled back to the CHPP or seeps to sumps in the open pit areas for recovery as mine water. The tailings dam embankments comprise undisturbed ground to the north, east and west and uncompacted mine spoil to the south. The mine spoil does allow some seepage to the south, which is unmeasured and hence a source of uncertainty to the site water balance.

7.3.4 Hunter River Salinity Trading Scheme

The Hunter River Salinity Trading Scheme (HRSTS) has been developed and initiated by the NSW Department of Environment and Conservation to protect the water quality of the Hunter River through management of saline discharges from industry. The scheme specifically focuses on the stretch of the Hunter River, and associated catchment, between Lake Glenbawn and the town of Singleton.

The objective of the scheme is to maintain the EC of the river below 900 $\mu\text{S}/\text{cm}$ in the middle and lower sections and below 600 $\mu\text{S}/\text{cm}$ in the upper reaches. This is done by dividing the river water into "blocks", each block representing the water that will flow past Singleton in one day. The flow rate and salinity of each block is measured at various monitoring points along the river and the maximum additional salt loading that can be accommodated without exceeding the EC limit for that section is calculated.

The maximum allowable salt loading for each block is then apportioned amongst saline discharge licensees according to the number of salt discharge credits currently held by each licensee. Each licensee must then equate their allocated salt quota into a volume of the water they require to be discharged according to the salinity of that water.

This method ensures that discharges are reduced during times of low flows, when the background salinity of the river is relatively high such that water required by primary producers for irrigation is maintained within acceptable levels. During periods of high flows, when the background salinity of the river is relatively low, additional discharge may occur.

8. NUMERICAL MODELLING

8.1 Model Set-up

The Rix's Creek groundwater model is based on the USGS MODFLOW code. The version used for this assessment was MODFLOW-Surfact, V4.0, developed by Hydrogeologic Inc. This version was also as used for the Final Void Management Plan (RPS 2012). An advantage of MODFLOW-Surfact as compared to standard MODFLOW is the ability to solve an equation of variable saturated flow.

The Graphical User Interface (GUI), Groundwater Vistas, V6.63 Build 1, was used as a pre- and post-processor of MODFLOW input and output files.

8.1.1 Model Review Process

As per the requirements of the Aquifer Interference Policy (NSW Office of Water 2012), which refer to the Australian Groundwater Modelling Guidelines (Barnett et al. 2012), a third party reviewer, Peter Dundon of Dundon Consulting Pty Ltd, has been appointed.

An initial meeting between RPS and Dundon Consulting Pty Ltd was held on 14 May 2014. During that meeting, the Hydrogeological Conceptual Model was discussed as well as the proposed extent of the numerical model and boundary conditions.

The adequacy assessment report was provided to Dundon Consulting Pty Ltd on 8 August 2014 and we have been advised that there are minimal comments at this stage. The formal statement of review will be completed in time for public exhibition.

8.1.2 Solver Settings

The PCG5, pre-conditioned conjugate gradient, module, V5, within MODFLOW-Surfact was adopted as the solver with a head closure tolerance of 0.05 m.

Table 8.1 presents the relevant settings adopted.

Table 8.1: Model Solver Settings

Model Parameter	Parameter Value
Number of Outer Iterations	100
Number of Inner Iterations	600
Maximum Orthogonalisation	10
Head Change Criterion	0.05m
Relative Convergence Criterion	0
Apply Damping Factor to Solution	1
Enable Newton-Raphson Linearisation	1
Backtracking Factor	0.5
Residual Reduction Factor	2

8.2 Model Domain

The model domain is centered on the mine and incorporates the following significant features:

- The Integra Mine Complex located immediately to the north of the Project.
- The Ashton Coal Mine located to the north-west of the Project which comprises an operational multi-seam underground mine, a historic open cut mine (North East Open Cut) and a proposed open cut mine (South East Open Cut).
- The outcrop of Permian coal measures to the east of the Project.
- The Hunter River to the south of the Project.

No-flow boundaries (NFB) were used to refine the active extent of the model. In the north-east corner, the Hunter Thrust was excised and in the west, Ashton Underground and Integra Underground were used as hydrologic divides and in the south-east, the topographic ridge was used to set the boundary.

Figure 8.1 presents the model domain as well as active extent of the model. The 1:100,000 Hunter Coalfields map is used as the background image.

8.3 Model Geometry

The model domain adopted for the FVMP was reconfigured and the model geometry updated. The model presented in this impact assessment extends from 316,600 mE, 6,394,500 mN (projection system is Map Grid of Australia, 1994, Zone 56) in the south-west to 327,800 mE, 6,410,000 mN in the north-east. The model consists of 227 rows and 168 columns, with cell width (Δx) ranging between 50 and 100 m and cell height (Δy) between 50 and 100 m. There are 19 layers in the vertical direction in the model. Refinement of the model grid is centered on the mine and overall the model comprises 724, 584 cells, of which 645,107 are active.

Table 8.2 presents a summary of the primary hydrogeological units represented by each model layer. Figure 8.2 presents the model grid including in vertical cross-sections. The current coal titles are also displayed in Figure 8.2, along with the hydrographic layer from NSW Lands and Property Information 1:25,000 topographic dataset.

The model geometry was based on detailed elevation data received from the mine within the mine site boundary and was inferred elsewhere based on the 1:100,000 Hunter Coalfields geological map and data extracted from environmental studies undertaken at adjacent mines supplied by the mine or publically available.

The top of the model was set using the 25 m DTM obtained from NSW Lands and Property Information 1:25,000 topographic dataset and was found to be consistent with the original surface provided by the mine.

An exception was during recovery simulation where the Top Elevation of Layer 1 was updated to reflect the filled areas, where appropriate. Cut areas were not included in the changes to model geometry since all layers would need to have been amended and the model simulation would not have had a stable initial condition. The cut areas were instead accounted for via an update of the evaporation surface, as presented in Section 8.5.3.

The relevant .DXF files used during construction of the model are noted in Table 8.2. The alluvial thicknesses within the Hunter River, Glennies Creek and Bowmans Creek were estimated from the NSW Office of Water PINNEENA database borehole logs and ranged between 2 and 20 m thick.

Table 8.2: Model Layers

Layer	Median Thickness (m)	Minimum Thickness (m)	Maximum Thickness (m)	Hydrogeological Unit	Source (.DXF)
1	3.99	2.0	20.0	Regolith/Alluvium	Topo-5, NSW 25m DTM or Alluvium
2	10.2	0.04	69.5	Overburden	P29_Roof
3	15.3	0.06	104.3	Overburden	Split
4	25.5	0.10	173.8	Overburden	Split
5	1.55	0.20	21.9	Pikes Gully	P26_Floor
6	8.56	0.20	66.5	Interburden	UA25_Roof
7	2.47	0.20	13.4	Arties	LA22_Floor
8	3.35	0.20	30.6	Interburden	UL21_Roof
9	1.14	0.20	15.2	Upper Liddell	UL20_Floor
10	5.47	0.20	28.6	Interburden	ML19_Roof
11	2.40	0.20	16.2	Middle Liddell	ML16_Floor
12	8.86	0.20	38.8	Interburden	LL13_Floor + 2m

Layer	Median Thickness (m)	Minimum Thickness (m)	Maximum Thickness (m)	Hydrogeological Unit	Source (.DXF)
13	1.08	0.20	2.15	Lower Liddell	LL13_Floor
14	14.6	0.20	46.8	Interburden	LB11_Roof
15	1.8	0.20	6.95	Lower Barrett	LB9_Floor
16	7.4	0.20	67.5	Interburden	H7_Roof
17	12.4	0.20	34.8	Hebden	H1_Floor
18	75.1	0.20	106.2	Saltwater Creek	H1_Floor - 50
19	89.7	0.20	103.4	Mulbring Siltstone	Saltwater - 100

8.4 Model Timestep

The model comprises three components:

- Calibration period (Jan 1999 to Apr 2014)
- Prediction period (May 2014 to Dec 2037)
- Recovery period (Jan 2038 to Dec 3037).

The calibration and prediction models used a stress period length of monthly and the recovery simulation used a varying stress period of between monthly and 25 years. The Adaptive Timestep and Output Control (ATO) model was enabled for all simulations.

Table 8.3 presents the model Stress Period and Timestep.

Table 8.3: Model Stress Period Length and Timestep

Period	Stress Period		Timestep				
	Number	Length (d)	Initial Step (d)	Minimum Step (d)	Maximum Step (d)	Multiplication Factor	Reduction Factor
Calibration	1	0.01d ^a	1E-5d	NA	NA	NA	NA
	2–185	28–31d	1d	1E-5d	20d	2.5	2.0
Prediction	1–284	28–31d	1d	1E-5d	20d	2.5	2.0
Recovery	1–94	28–18623d	1E-5–25d	1E-5–5d	20–3000d	2.5	2.0

a. Stress Period No. 1 is steady state. All other stress periods are transient.

8.5 Model Boundary Conditions

8.5.1 Surface Water Features

The Mine is bisected by Rix's Creek, between Pit 2 and Pit 3, which drains in a southerly direction toward the Hunter River. To the west of the mine, on the other side of the topographic ridge, Glennies Creek and Bowmans Creek flow in a south-westerly direction before joining the Hunter River adjacent the Ashton Coal Project site.

Rix's Creek is an ephemeral watercourse and was represented in the model using the drain, DRN, module along with other ephemeral watercourses.

The Hunter River, Glennies Creek and Bowmans Creek were modelled as perennial watercourses using the river, RIV, module.

The conductance parameter adopted in the model consists of:

- Streambed hydraulic conductivity
- Waterway width

- Streambed thickness
- Stream length.

For DRN cells, the streambed hydraulic conductivity was set at 0.05 m/d, waterway width was set at 4 m and streambed thickness was 0.5 m. For RIV cells, the streambed hydraulic conductivity was set at 0.1 m/d, waterway width was 20 m and streambed thickness was 1.5 m.

The components of conductance parameter for DRN and RIV boundary conditions were integrated together with grid cell size when imported and the range of values are summarised in Table 8.4.

The stage of DRN cells was set at ~1.5 m below ground surface and for RIV cells; the stage was set at 1 m below ground surface and the bottom elevation at 2 m below ground surface. Where ephemeral watercourses intersected perennial watercourses, the stage elevation of DRN cells were adjusted such that they matched the stage elevation of the downstream RIV cells.

Once imported into Groundwater Vistas, any DRN cell that had stage elevation below the bottom elevation of Layer 1 was corrected to be Bottom Elevation + 0.1 m.

Table 8.4: Model Surface Water Features

Boundary Condition	Conductance	Stage	Bottom Elevation
DRN	0.8 to 92 m ² /d, median 20 m ² /d	-1.5 m from TopEI_L01	NA
RIV	2.7 to 234 m ² /d, median 72m ² /d	-1 m from TopEI_L01	-2 m from TopEI_L01

Figure 8.3 presents the location of surface water features in Layer 1.

8.5.2 Rainfall Recharge

Rainfall recharge was applied to the top of the model using the Highest Active Layer. The distribution of recharge zones is presented in Figure 8.4 for the calibration model, prediction model and recovery model.

For the calibration model, the historical monthly rainfall record at site was used. For the prediction model, rainfall data was obtained from the BOM Station Jerry's Plains (No. 061086) and any missing monthly data was patched with median monthly values from climatic statistics at that station. The prediction period is 24 years, therefore to account for natural variability of the rainfall record, annual rainfall totals from the 061086 gauge were determined and the fiftieth percentile 24 year consecutive rainfall total from 1886 to present was calculated. This corresponded with the 24 year period commencing in 1973 to 1996. The lowest tenth percentile 24 year rainfall total was 1931 to 1954, and the highest ninetieth percentile 24 year rainfall total was 1990 to 2013.

For the prediction simulation the monthly record from May 1973 through to Dec 1996 was applied being the fiftieth percentile climatic conditions. For the uncertainty analysis conditions, presented in Section 8.9, the monthly rainfall record from May 1931 to Dec 1954 was used for the low rainfall condition and the rainfall record from May 1990 to Dec 2013 was used for the high rainfall condition.

Table 8.5 presents the long-term rainfall statistics for the BOM station at Jerry's Plain. Figure 8.4 presents the demarcation of recharge zones adopted in the model.

Table 8.5: Long-term Monthly Rainfall (mm/month) (Station No. 061086))

Stat.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
Tenth %	24.1	9.5	10.8	4.8	5.9	9.7	8.1	7.0	9.1	10.4	13.0	15.8	429.2
Med.	64.3	50.5	47.0	32.3	29.9	31.1	35.1	30.5	34.3	49.2	50.1	57.0	644.2
Ninetieth %	159.9	166.1	114.9	95.7	84.0	100.8	90.8	67.5	81.8	95.4	126.7	136.3	830.7

Table 8.6 presents a summary of the multiplication factors applied to the rainfall in the model.

Table 8.6: Rainfall Recharge Multiplication Factors (%)

Zone	Multiplication Factor	Description
Calibration		
1	1%	Regolith
2	2%	Alluvium (Hunter River, Glennies Creek, Bowmans Creek)
3	2.5%	Active Mining Area (NEOC, Integra, Rix's Creek)
4	4%	Urban Area
Prediction		
NA	As per calibration	
Recovery		
NA	As per calibration	
5	100%	Final Void and Pit 1 Access Portal ^b

a. Extent of alluvium assumed to be equivalent to water sources defined in the HUAWS 2009; b. Assumed to be lake surface.

It is noted that recharge rates were not altered during model calibration.

8.5.3 Evaporation

Evaporation was incorporated into the model using the EVT module and was applied to Top Layer only. The evaporation rate (Class A Pan) was obtained from long-term monthly average of the BOM Station Scone SCS (No. 061089) with a Pan Factor of 50% across the model domain. An exception was during the recovery simulation where the Pan A Factor was set at 70% over the extent of the final void. The evaporation surface was also updated in the recovery simulation to account for the final landform (filled areas) including final void geometry in Pit 3, as well as the small portal in the south-east corner of Pit 1.

Figure 8.5 presents the original Top Elevation of Layer 1 as well as the altered Top Elevation of Layer 1 used in the recovery model. The Top Elevation of Layer 1 was altered in the recovery model to account for the final landform. The evaporation surface used in the recovery model is also presented in Figure 8.5. The demarcation of evaporation zones corresponded to the location of final void in Pit 3 and the portal access in the south-east corner of Pit 1.

Table 8.7 presents mean daily evaporation rate from the BOM Station Scone SCS (No. 061089). For calibration and prediction simulations, the relevant evaporation rate for each month was adopted. For the recovery simulation, where the Stress Period length was monthly, the relevant evaporation rate was used. For the Stress Period length of one year or more, the annual average daily rate of 4.3 mm/d was used.

Table 8.7: Mean Daily Evaporation (mm/d) (BOM Station Scone SCS (No. 061089))

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann.
Mean Daily Evap.	7.1	6.1	5	3.5	2.2	1.6	1.8	2.7	3.9	5	6.1	7.1	4.3

8.5.4 Regional Throughflow

A general head boundary, GHB, was used to approximate the long-term impact of mining activity in the south-west corner of the model domain. General head boundaries are typically used in groundwater models to represent regional throughflow processes.

For the calibration model, the historical effect of open cut mining in the south-west corner of the model was approximated by groundwater level history recorded at GW080963. Table 8.8 presents the groundwater level record from GW080963. This record was extended linearly on either side of the observation record. As indicated, with the prediction and recovery model the groundwater level for the GH boundary was set at 30 m AHD. The conductance of the GH boundary cells was set at

100 m²/d. Figure 8.6 presents the location of the GH boundaries in the groundwater model. The layer to which the boundary applied was adjusted, as required. At the commencement the calibration period it was in Layer 4 and at the end of the calibration period it was in Layer 3.

Table 8.8: Regional Throughflow Boundary Conditions

Date	Stress Period	Head (m AHD)	Source
Calibration			
1/1/1999	1	-50	Assumed
25/11/2005	-	-3.65	PINNEENA
28/03/2006	-	-1.35	PINNEENA
22/08/2006	-	-0.48	PINNEENA
27/02/2007	-	1.14	PINNEENA
19/02/2008	-	7.57	PINNEENA
23/06/2009	-	14.78	PINNEENA
3/06/2010	-	18.69	PINNEENA
4/05/2011	-	21.36	PINNEENA
31/4/2014	185	30	Assumed
Prediction			
May 2014 to Dec 2037	1–284	30	Assumed
Recovery			
Jan 2038 to Dec 3038	1–94	30	Assumed

8.5.5 Mine Dewatering

Mine dewatering was represented in the model using the drain, DRN cells. The conductance of DRN cells was set to 100 m²/d.

There are several historical, current and future mines in the vicinity of the mine as well as Rix's Creek itself. These mines were represented in the model for the purpose of cumulative impact assessment. Details of assumed commencement and completion times are summarised in Table 8.9 and the location of adjacent projects indicated in Figure 8.7a. These included:

- Ashton Northeast Open Cut (all to Hebden Seam, assumed)
- Ashton Southeast Open Cut (all to Hebden Seam, assumed)
- Ashton Underground (Pikes Gully, Upper Liddell, Upper Lower Liddell, Barrett)
- Glendell Open Cut (all to Hebden Seam, assumed)
- Integra Underground (Middle Liddell and Hebden Seam)
- Integra North Open Cut (all to Lower Barrett Seam)
- Integra South Open Cut (all to Lower Barrett Seam), including Western Extension
- Rix's Creek Pit 1 (all to Upper Liddell Seam)
- Rix's Creek Pit 2 (all to Hebden Seam)
- Rix's Creek Pit 3 (all to Hebden Seam)
- Rix's Creek Pit 1 Access Portal (all to Hebden Seam).

It is noted that DRN cells from any Stress Period and any model layer in calibration and prediction simulations are displayed in Figure 8.7a, including underground operations, for the purpose of illustration.

Table 8.9: Mine Dewatering Assumptions

Site	Reach	Start ^a	Stop	Layers	Model
Ashton NEOC	21	Jan 2004 (SP62)	Mar 2010 (SP 136)	1–17	Calibration
Ashton SEOC	22	Jan 2016 (SP21)	Dec 2022 (SP134)	1–17	Prediction
Ashton Underground	23	Apr 2007 (SP101)	-	5 and 9	Calibration
		-	Jun 2015 (SP134)	5, 9, 13 and 15	Prediction
Glendell Open Cut	31	Oct 2013 (SP179)	-	1–17	Calibration
		-	Jun 2017 (SP38)	1–17	Prediction
Integra Underground	41	Aug 2002 (SP45)	-	11	Calibration
		-	Mar 2019 (SP179)	11 and 17	Prediction
Integra Former North Pit	NA	Already completed	Already completed	1–17	All
Integra South, including West Extension	42	Jan 1999 (SP2)	-	1–15	Calibration
		-	Apr 2020 (SP72)	1–15	Prediction
Integra North Open Cut	43	Aug 2009 (SP129)	-	1–15	Calibration
		-	Jul 2016 (SP27)	1–15	Prediction
Rix's Creek Pit 1	51	Jan 1999 (SP2)	-	1–10	Calibration
		-	Dec 2037 (SP284)	1–14	Prediction
Rix's Creek Pit 2	52	Jan 1999 (SP2)	-		Calibration
		-	Dec 2017 (SP44)	1–17	Prediction
Rix's Creek Pit 3	53	Jan 1999 (SP2)	-	1–16	Calibration
		-	Dec 2037 (SP284)	1–18	Prediction
Rix's Creek Pit 1 Portal	54	May 2014 (SP1)	Dec 2037 (SP284)	1–17	Prediction

a. For underground operations, start time refers to longwalls and not development headings.

It was assumed that DRN cells for underground operations, once activated, remained active until completion of multi-seam operation. Additional model detail such as the potential impact to hydraulic properties overlying longwalls was not included in this model. This was appropriate for the purpose of cumulative impact assessment. For open cut operations, mine dewatering was progressed quarterly in accordance with assumed active mine footprint. DRN cells representing points of access to open cuts were assumed to remain active throughout mining, as required. For simplicity, for mines surrounding the mine, it was assumed that DRN cells were applied to the active mine footprint in a vertically consistent manner to each model layer from Layer 1 to relevant coal seam. This was not a significant assumption where seams out-cropped or sub-cropped nor was it particularly significant with respect to dewatering against the highwall since model cells size was 50 m at minimum and benches were generally encompassed by one to two model cells. The approach adopted to represent open cut mining is a simplification of the bench mining method insofar there are several active benches operating simultaneously whereas the model approach assumed dewatering through to bottom of target seams and that footprint advanced in time. The impact of this assumption is not considered significant for the purpose of cumulative impact assessment, given that detailed mine plan information of adjacent operations is not available in the public domain. Where DRN cells were active at adjacent operations, either as open cut or underground operations, the stage elevation was set at 0.05 m above the bottom elevation of respective cells.

Detailed mine landform surfaces were available for the Project. These were used to define the spatial and temporal progression of the mine, including in the vertical plane. The model geometry was intersected with the mine landform surface and where the mine surface was below original ground surface relevant DRN cells identified. Filling was considered with respect to the recovery

simulation and is discussed further below. Backfilling of mine pits is also discussed below. The target stage of the DRN cells was set at 0.05 m above the bottom elevation of relevant layers and where the mine landform surface bisected a particular layer, the respective ground elevation was used as the target head.

For the calibration model, surfaces were available at the following:

- Dec 2004
- Dec 2006
- Dec 2008
- Dec 2010
- Dec 2012
- Dec 2013.

For the prediction simulation, the following surfaces were available:

- 2017
- 2020
- 2023
- 2026
- Final landform (2037).

Figure 8.7B presents the various mine surfaces. For the calibration simulation, given that the mine was already operating, dewatering was activated from January 1999 (SP2) using the December 2004 surface. For the period January 2005 to December 2006, the next mine landform surface was used to set the DRN cells and so on. Similarly, for in the prediction simulation, for the period May 2014 to December 2017, the 2017 mine landform surface was used to set the active DRN cells and so on. For the period, January 2027 to December 2037, the final landform was used. In the recovery simulation, from January 2038 to December 3038, there were no mine DRN cells active.

8.6 Model Parameters

8.6.1 Hydraulic Conductivity

The hydraulic conductivity, both horizontal and vertical, applied to each model layer are presented in Table 8.10. The values presented in Table 8.10.

Figure 8.8 presents the demarcation of hydraulic parameter zones in each model layer in the calibration model. It is noted that the same zone was used for both hydraulic conductivity and the storage parameters, which are discussed below. Figure 8.9 presents the hydraulic parameter zones adopted for the prediction simulation. Figure 8.10 presents the hydraulic parameter zones for the recovery simulation. As indicated in Table 8.10, backfilling of previous open cut operations was represented by an enhanced assumed hydraulic conductivity. The final void, Zone 6 in Table 8.10, was assigned a very high hydraulic conductivity.

It is noted that the zonation presented in Figure 8.8 to 8.10 was guided by the geological model insofar interpreted location of outcrop and/or subcrops.

Table 8.10: Calibrated Hydraulic Conductivity and Storage Parameters

Zone	Name	Hydrogeological Description	Kx	Kz	Ss	Sy
1	Regolith	Regolith	1.0E-02	1.0E-03	1.0E-05	0.09
2	WSP_Regolith	Regolith	1.0E-02	1.0E-03	1.0E-05	0.09
3	Alluvium – Glennies Creek / Bowmans Creek	Alluvium	8.0E-01	8.0E-02	1.0E-05	0.15
4	Alluvium – Hunter River	Alluvium	4.5E+00	4.5E-01	1.0E-05	0.15

Zone	Name	Hydrogeological Description	Kx	Kz	Ss	Sy
5	Backfill	Backfill	5.0E-02	5.0E-02	1.0E-04	0.09
6	Void	Void	1.0E+02	1.0E+02	1.0E-05	0.99
12	CMOB	Sandstone	5.0E-03	5.0E-05	1.0E-06	0.06
13	Pikes Gully	Coal Seam / Interburden	8.0E-02	8.0E-04	4.0E-06	0.01
14	Interburden	Sandstone	5.0E-03	5.0E-05	1.0E-06	0.06
15	Arties	Coal Seam / Interburden	8.0E-02	8.0E-04	4.0E-06	0.01
16	Interburden	Sandstone	5.0E-03	5.0E-05	1.0E-06	0.06
17	Upper Liddell	Coal	2.0E-02	2.0E-04	4.0E-06	0.01
18	Interburden	Sandstone	5.0E-03	5.0E-05	1.0E-06	0.06
19	Middle Liddell	Coal Seam / Interburden	2.0E-02	2.0E-04	4.0E-06	0.01
20	Interburden	Sandstone	5.0E-03	5.0E-05	1.0E-06	0.06
21	Lower Liddell	Coal	2.0E-02	2.0E-04	4.0E-06	0.01
22	Interburden	Sandstone	5.0E-03	5.0E-05	1.0E-06	0.06
23	Lower Barrett	Coal Seam / Interburden	1.0E-02	1.0E-04	4.0E-06	0.01
24	Interburden	Sandstone	5.0E-03	5.0E-05	1.0E-06	0.06
25	Hebden	Coal Seam / Interburden	1.0E-02	1.0E-04	4.0E-06	0.01
26	Interburden / Saltwater Formation	Sandstone	1.0E-03	1.0E-05	1.0E-06	0.06
27	Mulbring Siltstone	Siltstone	1.0E-03	1.0E-05	4.0E-06	0.01
36	Weathered Saltwater Formation	Sandstone (Weathered)	5.0E-03	5.0E-05	1.0E-06	0.06
37	Weathered Mulbring Siltstone	Siltstone (Weathered)	5.0E-03	5.0E-05	4.0E-06	0.02

8.6.2 Storage

The calibrated values for specific storage, Ss, and specific yield, Sy, are presented in Table 8.10.

The variably saturated flow mode (IREALSL=2; Van Genuchten's method for volumetric water content and Brooks-Corey method for estimation of unsaturated hydraulic conductivity) of MODFLOW-Surfact was used for groundwater modelling undertaken during this impact assessment. For consolidated materials it has been found that saturated porosity, n, in MODFLOW-Surfact's solution of Richards Equation, in practice, is closer to effective porosity, equivalent to specific yield, rather than saturated porosity, as opposed to flow exclusively within unconsolidated materials such as soil.

Table 8.11 presents the adopted parameters for Van Genuchten's and Brooks-Corey equations. The parameter values presented in Table 8.11 reflect desaturation behaviour approximately halfway between "clay-like" and a free draining 'sand-like' material. These parameter values were applied globally. It was found during early stages of modelling that variable unsaturated hydraulic parameters were not particularly numerically stable during model simulations.

Table 8.11: Adopted Parameter Values for Variably Saturated Flow

Parameter	Parameter Value
Van Genuchten's m (VANALPHA)	0.30
Van Genuchten's n (VANBETA)	2.0
Residual Saturation	0.001 (0.1%)
Brooks-Corey Exponent	2

8.7 Model Calibration

8.7.1 Observation Dataset

The groundwater model was calibrated against groundwater levels from standpipe piezometers, an old dewatering well at site as well as observed mine inflow data. Data was used from adjacent operations, where available, and the NSW Office of Water Database (PINNEENA 4.1) was also utilised.

Table 8.12 presents the observation dataset used during model calibration.

Table 8.12: Calibration Dataset (Groundwater Levels and Pressures)

ID	Description	Type	Layer	No. Obs.	Record Length (years)
BH1	Middle Liddell	SP	11	28	3.6
BH2	Lower Barrett	SP	15	14	1.5
BH3	Regolith	SP	16	30	3.7
BH4	Regolith	SP	16	31	3.7
BH5	Lower Barrett	SP	15	30	3.6
20BL170864	All Mined Seams	Well	15	21	3.2
GCP25	Glennies Creek Alluvium	SP	1	19	5.9
GCP26	Glennies Creek Alluvium	SP	2	42	6.2
GCP28	Glennies Creek Alluvium	SP	1	58	5.9
GCP31	Glennies Creek Alluvium	SP	2	32	3.5
GCP32	Coal Measures	SP	13	48	5.5
GCP34	Coal Measures	SP	9	71	5.5
GCP35_72m	Coal Measures	WVP	9	34	5.2
GCP35_147m	Coal Measures	WVP	16	30	5.3
GCP35_195m	Coal Measures	WVP	17	45	4.8
GCP36	Coal Measures	SP	2	53	5.5
GCP37_70 m	Coal Measures	WVP	13	34	5.3
GCP37_125m	Coal Measures	WVP	17	46	5.4
GCP38	Coal Measures	SP	3	51	5.4
SGD644_75.5	Coal Measures	WVP	15	47	3.2
SGD644_81.175	Coal Measures	WVP	16	56	3.7
SGD644_93.82	Coal Measures	WVP	17	31	3.7
SGD645_63.15	Coal Measures	WVP	17	52	3.7
GCP19	Glennies Creek Alluvium	SP	1	28	5.9
GCP21	Glennies Creek Alluvium	SP	1	49	6.1
GCP1	Coal?	SP	17	27	8.2
GCP5	Coal?	SP	15	61	8.4
GCP13	Coal?	SP	15	21	8.3
GCP3S	Bettys Creek and Main Creek Alluvium	SP	1	114	8.6
GCP11	Bettys Creek and Main Creek Alluvium	SP	2	72	11.9
GCP17	Bettys Creek and Main Creek Alluvium	SP	1	25	6.3
GCP4D	Coal Measures	SP	2	48	8.6
DDH223_80	Coal Measures	WVP	2	44	4.1

ID	Description	Type	Layer	No. Obs.	Record Length (years)
DDH223_120	Coal Measures	VWP	3	34	4.1
DDH223_170	Coal Measures	VWP	3	43	4.1
DDH223_230	Coal Measures	VWP	4	39	4.1
DDH223_290	Coal Measures	VWP	5	41	4.4
DDH223_350	Coal Measures	VWP	7	48	4.3
DDH223_416	Coal Measures	VWP	15	60	4.4
DDH223_478	Coal Measures	VWP	17	58	4.4
DDH224_100	Coal Measures	VWP	3	34	5.4
DDH224_130	Coal Measures	VWP	4	27	5.4
DDH224_160	Coal Measures	VWP	5	26	5.4
DDH224_200	Coal Measures	VWP	9	28	5.3
DDH224_245	Coal Measures	VWP	13	35	5.4
DDH224_290	Coal Measures	VWP	15	33	5.3
DDH224_315	Coal Measures	VWP	17	40	5.3
DDH224_336	Coal Measures	VWP	18	54	5.4
GW271026	Alluvium	SP	1	3	2.1
GW080963	Shale	SP	3	8	5.4

8.7.2 Calibration Results

The model control file associated with the calibration model is:

- 015a_CAL-Apr14_07a.gww.

Figure 8.11 presents the modelled inflow to the mine with respect to Pit 1 (DRN51), Pit 2 (DRN52) and Pit 3 (DRN53). The flow rates presented in Figure 8.11 are m³/d. It is noted that the short-term increases in flow rate in Figure 8.11 are due to the DRN cell assumption with respect to matching the mine landform surfaces that change every two years.

Figure 8.12 presents the model mass balance.

Figure 8.13 presents the modelled groundwater pressure and levels against observations. Table 8.13 presents a summary of the calibration statistics.

Table 8.13: Calibration Statistics

Parameter	Parameter Value
All Observations	
No. of Observations	2003
Root Mean Square (RMS) Error	40.8 m
Scaled Root Mean Square Error (SRMS)	16.2%

From Figure 8.12, the model mass balance indicates model mass balance error is acceptably small. Figure 8.12 also indicates the components of the model such as recharge (RCH), evaporation (EVT), river (RIV), ephemeral watercourses (DRN), mine dewatering (DRN) and storage are responsive in the model and overall the model is reasonably settled.

From Figure 8.13, the Root Mean Square (RMS) error is 40.8 m. The RMS error is an absolute measure that is problem dependent. i.e. its value is dependent on range in measured values. The Scaled Root Mean Square (SRMS) error is 16.2%. The SRMS is the ratio of error to total head.

As presented in Barnett et al. (2012), an SRMS of ~10% is an indicator of adequate calibration to pressure and level. Appendix A presents observed versus modelled hydrographs at each monitoring location.

Figure 8.14 presents the modelled groundwater levels as at Apr 2014 (SP185TS5) in each model layer. To allow comparison, the modelled groundwater level in each layer from a null case is also presented in Figure 8.14. The null case was prepared by making a direct copy of the calibration model and deleting the mine, including the adopted recharge zonation.

It is noted that dry cells are displayed in Figure 8.14, in purple, of layer-by-layer results and illustrate where the groundwater level is below the respective model layer. In those cases, reference should be made to the modelled groundwater level in the underlying layer for the predicted groundwater level. The processed uppermost water table is also presented in Figure 8.14.

The location of calibration targets is also presented in Figure 8.14.

8.7.3 Discussion

Model calibration results indicate reasonable agreement with shallow piezometers, BH03 and BH04. Model calibration is also reasonable for standpipe piezometer BH05 and dewatering well, 20BL170864. Calibration results for BH01, located to the west of the current extent of Pit 3 and BH02 at the northern corner of the project, are not particularly well matched, however, from Figure 8.14 and Appendix A, exhibits an appropriate dewatering trend. The explanation for the mismatch is also due to the assumption that mining commenced in 1999 whereas it has been ongoing since the late 1800s. Monitoring location GCP34 and WWP GC35_72 m to the north in the adjacent project at Integra South are very well matched.

From Figure 8.11, modelled inflows from the calibration model are approximately 400 m³/d for Pit 1, equivalent to 4.5 L/s (146 ML/a); ~200 m³/d for Pit 2 initially and reducing to zero; and initially 50 m³/d and increasing to 300 m³/d at Pit 3, equivalent to 3.5 L/s (110 ML/a). Anecdotally, the magnitude of these inflows is consistent with observation insofar relatively minimal inflow to various pits historically.

Modelled groundwater contribution to surface watercourses in the vicinity of the mine is presented in Figure 8.15. Of interest to this impact assessment is the potential impact on baseflow to Rix's Creek itself. Rix's Creek was represented in the model using DRN cells, however, the lower part was assigned a separate reach number given it resides in a separate surface water source compared to the upper part of Rix's Creek. The upper part of Rix's Creek (designated as DRN116), which bisects the mine site resides within the Singleton Water Source of the HUAWS 2009. The lower part of Rix's Creek (designated DRN104) lies within the Hunter Regulated River Alluvial Water Source of the HUAWS 2009. The Hunter River to the south of the mine lies in separate surface water Water Sharing Plan called the Hunter Regulated River Water Source and it was represented in the model using the river boundary condition. The management zone, downstream of Glennies Creek, which is of potential relevance to the mine, was designated as RIV Reach 4 (RIV4).

Figure 8.15 presents the modelled flux in DRN116 and DRN104 as well as flux in RIV4.

Table 8.14 summarises the modelled difference in groundwater contribution to surface water within DRN116, DRN104 and RIV4 during the period of maximum difference between the calibration model and null case.

Table 8.14: Calibration Model – Change in Groundwater / Surface Water Interaction

Stress Period	Time(d)	Modelled Flux (m ³ /d) Calibration Model	Modelled Flux (m ³ /d) Null Case Model	Difference (m ³ /d)
Rix's Creek – Upper Part (DRN116)				
155	4687	-3.8	-6.9	-3.1
156	4717	-8.2	-10.7	-2.5
157	4748	-3.4	-6.3	-2.9
158	4779	-4.9	-7.6	-2.7
159	4808	-7.1	-9.8	-2.6
160	4839	-5.1	-8.0	-2.9
161	4869	-3.0	-6.3	-3.3
162	4900	-2.5	-5.9	-3.4
163	4930	-5.0	-8.8	-3.9
164	4961	-3.5	-7.2	-3.7
165	4992	-2.3	-5.6	-3.3
166	5022	-2.2	-5.3	-3.1
167	5053	-2.1	-5.0	-2.9
168	5083	-2.8	-5.8	-3.0
169	5114	-3.5	-6.5	-3.0
170	5145	-6.0	-9.2	-3.1
171	5173	-8.1	-10.9	-2.8
172	5204	-5.5	-8.4	-2.9
Rix's Creek – Lower Part (DRN104)				
155	4687	-6.6	-6.6	0.0
156	4717	-13.8	-13.8	0.0
157	4748	-5.9	-5.9	0.0
158	4779	-8.1	-8.1	0.0
159	4808	-11.8	-11.8	0.0
160	4839	-8.9	-8.9	0.0
161	4869	-5.3	-5.3	0.0
162	4900	-4.2	-4.2	0.0
163	4930	-9.0	-9.0	0.0
164	4961	-6.4	-6.4	0.0
165	4992	-3.7	-3.7	0.0
166	5022	-3.5	-3.5	0.0
167	5053	-3.3	-3.3	0.0
168	5083	-4.6	-4.6	0.0
169	5114	-5.9	-5.9	0.0
170	5145	-11.1	-11.1	0.0
171	5173	-13.5	-13.5	0.0
172	5204	-9.7	-9.7	0.0

Stress Period	Time(d)	Modelled Flux (m ³ /d) Calibration Model	Modelled Flux (m ³ /d) Null Case Model	Difference (m ³ /d)
Hunter River – Downstream of Glennies Creek (RIV4)				
155	4687	5.6	5.6	0.0
156	4717	0.8	0.7	0.0
157	4748	60.6	60.5	0.0
158	4779	55.3	55.3	0.0
159	4808	13.3	13.3	0.0
160	4839	-8.4	-8.5	0.0
161	4869	-32.5	-32.6	0.0
162	4900	-63.3	-63.3	0.0
163	4930	-103.6	-103.6	0.0
164	4961	-91.3	-91.3	0.0
165	4992	-49.8	-49.8	0.0
166	5022	-6.5	-6.5	0.0
167	5053	34.1	34.1	0.0
168	5083	63.4	63.3	0.0
169	5114	84.2	84.2	0.0
170	5145	58.3	58.3	0.0
171	5173	16.2	16.1	0.0
172	5204	-5.0	-5.0	0.0

From Table 8.14, there has been no cumulative impact of the mine on the Hunter River or the lower part of Rix's Creek thus far. From Table 8.14 and Figure 8.15, modelling indicates that baseflow contribution to the upper part of Rix's Creek, along the whole creek length, is minimal (~18.0 m³/d at maximum, equivalent to 0.2 L/s) and there is a minor reduction baseflow of up to 3.9 m³/d (equivalent to 0.045 L/s). Accordingly, the impact is considered negligible. It is noted that modelled groundwater contribution to surface water is a loss from the groundwater system and therefore is reported as a negative flux.

8.8 Model Prediction

8.8.1 Model Set-up

Model setup comprised update of DRN dewatering cells, recharge and evaporation factors as well as application of hydraulic parameters relevant to backfill to Ashton NEOC. Integra North Pit was already backfilled in the calibration model. The hydraulic property values presented in the calibration model were used in the prediction and recovery simulation.

As indicated in Section 8.5.2, the historical rainfall record was processed to identify a climatic period consistent with median conditions. For evaporation, the long-term daily evaporation rate for each monthly Stress Period was again adopted.

8.8.2 Prediction Results

The model control file associated with prediction simulations is:

- 015a_PRD-MP1_04a.gww.

Figure 8.16 presents the modelled mine inflows and Figure 8.17 presents the prediction model mass balance.

From Figure 8.16, the predicted inflow to Pit 1 (DRN51) is $\sim 100 \text{ m}^3/\text{d}$ (1L/s, 36.5 ML/a) initially and reduces to zero; Pit 2 (DRN52) is zero; Pit 3 (DRN53) is approximately $700 \text{ m}^3/\text{d}$ (8L/s, 255 ML/a), reducing to $\sim 300 \text{ m}^3/\text{d}$ (3.5L/s, 110 ML/a). At a later stage in the project, the predicted inflow to Pit 1 Portal (DRN54) is $\sim 100 \text{ m}^3/\text{d}$ (1L/s, 36.5 ML/a).

Detailed licensing estimates are presented in Section 10.

From Figure 8.17, modelled mass balance indicates mass balance error is acceptably small and that components of the model are reasonably responsive.

Figure 8.18 presents the predicted groundwater level in each model layer at the end of mining in 2037 (SP284TS5). For the purpose of comparison, the cumulative impact null case (no Mine) is also presented in Figure 8.18. The interpreted uppermost surface is also presented in Figure 8.18.

Appendix B presents the prediction hydrographs at each monitoring location. It is highlighted that prediction simulation adopts an assumed rainfall condition that may be different to that encountered in the future.

The predicted impact to the uppermost water table is presented in Figure 8.19 at 2017 (SP44TS5), 2020 (SP80TS5), 2023 (SP116TS5), 2026 (SP152TS5) and at end of mining in 2037 (SP284TS5). The potential impacts were calculated with respect to both the null case (no extension to Pit 3) and the cumulative impact null case (no Mine).

The model control file associated with the extension only null case is:

- 015a_PRD-MP1_04a_NUL.gww.

This model comprised:

- Mine dewatering ceases in Apr 2014.
- Enhanced recharge zone maintained equivalent to calibration model.
- No change to hydraulic properties due to backfilling at the Project.
- Initial condition was 015a_CAL-Apr14_07a_SP185TS5.hds.

The model control file associated with the cumulative impact null case is:

- 015a_PRD-NUL_02a.gww.

This model comprised:

- No mine dewatering.
- No enhanced recharge zone.
- Initial condition was 015a_CAL-Apr14_07a_NUL_SP185TS5.hds.

From Figure 8.18, the modelled groundwater levels in the prediction simulation are essentially equivalent to the cumulative impact null case.

From Figure 8.19, the predicted decline in the uppermost water table is more than 50 m within the active mining area. However, at the boundary of the site the predicted decline in the uppermost water table is less than 2 m the site at all extracted time stamps.

Figure 8.20 presents the modelled groundwater contribution to Rix's Creek (DRN116 and DRN104) and the Hunter River (RIV4) together with the predicted contribution for the no extension null case and the cumulative impact null case.

Table 8.15 presents the modelled difference in groundwater contribution during the period of maximum difference.

Table 8.15: Prediction Model – Change in Groundwater / Surface Water Interaction

Stress Period	Time(d)	Modelled Flux (m ³ /d) Prediction Model	Modelled Flux (m ³ /d) No Extension Null Case	Modelled Flux (m ³ /d) Cumulative Impact Null	Difference (m ³ /d) No Extension	Difference (m ³ /d) Cumulative Impact
Rix's Creek – Upper Part (DRN116)						
218	6636	-2.4	-7.1	-7.0	-4.6	-4.5
219	6667	-2.2	-6.6	-6.7	-4.4	-4.4
220	6698	-1.5	-4.8	-5.5	-3.3	-4.0
221	6728	-1.8	-6.0	-6.4	-4.2	-4.6
222	6759	-1.7	-5.9	-6.4	-4.2	-4.7
223	6789	-1.7	-5.7	-6.3	-4.1	-4.6
224	6820	-4.3	-12.8	-10.8	-8.5	-6.5
225	6851	-1.9	-6.0	-6.3	-4.0	-4.4
226	6879	-7.9	-18.9	-14.7	-11.0	-6.9
227	6910	-2.3	-6.4	-6.5	-4.1	-4.2
228	6940	-2.1	-5.8	-6.1	-3.8	-4.0
229	6971	-1.6	-4.7	-5.3	-3.1	-3.6
230	7001	-1.5	-4.6	-5.2	-3.1	-3.7
231	7032	-1.6	-4.9	-5.4	-3.3	-3.8
232	7063	-1.7	-5.5	-5.9	-3.8	-4.2
233	7093	-2.1	-7.0	-7.1	-4.9	-5.0
234	7124	-1.7	-5.9	-6.4	-4.2	-4.7
235	7154	-2.7	-8.9	-8.3	-6.2	-5.6
Rix's Creek – Lower Part (DRN104)						
218	6636	-6.8	-6.8	-6.8	0.0	0.0
219	6667	-6.1	-6.1	-6.2	0.0	0.0
220	6698	-3.9	-3.9	-3.9	0.0	0.0
221	6728	-5.0	-5.0	-5.0	0.0	0.0
222	6759	-4.7	-4.7	-4.7	0.0	0.0
223	6789	-4.5	-4.5	-4.6	0.0	0.0
224	6820	-13.3	-13.3	-13.3	0.0	0.0
225	6851	-5.4	-5.4	-5.4	0.0	0.0
226	6879	-21.8	-21.8	-21.8	0.0	0.0
227	6910	-6.3	-6.4	-6.4	0.0	0.0
228	6940	-5.3	-5.4	-5.4	0.0	0.0
229	6971	-3.9	-4.0	-4.0	0.0	0.0
230	7001	-3.7	-3.7	-3.7	0.0	0.0
231	7032	-3.9	-3.9	-4.0	0.0	0.0
232	7063	-4.5	-4.5	-4.5	0.0	0.0
233	7093	-6.1	-6.2	-6.2	0.0	0.0
234	7124	-4.7	-4.7	-4.7	0.0	0.0
235	7154	-8.2	-8.2	-8.2	0.0	0.0

Stress Period	Time(d)	Modelled Flux (m ³ /d) Prediction Model	Modelled Flux (m ³ /d) No Extension Null Case	Modelled Flux (m ³ /d) Cumulative Impact Null	Difference (m ³ /d) No Extension	Difference (m ³ /d) Cumulative Impact
Hunter River – Downstream of Glennies Creek (RIV4)						
218	6636	89.0	88.9	88.8	0.0	-0.2
219	6667	61.2	61.1	61.0	-0.1	-0.2
220	6698	29.6	29.6	29.4	-0.1	-0.2
221	6728	-12.6	-12.7	-12.8	-0.1	-0.2
222	6759	-32.2	-32.2	-32.4	-0.1	-0.2
223	6789	-27.7	-27.8	-27.9	-0.1	-0.2
224	6820	-39.2	-39.2	-39.4	-0.1	-0.2
225	6851	17.2	17.2	17.0	-0.1	-0.2
226	6879	-16.9	-17.0	-17.1	-0.1	-0.2
227	6910	57.8	57.7	57.6	-0.1	-0.2
228	6940	93.2	93.2	93.0	-0.1	-0.2
229	6971	108.6	108.5	108.4	-0.1	-0.2
230	7001	94.6	94.6	94.5	-0.1	-0.2
231	7032	69.5	69.5	69.3	-0.1	-0.2
232	7063	27.2	27.2	27.0	-0.1	-0.2
233	7093	-18.6	-18.6	-18.8	-0.1	-0.2
234	7124	-35.0	-35.0	-35.2	-0.1	-0.2
235	7154	-45.4	-45.5	-45.6	-0.1	-0.2

From Figure 8.20 and Table 8.15, as found during the calibration period, there is a minor contribution of groundwater to Rix's Creek as baseflow where the creek is not dry in the model. The maximum contribution, in the cumulative impact null case, is 14.7 m³/d along the length of Rix's Creek. This is equivalent to 0.17 L/s and is considered minimal. The predicted impact is a reduction in groundwater contribution of up to 11.0 m³/d (0.1 L/s) and is not considered significant since groundwater contribution to Rix's Creek is minor to negligible. From Table 8.15, there is no impact of the mine on the lower part of Rix's Creek (DRN104) or the Hunter River (RIV4).

The predicted impact due to continuation at Rix's Creek Colliery on the adjacent mine operation at Integra is presented in Table 8.16 with respect to annual inflows based on water years.

Table 8.16: Prediction Model – Change in Take at Integra Mine (ML/a)

Water Year	Prediction Simulation (ML/a)	Continuation Null Case (ML/a)	Difference (ML/a)
2013–2014 ^a	112	112	0
2014–2015	675	675	0
2015–2016	783	783	0
2016–2017	812	812	0
2017–2018	787	787	0
2018–2019	828	828	0
2019–2020	836	836	0
2020–2021	739	739	0
2021–2022	760	760	0

Water Year	Prediction Simulation (ML/a)	Continuation Null Case (ML/a)	Difference (ML/a)
2022–2023	844	844	0
2023–2024	936	936	0
2024–2025	995	995	0
2025–2026	1025	1025	0
2026–2027	1027	1027	0
2027–2028	1027	1027	0
2028–2029	767	767	0
2029–2030	0	0	0
2030–2031	0	0	0
2031–2032	0	0	0
2032–2033	0	0	0
2033–2034	0	0	0
2034–2035	0	0	0
2035–2036	0	0	0
2036–2037	0	0	0
2037–2038 ^a	0	0	0

a. Partial Year;

From Table 8.16, the predicted difference to inflows at Integra due to continuation of Rix's Creek Colliery is negligible. The explanation of this finding is due to the hydrogeological divide between the two sites.

8.9 Uncertainty Analysis

The purpose of uncertainty analysis is to investigate the sensitivity of model predictions to model assumptions. Two uncertainty analysis cases were considered:

- Change in rainfall condition (10th percentile and 90th percentile rainfall).

The uncertainty analysis also provides a simulation of potential climate change, i.e. a long-term decline in expected rainfall, considering historical variability as discussed in Section 8.5.2.

8.9.1 Changed Rainfall Conditions

To investigate the impact of a low rainfall condition and a high rainfall condition on model predictions, two uncertainty analysis simulations were prepared.

As indicated in Section 8.5.2, the historical annual rainfall record was processed to identify the 10th percentile 24 year rainfall total. The historical record commencing in that year was then applied to the prediction simulation. Similarly, the 90th percentile 24 year rainfall total was identified and the historical record commencing from that year was applied.

The model control file associated with the low rainfall condition is:

- 015c_UNC-LowRf_01a.gww.

The model control file associated with the high rainfall condition is:

- 015c_UNC-HighRf_01a.gww.

Figure 8.21 presents the predicted mine inflows considering each uncertainty condition.

From Figure 8.21, the impact to mine inflows is small and has a median difference of 0%, with a range between -3% (10th percentile) and +3% (90th percentile) for the high rainfall condition. For the low rainfall condition, the difference was a median of -2% and range between -5% (10th percentile) and +1% (90th percentile). Modelling indicates that a period of sustained period of below average rainfall or above average rainfall does not significantly affect the groundwater model predictions.

Figure 8.22 presents the predicted groundwater contribution to Rix's Creek and the Hunter River under the low rainfall and high rainfall conditions together with the primary prediction results.

From Figure 8.22, the groundwater contribution is essentially identical to the primary prediction simulation results.

8.10 Recovery Simulation

8.10.1 Model Set-up

Following prediction simulation, a recovery simulation was prepared for the period Jan 2038 through to December 3037. As indicated in Section 8.5.2, given the extended time line of recovery simulation, the long-term annual average rainfall rate was adopted from 2063 (SP48) onward.

The recharge zone of the final void was defined considering the proposed diversion drains around the lip of the void.

8.10.2 Recovery Results

The model control file associated with recovery simulation is:

- 015a_RCV-MP1_05a.gww.

The model simulation comprised:

- No mine dewatering.
- Hydraulic properties updated to reflect backfilling and void location.
- Recharge and evaporation zonation updated to reflect location of final void and Pit 1 access portal.
- Increase in TopEl of Layer 1 to account for filling in the final landform to the west and south of the final void, in particular.
- Updated evaporation surface to reflect the final landform including void and Pit 1 access portal.
- Initial condition was 015a_PRD-MP1_04a_SP284TS5.hds.

Figure 8.23 presents the recovery model mass balance.

From Figure 8.23, the mass balance error is acceptably small.

Figure 8.24 presents the predicted groundwater level in each model layer at 20 years from the end of mining and Figure 8.25 presents the predicted groundwater level at 100 years from the end of mining. For the purpose of comparison, the cumulative impact null case (no Mining at Rix's Creek) is also presented. The interpreted uppermost water table is also presented in Figure 8.24 and 8.25.

The model control file associated with the cumulative impact null case is:

- 015a_RCV-NUL_01a.gww.

This model comprised:

- No mine dewatering.
- No enhanced recharge zone.
- No change to top elevation (TopEl) of Layer 1.

- No change to evaporation surface.
- No final void or Pit 1 access portal.
- Initial condition was 015a_PRD-NUL_02a_NUL_SP284TS5.hds.

From Figures 8.24 and 8.25, the predicted water table level in the final void is 41 m AHD at 20 years from the end of mining and 50 m AHD at 100 years from the end of mining. As will be presented below, the final level is 53 m AHD.

Figures 8.19.5 and 8.19.6 present the modelled drawdown in the Hebdon Seam with reference to the cumulative impact (No Continuation).

The modelled decline in water table is presented in Figure 8.26 at 20, 50, 100, 200 and 1000 years following the completion of mining. These predictions were calculated based on the difference between the recovery simulation and the cumulative impact null case.

Appendix C presents the modelled hydrographs at each of the monitoring locations.

From Figure 8.26, the predicted decline in level of the uppermost water table is more than 50 m following 1000 years of recovery. The extent of this level of drawdown is constrained to the backfill zone and final void.

Figure 8.27 presents the pressure head (m) distribution through the final void at Col 165 (328,000 mE) from north to south, at the commencement of recovery simulation in 2037, at 20 years, 50 years, 100 years, 200 years and at 1000 years from end of mining. The extent of the section is also marked in Figure 8.27.

Figure 8.28 presents the pressure head (m) distribution of a west to east cross-section through the final void at Row 141 (6,399,550 mN) at equivalent times to Figure 8.27. The location of the cross-section is also presented in Figure 8.28.

8.11 Water and Salt Balance of Final Void

8.11.1 Model Set-up

To predict the potential long-term salinity within the final void, the model mass balance was updated using the hydrostratigraphic unit module, HSU, of MODFLOW, to allow review of modelled inputs and outputs to the void. The spatial extent of the void in each model layer is presented in Figure 8.10 and the HSU Zones in Layer 1 is presented in Figure 8.29.

Inflows to the void comprise:

- Rainfall recharge to the surface of the lake.
- Exchange of groundwater from backfill to the void.

Outflows from the void comprise:

- Evaporation from the lake surface.
- Exchange of groundwater to the backfill from the void.

Table 8.17 presents the assumed salt concentration of inflows to the void as well as other relevant assumptions.

Table 8.17: Model Parameters for Salt Balance

Component	Concentration	Comment
Inflows		
Rainfall	10 mg/L	
Groundwater from Backfill	7,370 mg/L (maximum salinity of BH01 is 11,000 µS/cm)	Assumed to be "fresh" groundwater rather than recycled from the void
Outflows		
Evaporation	0 mg/L	
Groundwater to Backfill	Variable as dependent on concentration of the pit lake at the time.	Assumed to be constantly mixed and therefore homogeneous at all times. Assumed not to re-enter the void

Figure 8.30 presents the modelled inflows and outflows with respect to the final void.

From Figure 8.30, recharge and evaporation are the dominant components in the water balance.

8.11.2 Model Results

The water balance components presented in Figure 8.30 were combined with assumed concentrations presented in Table 8.17 to derive the long-term salinity in the void.

Figure 8.31 presents the predicted salt concentration in time. Table 8.18 presents salt balance results at selected times.

Table 8.18: Salt Mass Balance Results

SP	Time (years) ^a	Concentration (mg/L)	Recharge (m ³ /d)	Pit Inflow (m ³ /d)	Evaporation (m ³ /d)	Pit Outflow (m ³ /d)
1	1 month	7454	3428	1874	6715	31802
2	2 months	7416	7166	3017	5617	14141
3	3 months	7519	580	3057	4388	7729
4	4 months	7583	548	2975	2955	4971
6	6 months	7580	1560	2631	1243	2589
12	1	7537	725	1776	4366	830
24	2	7552	208	1050	3565	259
32	10	7144	1272	449	2149	88
42	20	6411	3021	409	2377	213
52	50	6370	2515	346	2466	153
62	100	6893	2515	331	2602	137
72	200	8876	2515	336	2696	125
84	500	14181	2515	339	2730	120
94	1000	18467	2515	339	2733	120
NA ^b	2000	20473	2515	339	2733	120
NA ^b	5000	20753	2515	339	2733	120

a. Time is elapsed time from end of mining in 2037; b. Water balance components assumed to be steady state after SP94.

From Figure 8.30 and Table 8.18, evaporation exceeds recharge in the water balance and inflow to the pit from backfill/hard-rock exceeds outflow. The long-term salinity of the lake formed in the void is 20,750 mg/L, equivalent to an EC of 31,000 μ S/cm (assuming a conversion of EC (μ S/cm) * 0.67 = TDS (mg/L)).

Modelling indicates that the void operates as a groundwater sink since groundwater inflow exceeds outflow and groundwater flux is minor compared to recharge and evaporation components.

The groundwater contribution from hard-rock (HSU Zone 1 in Figure 8.29) to the Hunter River Alluvium (HSU Zone 4 in Figure 8.29) is predicted to be 244 m³/d at the end of the recovery simulation. This demonstrates a minimal groundwater contribution to the Hunter River alluvium.

Although there is a small groundwater outflow from the pit, the long-term impact to off-site groundwater quality is considered minimal.

9. POTENTIAL GROUNDWATER IMPACTS

9.1 Overview of Potential Impacts on the Groundwater System

This section contains a summary of the potential impacts on the hydrogeological environment from the proposed Project and the subsequent period of post-mining recovery.

Open cut mining, and the associated intersection of groundwater has a number of impacts on the hydrogeological system that have been evaluated as part of this assessment. The natural landform surrounding the Project forms an open basin-like structure that encompasses the mine. This geological basin restricts groundwater flow and effectively buffers the propagation of groundwater drawdown. The potential groundwater related impacts of the Project can be summarised as follows:

- Drawdown impacts on groundwater levels both within the Permian hard rock strata and shallow groundwater table during and following the completion of mining.
- Impacts to baseflows to watercourses and surface water features in the vicinity of the proposed development during and following the completion of mining.
- Impacts on existing groundwater users.
- Impacts on groundwater dependent ecosystems.
- Impacts on water quality within Rix's Creek and downstream.
- Variation of predicted impacts under differing climate change scenarios.

These impacts have potential to endure long after mining has ceased and the groundwater system rebounds and attains a new equilibrium under the altered hydrogeological regime.

The groundwater model, discussed in Section 8, has been used to predict the cumulative impacts of the Project with other existing and proposed mining operations, the incremental impacts that are directly attributable to the mine and the proposed continuation of mining.

In addition to the predictive modelling, the Project Application Area has an established network of groundwater and surface water monitoring. The observed impacts of past mining activity have been used as a verification of the predicted model impacts.

9.2 Evaluation of Impacts (during Mine Operations)

The "cumulative null case" scenario (Section 8.8) has been used as the baseline condition for the impact analysis. This scenario refers to a condition where there is no open cut mining at Rix's Creek. The presented impacts therefore represent the incremental impacts resulting from the mining operations at Rix's Creek, including the impacts from the approved mining to date at Pits 1, 2 and 3.

As this assessment relates to the continuation of the mine at Rix's Creek reference is also made to a "null case" which includes the impacts and recovery from approved mining operations at the mine. This allows for the quantification of impacts related to only the proposed continuation of mining at Rix's Creek.

Where appropriate all results relating to the period of operational mining have been presented as the total change from the baseline conditions, or the change that would have occurred due to other influences (adjacent mining) if the Rix's Creek Mine was not mined (the cumulative null case). This approach allows the net impact of the Rix's Creek Mine to be evaluated separately from the other regional impacts.

9.2.1 Predicted Mine Inflows

Section 8.8.2 describes the predicted inflows to the various open cuts associated with the mine with the fluxes shown in Figure 8.16 and total mine inflows shown in Figure 9.1. Inflow spikes relate to the progressive implementation of the mine plan, such as pit development and back filling, within the model. Key points regarding the predicted inflows are as follows:

- Inflows to Pit 1 are predicted to be between approximately 100 and 120 m³/d (37 and 44 ML/a) prior to backfilling in 2020.
- Predicted inflows to Pit 2 are negligible (less than 1 m³/d). Following the implementation of the 2017 surface landform inflows to Pit 2, although only very small initially, reduce to zero.
- Inflows to Pit 3 are predicted to be of the order 500 to 800 m³/d (182 to 292 ML/a) through to 2023, and then gradually tail off to around 264 m³/d by the end of mining.
- Predicted inflows to the Pit 1 Portal range from 150 to 800 m³/d (550 to 290 ML/a) over the duration of mining.
- The total mine inflows are predicted to peak at around 960 m³/day (350 ML/a) in 2017, declining to around 344 m³/d (125 ML/a) by the end of mining.

9.2.2 Groundwater Level Impacts

From the predicted groundwater drawdown presented in Figure 8.19, it is apparent that groundwater levels are considerably impacted by mining in close proximity to the proposed Project.

Figures 8.19.1 and 8.19.2 present the drawdown attributable to the Project only, while Figures 8.19.3 and 8.19.4 present the cumulative drawdown over the life of mining. Corresponding water level contours are also provided for comparison.

In both scenarios, groundwater drawdown is predicted to exceed 50 m immediately adjacent to Pit 3 with this impact directly associated with the proposed Project. The extent of the cumulative drawdown is limited as drawdown propagation is confined by the geological syncline.

Taking into account all mining influences (cumulative impacts) no drawdown impacts within the regolith/alluvium (Layer 1) are predicted outside of the coal lease boundary.

Groundwater impacts (drawdown of up to 10 m) are predicted outside of the lease boundary to the north of the Project. In this area, the regolith/alluvium (Layer 1) is shown to be dry in the absence of mining influences as shown in the cumulative impact null case. The predicted drawdown impact is therefore within the underlying Permian hardrock.

Figures 8.19.5 and 8.19.6 show that the drawdown impact within the underlying Hebden coal seam propagates to the north as mining progresses. The drawdown within the Hebden Seam to the north is exacerbated in the cumulative impact scenario.

9.2.3 Baseflow Impacts

The predictive modelling has allowed for an assessment of the degree of interaction and influence the proposed Project will have on Rix's Creek.

The baseflow fluxes for Rix's Creek are depicted in the null and cumulative null case scenarios in Figures 8.19.1 to 8.19.4. The cumulative null case demonstrates that, in the absence of mining influences, Rix's Creek is a net losing, or influent, stream in the vicinity of the mine.

While some sections of Rix's Creek are shown to receive a baseflow contribution it is only very minor at ~0.1 L/sec and considered negligible.

Impacts from approved mining operations at the mine can be seen in a comparison of the null case and the cumulative null case. In the null case the regolith (Layer 1) in areas adjacent to Rix's Creek is predicted to recover resulting in an increased baseflow contribution (<0.01 L/sec). Impacts from the proposed Project are shown to negate this recovery with the regolith adjacent to Rix's Creek remains dry throughout the life of the Project.

9.3 Impacts Following Post-mining Recovery

The long-term impacts of mining following 100 years of recovery after the end of mining are described below.

9.3.1 Groundwater Recharge and Groundwater Levels

Predicted potentiometric heads are presented across all layers in Figures 8.24 and 8.25. Following 100 years of recovery, the figures demonstrate that:

- The predicted water level in the backfilled void is approximately 55 m AHD with a pit lake level of approximately 50 m AHD.
- Predicted residual drawdown levels in excess of 50 m are constrained to the backfill zones, the Pit 1 portal and the final void.
- Predicted residual drawdown levels between 20 and 50 m are constrained within the syncline formation and do not extend outside of the mine lease boundary.
- The predicted residual drawdown within the regolith/alluvium (Layer 1) outside of the mine lease boundary is less than 2 m.

The groundwater heads are also depicted on two head-distribution sections during the recovery period (Figure 8.28). The sections run east to west and south to north through the final void and illustrate the reduction of the pressure gradients between the final void and surrounding formation over time.

At 100 years following recovery, the groundwater level is shown to reach equilibrium as the final void acts as a net sink with evaporation and outflow in equilibrium with rainfall recharge and inflow.

9.3.2 Potential Baseflow Impacts

The modelling indicates that there will be no significant baseflow contribution to the creek following 100 years of recovery and therefore water quality impacts (based on the current simulations) are considered negligible.

9.3.3 Water Quality

The modelling indicates that the inflows to the pit void will exceed outflows and the evaporative losses will exceed rainfall. On this basis the pit void will act as a groundwater sink with evaporative salinification predicted to increase the salinity of the pit water. A conservative salinity level of 7,454 mg/L (11,125 $\mu\text{S/cm}$) at the end of mining is predicted to increase to above 20,000 mg/L ($\sim 30,000 \mu\text{S/cm}$) by 2,000 years after mining.

Due to the low outflows from the pit void and hence the marginal contribution the void water will make to the surrounding groundwater system the risk of adverse impacts to water quality is considered to be negligible.

As such, the potential impacts on the Hunter River Alluvium are also considered to be negligible.

9.4 Potential Impacts on Existing Groundwater Users

There are no identified groundwater users within the mine lease boundary or the predicted extent of groundwater drawdown, aside from the adjacent operation at Integra. As presented in Section 8.8.2, the modelled difference in mine inflow is $1.8 \text{ m}^3/\text{d}$ at maximum and is $<1 \text{ ML/a}$ with respect to annual accounting based on water year.

9.5 Potential Impacts on Groundwater Dependent Ecosystems

There are no identified GDEs within the mine lease boundary or the predicted extent of groundwater drawdown.

9.6 Cumulative Impacts

The cumulative water level decline is presented in Figures 8.19.3 and 8.19.4. The cumulative drawdown within the uppermost water table is shown to propagate further northwards in the cumulative impact scenario. However, this greater extent of drawdown does not detrimentally affect the groundwater resource, nor does it impinge on other groundwater users or groundwater dependent ecosystems.

9.7 Aquifer Interference and Minimal Impacts Considerations

With regard to potential impacts on groundwater, this section summarises the analysis carried out for this report of two aspects of the AIP policy requirements, namely water source classification and minimal impact consideration. Where considerations of the Water Sharing Plan, water accounting and licensing are concerned, these matters are considered in Section 10.

Water Source Classification

The AIP defines “water sources” into two primary categories, namely, “highly productive” (HPWS) and “less productive” (LPWS). HPWS groundwater is defined in the Policy as a groundwater source (alluvial, coastal sands, porous rock or fractured rock) that is *declared* in the Regulations and will be based on the following criteria:

- a) Has total dissolved solids of less than 1,500 mg/L.
- b) Contains water supply works that can yield water at a rate greater than 5 L/sec.

Categories of less productive groundwater sources are alluvial, porous rock or fractured rock. Categories for highly productive groundwater sources are alluvial, coastal sands, porous rock and fractured rock.

It is highlighted that the Singleton Water Source of the Hunter Unregulated and Alluvial Water Sources and the Hard Rock Water Source (*Water Act 1912*) are both categorised by the NSW Office of Water as LPWS.

The AIP provides thresholds for key minimal impact considerations for each of the HPWS and LPWS sources. These thresholds deal with water table and groundwater pressure drawdown as well as groundwater and surface water quality changes. The Policy provides for an adaptive management approach to the minimal impact considerations, which involves regularly reviewed and updated, if required, based on scientific information and experience during implementation.

Minimal Impact Considerations

The AIP requires that groundwater sources within the potential regional influence of a Project are considered with respect to predefined thresholds for minimal impacts. These thresholds deal with two key potential impacts:

- Water table and groundwater pressure (level) drawdown changes.
- Groundwater quality changes.

An analysis of the thresholds for key minimal impact considerations defined in the Table 1 of the AIP policy (NSW Office of Water 2012) has been carried out for each of the groundwater sources potentially impacted by the Project. The outcome of this analysis is presented in Tables 9.1 and 9.2.

Table 9.1: Minimal Impact Considerations: Hard Rock Water Source

Category	Water Table (WT)	Water Pressure (WP)	Water Quality (WQ)
Porous and Fractured Rock water sources	Consideration WT-1 The predicted cumulative drawdown in the Hard-Rock (unconfined) aquifer at the end of mining is presented in Figure 8.19. Drawdown of up to 10 m, are predicted outside of the lease boundary to the north of the Project within the underlying Permian hardrock. In this area the regolith/alluvium (Layer 1) is shown to be dry in the absence of mining a) There are no high priority GDEs within 40 m of the area of drawdown b) There are no culturally significant sites within 40 m of the area of drawdown There are no water supply works within the area of influence and as such, cumulative impact on any water supply work is less than 2 m.	Consideration WP-1 The Permian Coal Measures aquifer at the end of mining is not a confined aquifer inside/outside of the proposed Project Applicable Area boundary. As such, the Water Pressure Criterion does not apply.	Consideration WQ-1a The Permian groundwater quality are characterised as brackish to saline. Mining activity will not change the beneficial use of this groundwater source inside/outside of the Project Application Area boundary.
	Consideration WT-2 Does not apply as the activity does not trigger the requirement	Consideration WP-2 Does not apply as the activity does not trigger the requirement	Consideration WQ-2 Does not apply as the activities do not trigger the requirement.

Table 9.2: Minimal Impact Considerations: Singleton Water Source

Category	Water Table (WT)	Water Pressure (WP)	Water Quality (WQ)
Alluvial water sources	Consideration WT-1 The predicted cumulative drawdown in the alluvial/regolith (unconfined) aquifer at the end of mining is presented in Figure 8.19. Taking into account all mining influences (cumulative impacts) no drawdown impacts within the regolith/alluvium (Layer 1) are predicted outside of the coal lease boundary. The predicted residual drawdown within the regolith/alluvium (Layer 1) outside of the mine lease boundary is less than 2 m. a) There are no high priority GDEs within 40 m of the area of drawdown b) There are no culturally significant sites within 40 m of the area of drawdown There are no water supply works within the area of influence and as such cumulative impact on any water supply work is less than 2 m.	Consideration WP-1 The alluvial/regolith aquifer at the end of mining is not a confined aquifer inside/outside of the proposed Project Applicable Area boundary. As such, the Water Pressure Criterion does not apply.	Consideration WQ-1a The alluvial/regolith quality are characterised as brackish to saline. Mining activity will not change the beneficial use of this groundwater source inside/outside of the Project Application Area boundary.
	Consideration WT-2 Does not apply as the activity does not trigger the requirement	Consideration WP-2 Does not apply as the activity does not trigger the requirement	Consideration WQ-2 Does not apply as the activities do not trigger the requirement.

10. WATER LICENSING

Water licensing is administered under the *Water Management Act 2000* and *Water Act 1912*.

Access to surface water and alluvial licences at the mine is governed by the *Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009* (HUAWS 2009).

Access to hard-rock licences at the mine is governed by the *Water Act 1912* as the draft *Water Sharing Plan for the North Coast Fractured and Porous Rock Groundwater Sources* is yet to commence.

Conditions in regard to hard-rock licences are specified on individual licence certificates. In general, access licences specify the volumetric limit of take, usually informed by analysis to demonstrate the requested yield can be sustainably achieved, and the details as to parcel of land to which the access licence is tied.

10.1 Current Licence Allocations

Table 10.1 shows the currently held licences at Rix's Creek.

Table 10.1: Rix's Creek Licence Allocations

Current Licence	Hard-Rock (ML/a)	Singleton Water Source (ML/a)
20BL170863 – Dust suppression	100	-
20BL170864 – Dewatering Bore	-	100
20SI049786 – Rix's Creek	-	300
20SI048955 – Stone Quarry Gully	-	150
20SL050160 – Black Bottle Creek	-	5
Total	100	555

10.1.1 Estimate of Licensing Requirement

There are two water sources from which access licences may be required to be held. These comprise:

- Singleton Water Source of the Water Sharing Plan for the Hunter Unregulated and Alluvial Water Sources 2009, administered under the *Water Management Act 2000*.
- Hard-Rock administered under the *Water Act 1912*.

Table 10.2 presents the estimated licensing requirement from each of the above water sources.

The licensing estimate for hard-rock was based on the modelled mine inflow rates presented in Figure 8.16 that were then processed into cumulative inflow volume. This is a somewhat conservative approach insofar there is a large modelled increase in mine inflow immediately following the change in mine landform surface.

The licensing estimate for Singleton Water Source was based on differences between the prediction simulation and the cumulative impact null case for the upper part of Rix's Creek, DRN116, as presented in Figure 8.20.

The water year was assumed to be July through to June in the following year. The modelled licence requirements are shown in Table 10.2.

Table 10.2: Modelled Licence Requirement (ML/a)

Water Year	Hard-Rock (ML/a)	Singleton Water Source (ML/a)
2013–2014 ^a	65	0
2014–2015	271	1
2015–2016	235	2
2016–2017	224	2
2017–2018	283	2
2018–2019	275	2
2019–2020	251	2
2020–2021	305	2
2021–2022	270	2
2022–2023	238	2
2023–2024	205	2
2024–2025	157	2
2025–2026	153	2
2026–2027	185	2
2027–2028	165	2
2028–2029	153	2
2029–2030	148	2
2030–2031	143	2
2031–2032	137	2
2032–2033	135	2
2033–2034	132	2
2034–2035	131	2
2035–2036	128	2
2036–2037	126	2
2037–2038 ^a	63	1

a. Partial Year;

10.1.2 Groundwater Peak Licence Requirement

The peak licensing requirement is predicted to occur in the 2020–2021 water year (Table 10.2), with a total modelled inflow of 305 ML/a (840 m³/d) during that water year. The predicted annual inflow diminishes to 126 ML/a (345 m³/d) during the final full water licensing year. During recovery, modelling shows that the rate of inflow is less than during mining.

The total groundwater licence currently held is 100 ML/a, therefore it is anticipated that additional groundwater licences will need to be obtained prior to the first year of mining.

10.1.3 Surface Water Peak Licence Requirement

The peak licensing requirement is predicted to occur around 2015 to 2016 (Table 10.2) and persist throughout the life of mine, with a total modelled alluvial water take of 2 ML/a (5.5 m³/d). During recovery, modelling shows that the rate of inflow is less than during mining.

The total surface water licences currently held are 555 ML/a, of which, 300 ML/a pertains to Rix's Creek so the modelled alluvial water take can be accommodated by the currently held licences.

Water Sharing Rules

The WM Act 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 WSP sets out Water Sharing Rules that operate under these water management principles. The Water Sharing Rules that pertain to the Singleton Water Source are provided in Table 10.3.

Table 10.3: Singleton Water Source Water Sharing Rules

Subject	Singleton Water Source
Plan Commencement Date ☐	1 August 2009 ☐
Term of the Plan	10 years ☐
Access Rules	
Cease to Pump	Existing licence conditions remain for the first five years. From year six of the mine plan, cease to pump is when there is either no visible inflow to, or outflow from, the pumping pool. NB: From year six of the plan the cease to pump condition will apply to aquifer access licences extracting from all alluvial aquifers within 40 m of an unregulated river, except for existing Domestic and Stock access licences and Local Water Utilities Access licences. ☐
Reference Point	Riffles upstream and downstream of pump
Trading Rules	
Trading INTO the management zone	Permitted, subject to assessment
Trading WITHIN the management zone	Permitted, subject to assessment
Conversion to High Flow Access Licence	Not permitted.
Conversion to Aquifer Access Licence	Not permitted.

11. MANAGEMENT AND MONITORING

11.1 Impact Mitigation Measures

The results of the numerical groundwater modelling indicate that impacts from the mine have been mitigated largely by the proposed final landform configuration at 2037. Drawdown propagation is also constrained within the basin like structure of the Rix's Creek Syncline.

The simulated backfilling of the pit (to above aquifer levels) minimises evaporative loss and salinification of pit lake water following mine closure. The progressive infilling of voids is generally regarded as the most effective and preferred means of minimising the long-term impacts of mining activity after closure.

Groundwater levels are predicted to recover partially following mine closure; however, due to the presence of the final void, groundwater levels will remain artificially suppressed in the vicinity of the mine. No significant salinity impacts are predicted based on the final 2037 pit configuration and therefore no significant impact on downstream groundwater (and surface water) flows and quality are expected.

11.2 Monitoring of Impacts of Groundwater Extraction

The current monitoring network which exists across the Project Area is described in Section 5. The monitoring network is designed to provide data on the identified groundwater groups in the Project area, namely:

- The shallow regolith/alluvial groundwater system.
- The deeper coal measures groundwater system including the historic underground workings.

It is recommended that the current groundwater monitoring network be maintained which includes the replacement of any destroyed or damaged bores.

11.3 Existing Environmental Management System

Bloomfield has a firm commitment to minimising the impact of its operations on the local environment and community, and has a comprehensive Environmental Management System (EMS) in place at Rix's Creek to fulfil this commitment.

The EMS has been developed and implemented to ensure the effective management of environmental aspects and impacts and compliance with regulatory requirements while providing a means for continued improvement in the environmental performance at the mine. The EMS incorporates a number of environmental management plans that are designed to assist in meeting community and regulatory expectations.

As part of the relevant management plans, performance measures and indicators have been designed to provide a link between monitoring data and the response triggers (triggers) that determine whether mining related impacts are occurring. Management actions are implemented if trigger levels are exceeded.

Groundwater monitoring data is currently reconciled against ANZECC guidelines (ANZECC 2000). There are plans in place to derive Site Specific Trigger Values (SSTV) through statistical analysis of monitoring data. Trigger values are dynamic and are required to be reviewed and updated as more monitoring data is collected.

11.4 Review and Reporting

The existing monitoring and management plan for Rix's Creek should be updated to reflect the above monitoring recommendations. The 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 impact modelling.

It is also recommended that, in accordance with industry best practice (Barnett et al. 2012) modelling post-audits should be carried out following the commencement of the Project. We recommend a modelling post-audit is completed five years after project initiation and if necessary, the Project model should be recalibrated 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, they 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 groundwater levels, then the implications of such variance should be assessed and appropriate response actions implemented in accordance with the protocols described in the appropriate management plan.

12. REFERENCES

- ANZECC, 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council, October 2000.
- Australasian Groundwater and Environmental Consultants Pty Ltd, 1984. Effects of Mining on Groundwater Resources in the Upper Hunter Valley, New South Wales Coal Association
- Australasian Groundwater and Environmental Consultants Pty Ltd, 2007. Glennies Creek Open Cut Coal Mine Groundwater Assessment. Prepared for Integra Coal Operation Pty Ltd
- Aquaterra, 2010a. Rix's Creek Gap Study. Prepared for Bloomfield Collieries Pty Limited.
- Aquaterra, 2010b. Monitoring Piezometer Installations at Rix's Creek,
- Aquaterra, 2009, Bowmans Creek Diversion: Groundwater Impact Assessment Report, prepared for Ashton Coal Operations Pty Limited, October 2009
- Barnett B., Townley L.R., Post-V., Evans R.E., Hunt R.J., Peters L., Richardson S., Werner A.D., Knapton A., Boronkay A., 2012. Australian Groundwater Modelling Guidelines, Waterlines Report No. 82, National Water Commission, Canberra. Report No. ISBN 978-1-921853-91-3.
- Bloomfield Group, 2014. Mining Operations (Rix's Creek Mine) Water Management Plan. Version 3a
- Croft and Associates, 1988, Rix's Creek Coal Mine. Environmental Impact Statement, Prepared for Bloomfield Collieries Pty Limited.
- Geoterra, 2008, Integra Open Cut Project and Open Cut Extension Groundwater Assessment, Singleton NSW
- National Uniform Drillers Licensing Committee, 2012, Minimum Construction Standards for Water Bores in Australia (3rd Edition).
- NSW Government, 2012. Strategic Regional Land Use Policy.
- NSW Office of Water, 2012, NSW Aquifer Interference Policy: NSW Government policy for the licensing and assessment of aquifer interference activities. NSW Department of Primary Industries, a division of NSW Department of Trade and Investment, Regional Infrastructure and Services, September 2012
- RPS Aquaterra, 2012, Rix's Creek Mine. Final Void Management Plan, Prepared for Bloomfield Collieries Pty Ltd
- R.W. Corkery & Co. Pty. Limited, 2007, Environmental Assessment. Glennies Creek Open Cut Coal Mine, Prepared on behalf of Integra Coal Operations Pty Ltd.

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Figure 8.19.2: Prediction Model – Modelled Decline in Uppermost Water Table – Extension Only

Figure 8.19.3: Prediction Model – Modelled Decline in Uppermost Water Table – Cumulative Impact

Figure 8.19.4: Prediction Model – Modelled Decline in Uppermost Water Table – Cumulative Impact

Figure 8.19.5: Prediction Model – Modelled Drawdown in Hebden Seam

Figure 8.19.6: Prediction Model – Modelled Drawdown in Hebden Seam

Figure 8.20: Prediction Model – Groundwater/Surface Water Interaction

Figure 8.21: Uncertainty Analysis – Mine Inflows

Figure 8.22: Uncertainty Analysis – Groundwater/Surface Water Interaction

Figure 8.23: Recovery Model – Model Mass Balance

Figure 8.24.1: Recovery Model – Modelled Groundwater Contours – 2057

Figure 8.24.2: Recovery Model – Modelled Groundwater Contours – 2057

Figure 8.24.3: Recovery Model – Modelled Groundwater Contours – 2057

Figure 8.24.4: Recovery Model – Modelled Groundwater Contours – 2057

Figure 8.24.5: Recovery Model – Modelled Groundwater Contours – 2057

Figure 8.25.1: Recovery Model – Modelled Groundwater Contours – 2137

Figure 8.25.2: Recovery Model – Modelled Groundwater Contours – 2137

Figure 8.25.3: Recovery Model – Modelled Groundwater Contours – 2137

Figure 8.25.4: Recovery Model – Modelled Groundwater Contours – 2137

Figure 8.25.5: Recovery Model – Modelled Groundwater Contours – 2137

Figure 8.26.1: Recovery Model – Modelled Decline in Uppermost Water Table – Cumulative Impact

Figure 8.26.2: Recovery Model – Modelled Decline in Uppermost Water Table – Cumulative Impact

Figure 8.26.3: Recovery Model – Modelled Drawdown in Hebden Seam

Figure 8.26.4: Recovery Model – Modelled Drawdown in Hebden Seam

Figure 8.27.1: Recovery Model – Pressure Head Distribution (COL 88)

Figure 8.27.2: Recovery Model – Pressure Head Distribution (COL 88)

Figure 8.28.1: Recovery Model – Pressure Head Distribution (ROW119)

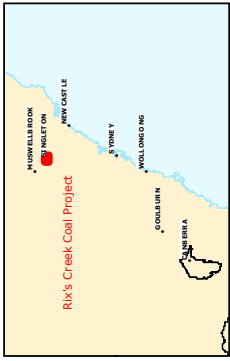
Figure 8.28.2: Recovery Model – Pressure Head Distribution (ROW119)

Figure 8.29: Recovery Model – Hydrostratigraphic Zones

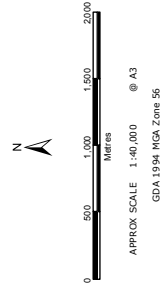
Figure 8.30: Water Balance of the Final Void

Figure 8.31: Salt Balance of the Final Void

Figure 9.1: Predicted Mine Inflows



- LEGEND**
- Mine lease
 - Lease Extension Area
 - Main Highway
 - Railway
 - Watercourse
 - Non-perennial
 - Perennial



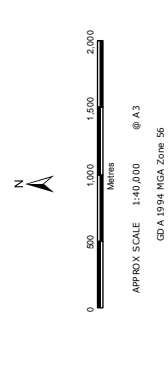
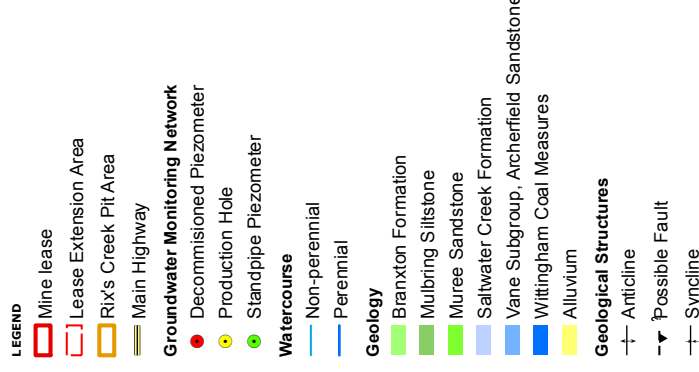
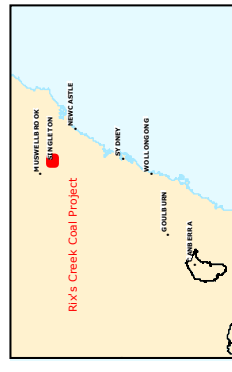
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FIGURE 1.1

**Rix's Creek
Project Location**



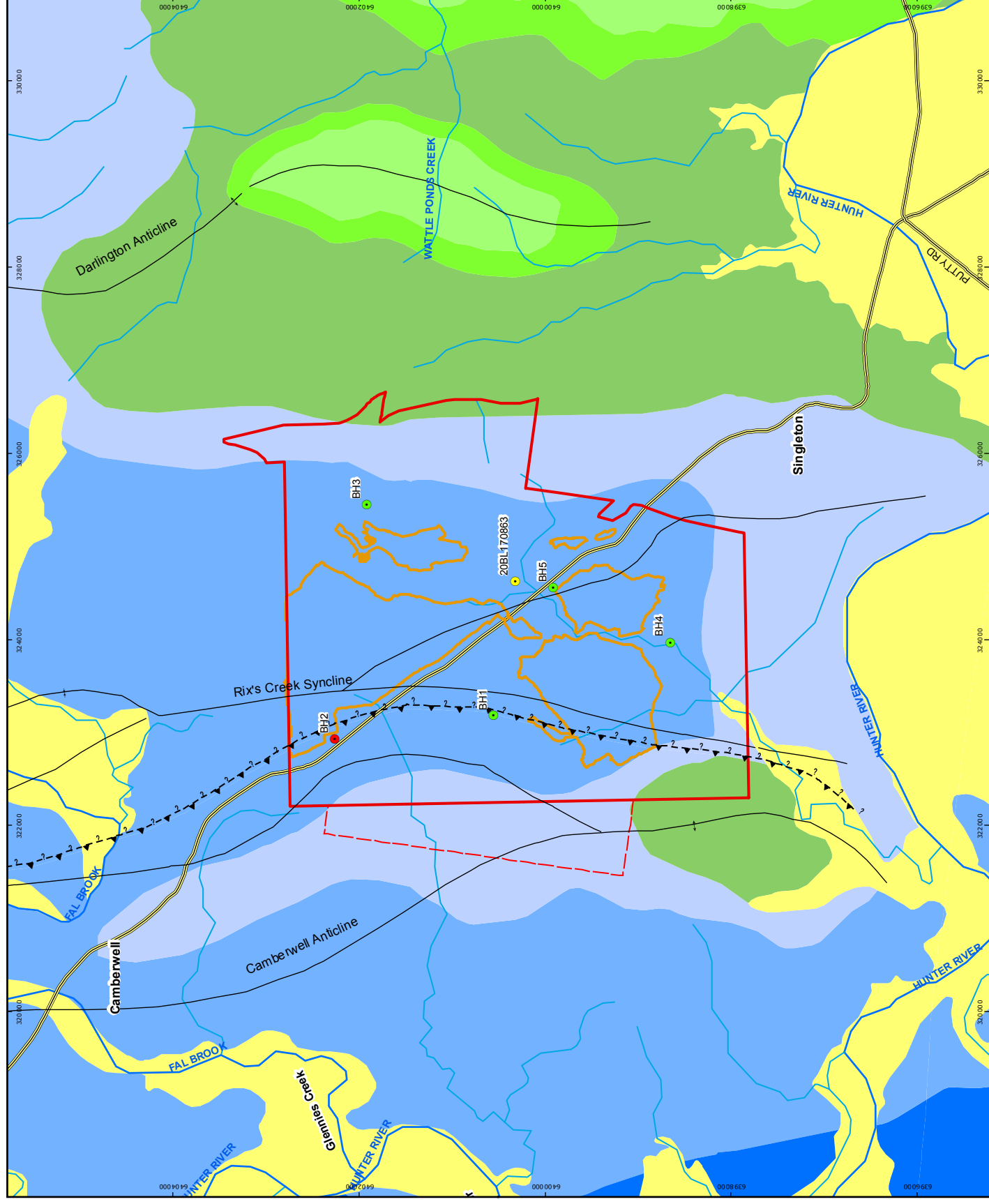


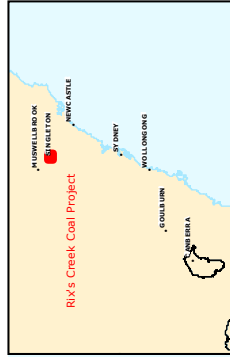
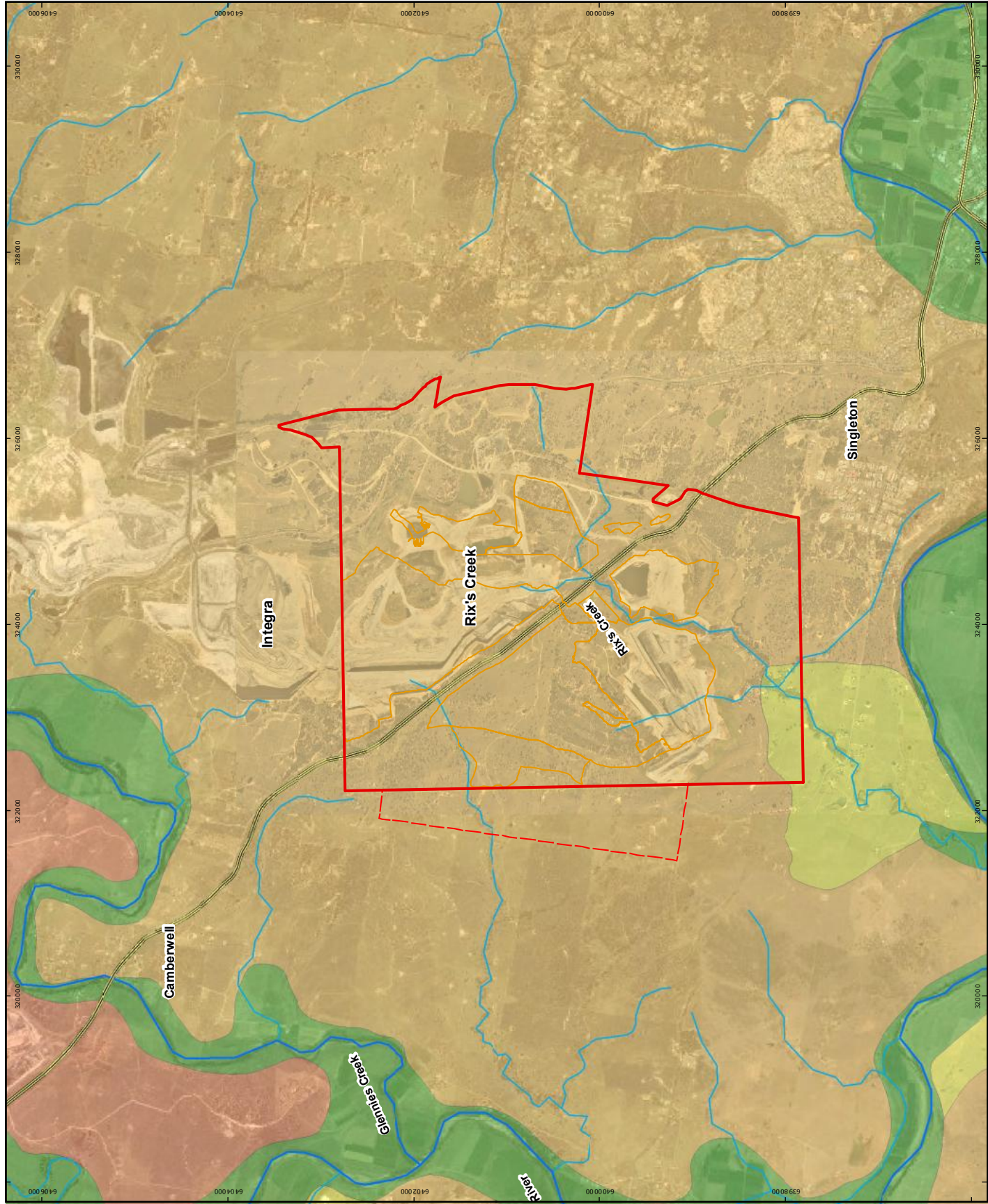
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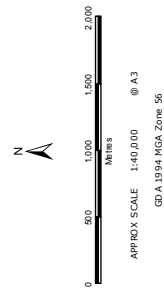
FIGURE 2.1

**Rix's Creek
Geology**





- LEGEND**
- Mine lease
 - Lease Extension Area
 - Rix's Creek Pit Area
 - Main Highway
 - Watercourse**
 - Non-perennial
 - Perennial
 - Strategic Land Use - Land/Soil Capability Classes**
 - High Capability Land
 - Moderate Capability Land
 - Moderate - Low Capability Land
 - Low Capability Land

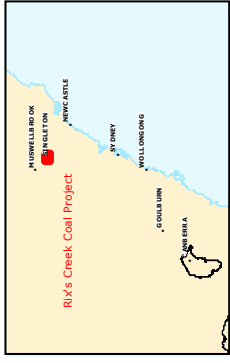


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FIGURE 3.1

**Rix's Creek
Upper Hunter Strategic Land Use**



LEGEND

Mine lease

Lease Extension Area

Rix's Creek Pit Area

Main Highway

Watercourse

Non-perennial

Perennial

Water Sharing Plan

Draft North Coast Fractured and

Porous Rock Groundwater

Sources

Hunter Unregulated and Alluvial

Water Sources 2009



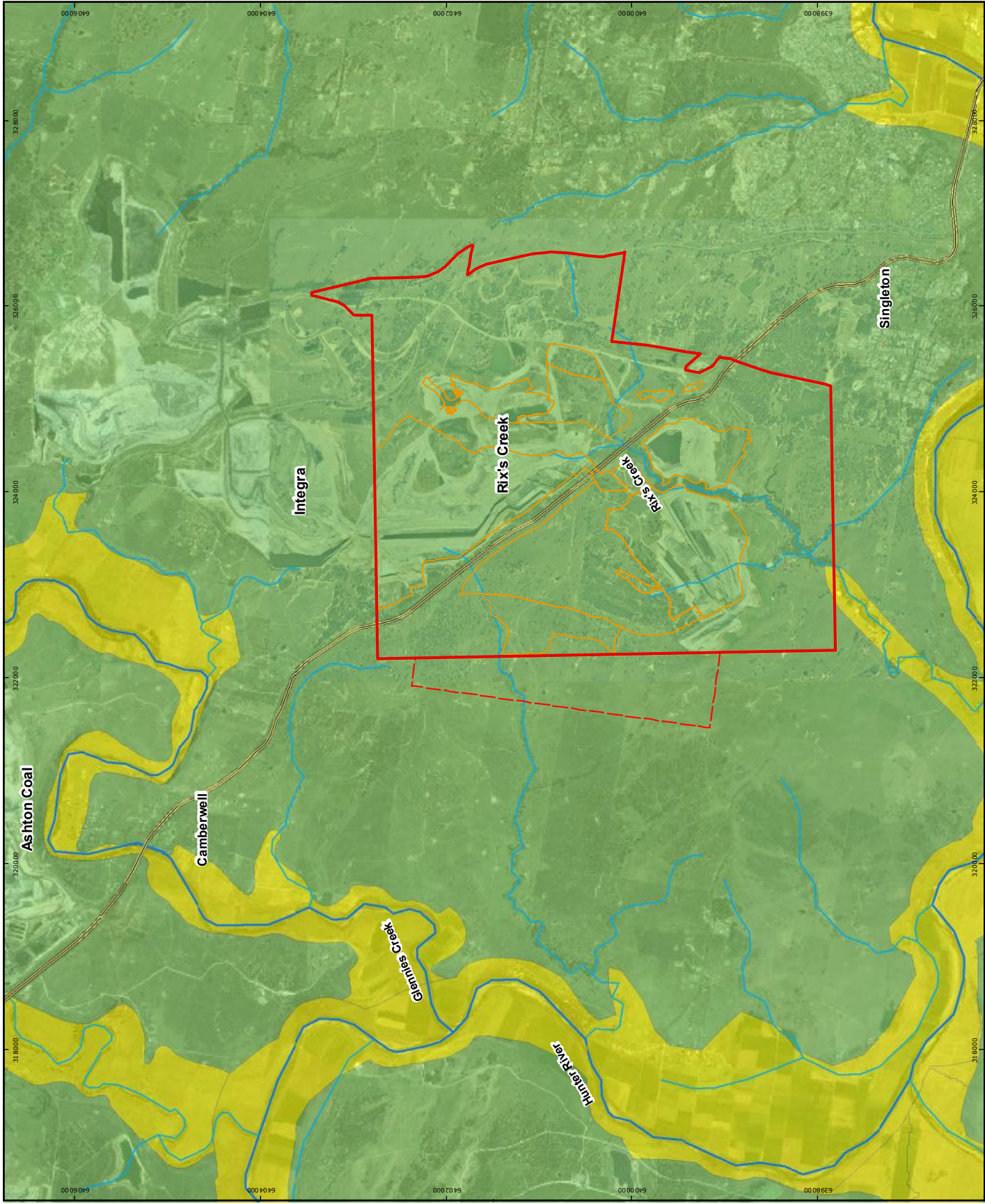
APPROX. SCALE 1:40,000 @ A3
GDA 1994 MGA Zone 56

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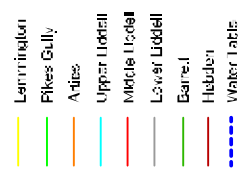


FIGURE 3.2

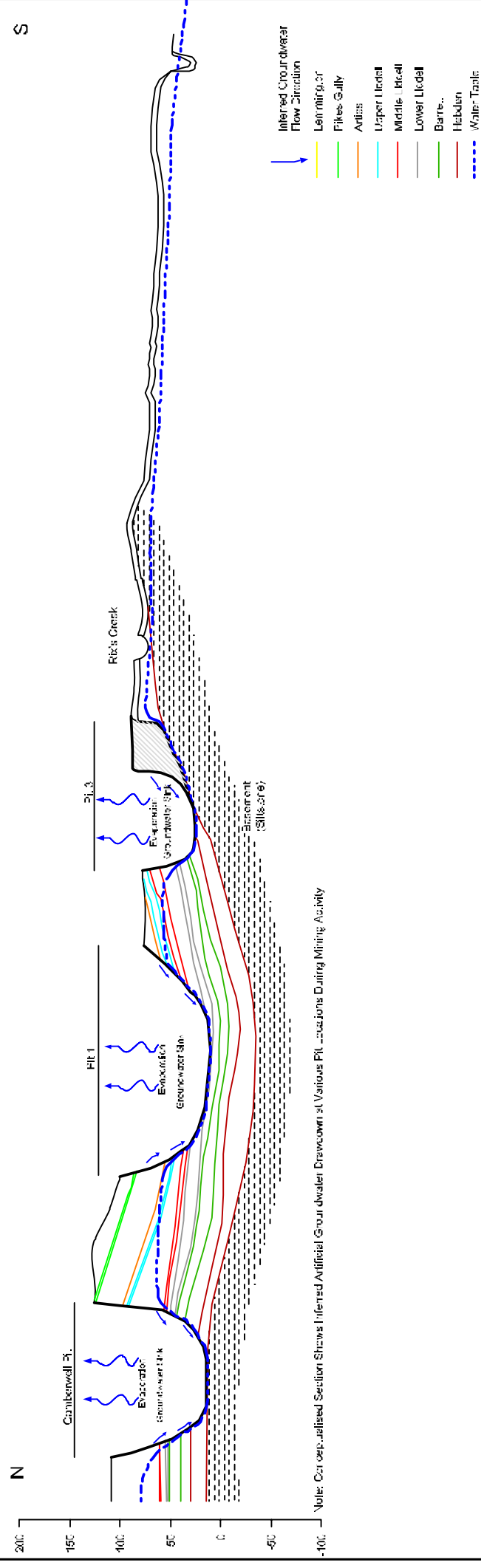
Rix's Creek Water Sharing Plans



An aerial photograph of a river valley. A red boundary line outlines a specific area. A yellow line runs vertically through the center, and another yellow line runs horizontally across the middle. A yellow arrow points to a small feature on the horizontal line. A yellow label 'B' is placed near the horizontal line on the left. A yellow label 'C' is placed near the top right corner of the red boundary. The terrain is a mix of brown, grey, and green, with blue lines representing water bodies.



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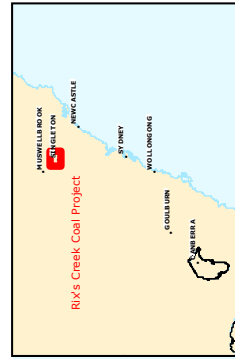
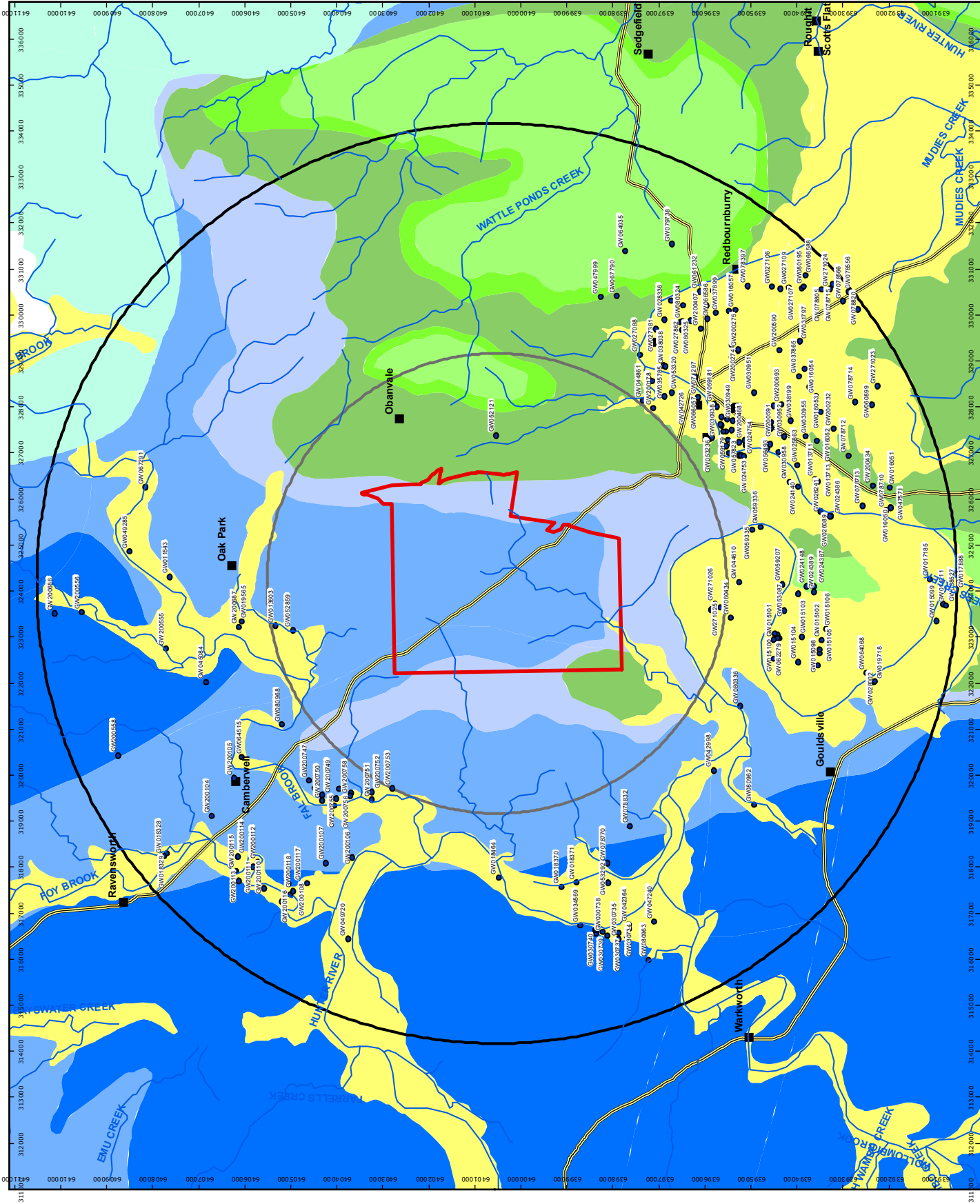
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			DHANA	JOB PAU
			EZ	506E
			BREAST CHICKS	SCALED
				AIR SHAW
REV.	EXPONENT	DATE		



Conceptualised Sections During Mining Activity

SIZE A3	SCALE As Shown	APP. NO. 6060	DRAWING NO. E-11-42	REV. A
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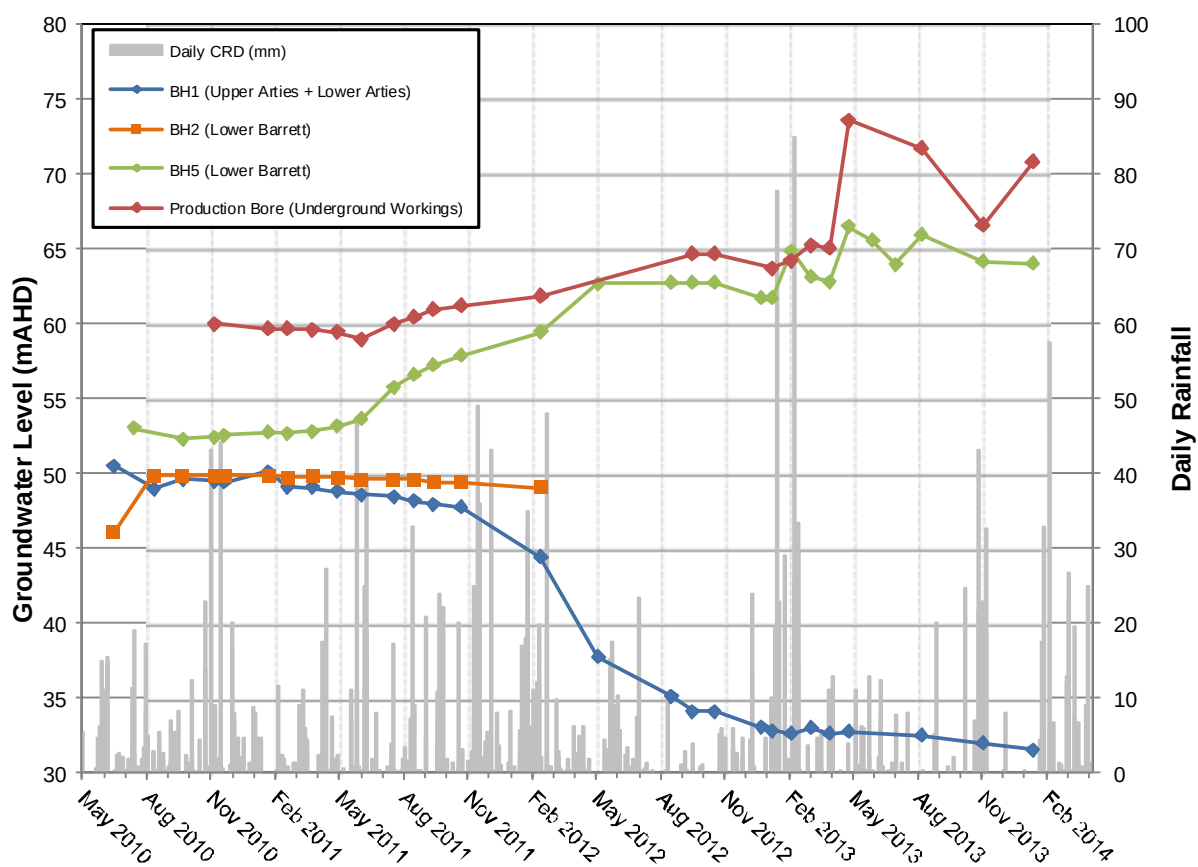
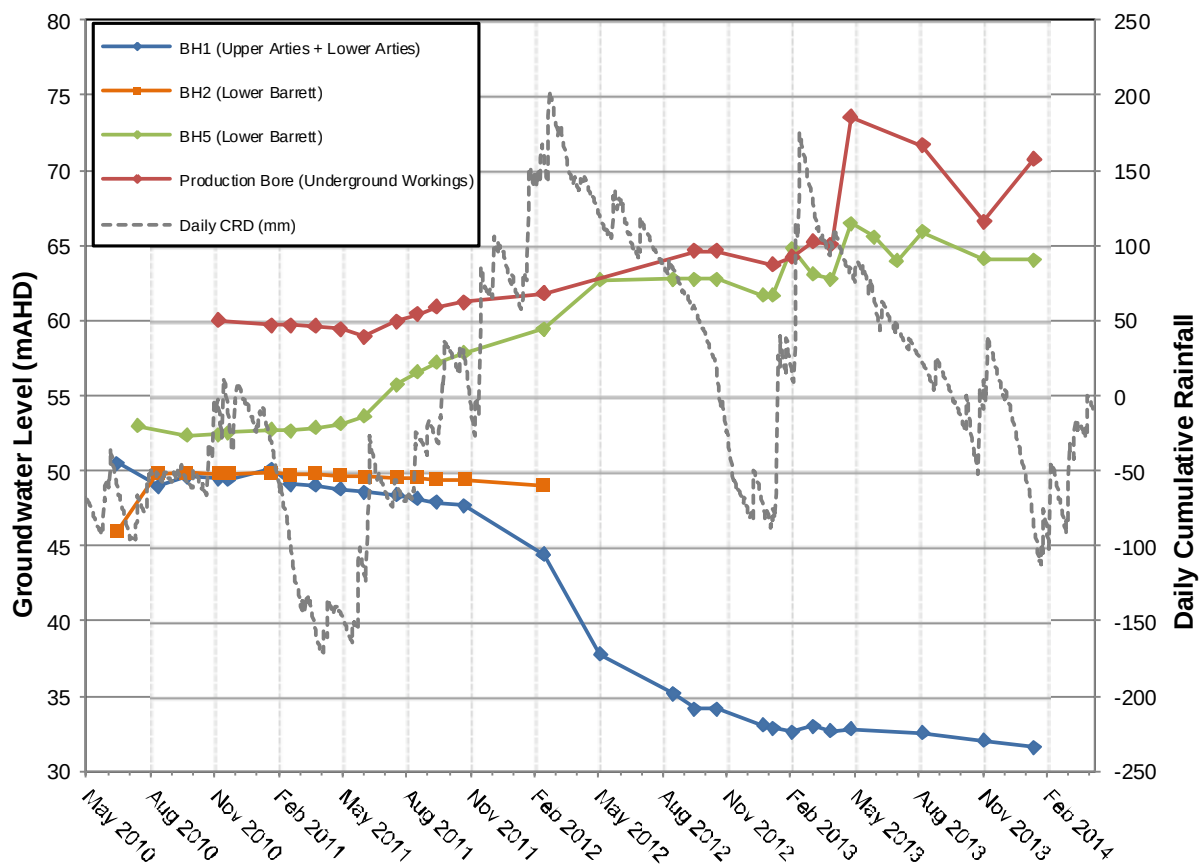
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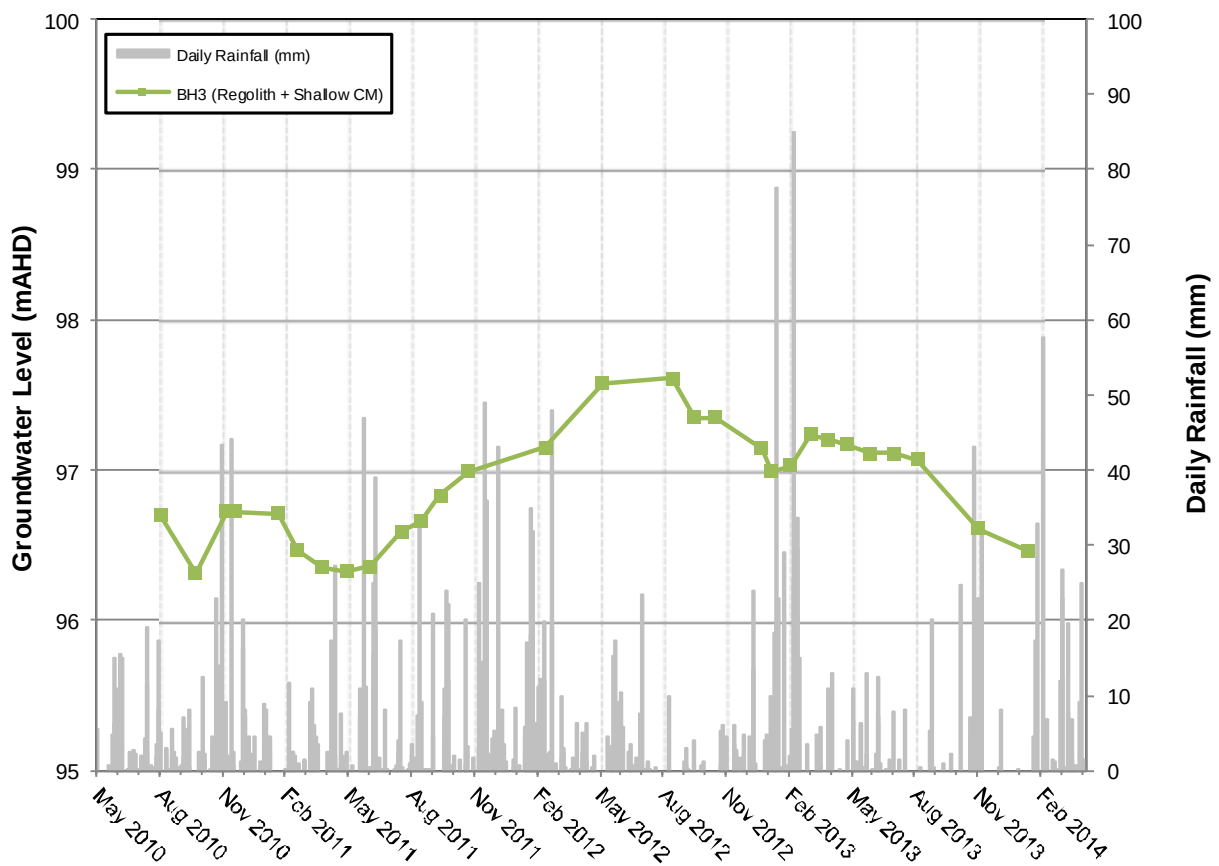
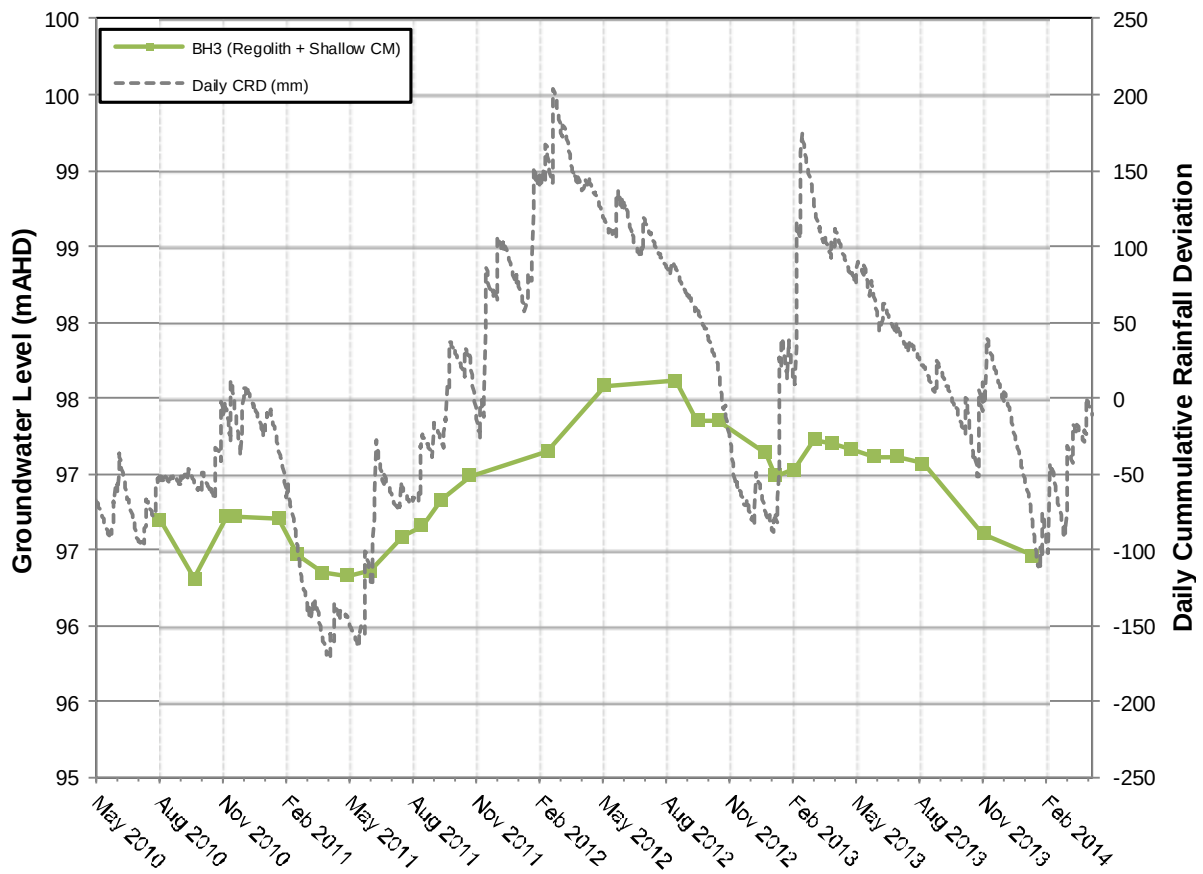
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FIGURE 4.4

Rix's Creek

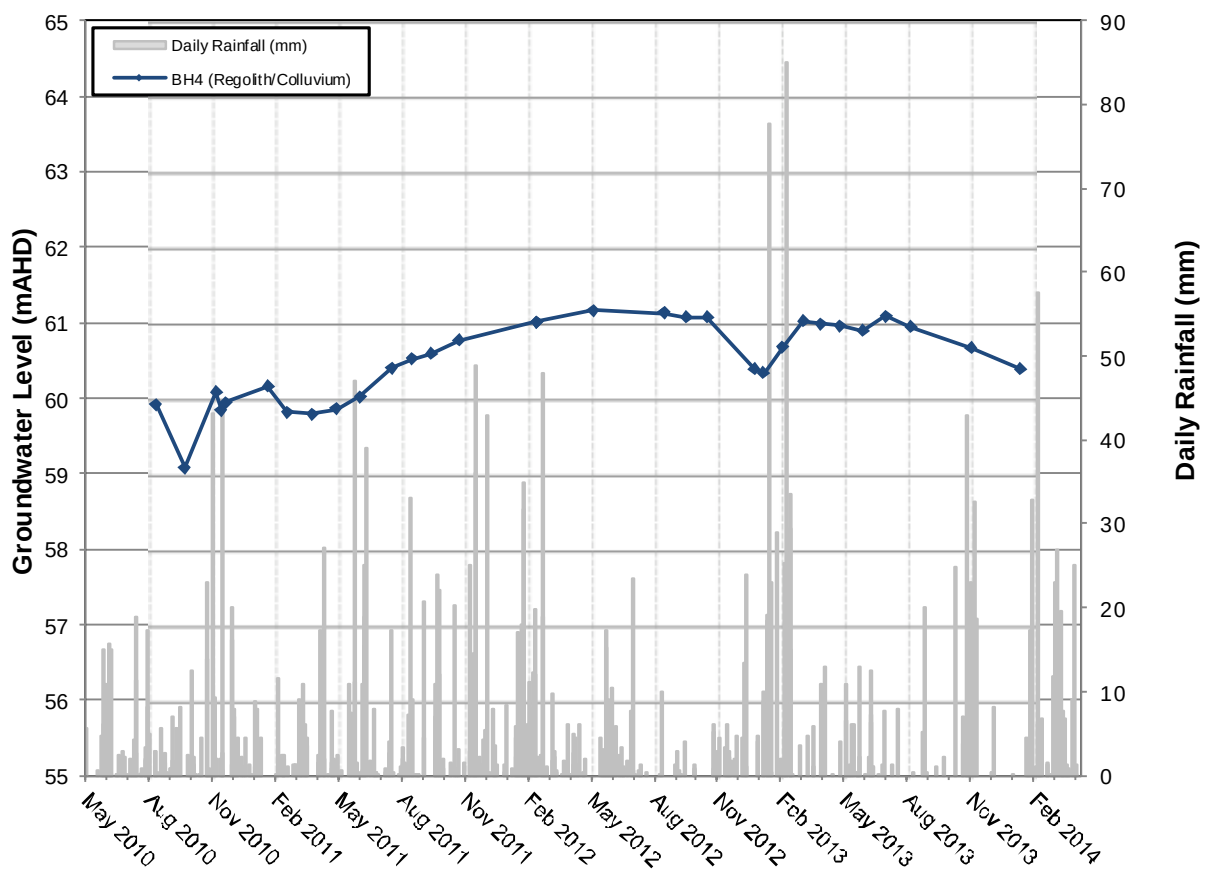
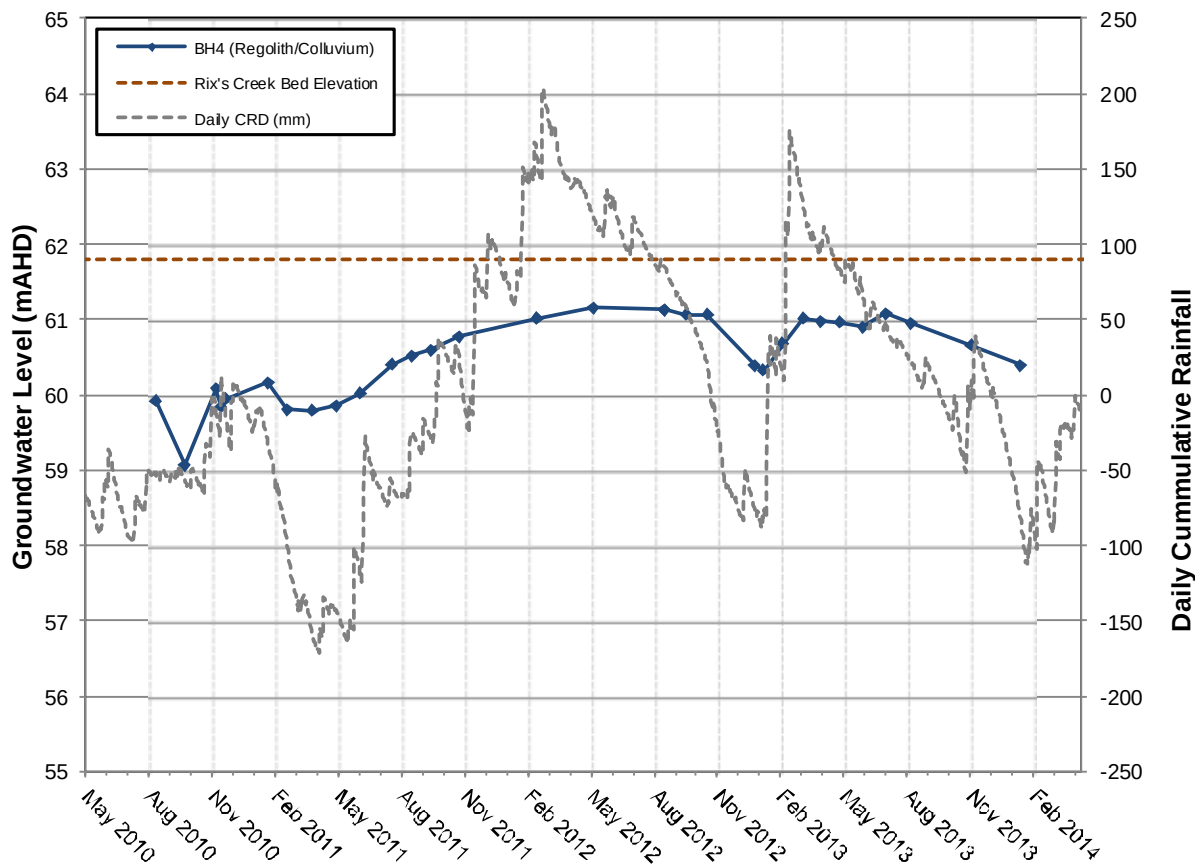
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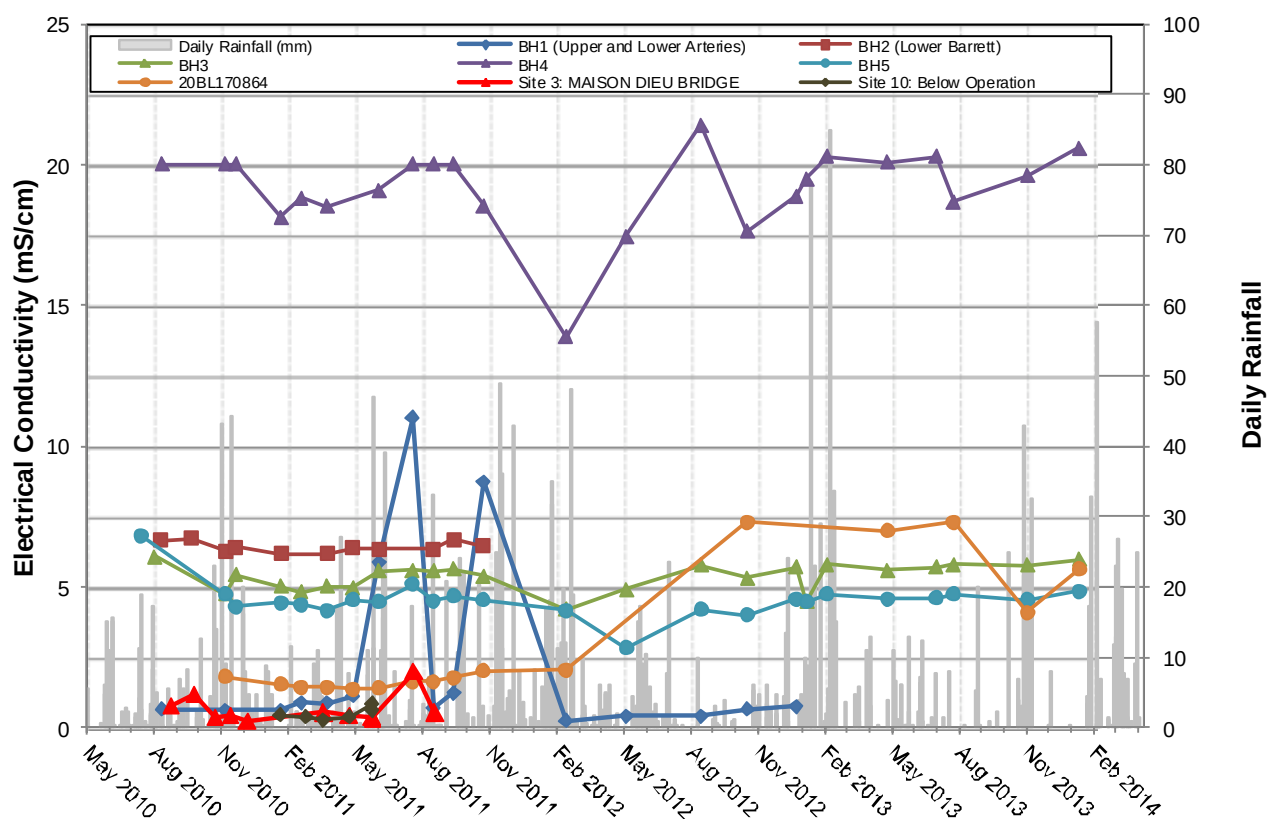
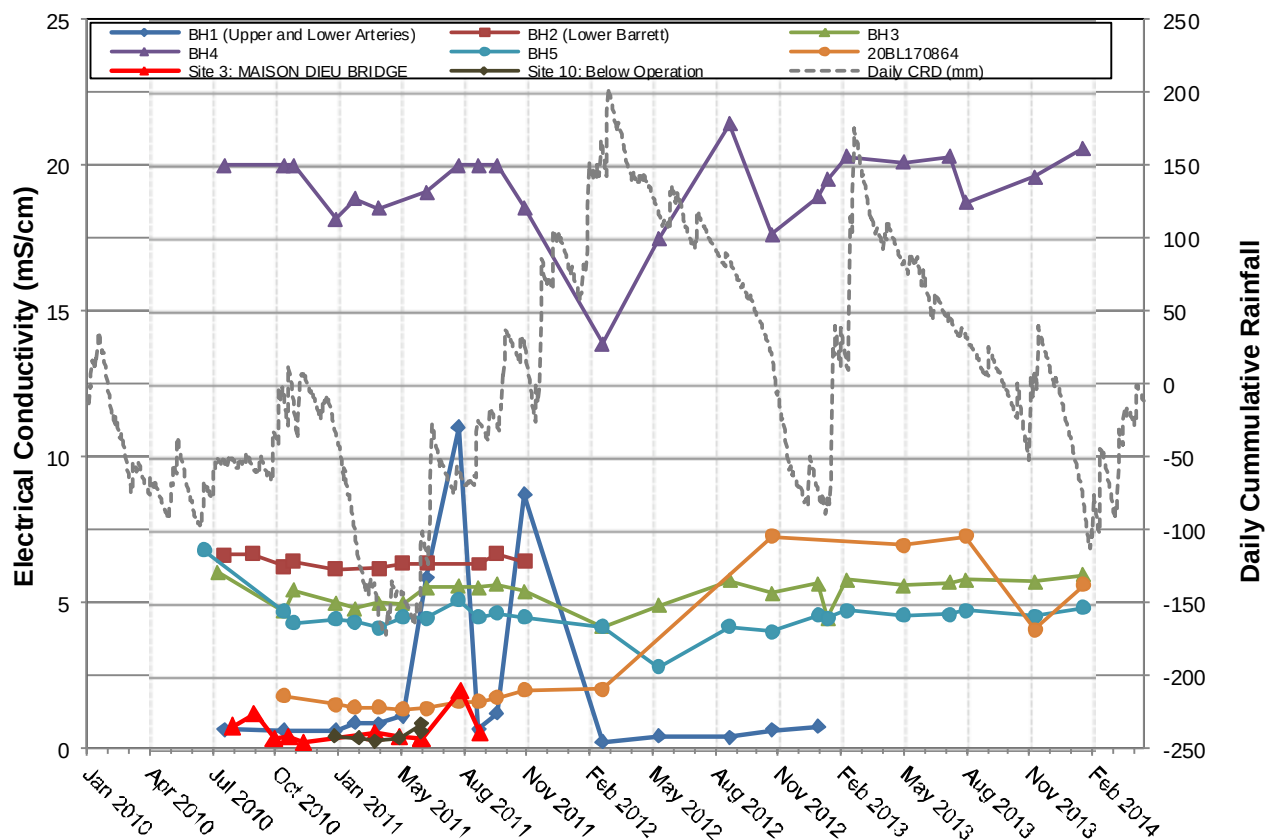


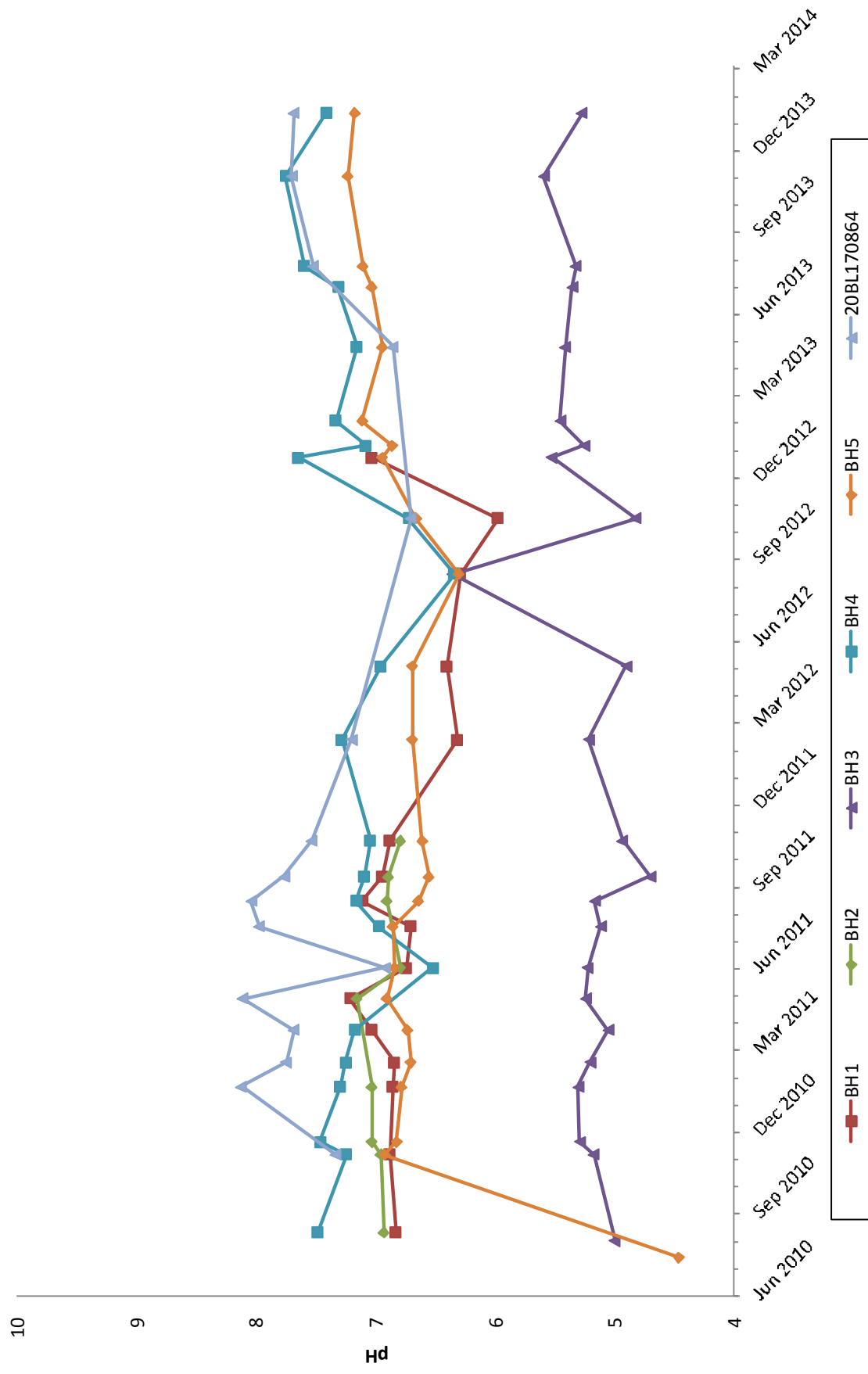


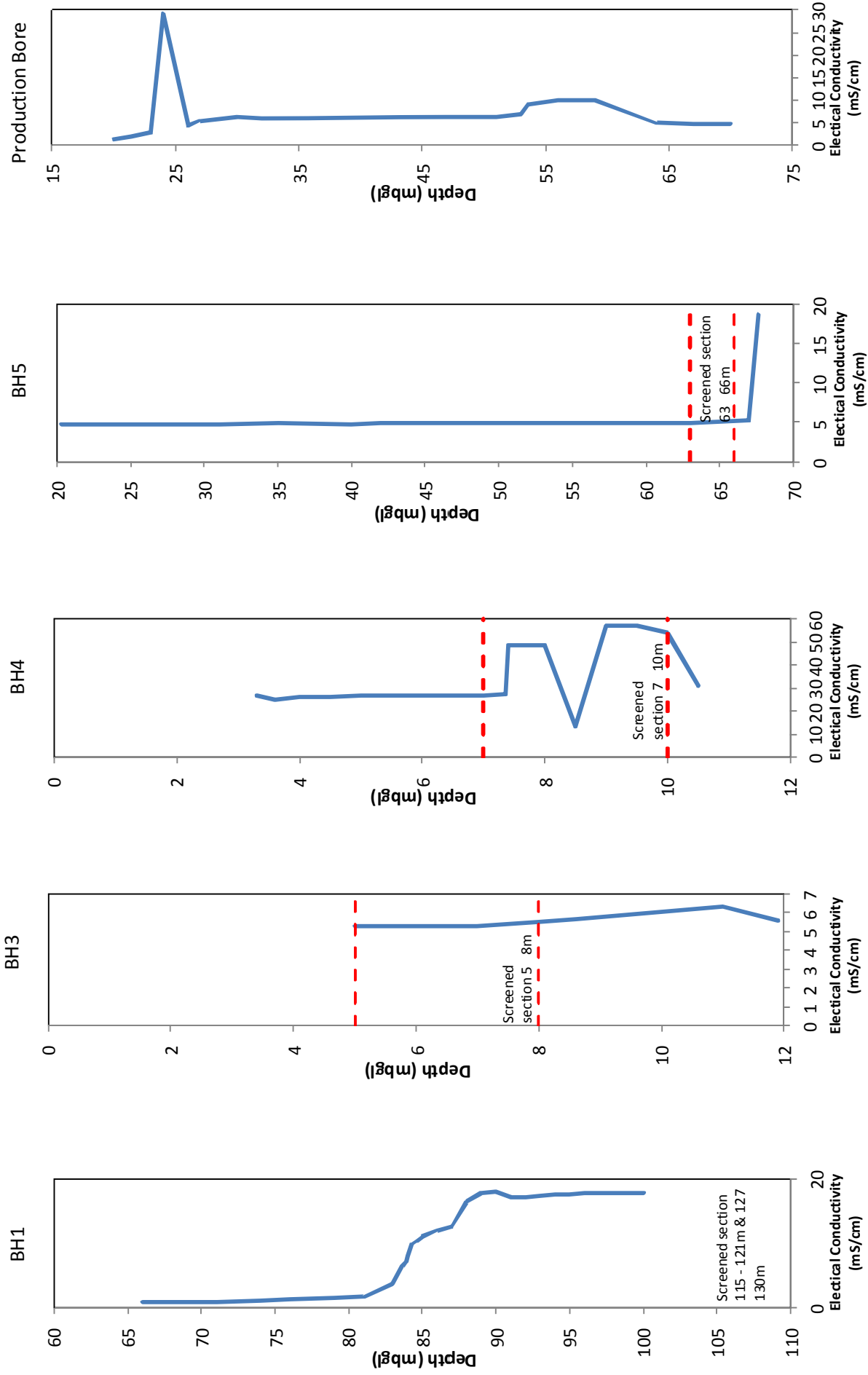
Hydrograph: Regolith - Figure 5.2

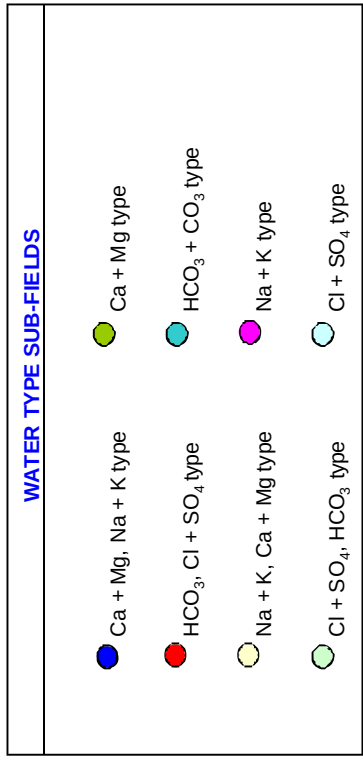
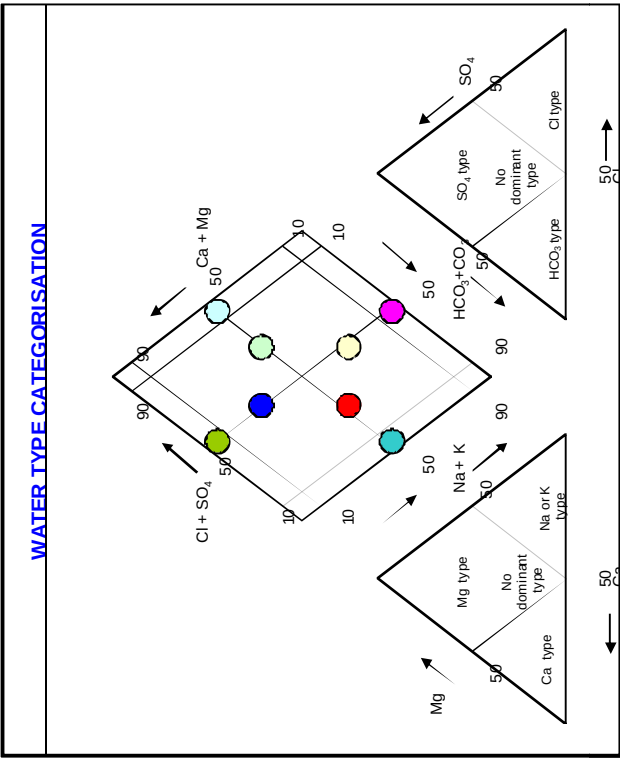
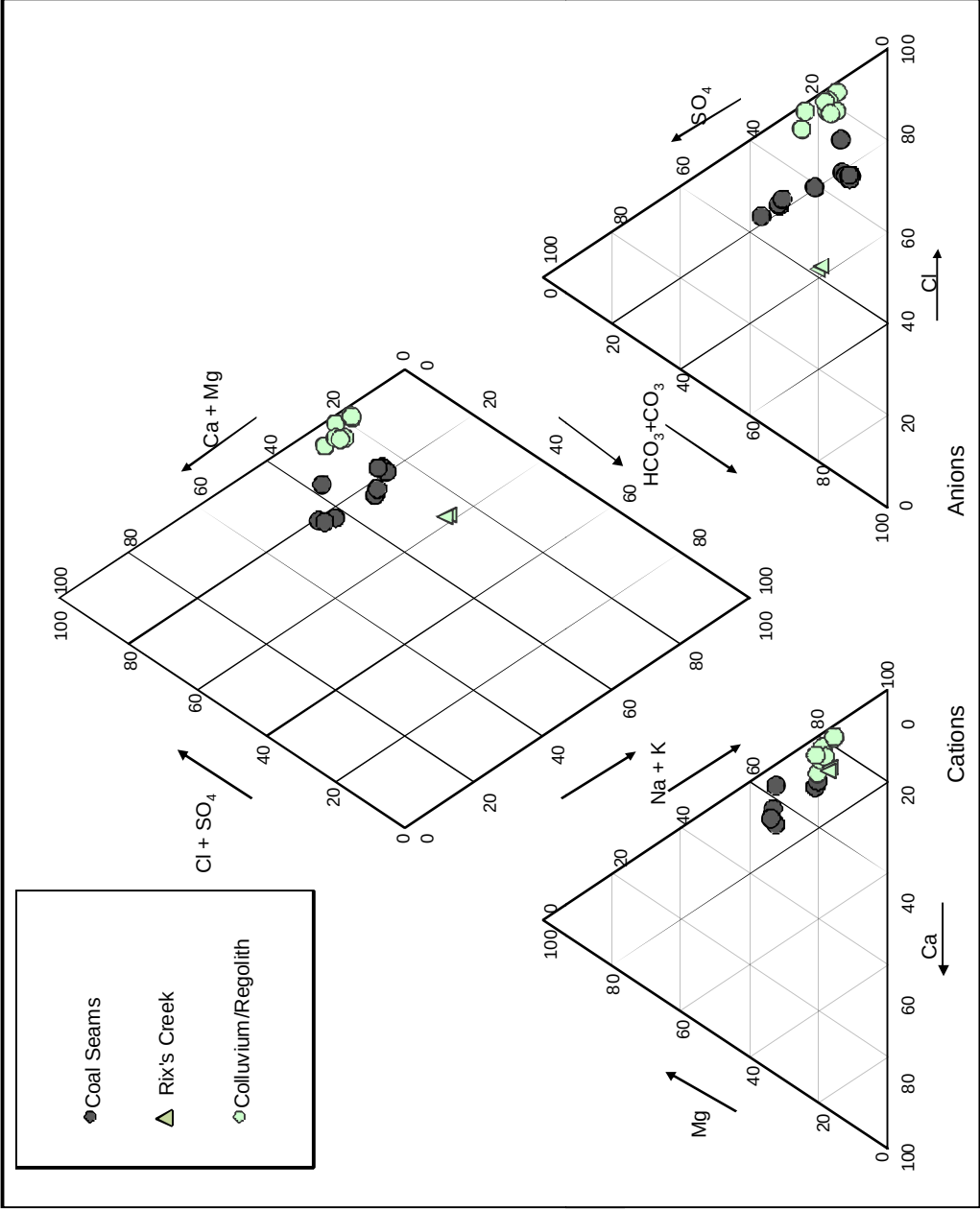
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Date: 23/07/14

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Project: Rix's Creek
Project No: S66D

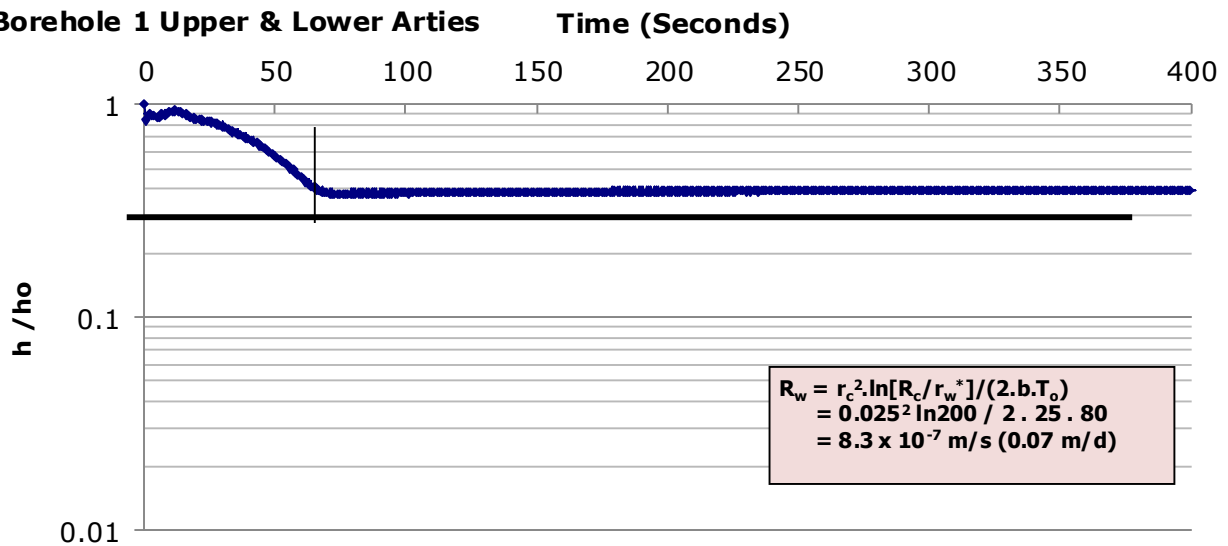
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Client: The Bloomfield Group

Piper Diagram

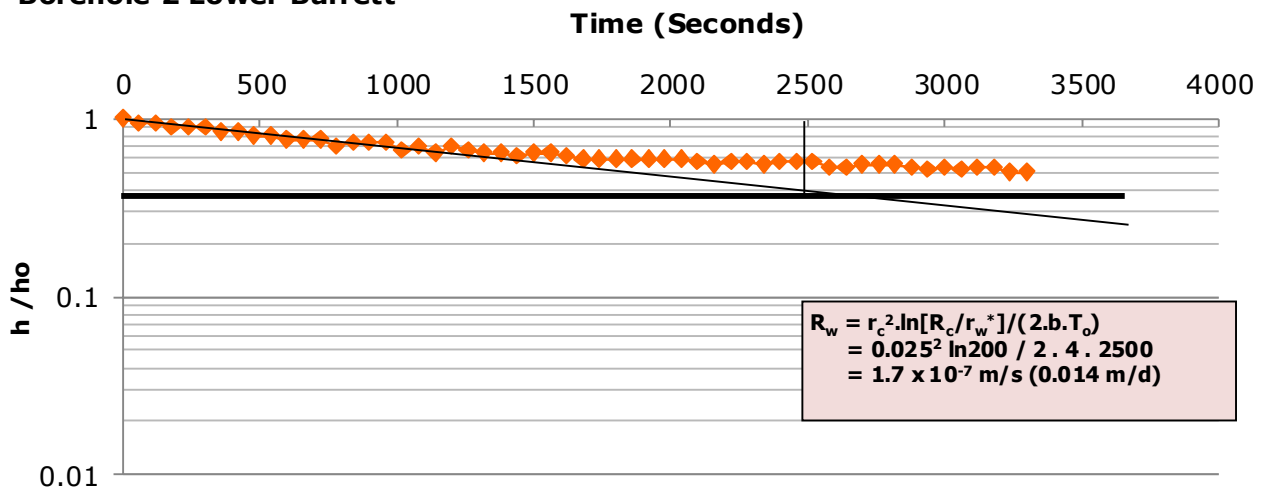
Figure 5.7

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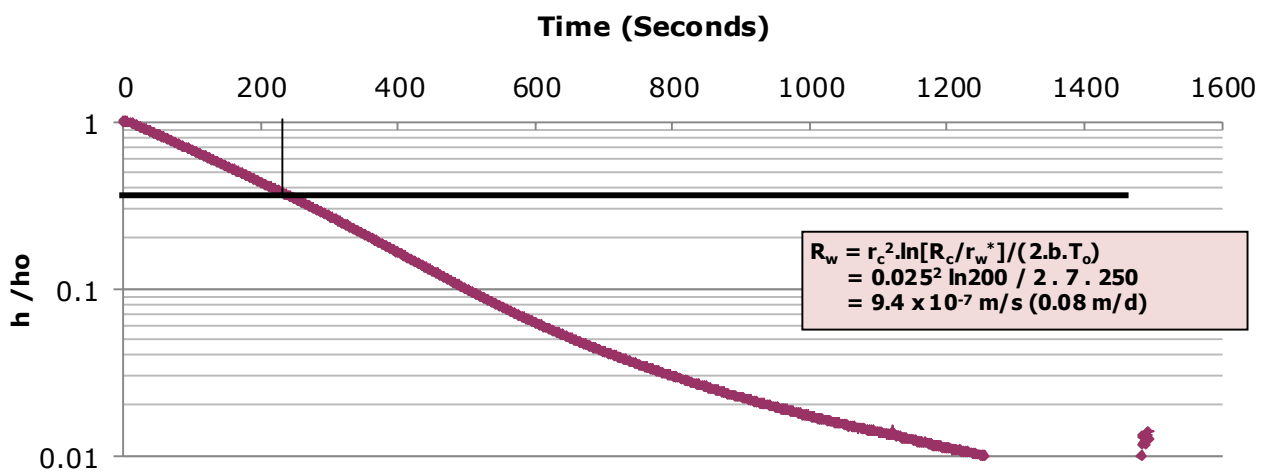
Borehole 1 Upper & Lower Artes

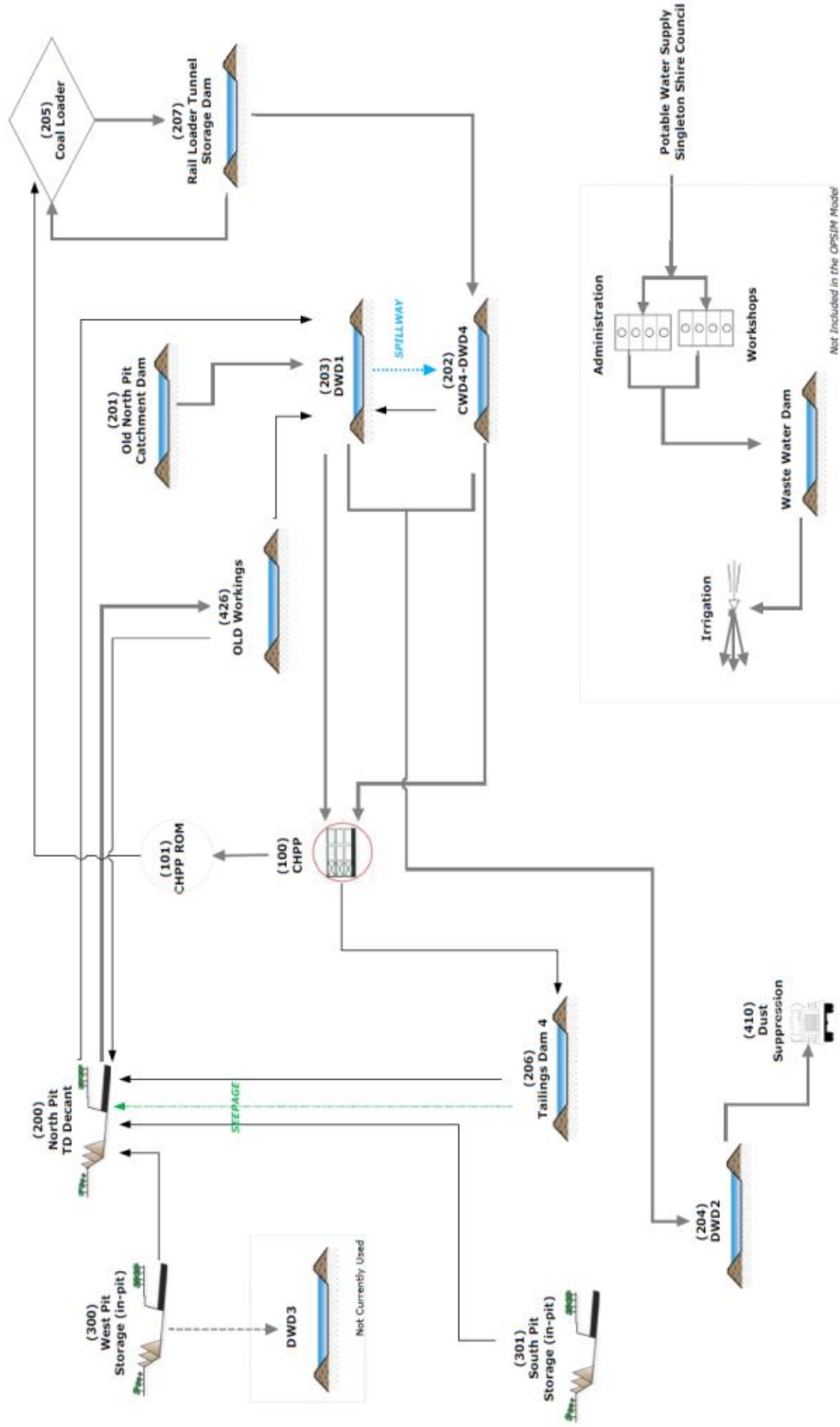


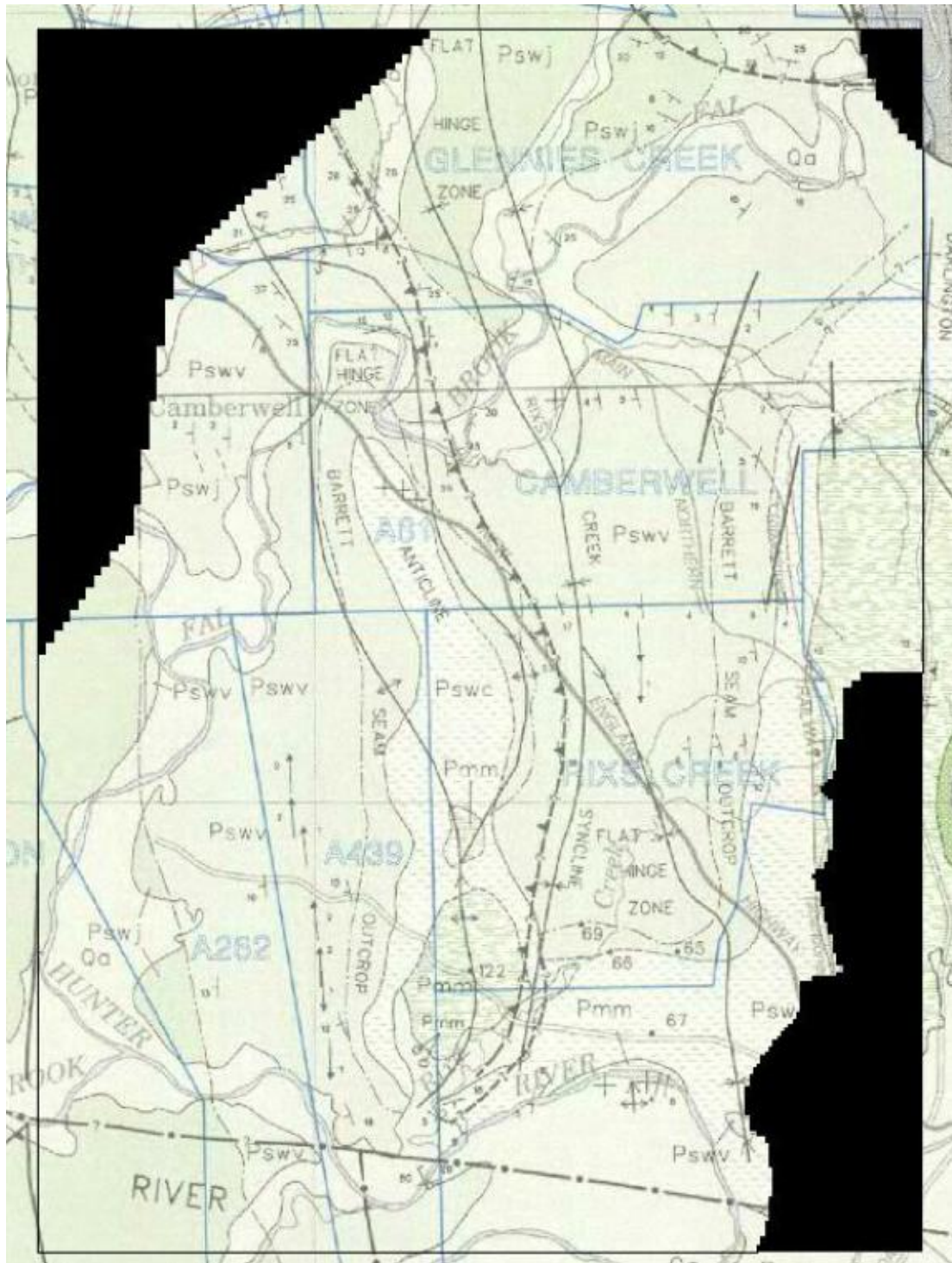
Borehole 2 Lower Barrett



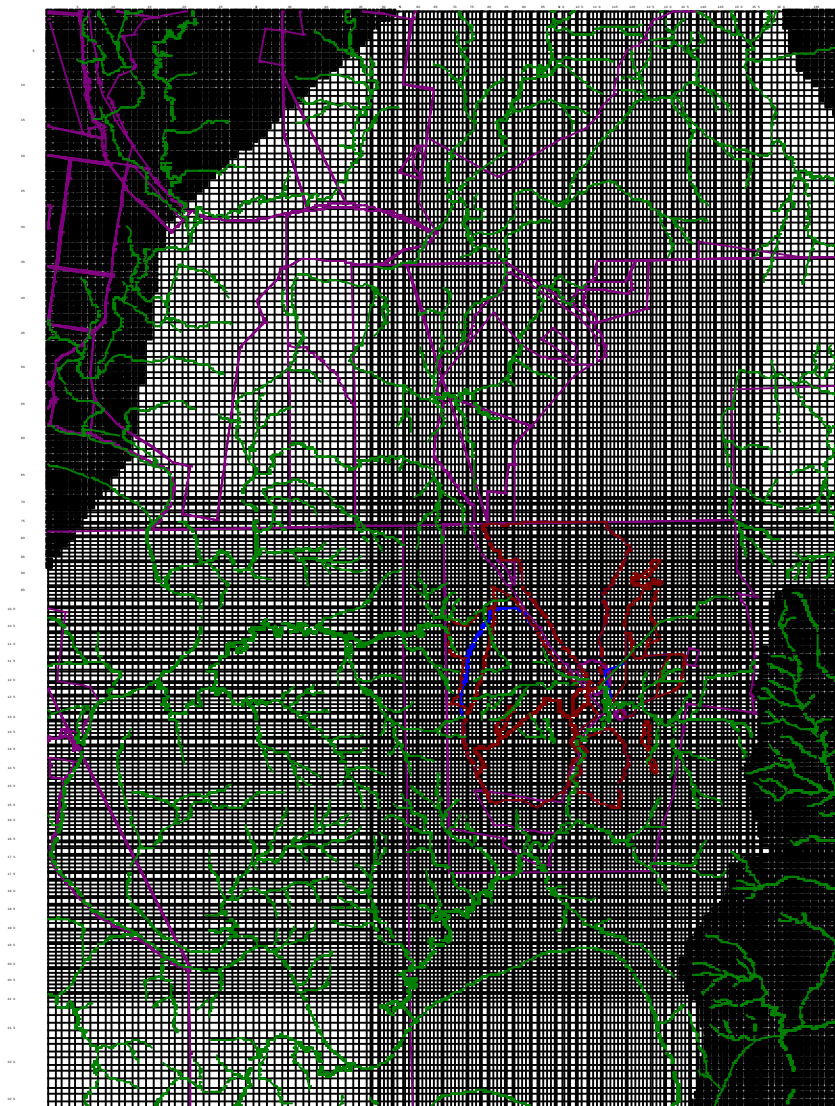
Borehole 5 Lower Barrett



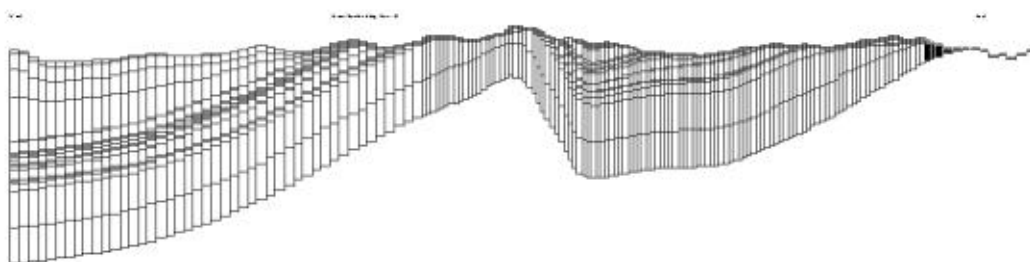




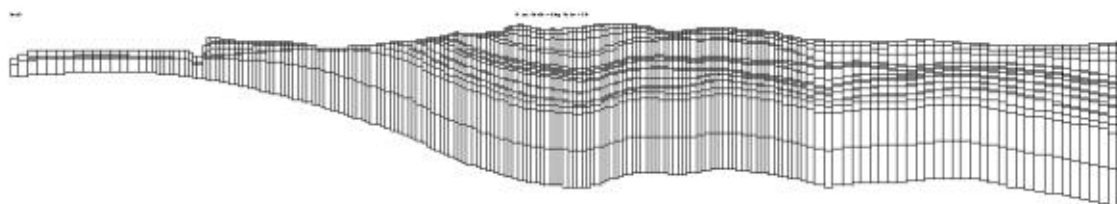
015A_CAL-APR14_07A.GWV



PLAN VIEW

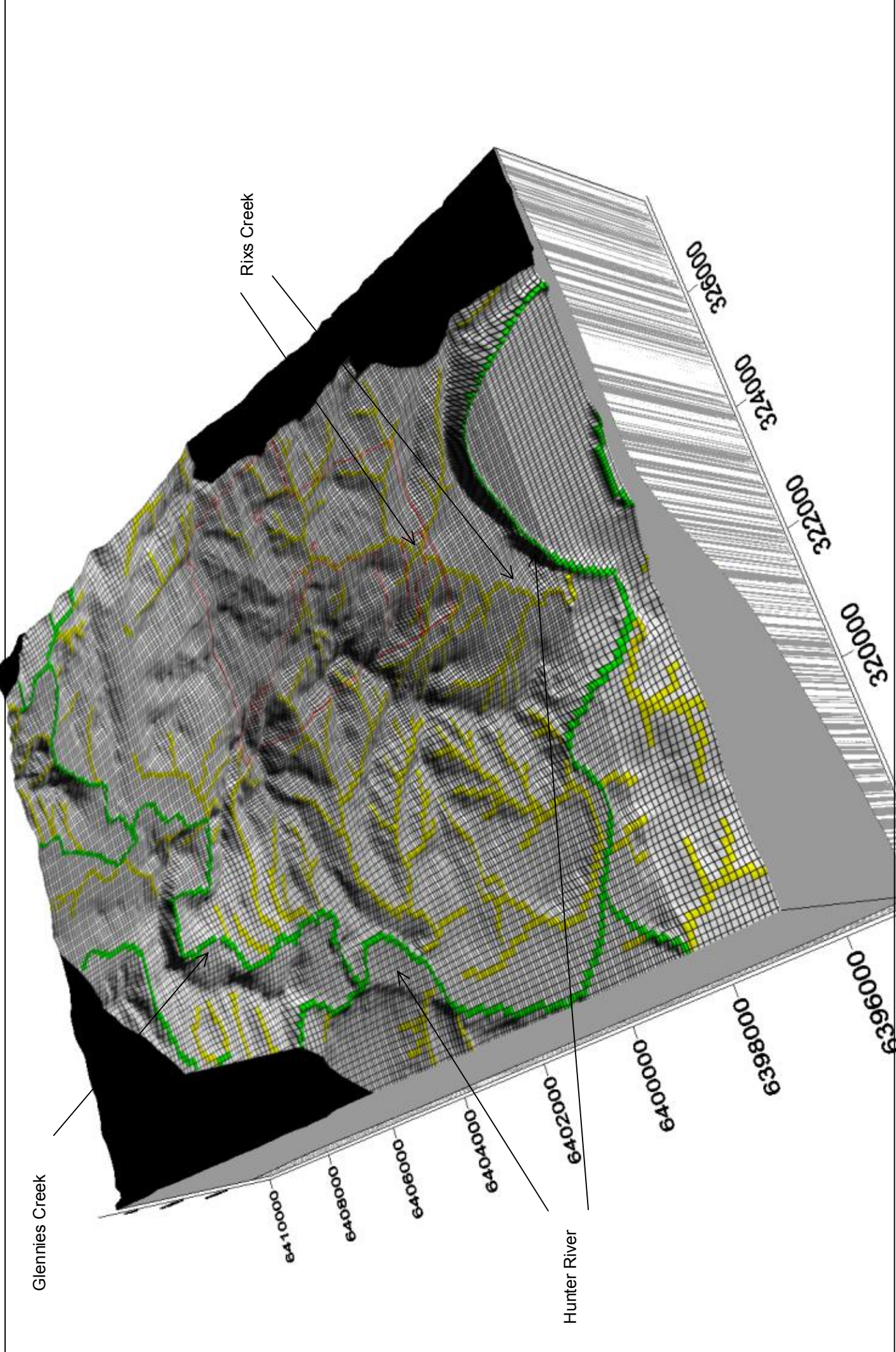


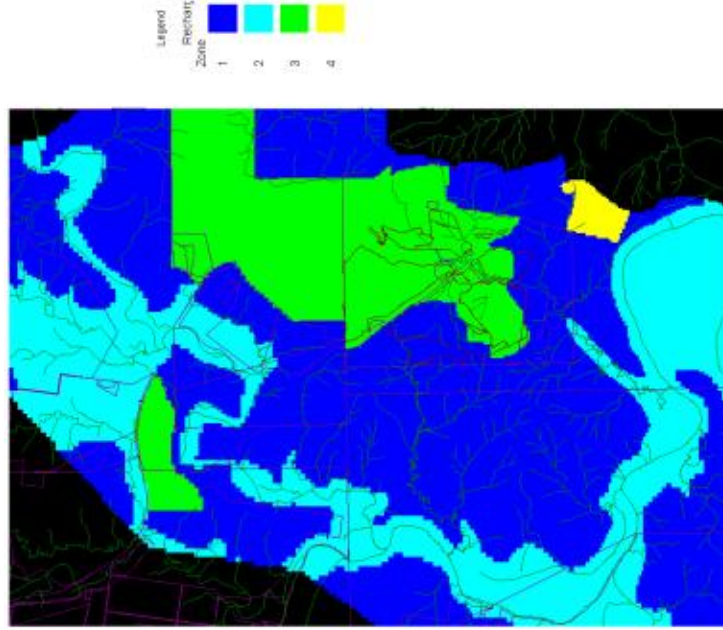
ROW 142 – VERTICAL EXAGGERATION 1:4



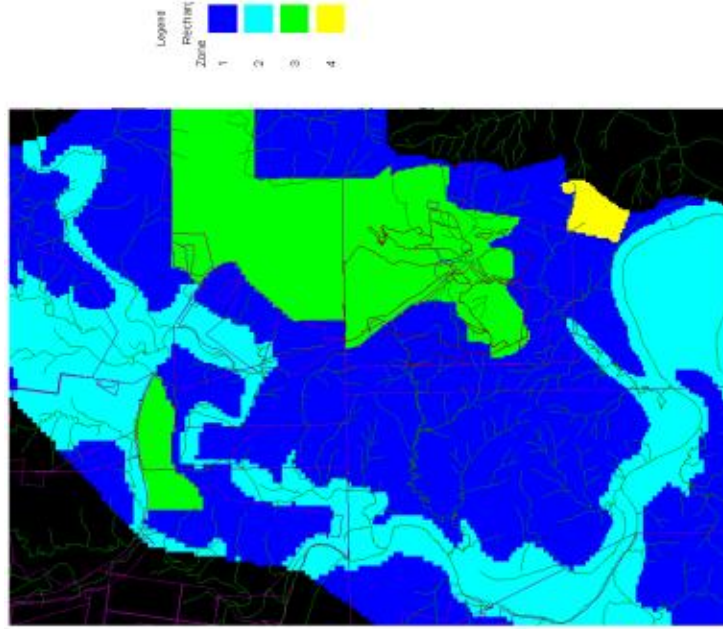
COLUMN 89 – VERTICAL EXAGGERATION 1:4

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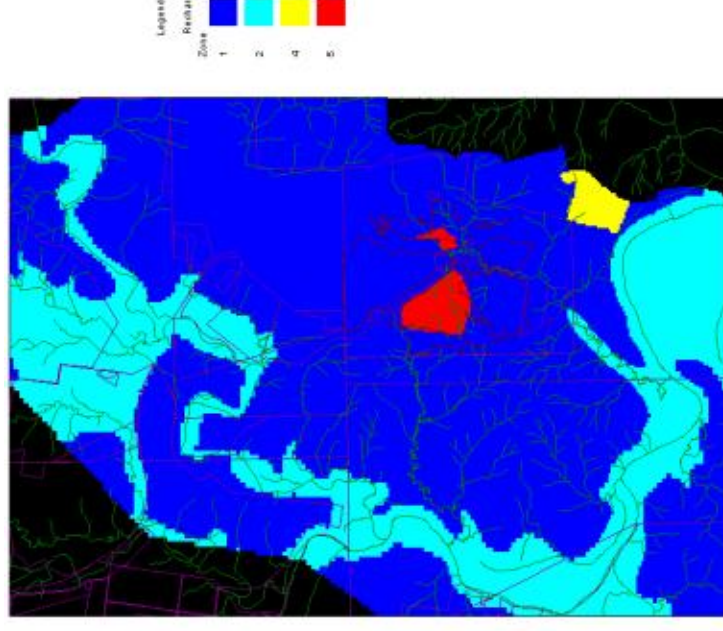




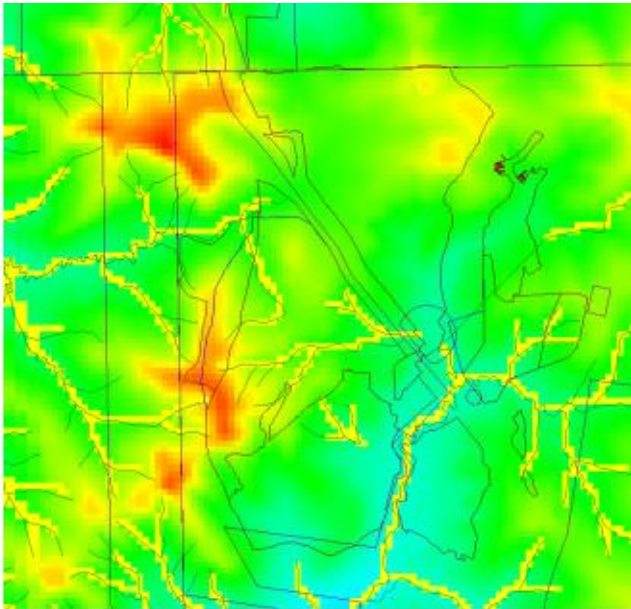
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CALIBRATION MODEL



015A_PRD-MP1_04A.GWV
PREDICTION MODEL

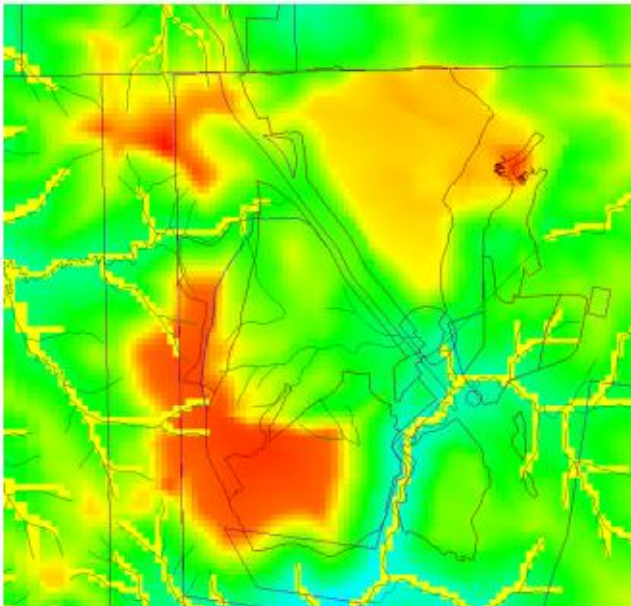


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RECOVERY MODEL



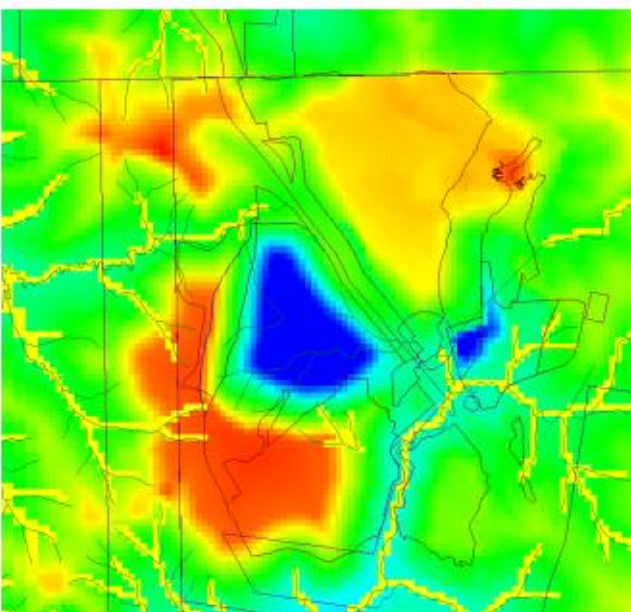
Top Elevation L01 – Calibration and Prediction

015a_CAL-Apr14_07a.gww; 015a_PRD-MP1_04a.gww



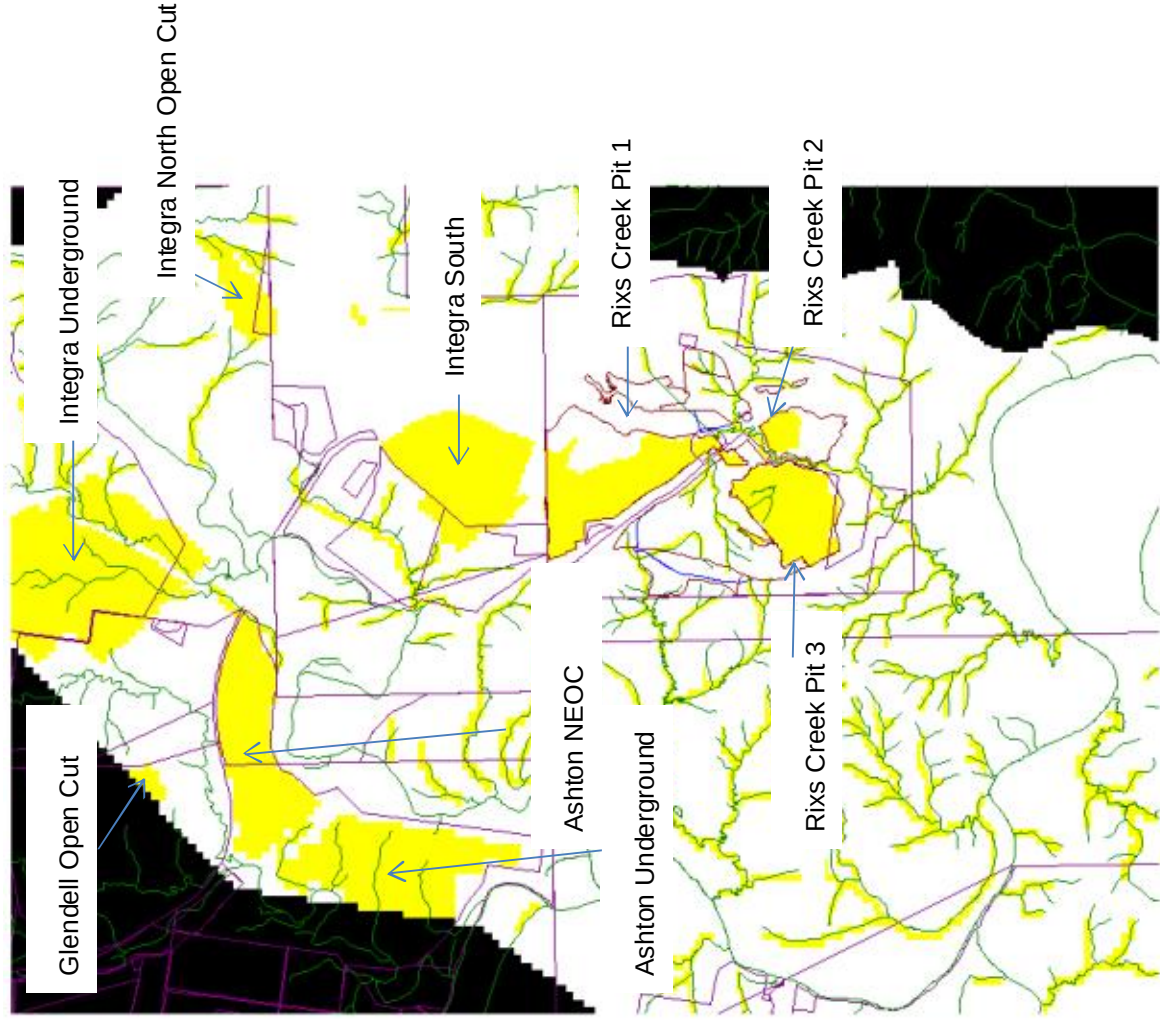
Top Elevation L01 – Recovery Model

015a_RCV-MP1_05a.gww



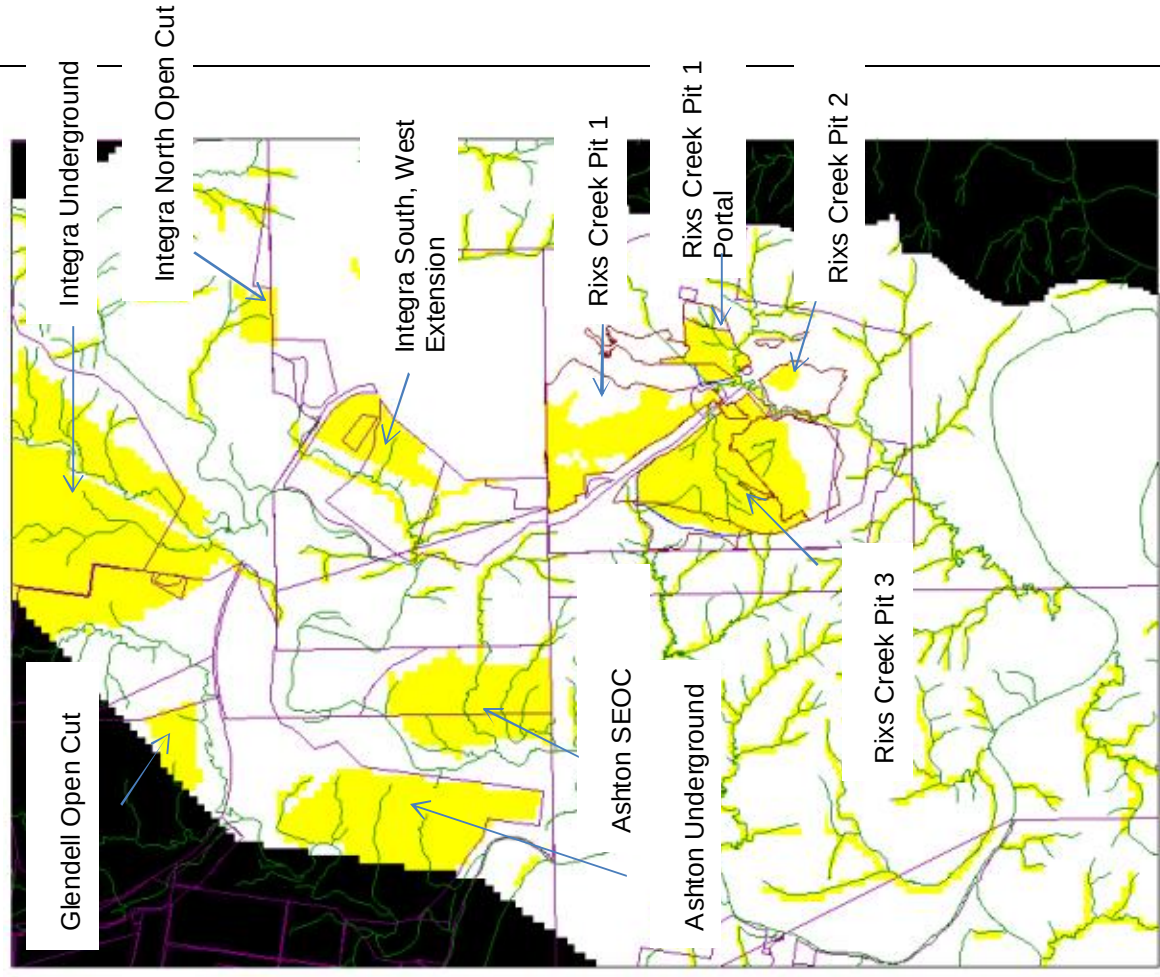
Evaporation Surface – Recovery Model

015a_RCV-MP1_05a.gww



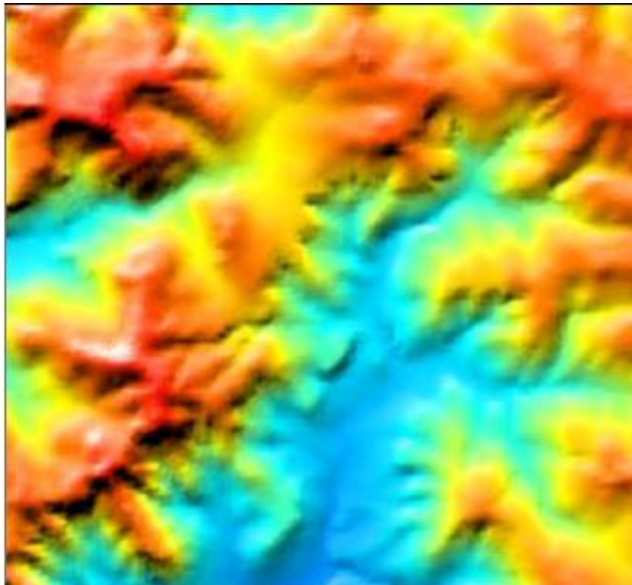
015a_CAL-Apr14_07a.gww

CALIBRATION MODEL

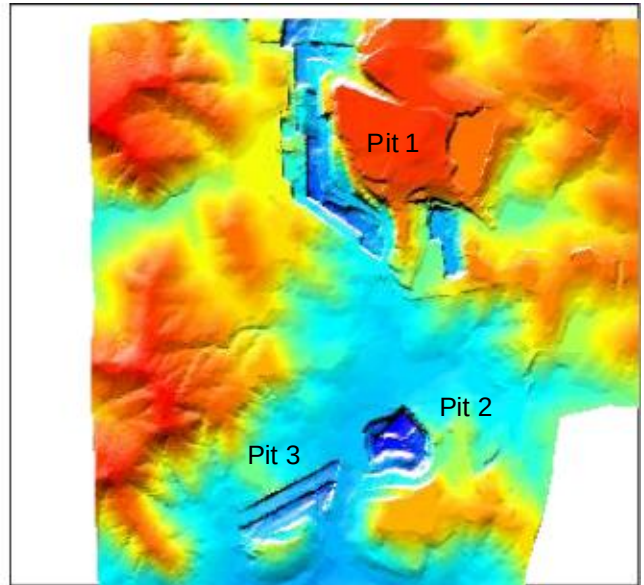


015a_PRD-MP1_04a.gww

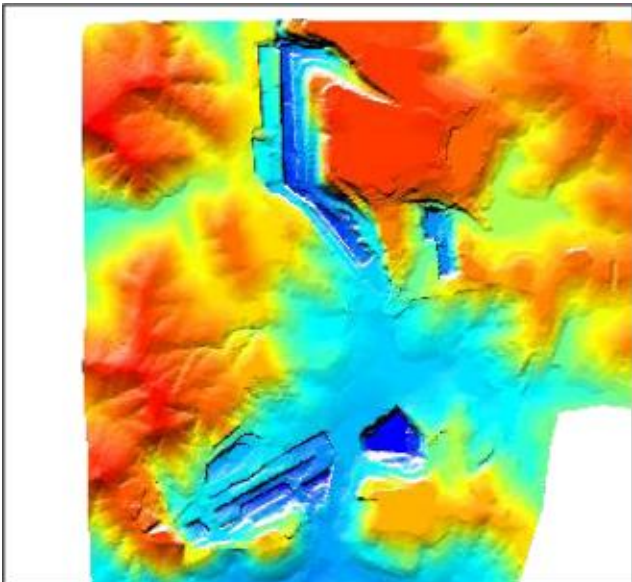
PREDICTION MODEL



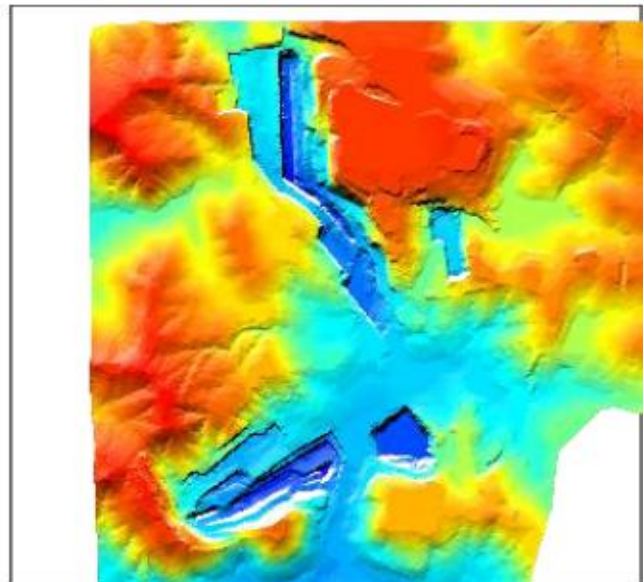
Original Surface (from NSW Lands DEM)



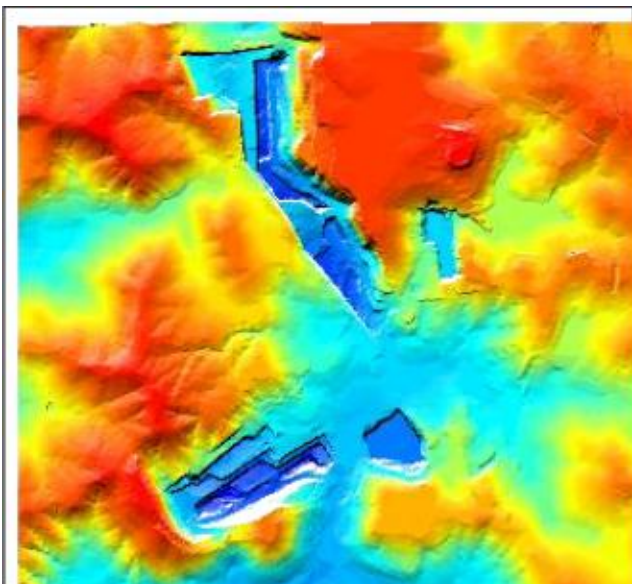
December 2004



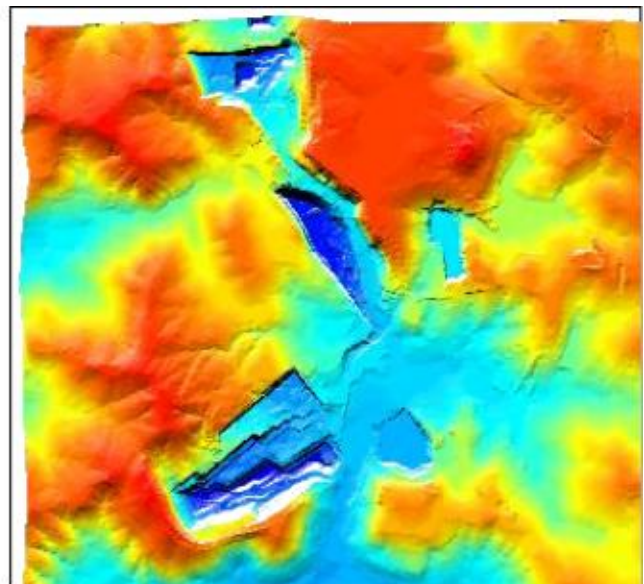
December 2006



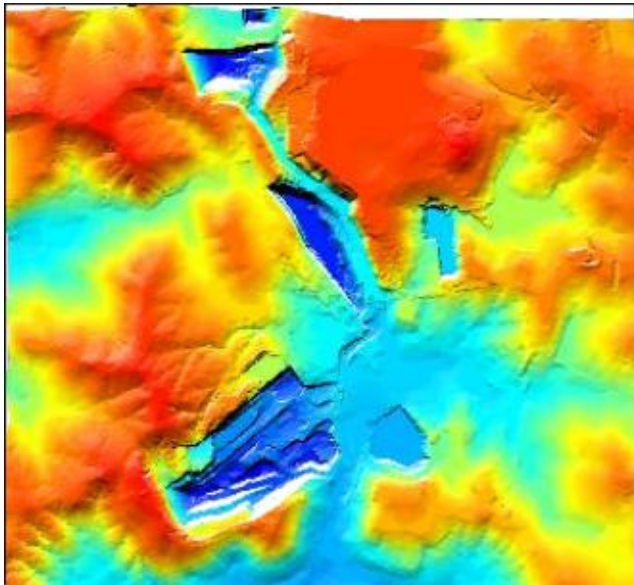
December 2008



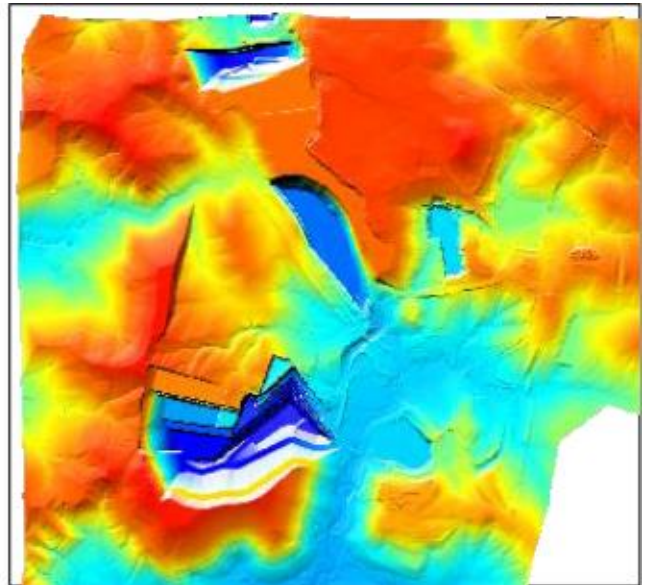
December 2010



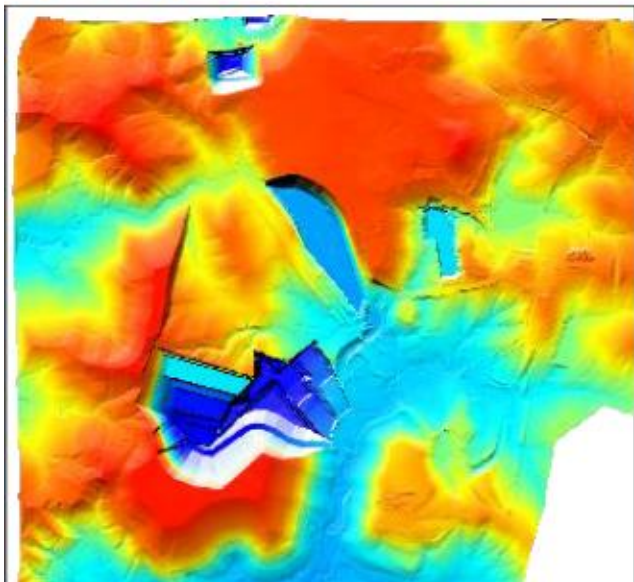
December 2012



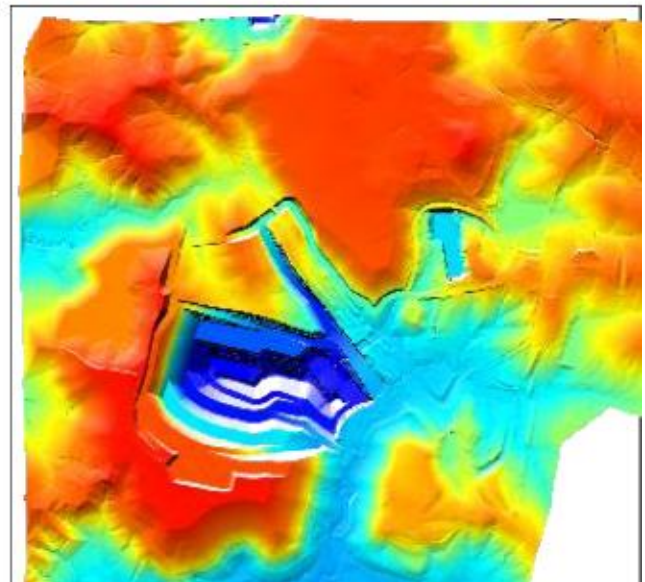
December 2013



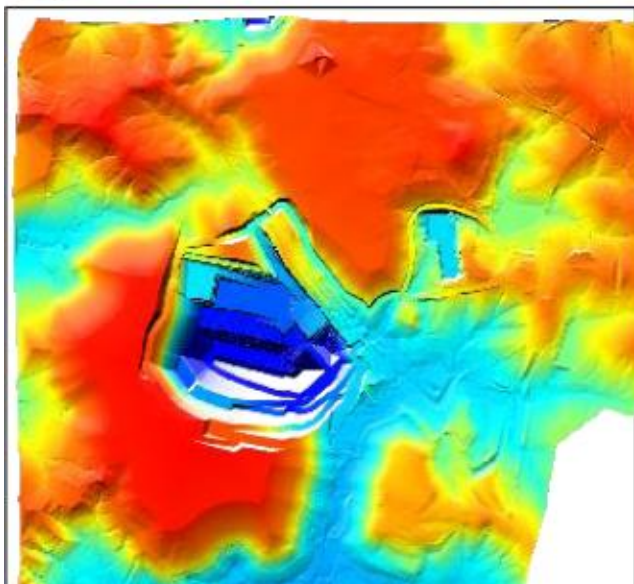
2017



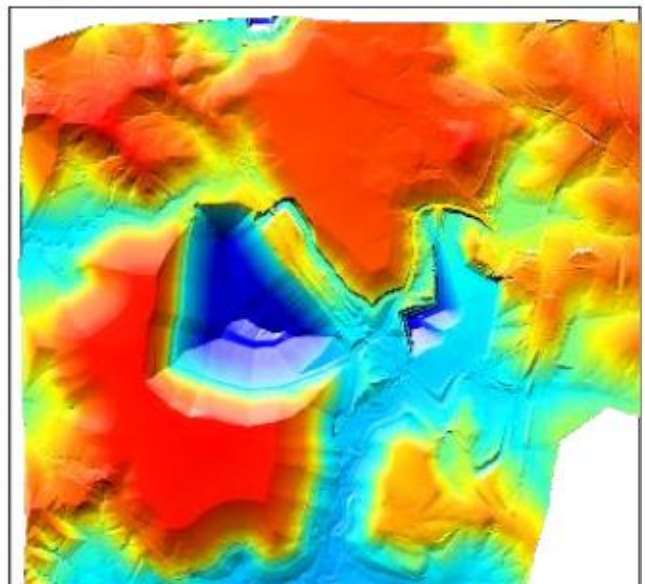
2020



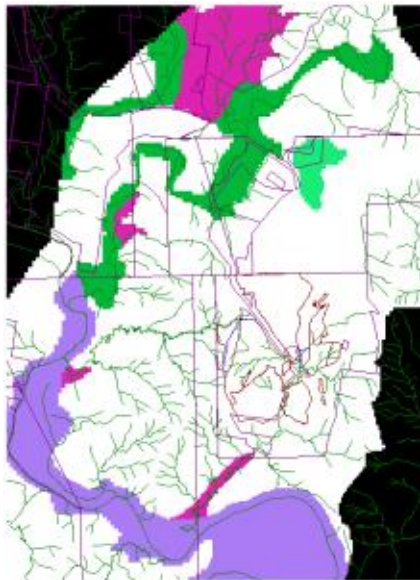
2023



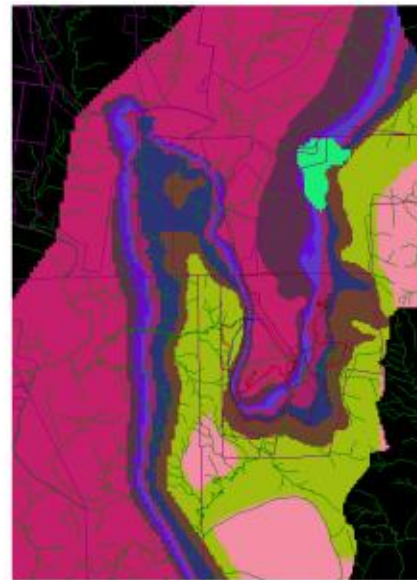
2026



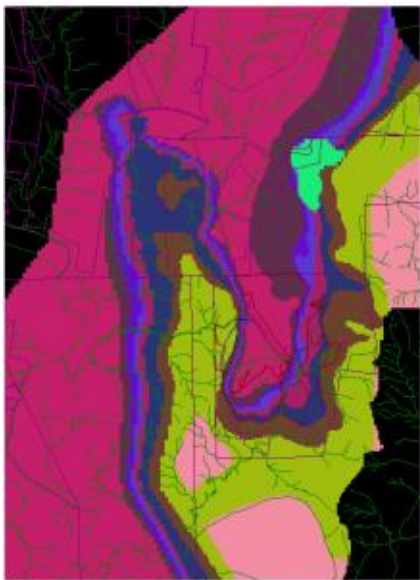
Final Landform (~2037)



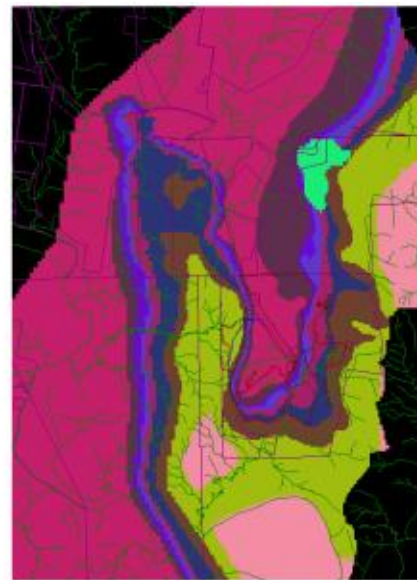
L01



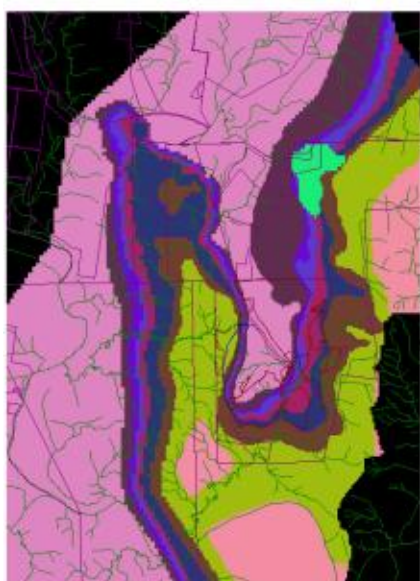
L02



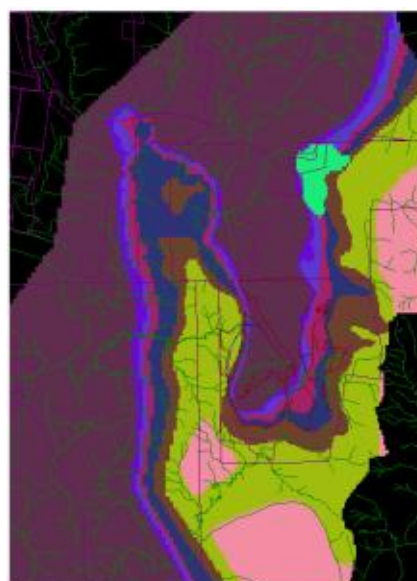
L03



L04

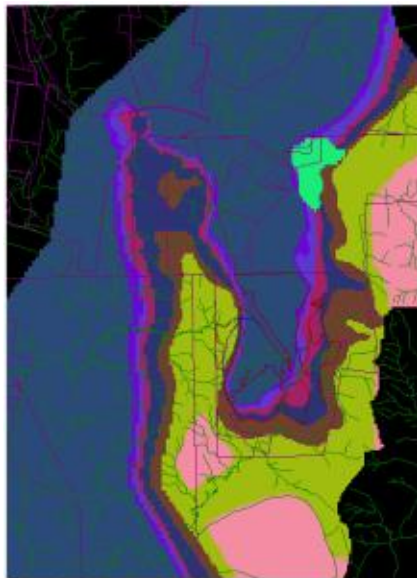


L05

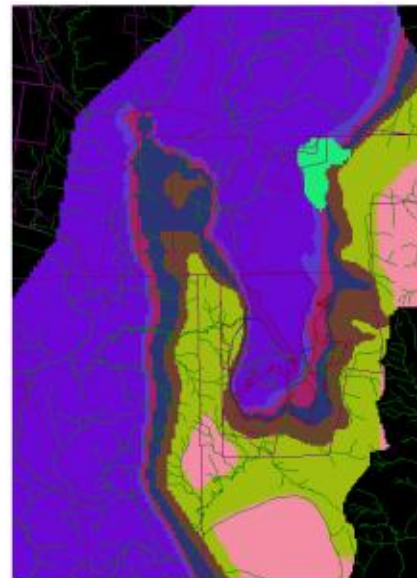


L06

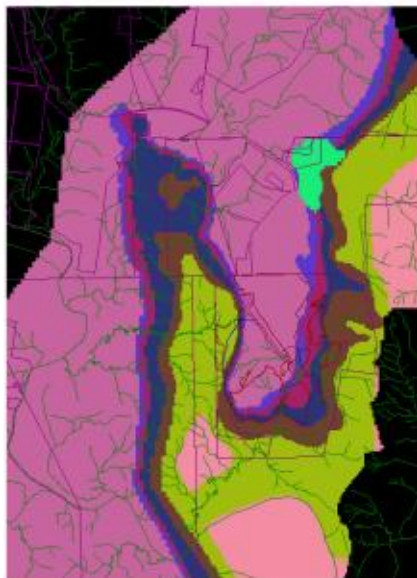
015a_CAL-Apr14_07a.gww



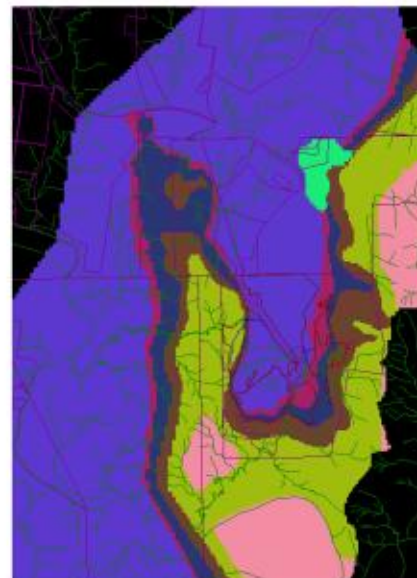
L07



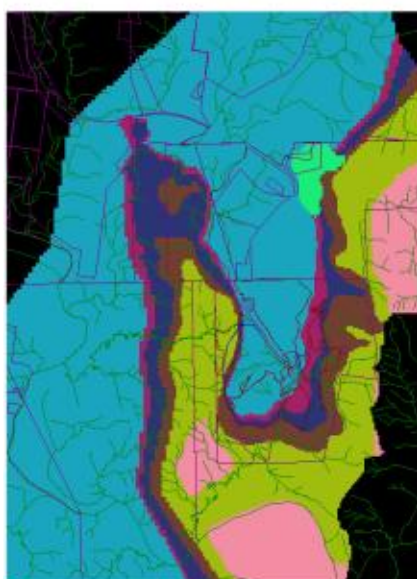
L08



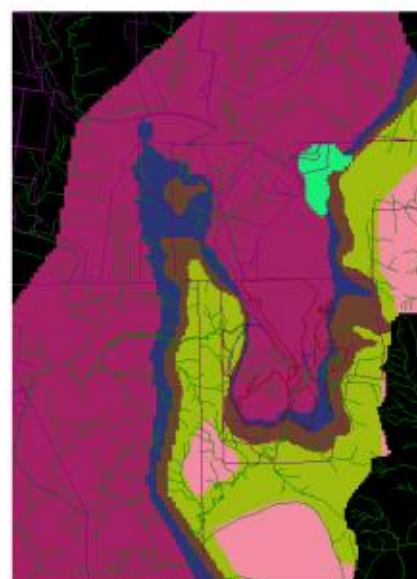
L09



L10

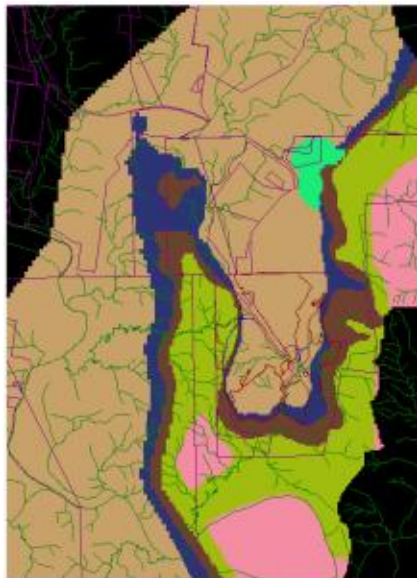


L11

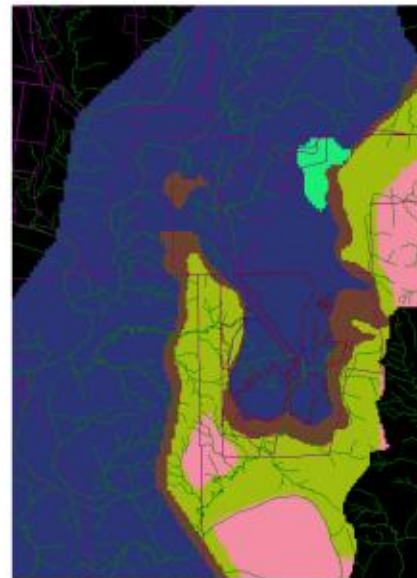


L12

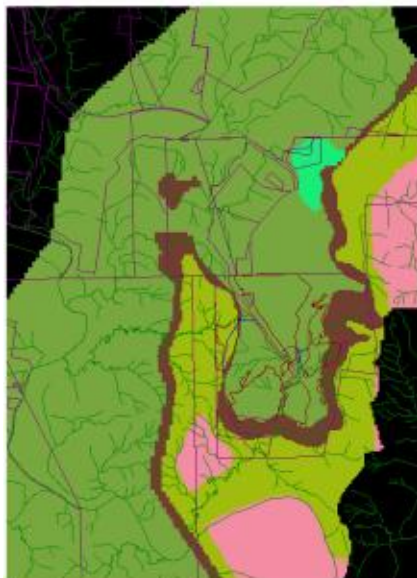
015a_CAL-Apr14_07a.gww



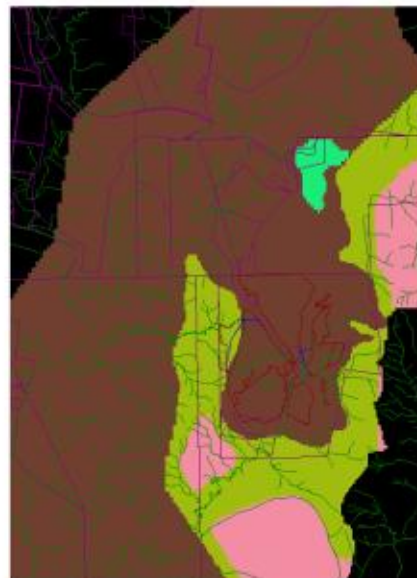
L13



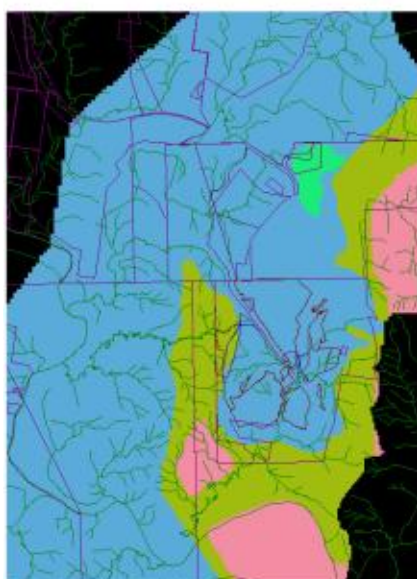
L14



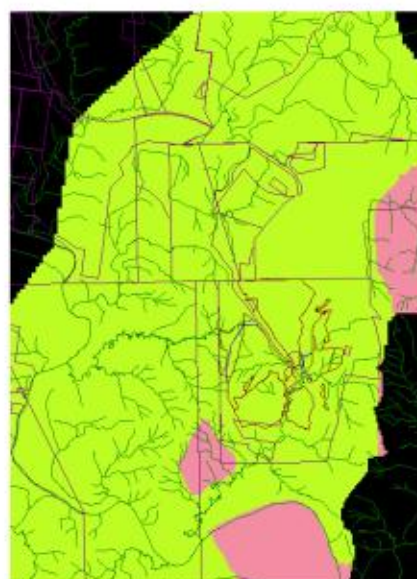
L15



L16

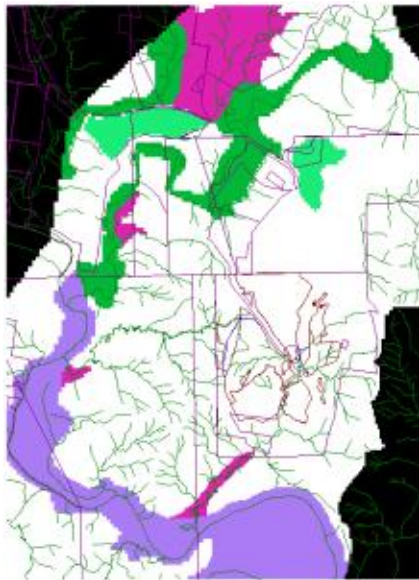


L17



L18

015a_CAL-Apr14_07agwv



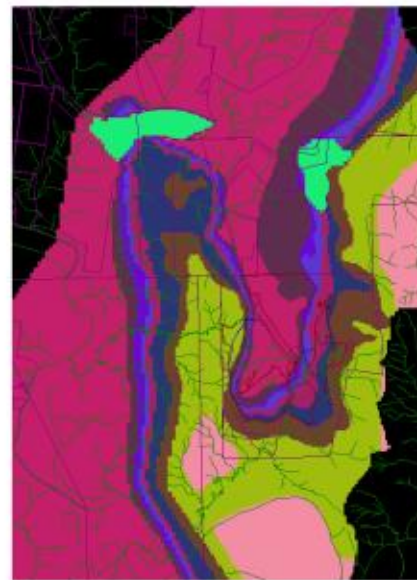
L01



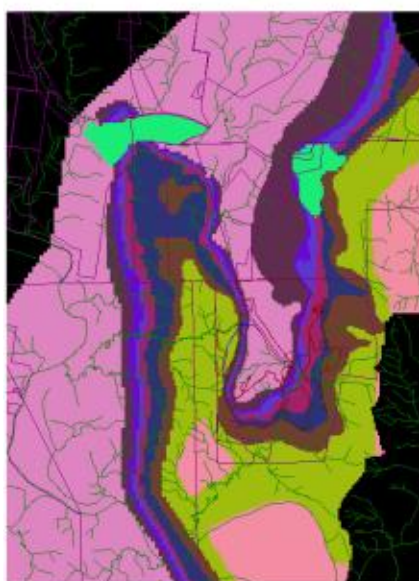
L02



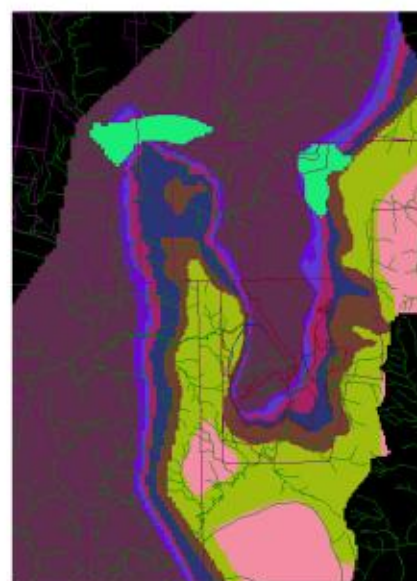
L03



L04

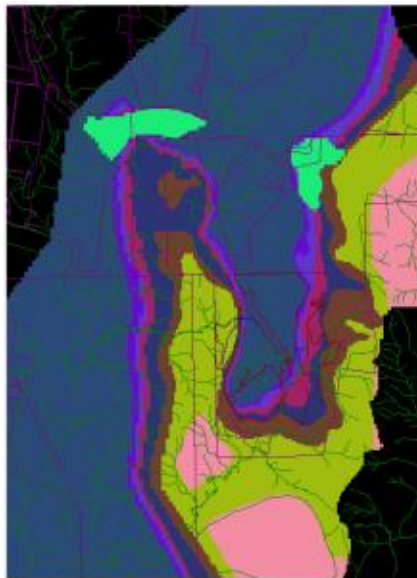


L05

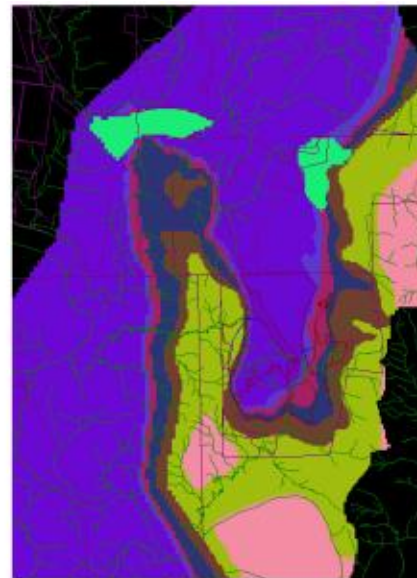


L06

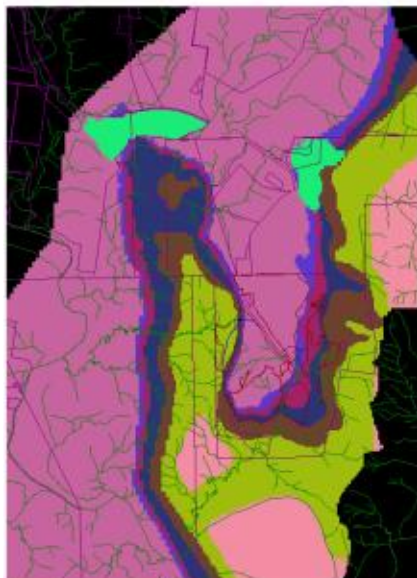
015a_PRD-MP1_04a.gww



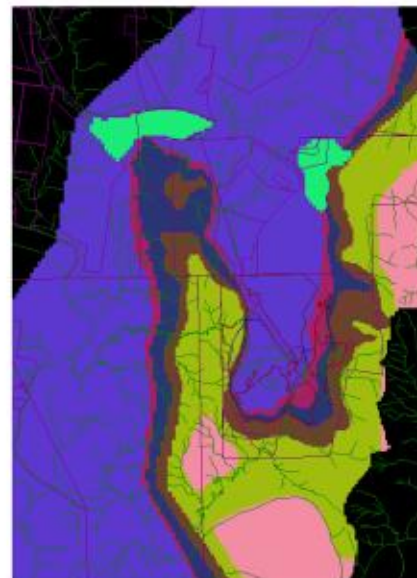
L07



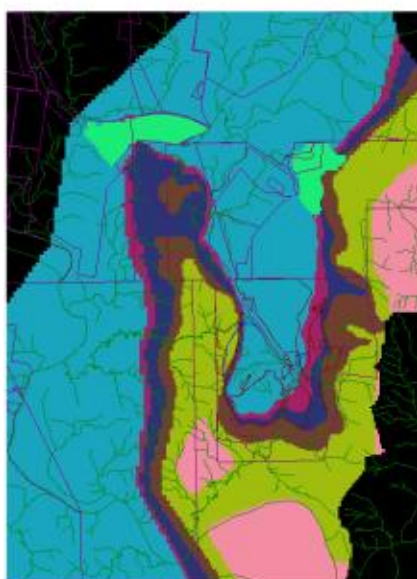
L08



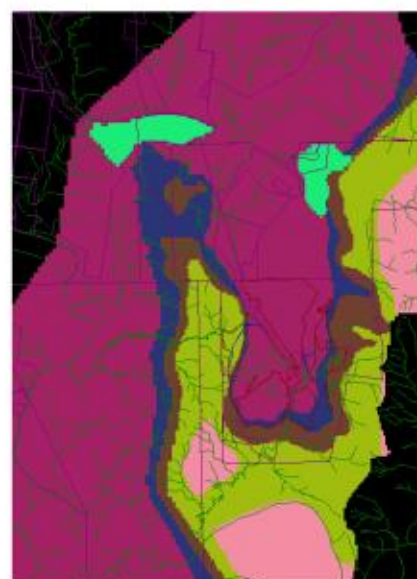
L09



L10

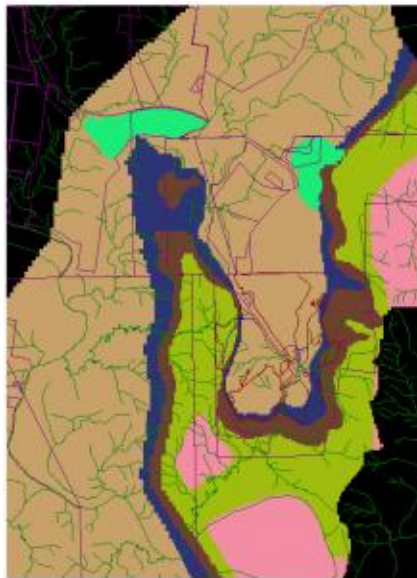


L11

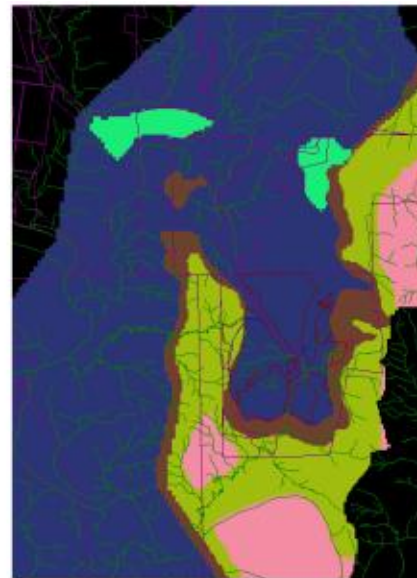


L12

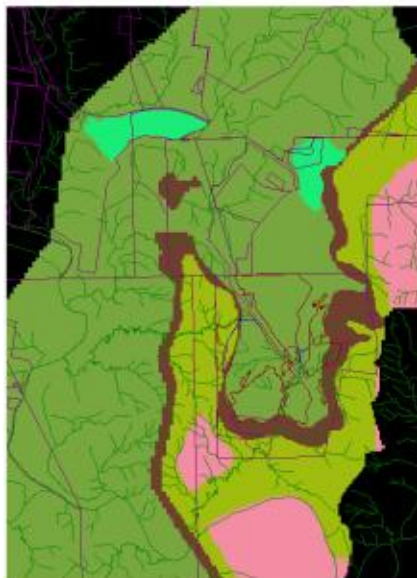
015a_PRD-MP1_04a.gww



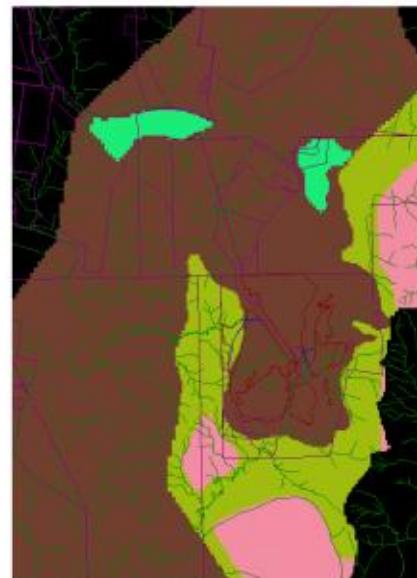
L13



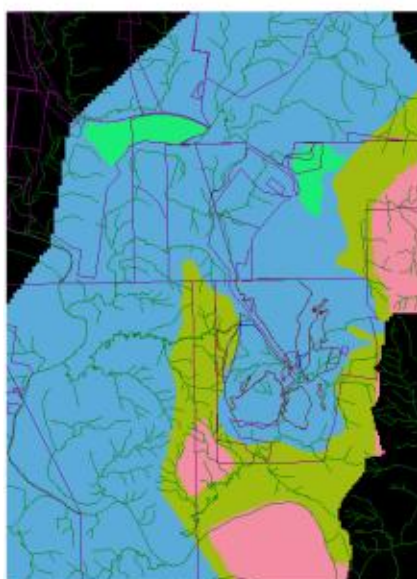
L14



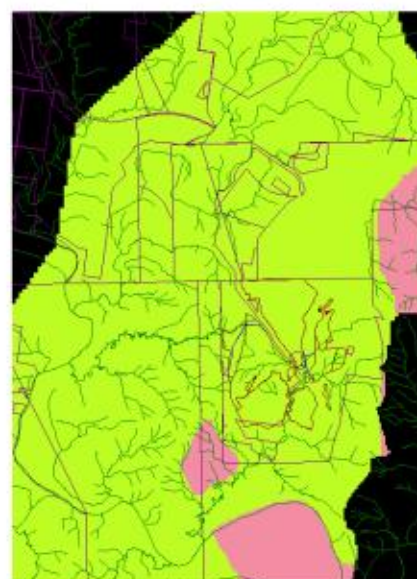
L15



L16

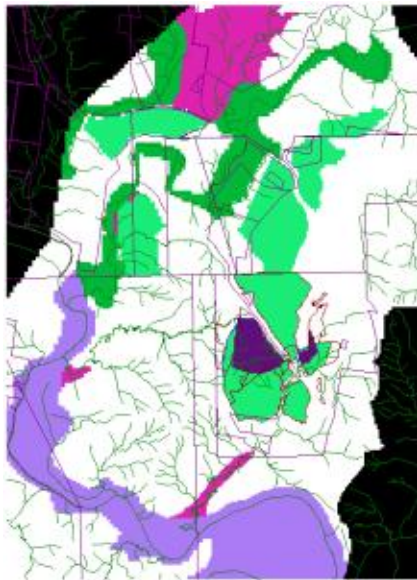


L17

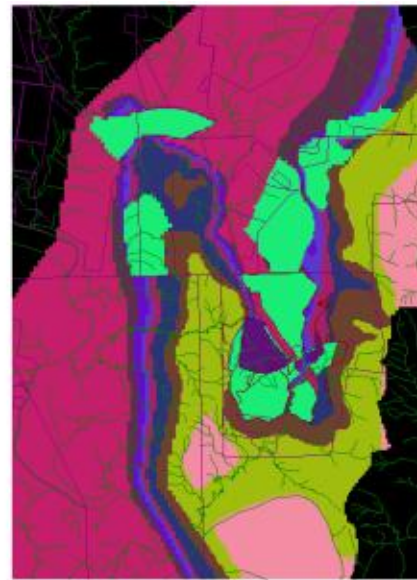


L18

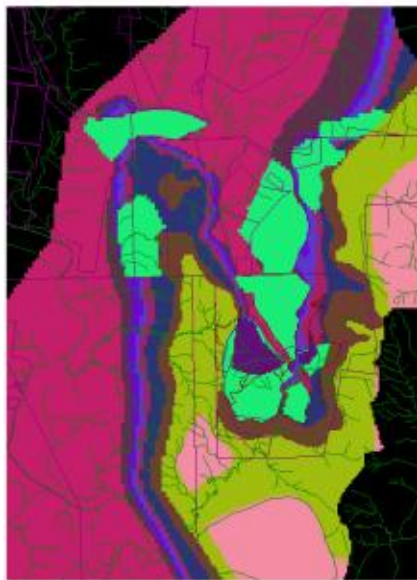
015a_PRD-MP1_04a.gvw



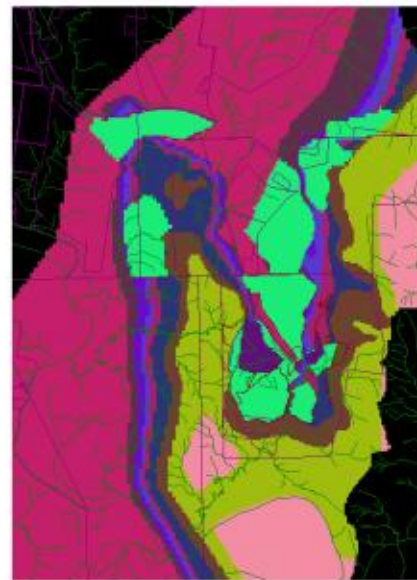
L01



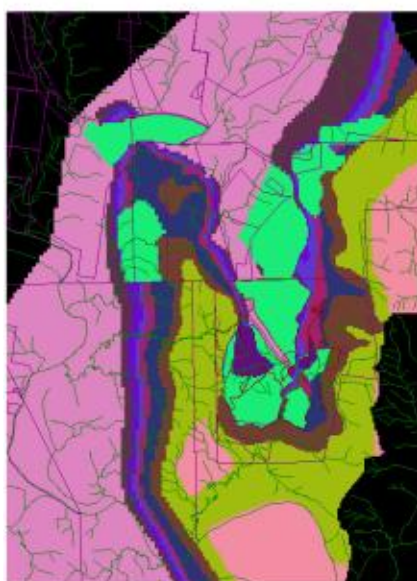
L02



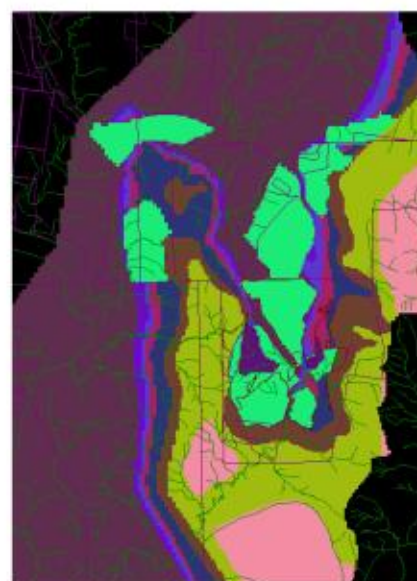
L03



L04

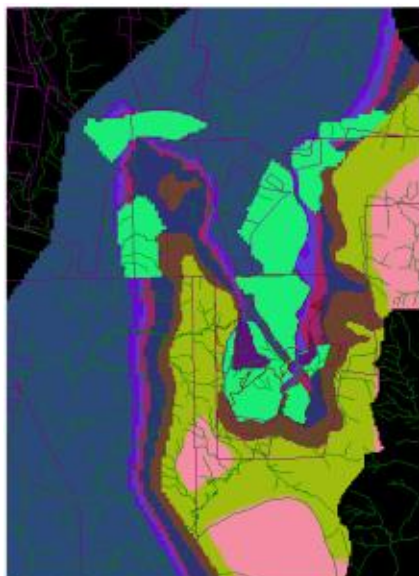


L05

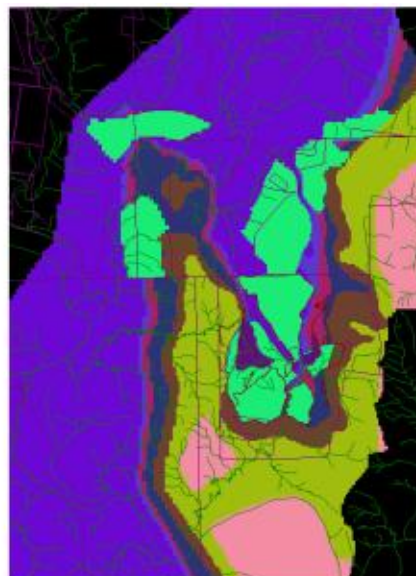


L06

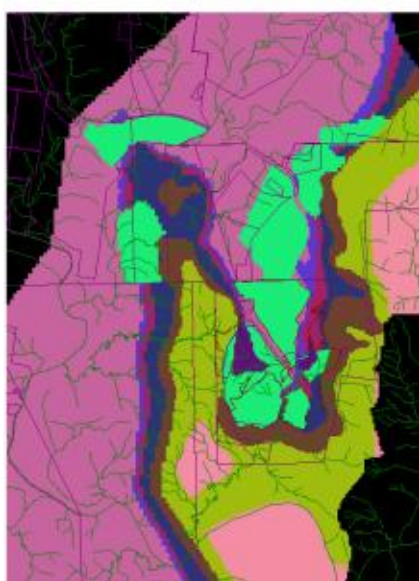
015a_RCV-MP1_05a.gww



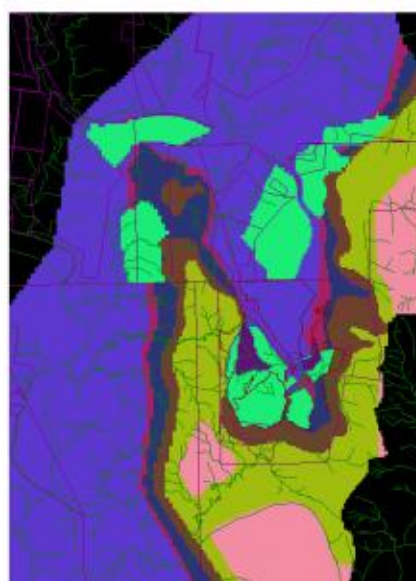
L07



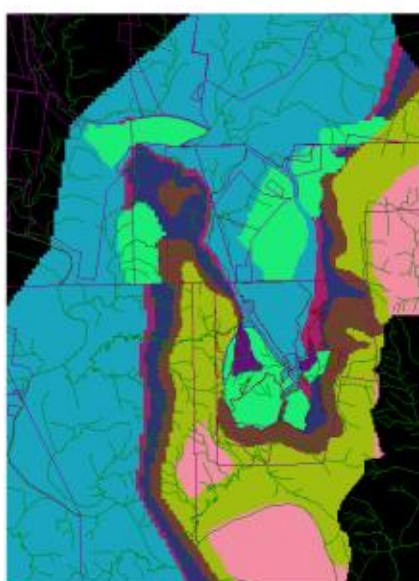
L08



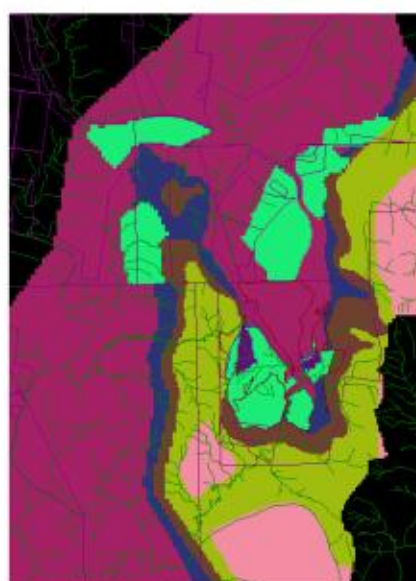
L09



L10

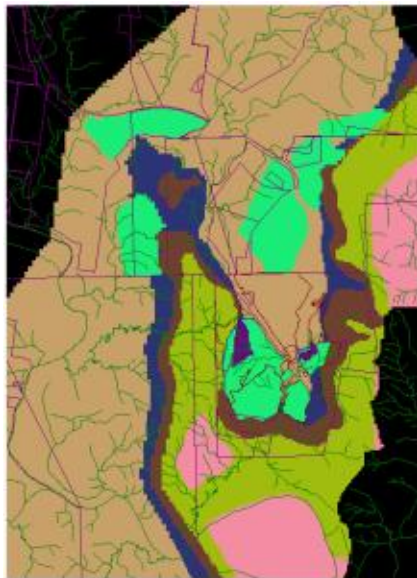


L11

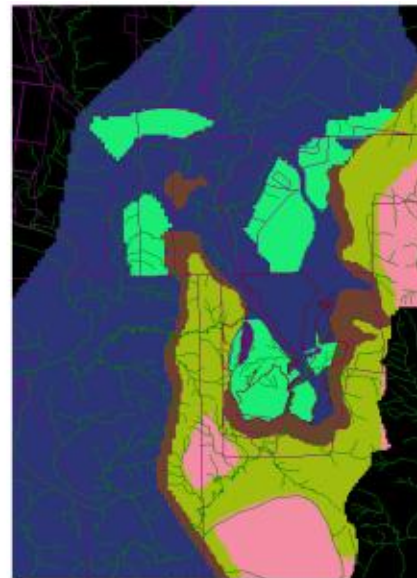


L12

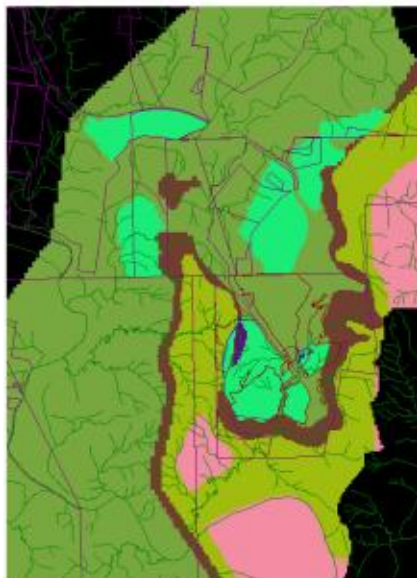
015a_RCV-MP1_05a.gww



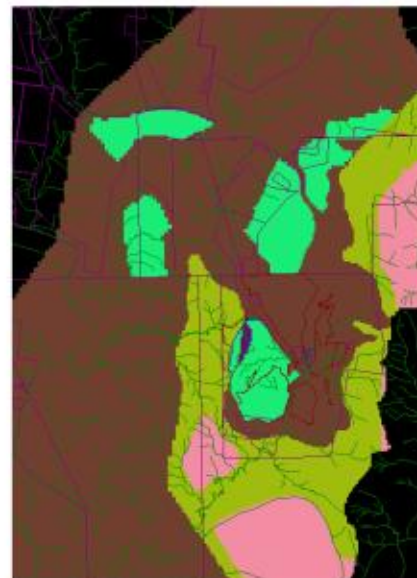
L13



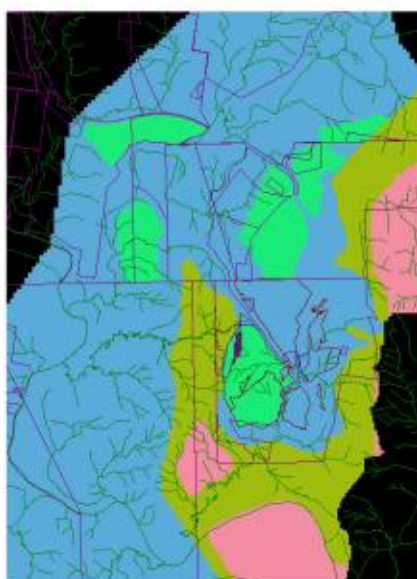
L14



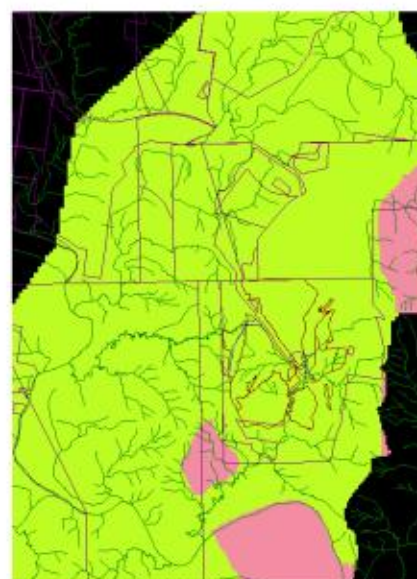
L15



L16



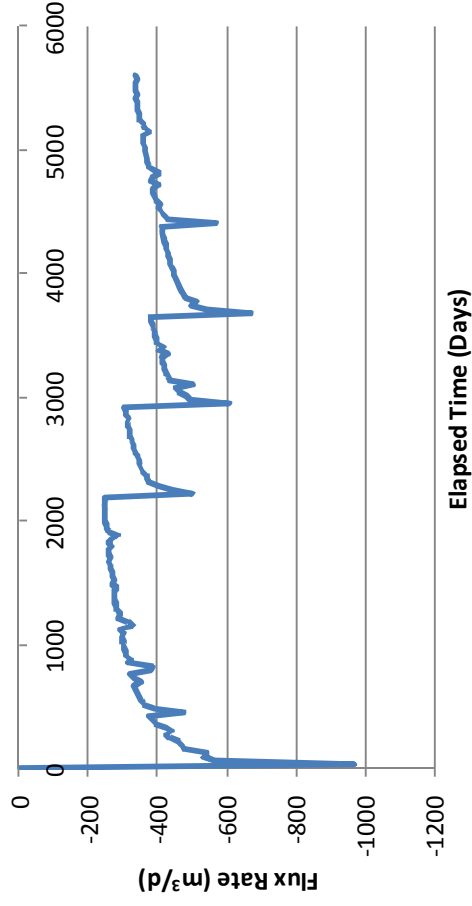
L17



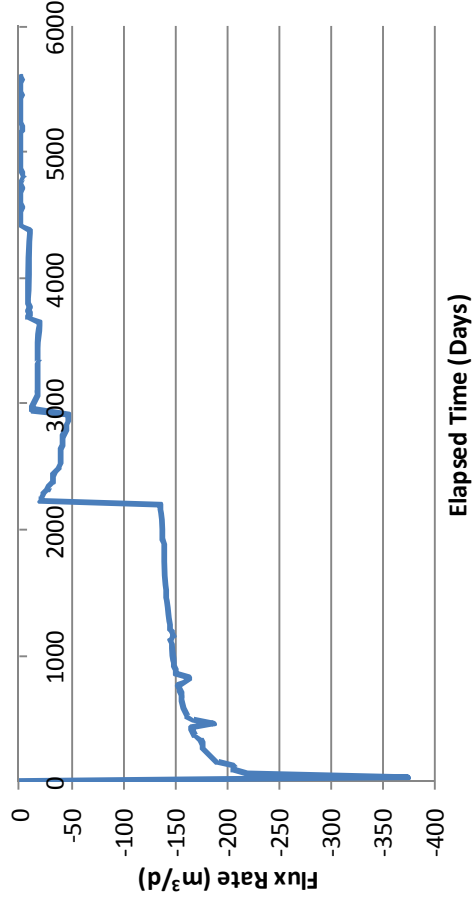
L18

015a_RCV-MP1_05a.gww

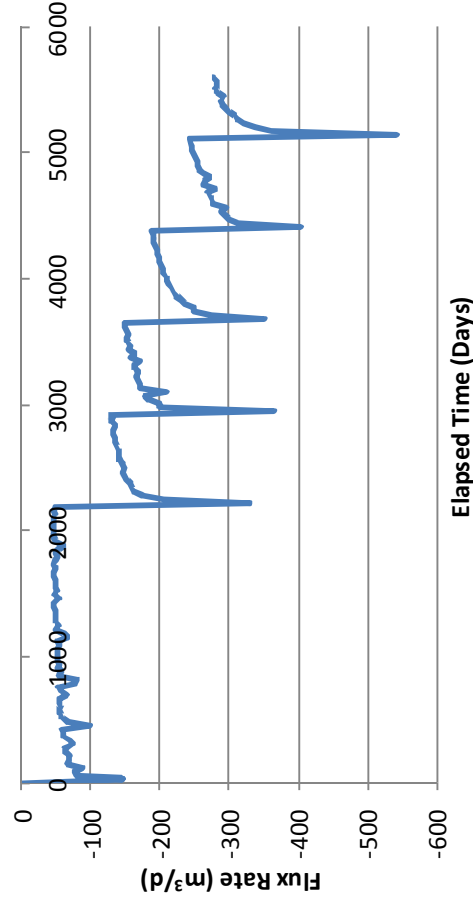
Flux vs. Time at Pit 1 (Drain Reach 51)

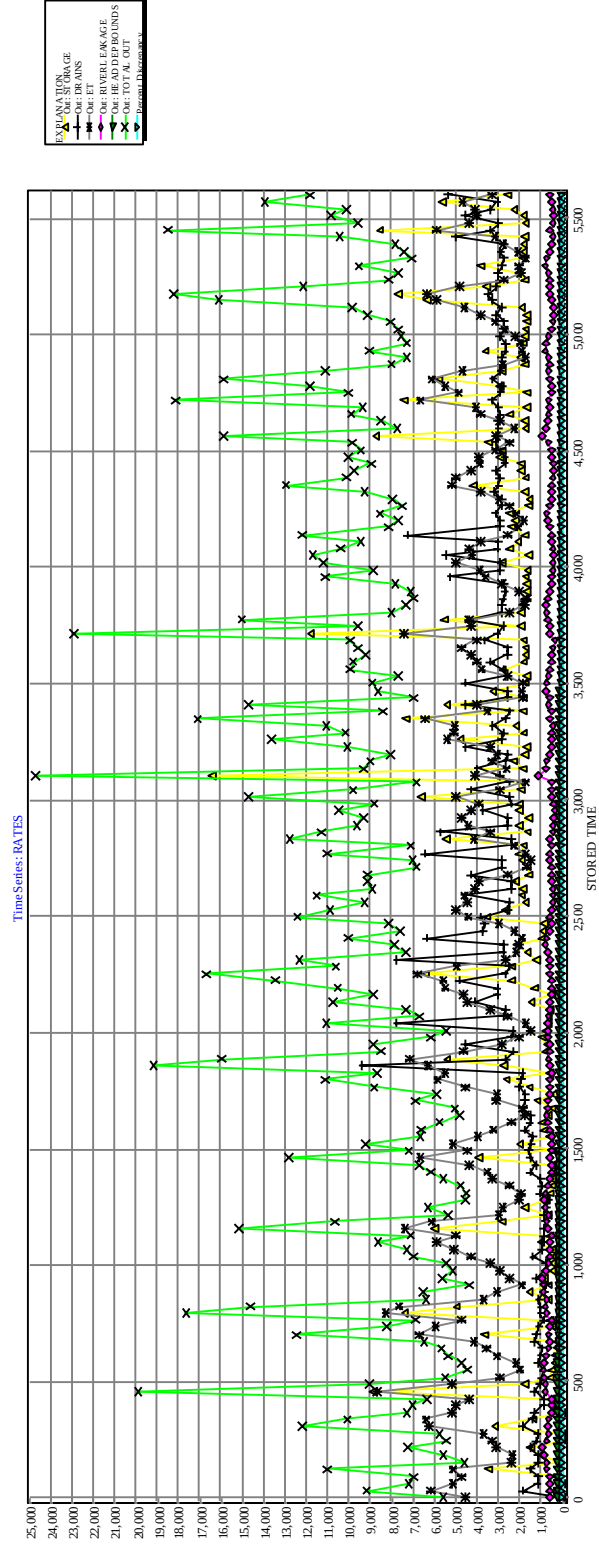
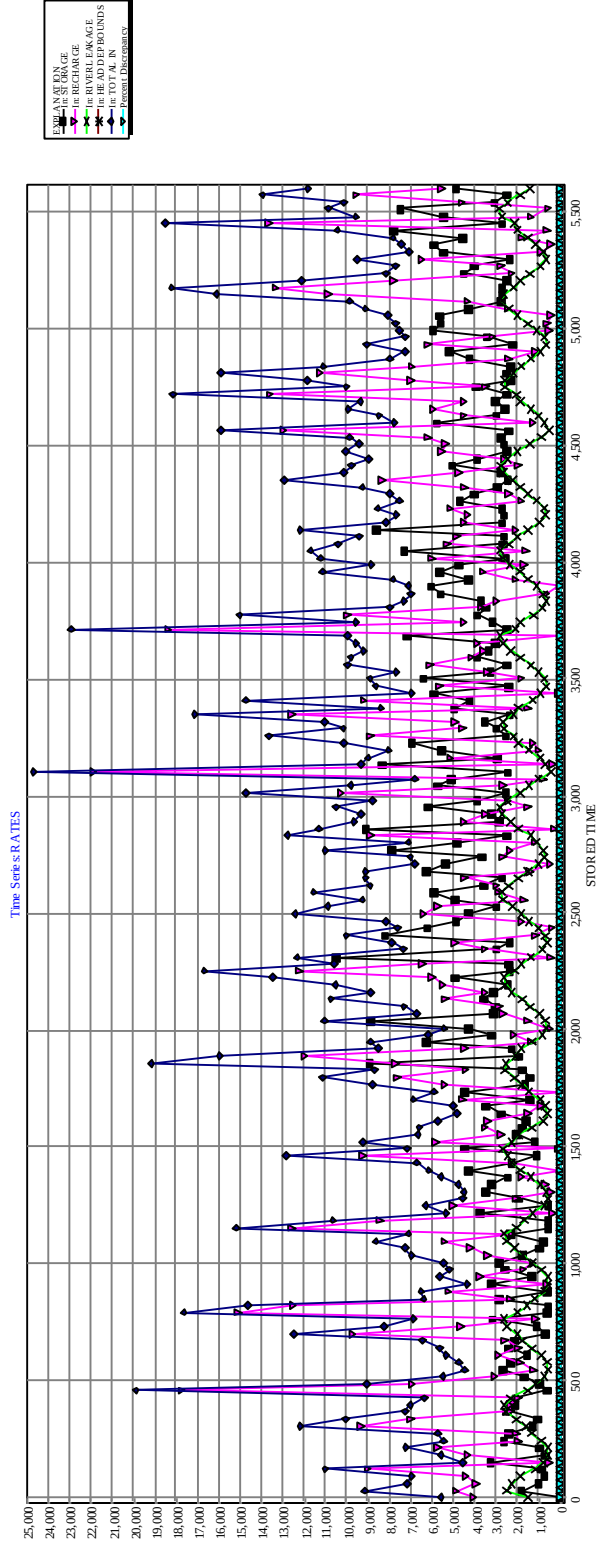


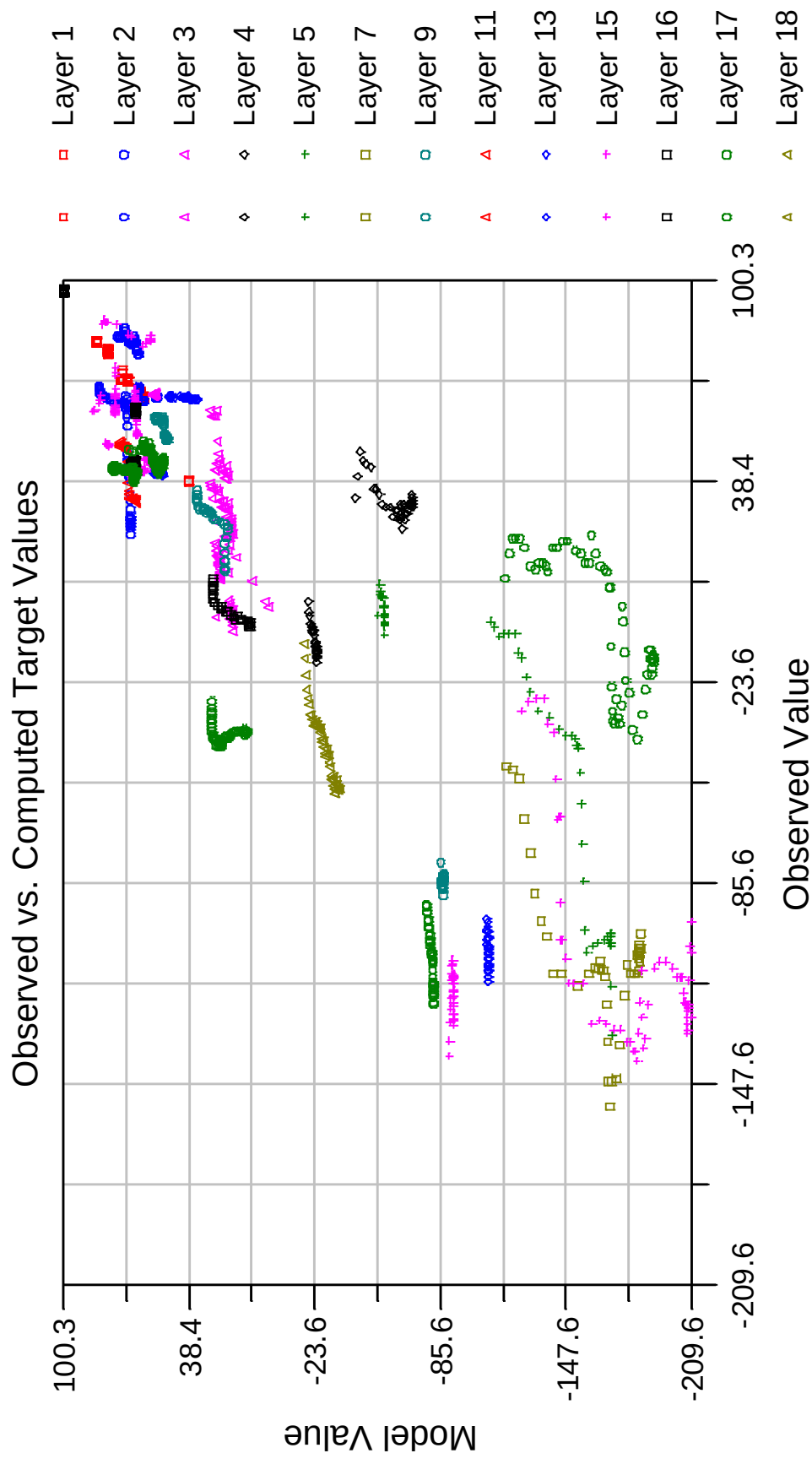
Flux vs. Time at Pit 2 (Drain Reach 52)

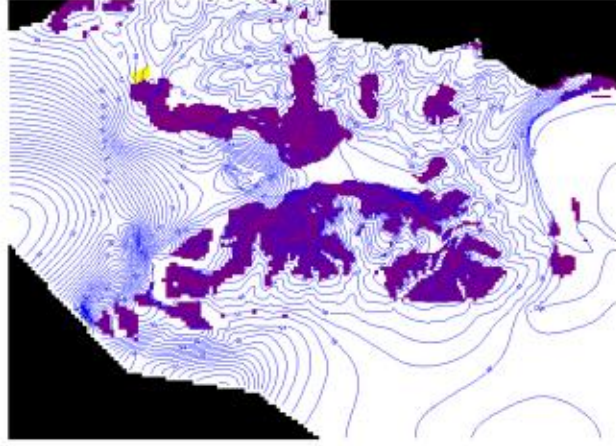
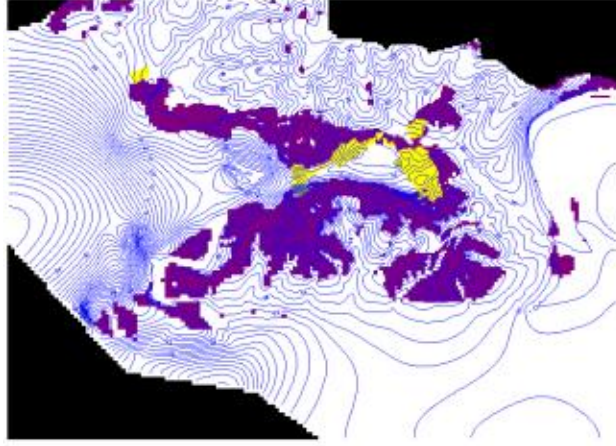
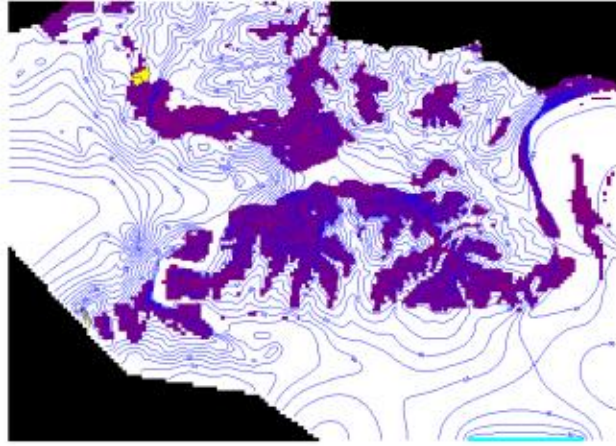
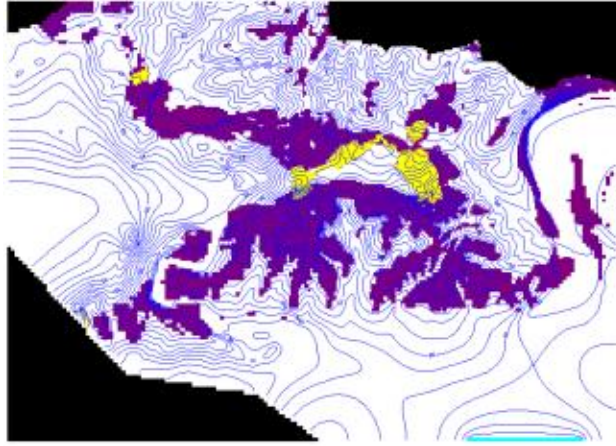
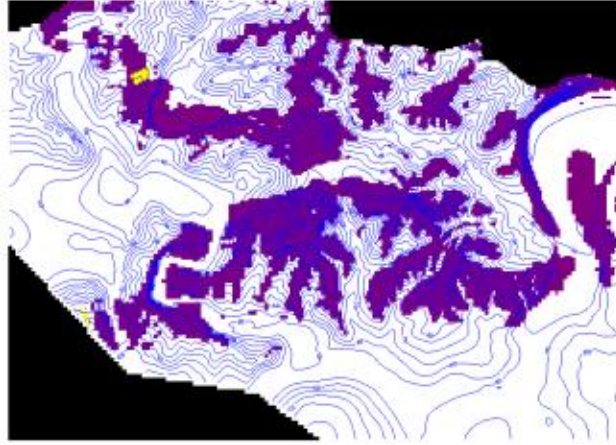
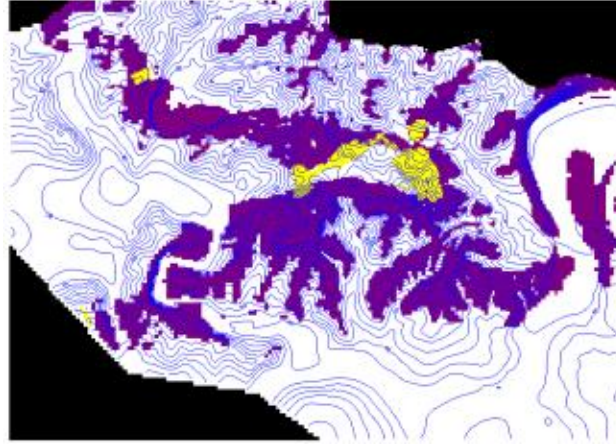
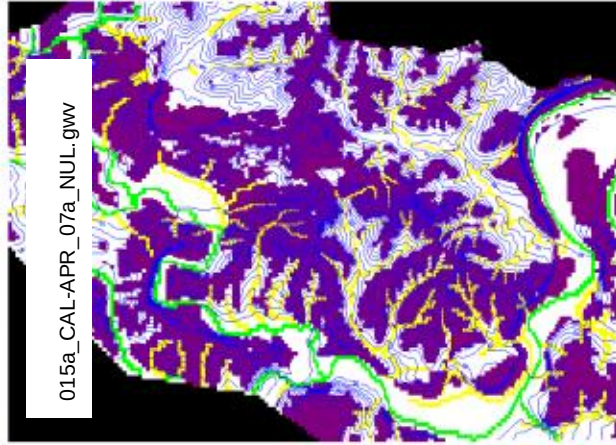
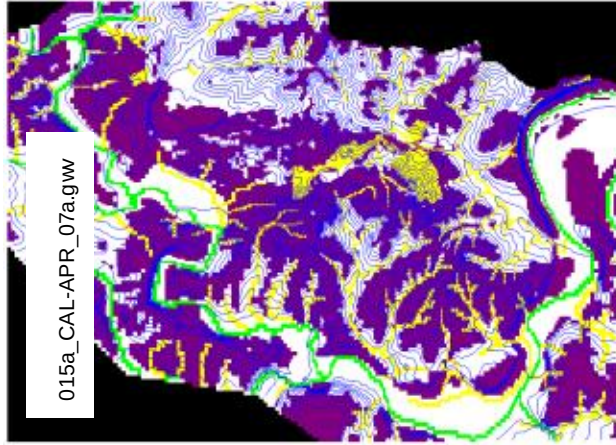


Flux vs. Time at Pit 3 (Drain Reach 53)







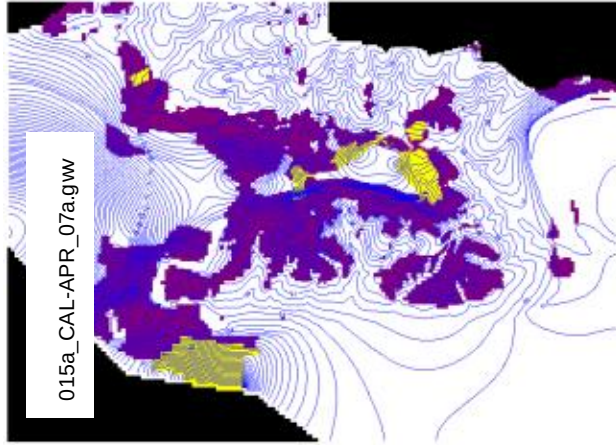


Layer 1

Layer 2

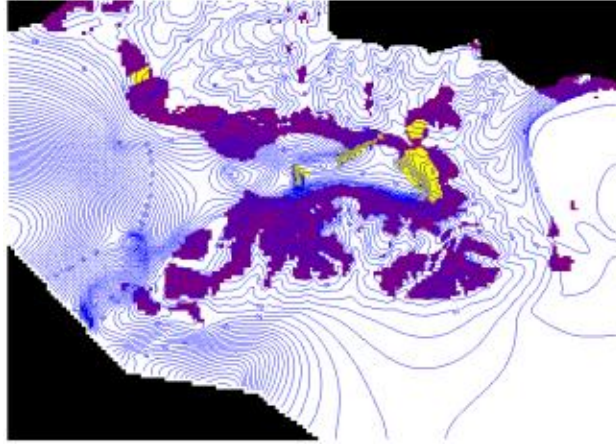
Layer 3

Layer 4

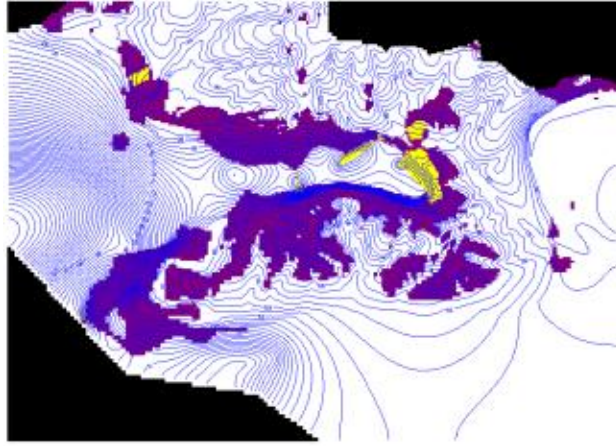


015a_CAL-APR_07a.gww

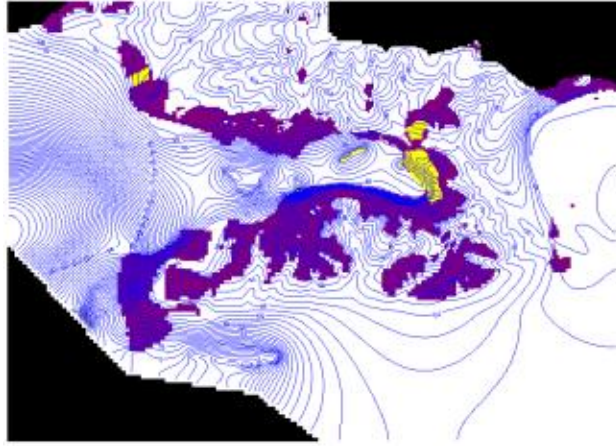
Layer 5



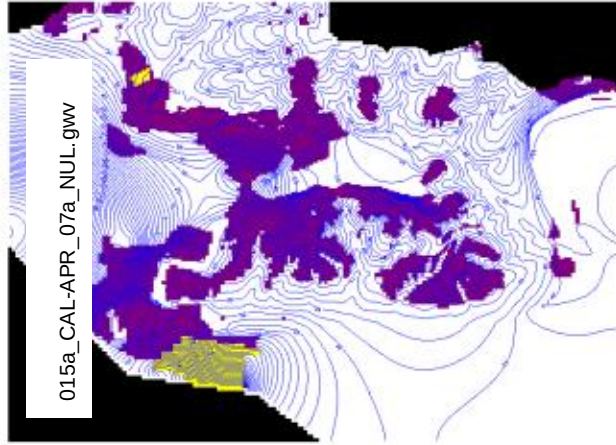
Layer 6



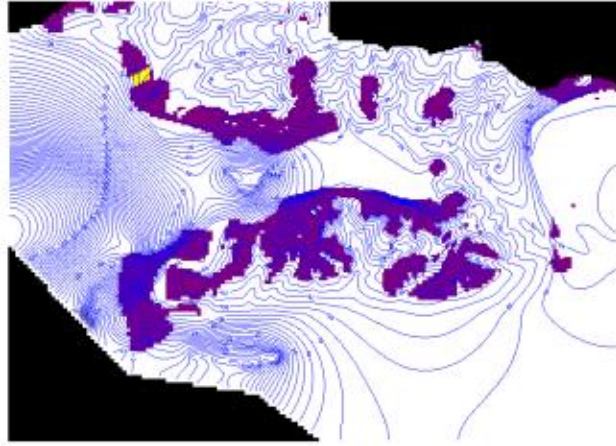
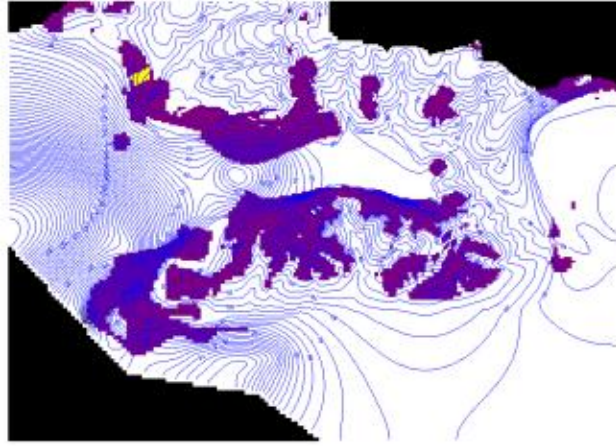
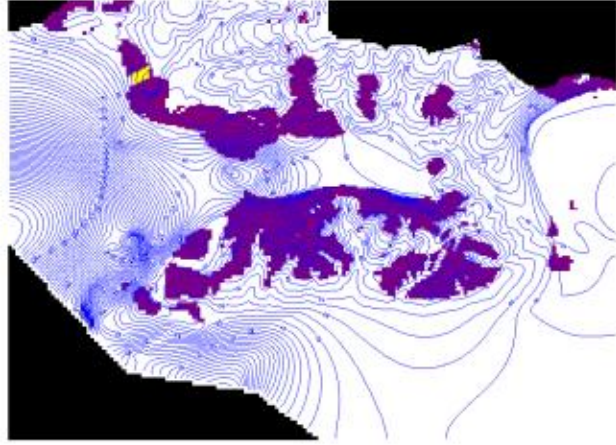
Layer 7

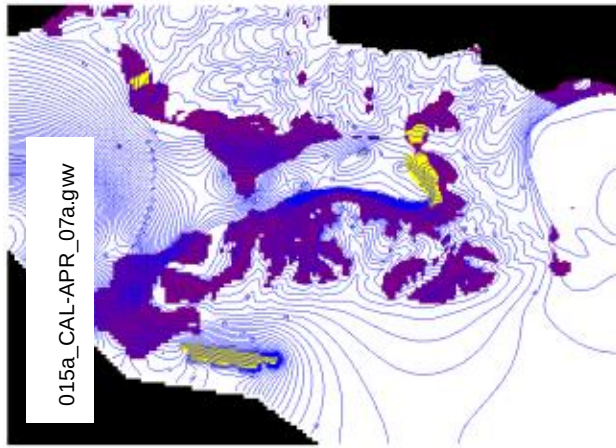


Layer 8



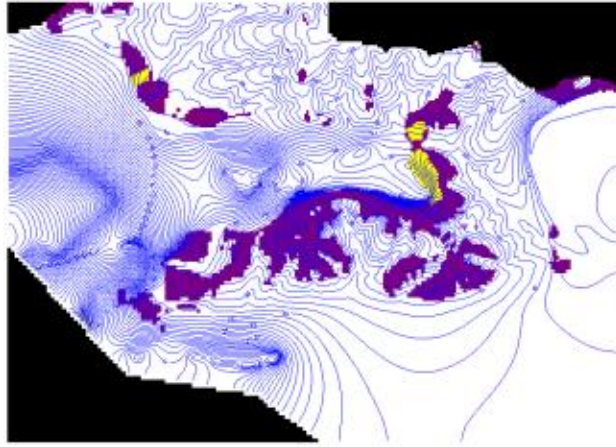
015a_CAL-APR_07a_NUL.gww



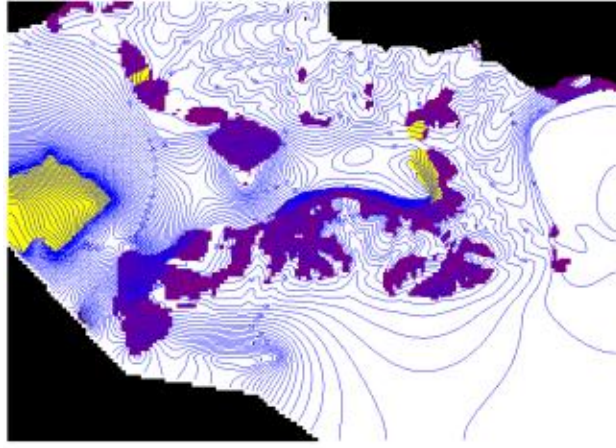


015a_CAL-APR_07a.gww

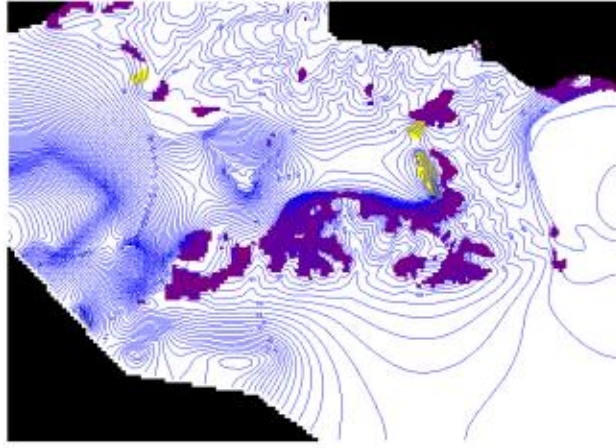
Layer 9



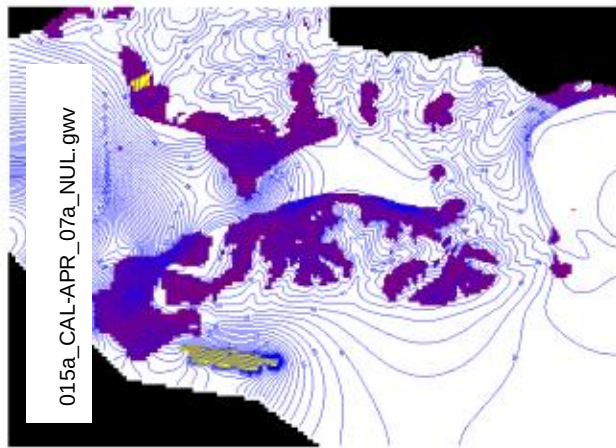
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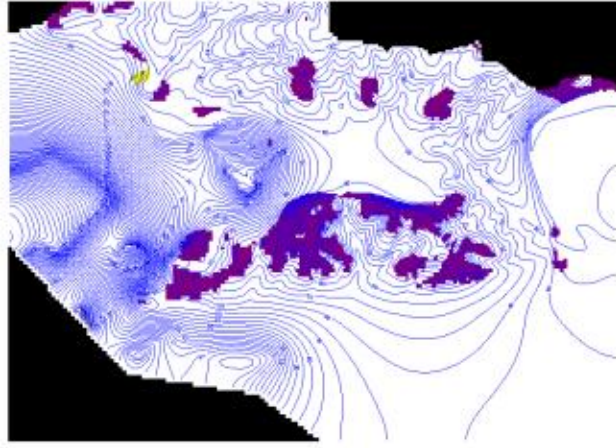
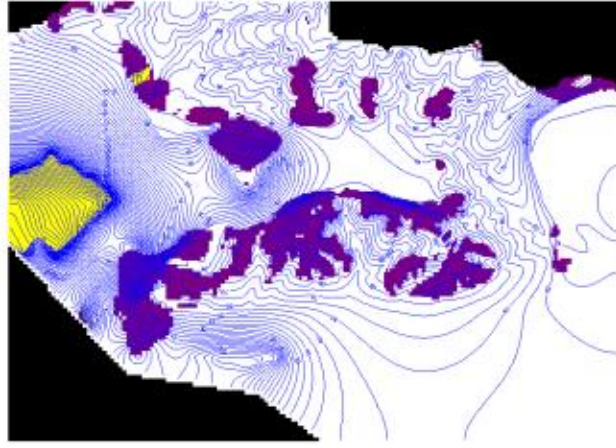
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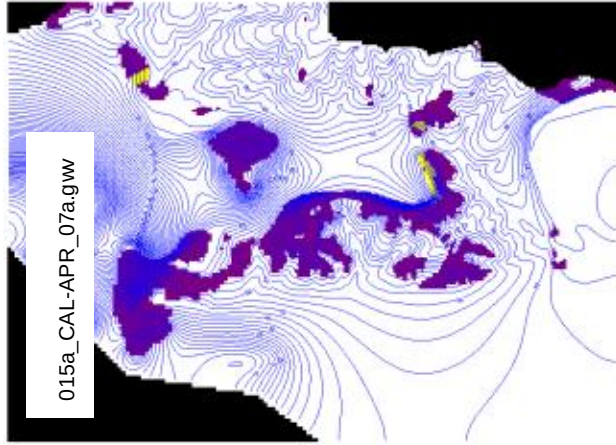


Layer 12

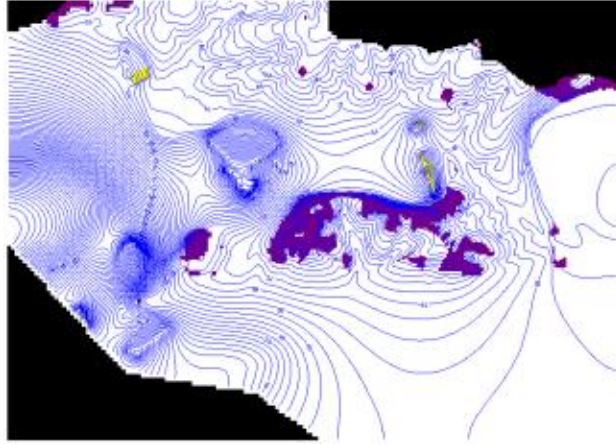


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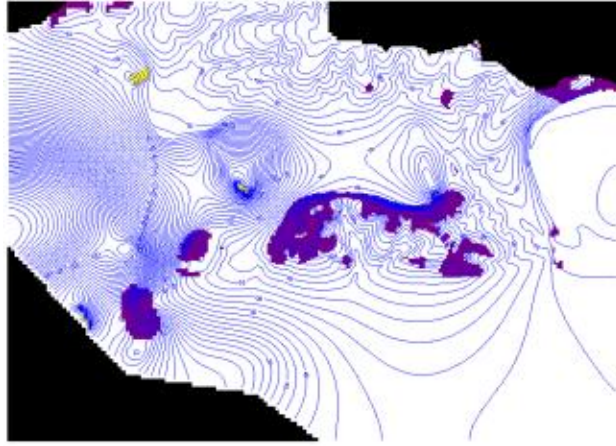




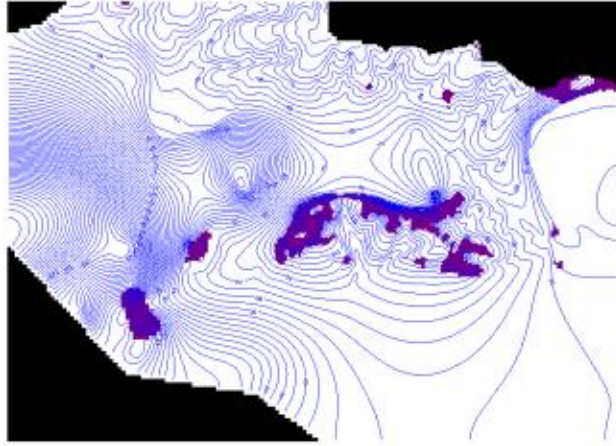
Layer 13



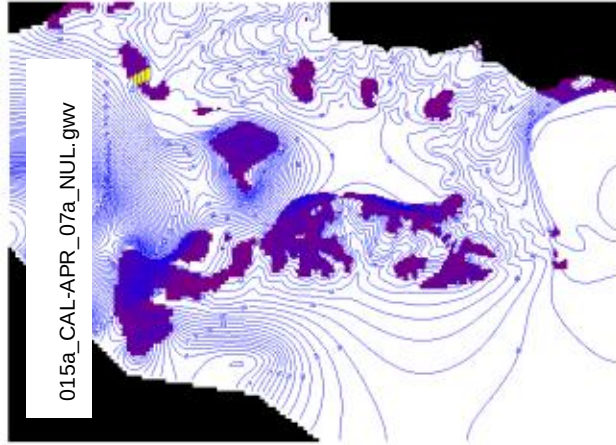
Layer 14



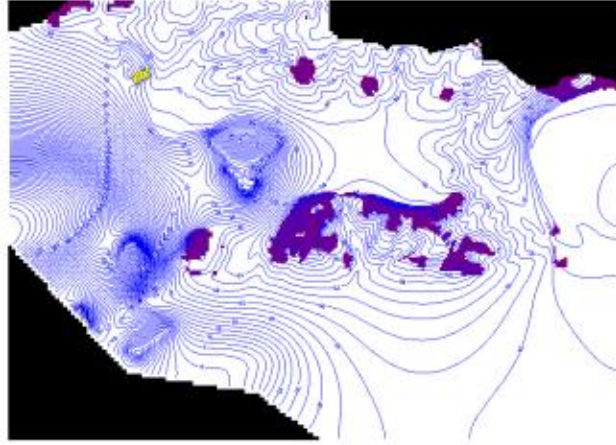
Layer 15



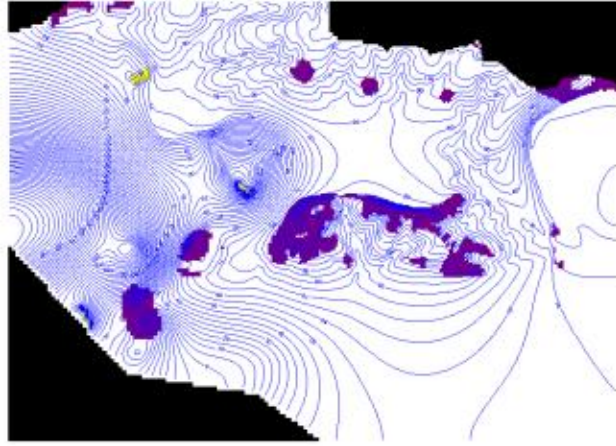
Layer 16



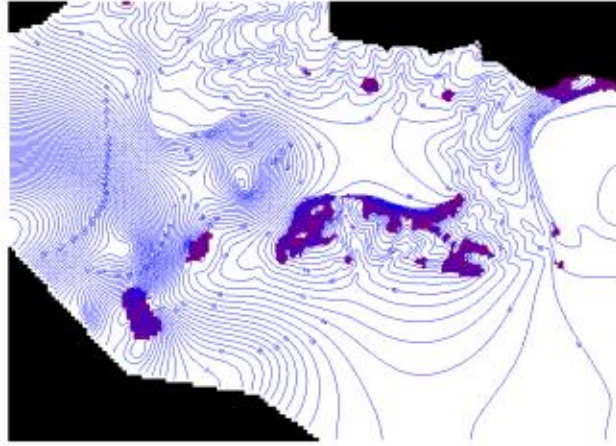
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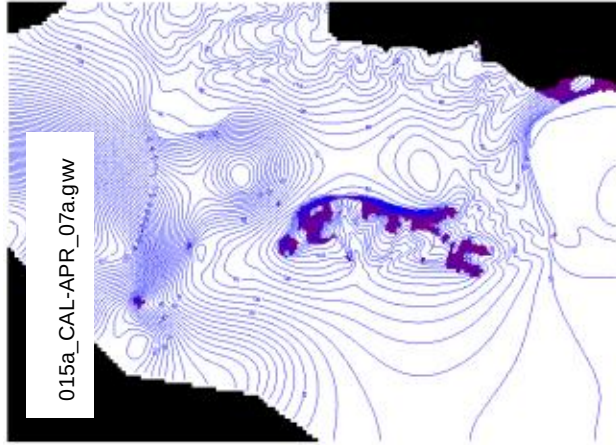
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Layer 15

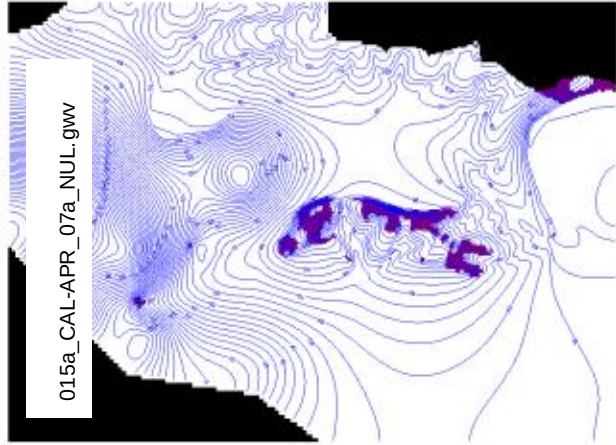


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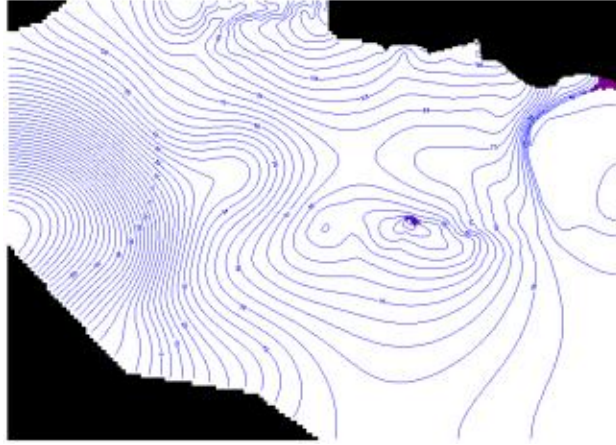


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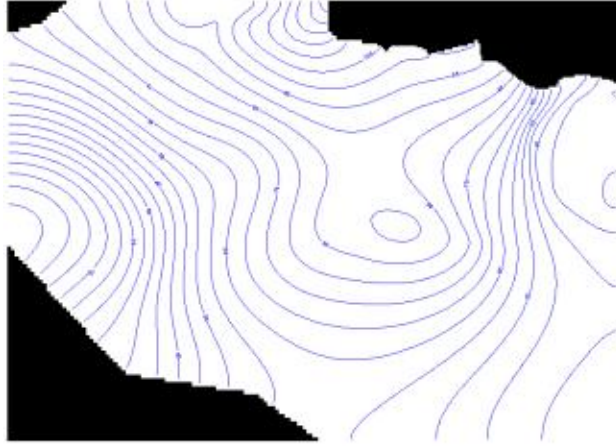
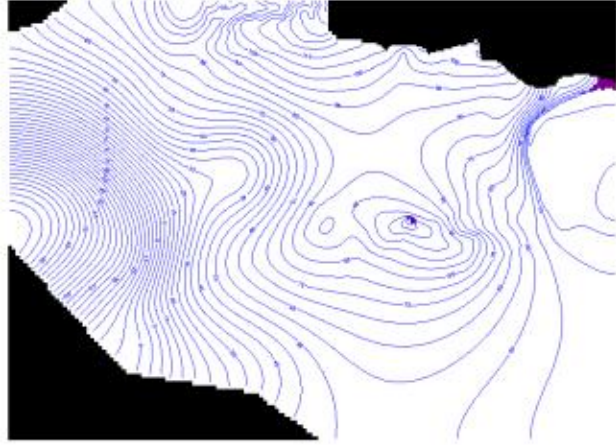
Layer 17



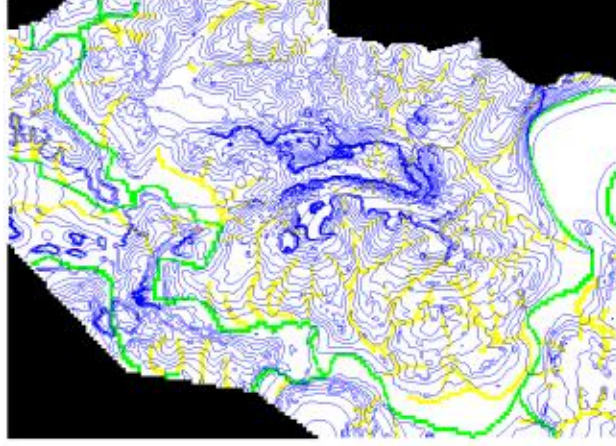
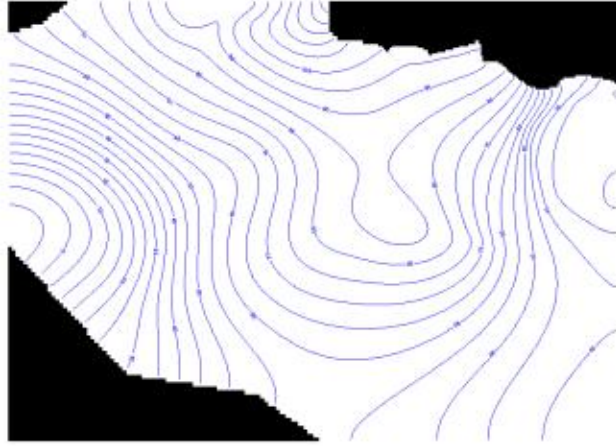
015a_CAL-APR_07a_NUL.gww



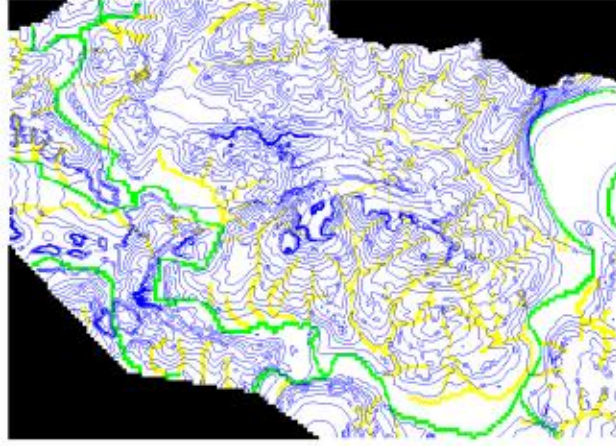
Layer 18

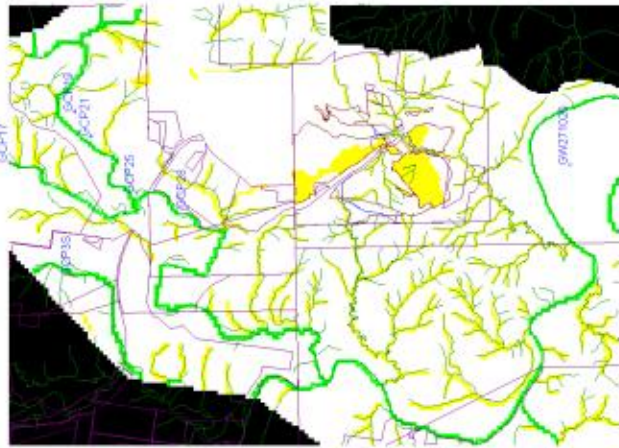


Layer 19

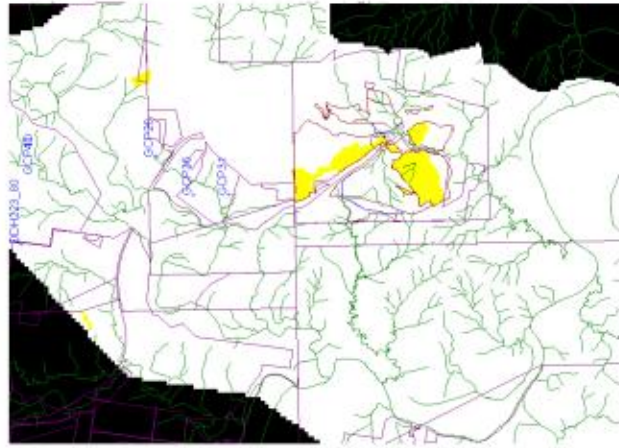


Uppermost Water Table

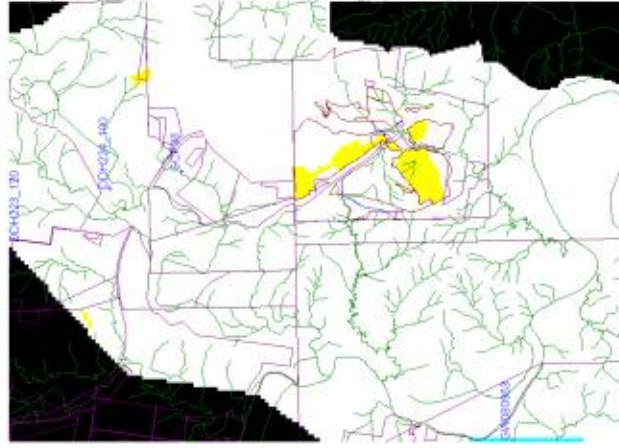




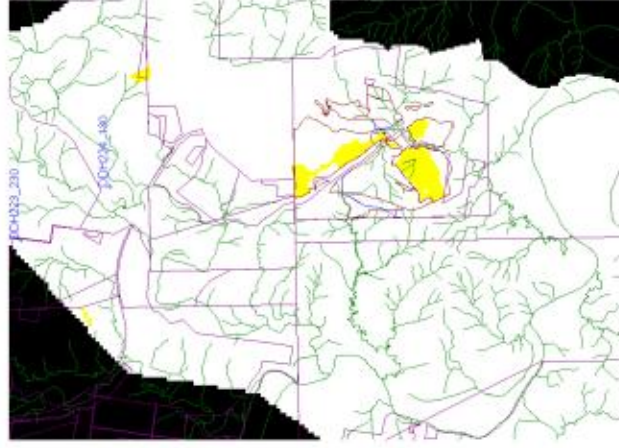
Layer 1



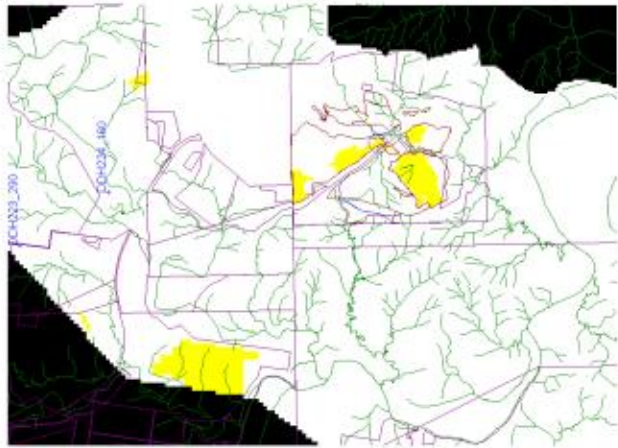
Layer 2



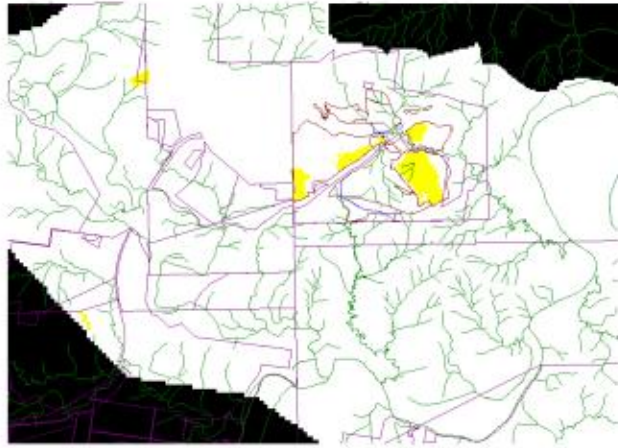
Layer 3



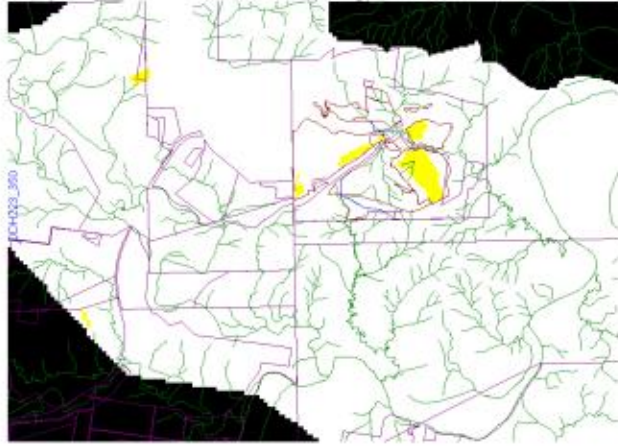
Layer 4



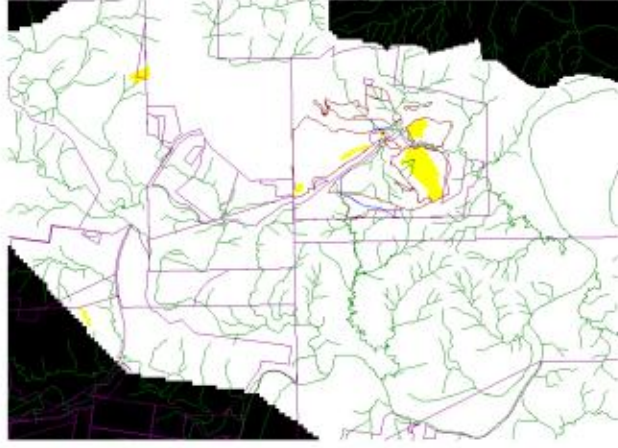
Layer 5



Layer 6

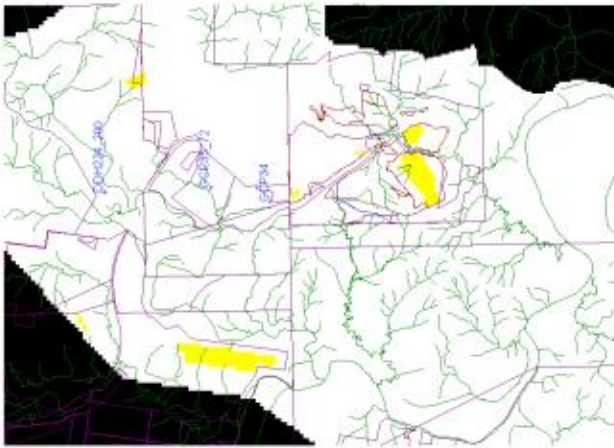


Layer 7

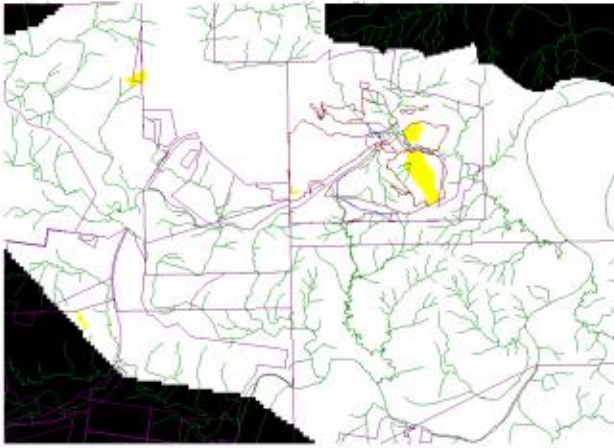


Layer 8

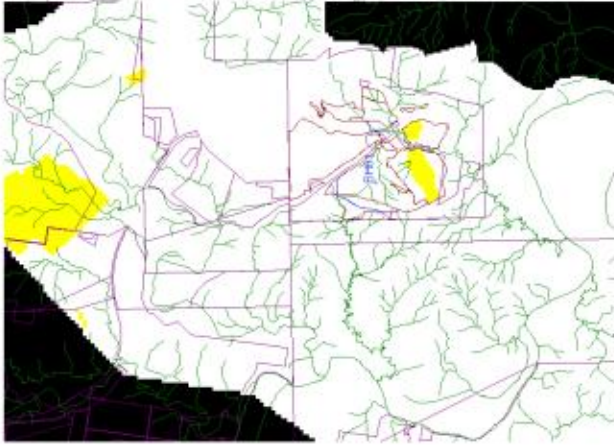
015a_CAL-Apr14_07a.gww



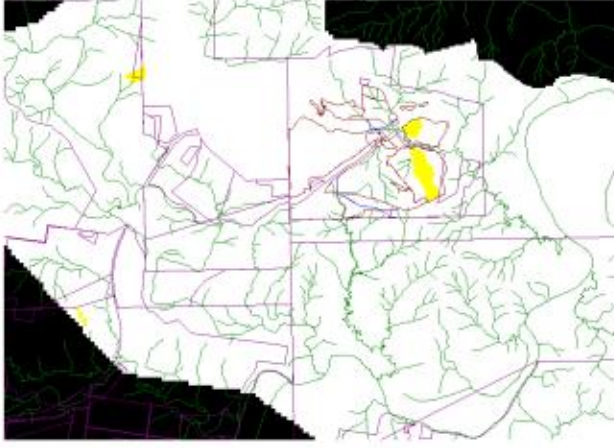
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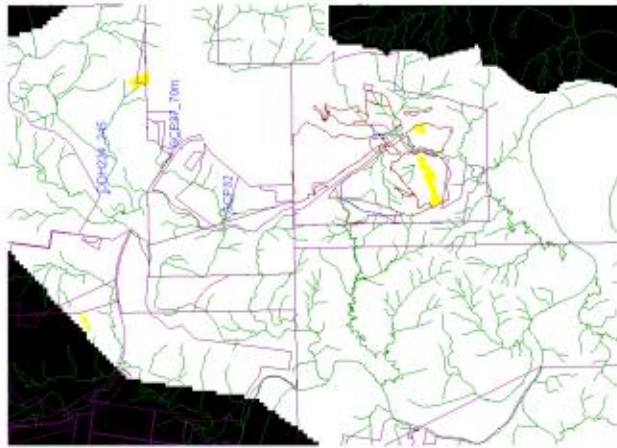
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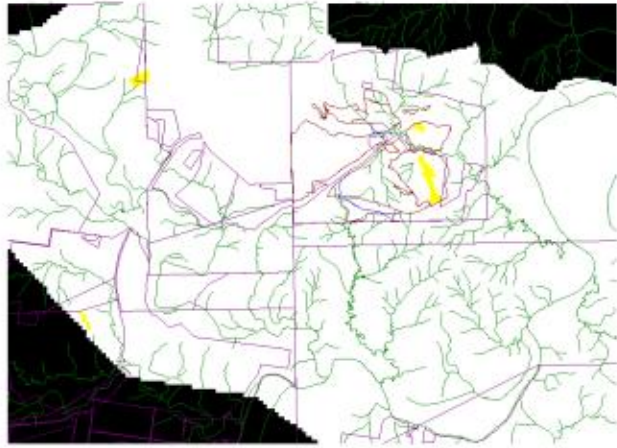
Layer 11



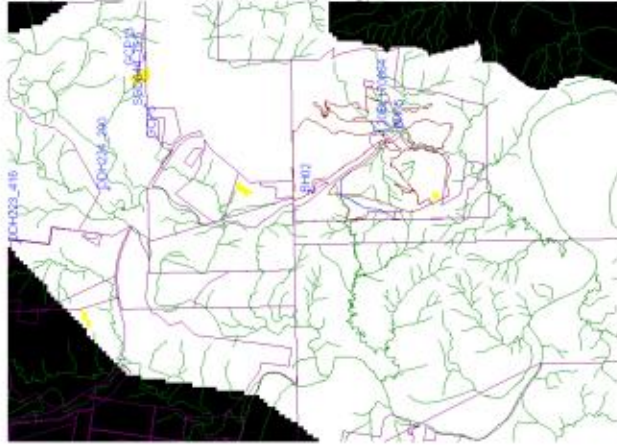
Layer 12



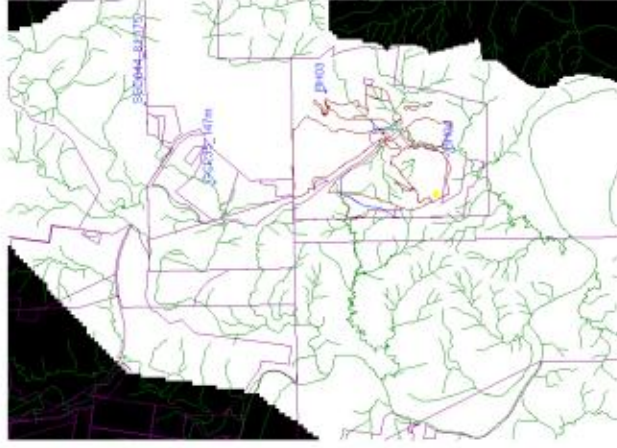
Layer 13



Layer 14

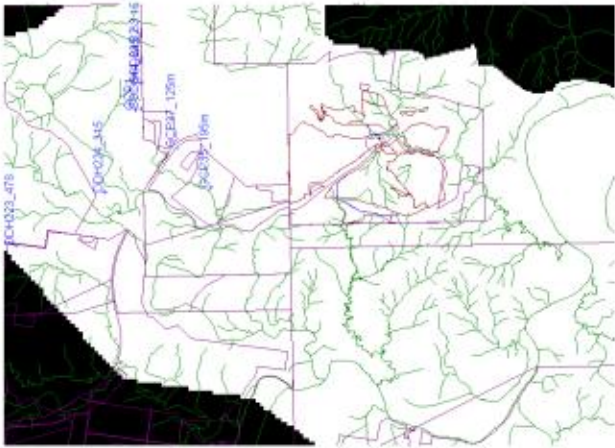


Layer 15

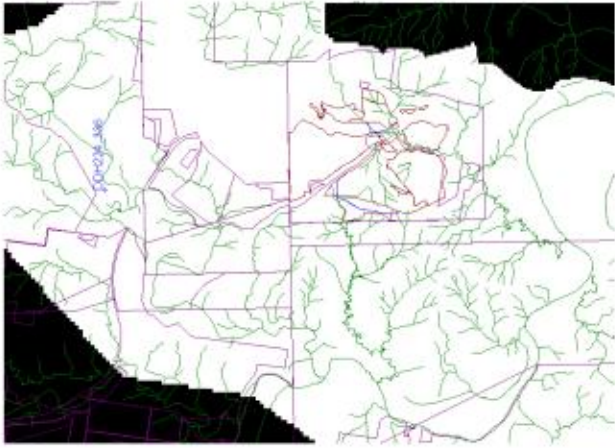


Layer 16

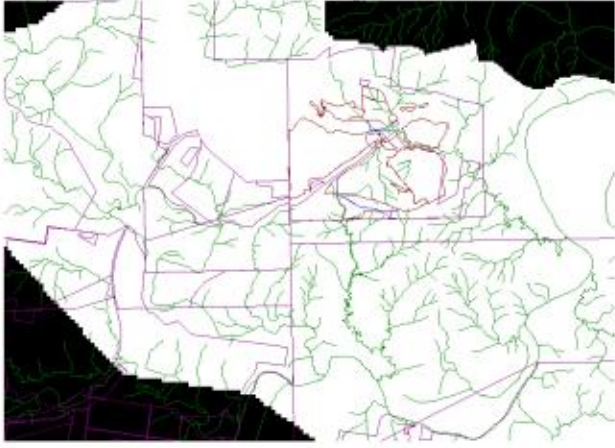
015a_CAL-Apr14_07a.gww



Layer 17



Layer 18



Layer 19