STRATFORDCOAL
Part of the Yancoal Australia Group

Stratford Extension Project
Environmental Impact Statement



APPENDIX A

GROUNDWATER ASSESSMENT



On Thursday 28 June 2012, Yancoal Australia Limited was listed on the Australian Stock Exchange and merged with Gloucester Coal Ltd (GCL) under a scheme of agreement on the same date. Stratford Coal Pty Ltd is now a wholly owned subsidiary of Yancoal Australia Limited. Any reference to GCL in this Appendix should be read as Yancoal Australia Limited.

HERITAGE COMPUTING REPORT

APPENDIX A

GROUNDWATER ASSESSMENT

A HYDROGEOLOGICAL ASSESSMENT IN SUPPORT OF THE STRATFORD COAL PROJECT ENVIRONMENTAL IMPACT STATEMENT

FOR

STRATFORD COAL PTY LTD

By

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Heritage Computing Pty Ltd

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Andrew Fulton	Groundwater Exploration Services Pty Ltd	Report sections

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A1 INTRODUCTION

This report has been prepared for Stratford Coal Pty Ltd (SCPL). SCPL is a wholly owned subsidiary of Gloucester Coal Limited (GCL). SCPL owns and operates the Stratford Coal Mine (SCM) and Bowens Road North Open Cut (BRNOC), collectively referred to as the Stratford Mining Complex. The Stratford Mining Complex is located approximately 100 kilometres (km) north of Newcastle and 10 km south of Gloucester in New South Wales (NSW) (**Figure A-1**).

Seven mining leases (MLs) cover the operations at the Stratford Mining Complex (i.e. ML 1577, ML 1528, ML 1409, ML 1447, ML 1360, ML 1538 and ML 1521) (**Figure A-2**). The Project extensions to the Stratford Mining Complex would require additional Mining Lease Applications (MLAs) 1, 2 and 3 as shown on **Figure A-2**.

Operations at the Stratford Mining Complex commenced in 1995 at the SCM and 2003 at the BRNOC. The current mining operations at the Stratford Mining Complex are approved to produce up to 2.1 and 1 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal at the SCM and BRNOC, respectively.

This report provides a groundwater assessment of the proposed Stratford Extension Project (the Project). The proposed extension would increase the life of the Project by approximately 11 years, to 2024.

The approximate extents of the existing and approved surface development (including open cut, mine waste rock emplacement, soil stockpiles and infrastructure areas) at the Stratford Mining Complex are shown on **Figure A-2**. The approximate extent of the Project surface development (incorporating the existing and approved development) lies within MLAs 1, 2 and 3 as well as within existing MLs, and is also shown on **Figure A-2**.

Mining is currently conducted at the BRNOC and the Roseville West Pit, with backfilling of the BRNOC, Stratford Main Pit and Roseville Extended Pit ongoing. Mining has been completed at the Stratford Main Pit and the Roseville Pit (**Figure A-2**). The Stratford Main Pit is now used for water storage and as an emplacement area for co-disposed rejects from the coal handling and preparation plant (CHPP). The Roseville Pit has been backfilled and rehabilitated (**Figure A-2**).

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

A1.1 SCOPE OF WORK

The key tasks for this assessment were:

- Characterisation of the existing groundwater regime, including identification of groundwater users (including a bore census) and potential groundwater dependent ecosystems in consultation with other relevant specialists.
- Collation and review of baseline geological and groundwater data including:
  - existing SCPL exploration programme (i.e. geological) data;
  - results of searches of NSW Office of Water (NOW) Pinneena database including registered bores and continuous monitoring data;
  - existing water management records at the SCM (past and present);
  - groundwater monitoring data from monitoring programs and investigations undertaken by SCPL at the SCM and surrounding operations (past and present);
  - groundwater quality data from the above monitoring programs and investigations; and
  - other additional geological and regional mapping data available.
- Development and refinement of a conceptual groundwater model as a basis for development and calibration of a numerical groundwater model to predict potential impacts of future mine development on the existing groundwater regime.
- Preparation of a Groundwater Assessment report for inclusion in the EIS that includes the following:
  - assessment of potential mine groundwater impacts (e.g. pit inflows, depressurisation/drawdown, groundwater quality and recharge mechanisms), including assessment of mining scenarios and cumulative impacts with other proposed/approved surrounding mines in the area and coal seam gas (CSG) operations;
  - assessment of post-mining groundwater impacts (e.g. recovery of groundwater levels and groundwater quality); and
  - assessment of any potential groundwater impacts associated with other Project-related infrastructure.
- Development of measures to avoid, minimise, mitigate and/or offset (if necessary) potential impacts on groundwater resources and provide recommendations for future groundwater monitoring for the purposes of model validation and to measure actual impacts on groundwater resources, as the mine develops.

In accordance with the NSW Department of Planning and Infrastructure (DP&I) Director-General's Requirements (DGRs) for the Project, this assessment has been prepared in consideration of the following groundwater-related technical policies, guidelines and plans:

- *National Water Quality Management Strategy Guidelines for Groundwater Protection in Australia* (Agriculture and Resource Management Council of Australia and Australian and New Zealand Environment and Conservation Council [1995]);
- *NSW State Groundwater Policy Framework Document* (NSW Department of Land and Water Conservation [DLWC], 1997);
- *NSW State Groundwater Quality Protection Policy* (DLWC, 1998);
- Draft *NSW State Groundwater Quantity Management Policy* (DLWC, 2002a);
- *NSW Wetlands Policy* (DECCW, 2010);
- *NSW State Groundwater Dependent Ecosystem Policy* (DLWC, 2002b);
- *Water Sharing Plan for the Lower North Coast Unregulated and Alluvial Water Sources 2009* (the WSP) under the *Water Management Act, 2000*;
- *Murray-Darling Basin Groundwater Quality Sampling Guidelines. Technical Report No 3* (Murray-Darling Basin Commission [MDBC], 1997);
- *MDBC Groundwater Flow Modelling Guideline* (MDBC, 2001); and
- *Guidelines for the Assessment and Management of Groundwater Contamination* (NSW Department of Environment and Conservation, 2007).

The specific DGRs of relevance to water resources (including groundwater components) are:

*"**Water Resources – including:***

- *detailed assessment of potential impacts on the quality and quantity of existing surface and groundwater resources, including:*
  - *detailed modelling of potential groundwater impacts;*
  - *impacts on affected licensed water users and basic landholder rights; and*
  - *impacts on riparian, ecological, geo-morphological and hydrological values of watercourses, including environmental flows;*
- *a detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures;*
- *an assessment of proposed water discharge quantities and quality/ies against receiving water quality and flow objectives;*
- *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;*
- *identification of any licensing requirements or other approvals under the Water Act 1912 and/or Water Management Act 2000;*
- *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);*

- *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;*
- *a detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts; and*
- *a detailed flood impact assessment, which identifies impacts on local flood regimes, including:*
    - *an assessment of the potential for flooding to occur in the open-cup pits; and*
    - *any measures proposed to mitigate potential flood impacts."*

The surface water components of the assessment are provided separately in the Surface Water Assessment (Gilbert & Associates, 2012) (Appendix B of the EIS).

In addition, this assessment has considered the mapped biophysical strategic agricultural lands in the region that are defined in the Draft Upper Hunter Strategic Regional Land Use Plan (DP&I, 2012) and the Draft NSW Aquifer Interference Policy – Stage 1 (NSW Department of Trade and Investment, Regional Infrastructure and Services [DTIRIS], 2012).

As part of the assessment process an environmental risk assessment (ERA) (Appendix R of the EIS) was undertaken. This included a facilitated, risk based workshop involving experts across a range of disciplines and experienced SCPL personnel. The risk assessment team included a representative of Heritage Computing. The workshop was conducted on the 19th January 2012 and was facilitated by a risk assessment specialist (Safe Production Solutions Pty Ltd). The objective of the assessment was to identify key potential environmental issues for further assessment in the EIS. The key potential groundwater related issues identified in the ERA (Appendix R of the EIS) are summarised below:

- Potential cumulative groundwater impacts as a result of the AGL Gloucester LE Pty Ltd (AGL) Gloucester Gas Project, proposed Rocky Hill Coal Project and the Project.
- Final void water management and development of groundwater sinks in the long-term.
- Potential groundwater related impacts (e.g. baseflow loss) on Dog Trap Creek, Avondale Creek and associated alluvium.
- Potential reduction in yield in surrounding landholder bores (e.g. Stratford) resulting from the Project.
- Potential leakage of stored mine water in the Stratford East Dam through underlying coal seams to Stratford East Open Cut – resulting in higher groundwater inflows requiring management.

A1.2 PROPOSED MINE DEVELOPMENT

The main activities associated with the development of the Project would include (**Figure A-2**):

- ROM coal production up to 2.6 Mtpa for an additional 11 years (commencing approximately 1 July 2013 or upon grant of all required approvals) including mining operations associated with:
  - completion of the BRNOC;
  - extension of the existing Roseville West Pit; and
  - development of the new Avon North and Stratford East Open Cuts;
- exploration activities;
- progressive backfilling of mine voids with waste rock behind the advancing open cut mining operations;
- continued and expanded placement of waste rock in the Stratford Waste Emplacement and Northern Waste Emplacement;
- progressive development of new haul roads and internal roads;
- coal processing at the existing CHPP including Project ROM coal, sized ROM coal received and unloaded from the Duralie Coal Mine (DCM) and coal recovered periodically from the western co-disposal area;
- stockpiling and loading of product coal to trains for transport on the North Coast Railway to Newcastle;
- disposal of CHPP rejects via pipeline to the existing co-disposal area in the Stratford Main Pit and, later in the Project life, in the Avon North Open Cut void;
- realignments of Wheatleys Lane, Bowens Road, and Wenham Cox/Bowens Road;
- realignment of a 132 kilovolt power line for the Stratford East Open Cut;
- continued use of existing contained water storages/dams and progressive development of additional sediment dams, pumps, pipelines, irrigation infrastructure and other water management equipment and structures;
- development of soil stockpiles, laydown areas and gravel/borrow areas including minor modifications and alterations to existing infrastructure as required;
- monitoring and rehabilitation;
- all activities approved under Development Application (DA) 23-98/99 and DA 39-02-01; and
- other associated minor infrastructure, plant, equipment and activities, including minor modifications and alterations to existing infrastructure as required.

A2 HYDROGEOLOGICAL SETTING

A2.1 RAINFALL AND EVAPORATION

The Project area generally experiences a temperate climate with rainfall in the moderate to high range. Rainfall records are available from Gloucester and Stroud Post Offices (PO), Craven and Commonwealth Bureau of Meteorology (BoM) rainfall gauges, with averages between approximately 985 millimetres (mm) and 1,146 mm per year. Average potential (pan) evaporation (based on the Chichester Dam station) is 1,061 mm per year. The average monthly rainfall and potential evaporation statistics from Gloucester and Stroud POs and Craven stations are summarised in **Table A-1**, and indicate that rainfall over the Project area is typically lower during the winter months with maxima generally experienced during the summer months. **Figure A-3** illustrates the spatial pattern for average annual rainfall.

Table A-1. Monthly Average Rainfall and Daily Evaporation

Month	Monthly Average Rainfall (mm)			Monthly Average Pan Evaporation (mm)
	Craven (Longview)[1] (Site 060042)	Gloucester (PO)[2] (Site 060015)	Stroud (PO)[3] (Site 061071)	Chichester Dam[4]
Jan	125.3	114.8	115.5	139.5
Feb	136.8	121.7	125.2	110.2
Mar	133.9	127.9	145.2	93.0
Apr	85.2	77.3	101.8	69.0
May	88.3	68.6	92	46.5
Jun	79.2	68.4	99	33.0
Jul	40.3	51.4	75.1	40.3
Aug	44.3	46.6	65.4	58.9
Sep	47.4	51.2	63.9	87.0
Oct	79.3	69.2	78.5	108.5
Nov	91.8	83.9	82.1	123.0
Dec	98.5	104.4	102.9	151.9
Annual Average*	**1,050.3**	**985.4**	**1,146.6**	**1,060.8**

Source: BoM, 2011.

* Sum of average monthly records.

1 Craven Station Record 1961 - 2011.

2 Gloucester PO Station Record 1888 - 2011.

3 Stroud PO Station Record 1889 - 2009.

4 Chichester Dam Station Record 1974 - 2011.

The actual evapotranspiration in the district is about 750 mm per annum according to BoM (2011). The definition for actual evapotranspiration is: "*... the ET that actually takes place, under the condition of existing water supply, from an area so large that the effects of any upwind boundary transitions are negligible and local variations are integrated to an areal average. For example, this represents the evapotranspiration which would occur over a large area of land under existing (mean) rainfall conditions*".

Rainfall intensity is a particular feature of the area which has a significant bearing on the moisture levels in catchment soils, and on the hydrological response of the local catchments.

Fluctuations in the groundwater table result from temporal changes in rainfall recharge to aquifers. Typically, changes in the groundwater elevation reflect the deviation between the long-term monthly (or yearly) average rainfall, and the actual rainfall often illustrated by the Residual Mass Curve (RMC).

The groundwater levels recorded during periods of rising RMC are expected to rise, while those recorded during periods of declining RMC are expected to decline. A plot of RMC at Gloucester PO since 1888 is shown in **Figure A-4**, and a detailed view at the Stratford Mining Complex (based on an on-site weather station) is shown in **Figure A-5** since the commencement of BRNOC mining in 2003. The long-term plot at Gloucester (**Figure A-4**) shows major dry periods from 1899 to 1928 and from 1935 to 1949. Since then, less emphatic wet and dry cycles of about 10 years duration have occurred. The short-term plot at SCM (**Figure A-5**) shows a similar pattern to Gloucester for the same period (since 2003), with dry periods from mid-2003 to mid-2004, early 2006 to mid-2007, and mid-2008 to early 2009.

A2.2 TOPOGRAPHY AND DRAINAGE

Surface elevations in the area vary from approximately 100 metres (m) Australian Height Datum (AHD) along the river flats of Avondale Creek and Dog Trap Creek to a maximum of 475 m AHD along the ridge line to the east (**Figure A-6**). Lower ridge lines typically rise between 50 m and 150 m above the drainage floor. The land within the Project area is gently sloping and undulating.

The Stratford Mining Complex is located wholly within the Avon River Catchment. A catchment divide at Craven separates the Avon River Catchment from the Karuah River Water Source to the south.

The main local drainage systems associated with the Project area are Avondale Creek and Dog Trap Creek. Avondale Creek runs northwards and flows into the Avon River. Dog Trap Creek runs to the north-west along the northern boundary of the Stratford Mining Complex. A number of minor ephemeral drainage lines also cross the Project area.

Under normal conditions these streams have low to zero flow for long periods. The water chemistry of Dog Trap Creek suggests that it is fed by groundwater seepage (Parsons Brinckerhoff, 2012). Short duration high peak flows and shallow flooding of alluvial lowlands, principally due to rapid runoff from steeper slopes, can result following heavy rain events.

Surface water hydrology is addressed in detail in Appendix B of the EIS.

A2.3 LAND USE

The Stratford Mining Complex is located in a rural area characterised by cattle grazing on native and improved pastures, along with some poultry farming and other agricultural production. The majority of the Project area and surrounds has been cleared as part of past land use practices.

Other land uses in the district include dairying, timber milling, cropping and recreation.

The Stratford Mining Complex and the DCM (located some 20 km to the south) (**Figure A-1**) are the main mining developments in the area. AGL has commenced CSG exploration in the area, and Gloucester Resources Ltd (GRL) is undertaking investigations for a proposed open cut coal mine approximately 5 km to the north of the Stratford Mining Complex.

A2.4 STRATIGRAPHY AND LITHOLOGY

The Gloucester Basin coal measures are of Permian age and contain conglomerate, sandstone, siltstone, mudstone and coal. The underlying Early Permian and Carboniferous strata, principally tuffs, mudstones and acid volcanics were also folded during formation of the basin. They form two sub-parallel lines of hills, are typically erosion-resistant and form the more prominent ridges to the east and west of the SCM, while the Permian Coal Measures occupy the valley floor between.

Gloucester Coal Measures are separated into two subgroups: (1) Avon Subgroup (Middle Permian) and (2) Craven Subgroup (Upper Permian) (**Figure A-7**). They subcrop over a major portion of the SCM (**Figure A-8**) and consist of coarse and medium grained sandstones with minor siltstone, conglomerate and coal seams. The Craven Subgroup hosts the Cloverdale, Roseville and Bowens Road coal seams, while the Avon Subgroup hosts the Avon coal seam. The underlying Dewrang Group (Early Permian) hosts the Weismantel and Clareval coal seams.

The main stratigraphic units (Figure A-7), from youngest to oldest, include:

- Alluvium/Regolith;
- Craven Subgroup;
- Crowthers Road Conglomerate;

- Leloma Formation - including Bindaboo and Deards coal seams;
- Jilleon Formation - including Cloverdale and Roseville coal seams;
- Wards River Conglomerate;
- Wenhams Formation - including Bowens Road coal seam;
- Speldon Formation;
- Avon Subgroup;
- Dog Trap Creek Formation;
- Waukivory Creek Formation - including Avon coal seam;
- Dewrang Group;
- Mammy Johnsons Formation;
- Weismantel Formation - including Weismantel coal seam;
- Duralie Road Formation - including Clareval coal seam; and
- Alum Mountain Volcanics.

Leloma Formation
The Leloma Formation (formerly Woods Road Formation) contains numerous thin coal seams in upper 200-300 m, particularly within the eastern limb of the syncline. It is characterised by fine-medium sandstone and interbedded siltstone. There are occasional conglomerate lenses which are more prevalent in the syncline's western limb and core area.

Jilleon Formation
The Jilleon Formation contains sandstone, shale, mudstones, and numerous thin coal seams. Significant coal seams within this formation include the Cloverdale Seam (uppermost) and Roseville Seam (with heavy banding in thicker seams).

Wards River Conglomerate
The Wards River Conglomerate is dominantly a conglomerate and sandstone. It thickens rapidly on the western side of the basin but thins (to 15 m) on eastern limb. Along the western margin of the basin, the Wards River Conglomerate occupies the entire Gloucester Coal Measure sequence.

Wenham Formation
The Wenham Formation consists of bioturbated and alluvial plain sediments. Coal is present with the Lower Bowens Road Coal Seam and Bowens Road Seam.

Speldon Formation
This separates the lower Avon Subgroup from the upper Craven Subgroup of the Gloucester Coal Measures. It contains a mixture of bioturbated mudstones, sandstone and poorly sorted conglomerate. It also contains the Glenview Coal Seam.

Dog Trap Creek Formation
Near Stratford the lowest unit of the Dog Trap Creek Formation is a weak laminated mudstone overlain by siltstones, mudstones and sandstones. The upper part of the formation contains the Glenview Coal Seam. As with all other formations the stratigraphic interval occupied by the Dog Trap Creek Formation is represented almost exclusively by conglomerate on the western limb.

Waukivory Creek Formation
The Waukivory Creek Formation contains well developed coal on the eastern limb with major seams including Parkers Road Seam, Valley View Seam, Glen Road Seam, Rombo Seam, Triple Coal Seam, Avon Seam and the Lower Avon Seam. It generally becomes coarser to the west where medium grained lithic sandstones are frequent.

Mammy Johnsons Formation
The Mammy Johnsons Formation is highly compressed and is equivalent to the uppermost formation at the DCM. It generally contains coarse grained lithic sandstones with minor poorly developed coal. The uppermost layer is thick shale.

Weismantel Formation
The Weismantel Formation comprises fine to medium grained sandstones over thick shale covering the Weismantel Seam.

Duralie Road Formation
The Duralie Road Formation forms the base of the Dewrang Group and comprises mostly marine sandstones and conglomerate covering the Clareval Seam.

Alum Mountain Volcanics
The Alum Mountain Volcanics are a rhyolitic rock unit, which is underlain by undifferentiated rocks of Carboniferous age.

A2.5 STRUCTURAL GEOLOGY

The Project coal resource is located within the Permian-aged Gloucester Basin in NSW, within a north-south trending synclinal structure some 40 km long by 13 km wide.

The geological structure in the project area (**Figure A-8**) is dominated by a synclinal structure with the coal outcropping at fairly steep angles (up to 45 degrees (^{o}) dip) on the eastern and western limbs. The eastern flank and southern core of the coal measures are significantly affected by low-angle thrust faulting which has caused coal members in places to be stacked on top of each other, often with several repetitions of the main coal seams. The thrust fault planes are generally parallel to the axis of the syncline and range in inclination from sub-horizontal to 60o. Coal seams in close proximity to the fault planes show highly distorted bedding and cleating but are not intensely brecciated. Normal faulting has also been observed. A significant east-west fault along Bowens Road (with about 60 m throw) separates the Stratford Main Pit from the Bowens Road North Pit.

Both normal and reverse faults are characteristic of the basin. The Gloucester Basin is a fault-controlled depositional trough, and subsequent compression tectonics has induced folding, which has accentuated the dip of the strata and, in places, has resulted in the thrust-faulted repetition of the stratigraphic units.

Independent of the formation present, the overburden is almost always described as variable, and showing consistent variation from south to north. Siltstones and mudstones in the south give way to sandstones to the north. There are variable numbers of weak layers. The coal seams are reported to have reasonably constant thicknesses except on the eastern limb where thrust faulting has thickened and repeated strata, complicated further by steep dips. The Avon Seam for example is about 15 m thick but can have an apparent vertical thickness of 50 m.

A2.6 ALLUVIAL GEOLOGY

A thin and narrow deposit of Quaternary to Recent Age alluvial deposits occurs in association with Avondale Creek and Dog Trap Creek in the vicinity of the SCM (**Figure A-6**). The alluvium consists of silty sands and silts with lenses of gravelly sands and sandy, coarse gravel, particularly towards the base of the alluvium. The gravel lenses correspond to former channel deposits and are evident in the present bed and banks of the creeks.

Monitoring bores in the alluvium are drilled to maximum depths of 4.1 m; other evidence from exploration holes suggests an average thickness of about 9 m for the alluvium, but the maximum thickness is unknown.

To better define the geometry and properties of the Dog Trap Creek alluvium to the immediate north of the Project area, SCPL installed a transect of three shallow boreholes (DTTR1 – DTTR3) and commissioned a transient electromagnetic (TEM) survey (Groundwater Imaging, 2011). The bore transect revealed thin alluvial thickness from 1.5 m to 4 m with a median thickness of 3 m. Bore locations are shown in **Figure A-9**. A TEM survey was also conducted on alluvium associated with Avondale Creek to the south.

The TEM survey results are shown in **Figure A-10** (Dog Trap Creek) and **Figure A-11** (Avondale Creek) in terms of (inverted) true resistivity (ohm.metres) for depths 1 m and 7 m. The white-red tones indicate the most conductive material, either dry weathered rock or alluvium with a high clay content or high salinity. The green-blue tones show more resistive material, generally associated with alluvium at shallow depths.

The TEM survey was successful in mapping a narrow alluvial channel along Dog Trap Creek, with resistivities of 30-100 ohm.metres typical of sandy material. The depth of alluvium was found to be variable but generally less than about 10 m. The TEM survey at Avondale Creek had less continuous coverage (due to access constraints) and was able to track only portions of the alluvial channel. Alluvial resistivities are generally 30-60 ohm.metres in the central part of the survey area and are very low (4-10 ohm.metres) in the southern part, typical of clay.

The inferred alluvial channel outlines, as shown in **Figure A-6**, have been represented in the groundwater model as higher-permeability features.

A2.7 GROUNDWATER BORE CENSUS

Locally, there is little reliance on groundwater bores as a source of water, as agricultural enterprises predominantly rely on surface water sources which are more abundant and generally better quality. The number of privately held bores in the Stratford Mining Complex area and surrounds is low due to the generally poorer groundwater quality, high rainfall and subsequent high rates of runoff. A search of the NOW Pinneena Groundwater Works Database identified 62 registered bores and wells within approximately 5 km of any proposed pit (**Figure A-12**).

The majority (48) of the registered bores are on land owned by GCL/SCPL. One registered bore is on land owned by AGL.

Privately owned bores in the vicinity of the Project include:

- 11 bores in Stratford; and
- One private bore to the south (GW079759 at northing 6438780).

The bores are licensed for stock and domestic use. Another privately owned bore is located more than 5 km from the proposed pits (GW200398) (**Figure A-12**).

A2.8 GROUNDWATER LICENSING

The Project is located in the NSW Lower North Coast Water Management Area.

The Project area is covered by the WSP under the *Water Management Act, 2000* and is located within the Avon River Water Source in the Manning Extraction Management Unit. The WSP applies to all surface water and groundwater (i.e. water beneath the ground surface in the saturated zone) within alluvial sediments.

The WSP provides the detailed rules by which water is preserved for basic landholder uses and the environmental needs of the river, and by which the water available for extraction is shared amongst access licence holders. The WSP contains the rules for managing water allocation accounts, trading of licences and the making of water allocations under the different classes of licence.

Although the Project coal resource is located within the boundary defined in the WSP, the WSP does not apply to the groundwater contained in the fractured rocks and basement rocks within which the Project coal resource exists.

As no water sharing plan applicable to the Project coal resource has commenced, the *Water Act, 1912* remains the relevant Act for approval of groundwater extraction. There are currently no embargoes on applications for groundwater licences applicable to the Project area.

A summary of the existing groundwater licensing regime at the Stratford Mining Complex is provided below. Future groundwater licensing for the Project is discussed in Section A8.2.

Licences Pursuant to Part 5 of the Water Act, 1912

SCPL holds existing groundwater licences (20BL168400; 20BL169101; 20BL169102; 20BL169104) under Part 5 of the *Water Act, 1912* for pit dewatering activities at the Stratford Mining Complex that allows for the extraction of up to 1,021 megalitres (ML) of groundwater in any 12 month period:

- Stratford Main Pit (20 megalitres per annum [ML/annum]);
- Roseville Pit (315 ML/annum);
- Bowens Road North Pit (500 ML/annum); and
- Parkers (Bowens Road West) Pit (186 ML/annum).

Groundwater monitoring boreholes at the Stratford Mining Complex are also licensed which set out conditions of use for the monitoring bores.

Licences Pursuant to Water Management Act, 2000

The water sharing rules for the Avon River Water Source apply to all surface waters, as well as alluvial groundwater that is highly connected to the surface waters (NSW Department of Water and Energy, 2009).

At August 2009, there were 43 surface water licences with a total entitlement of 1,997 ML/annum in the Avon River Water Source. Some trading between water sources is permitted within water sources in the Manning Extraction Management Unit.

The existing operations at the Stratford Mining Complex do not involve extraction of surface waters or alluvial groundwater within 40 m of an unregulated tributary in the Avon River Water Source (e.g. Avondale Creek or Dog Trap Creek). Therefore, no aquifer interference approvals or licences under the *Water Management Act, 2000* are currently required or held by SCPL.

Notwithstanding, SCPL holds existing access licences (WAL 19536; WAL 19514) within the Avon River Water Source:

- 133 Units (Irrigation and Farming); and
- 7 ML (Unregulated River).

A2.9 GROUNDWATER DEPENDENT ECOSYSTEMS

The *NSW State Groundwater Dependent Ecosystems Policy* (DLWC, 2002b) describes the five broad types of groundwater systems in NSW, each with associated dependent ecosystems as follows:

- **Deep Alluvial Groundwater Systems –** occurring under floodplains of major rivers west of the Great Dividing Range (e.g. Namoi, Macquarie, Lachlan, Murrumbidgee and Murray alluvium).
- **Shallow Alluvial Groundwater Systems –** coastal rivers and higher reaches west of the Great Dividing Range (e.g. Hunter, Peel and Cudgegong alluvium, and beds and lateral bars of the lower Macleay, Bellinger and Nambucca Rivers).
- **Fractured Rock Groundwater Systems** – outcropping and sub-cropping rocks containing a mixture of fractures, joints, bedding planes and faults that contain and transmit small and occasionally large amounts of groundwater (e.g. Alstonville Basalt, Molong Limestone and the Young Granite).
- **Coastal Sand Bed Groundwater Systems –** significant sand beds along the coast of NSW (e.g. Botany and Tomago sand beds).
- **Sedimentary Rock Groundwater Systems –** sedimentary rock aquifers including sandstone, shale and coal (e.g. Great Artesian Basin, Sydney Basin and Clarence Moreton Basin).

The Project coal resource is located within the Craven and Avon Subgroups of the Gloucester Coal Measures and the underlying Dewrang Group (refer Section A2.4) which is within the fractured rock groundwater systems of the Gloucester Basin. These fractured rock groundwater systems lie within the boundary defined in the WSP (as described in Section A2.8).

Groundwater resources in the north and north-west of the Project area are associated with alluvial groundwater of unregulated tributaries in the Avon River Water Source (Section A2.8). There are no high priority groundwater dependent ecosystems identified in the WSP in the Avon River Water Source.

The *NSW State Groundwater Dependent Ecosystems Policy* (DLWC, 2002b) also recognises the four Australian groundwater dependent ecosystem types (Hatton and Evans, 1998) that can be found in NSW, namely:

- terrestrial vegetation;
- base flows in streams;
- aquifer and cave ecosystems; and
- wetlands.

Parsons Brinckerhoff (2012), for the AGL Gloucester Gas Project, noted that there are "no known wetlands, lakes or other surface features that are indicative of shallow groundwater processes and possible groundwater dependent ecosystems". Furthermore, they note that the brackish-saline nature of groundwater baseflow is unlikely to be conducive to the sustenance of groundwater dependent ecosystems.

The Flora Assessment (Appendix E of the EIS) concludes that there is no groundwater dependent terrestrial vegetation known to occur within the Project area.

The Aquatic Assessment (Appendix G of the EIS) concludes that there are no aquatic ecosystems or wetlands in the Project area or surrounds that are dependent on groundwater.

Notwithstanding, the potential impacts of the Project on base flows in streams are described in the Surface Water Assessment (Appendix B of the EIS) and potential aquifer ecosystems (stygofauna) are described in the Main Report of the EIS.

A2.10 GROUNDWATER MONITORING

The locations of groundwater monitoring locations (past and present) at the SCM and surrounds are shown on **Figure A-13**. A number of monitoring bore designations have been developed for specific areas of the SCM. Four bores (RB1 – RB4) were installed in compliance with amended Development Consent conditions issued in 1996 for the Roseville Pit. Between the backfilled Roseville Pit / western co-disposal area and the Stratford Main Pit and Waste Emplacement area, groundwater levels are monitored by the GW series introduced in 1999; six groundwater monitoring wells (designated GW1 – GW5 and GW7). GW8 was installed in 2001 at the time of approval of the Roseville void for storage of washery reject material. Following approval for the deposition of rejects within the Bowens Road West North pit in May 2003, monitoring bore BRWN1 was also added to the network in this area. Bores MW1-MW9 were installed around the perimeter of the BRNOC in 2002, and additional bores (MW10-MW12) have followed in 2005-2007. SCPL also monitors a number of bores in Stratford Village and a disused SCPL bore on the eastern edge of the village, as well as bores on the former Griffin and Bramley properties.

The groundwater monitoring program (**Table A-2**) has been developed in accordance with Condition 29(b), Schedule 3 *Environmental Performance Conditions* of the SCM Development Consent.

Table A-2. Groundwater Monitoring Program

Monitoring Locations	Frequency	Parameters
Stratford (Village) Bores	Six monthly	• Water level.
	Annually	• Electrical Conductivity (EC), pH, Oxygen Reduction Potential (ORP), Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Cholride (Cl), Sulphate (SO_4), Iron (Fe), Manganese (Mn), Lead (Pb), Zinc (Zn), Phosphorous (P), Bicarbonate.
MW1 – MW9, MW11, MW12, Griffin	Monthly	• Water level.
	Quarterly	• EC, pH, ORP, Na, K, Ca, Mg, Cl, SO_4, Fe, Mn, Pb, P, Bicarbonate.
GW1-GW3	Quarterly	• Water level.
	Quarterly	• EC, pH, Total Suspended Solids (TSS), ORP, Na, Cl, SO_4, filtered Fe.
RB1 – RB3	Quarterly	• Water level.
	Quarterly	• EC, pH, Na, Cl, SO_4.
GW4, GW5, GW7, GW8, BRWN1	Six monthly	• Water level.
	Six Monthly	• EC, pH, TSS, ORP.

Groundwater monitoring, water level measurements and sample collection, storage and transportation are undertaken in accordance with the procedures outlined in the *Murray-Darling Basin Groundwater Quality Sampling Guidelines* (MDBC, 1997), and in accordance with the mine's Water Management Plan (currently in review). Analysis is undertaken by a laboratory which has been accredited by the National Association of Testing Authorities, Australia (NATA) to undertake testing for the parameters being determined.

Additional groundwater level monitoring and groundwater quality sampling/analysis have also been undertaken as part of the groundwater investigation testwork commissioned by SCPL in 2011.

The lithologies being monitored are summarised in **Table A-3**.

Table A-3. Groundwater Monitoring Lithologies

Lithology	Monitoring Site	Maximum Depth (m)
Alluvium / Regolith / Waste	MW8, MW9, GW1, GW2, GW4, GW5, GW7, RB1, RB2,RB4, CD9, CD10, PBM2	17
Coal	MW1, MW2, MW3, MW4, MW6, GW3, CD6, Griffin, PB1	15
Coal Measures (interburden)	MW5, MW7, MW10, MW11, MW12, RB3,BRWN1, Bagnell Shop, Bramley, Butler, Forbes, Fardell, Germon, Hooker, Mitchell, Nelson, Smith, SCPL Bore, PBM1	95

In addition to the existing monitoring network, SCPL in 2011 installed monitoring standpipes in five locations and vibrating wire piezometers in four holes surrounding SCM and installed pump and monitoring bores in the Avon seam and overlying alluvium adjacent to Dog Trap Creek (**Figure A-13**). Details are provided in **Table A-4** and **Table A-5**. Bore NS246 (5 piezometers) is located to the west of the backfilled Roseville Pit, NS585 (6 piezometers) is located to the east of Stratford Main Pit, GC207 (5 piezometers) is located in the vicinity of Craven and NS256 (5 piezometers) is located in elevated terrain within the south-eastern margin of the mine lease just to the north of Glen Road. The monitored depths and lithologies are summarised in **Table A-4**.

As part of the groundwater investigation programme undertaken in 2011, SCPL also installed standpipe piezometers in PB1, PBM1 and PBM2 for the pumping test, and a number of standpipe piezometers comprising 50 mm Polyvinyl Chloride [PVC] standpipes. Locations are shown in **Figure A-13**. The installation details are summarised in **Table A-5**. The results of the aquifer tests are presented in Section A3.1.

Separate groundwater monitoring networks have been established for neighbouring developments. A network of 13 groundwater monitoring bores has been established for the proposed Rocky Hill Coal Project for GRL (R.W. Corkery & Co. Pty. Limited, 2012), to the north of the Stratford Mining Complex. Parsons Brinckerhoff (2012) has established a network of 22 groundwater monitoring bores for the AGL Gloucester Gas Project for the Stage 1 Gas Field Development Area surrounding and coincident with the Stratford Mining Complex.

Table A-4. Multi-Level Groundwater Monitoring Piezometers

Monitoring Site	Depth (m)	Lithology
Avon North (NS585 Site 12)	(1) 13	(1) Dog Trap Creek Formation
	(2) 27	(2) Dog Trap Creek Formation
	(3) 49	(3) Avon Seam
	(4) 89	(4) Waukivory Creek Formation
	(5) 99	(5) Waukivory Creek Formation
	(6) 119	(6) Waukivory Creek Formation
South Stratford (GC207)	(1) 45	(1) Dog Trap Creek Formation
	(2) 62	(2) Dog Trap Creek Formation
	(3) 84	(3) Avon Seam
	(4) 105	(4) Waukivory Creek Formation
	(5) 125	(5) Waukivory Creek Formation
Stratford East (SS256)	(1) 51	(1) Duralie Road Formation
	(2) 71	(2) Duralie Road Formation
	(3) 101	(3) Clareval Seam
	(4) 121	(4) Lower Duralie Road Formation
	(5) 140	(5) Lower Duralie Road Formation
Roseville West (NS246)	(1) 28	(1) Woods Road Formation
	(2) 69	(2) Cloverdale Seam (CV6)
	(3) 88	(3) Cloverdale Seam (CV8)
	(4) 126	(4) Jilleon Formation
	(5) 148	(5) Roseville Seam (RV1)

Table A-5. Standpipe Piezometer Installation Details

Bore	Coordinates		Drilled Depth	Screened Interval	Formation Screened	Water Level August 2011
	Easting	Northing	(m BGL)	(m BGL)		m BGL
NS581	403775	6445688	37.5	6 - 12m	Avon Seam	0.51
				31.5 - 37.5	Waukivory Creek Formation	2.42
NS581R	403775	6445693	37.5	5 - 9m	Avon Seam	2.01
				31.5 - 37.5	Waukivory Creek Formation	2.4
PBM2	404079	63446426	4	2.5 - 4	Dog Trap Creek Alluvium	1.69
PBM1	404076	6446420	23	18.5 - 23	Dog Trap Creek Formation	1.77
PB1	404080	6446426	49	42 - 48	Avon Seam	1.82
DTTR1	404096	6446520	1.5	N/A	Dog Trap Creek Alluvium	-
DTTR2	404114	6446566	1.9	N/A	Dog Trap Creek Alluvium	-
DTTR3	404136	6446613	2.7	N/A	Dog Trap Creek Alluvium	-
NS584	403399	6445369	37.5	31.5 - 37.5	Dog Trap Creek Formation	21.4
NS584R	403398	6445374	37.5	31.5 - 37.5	Dog Trap Creek Formation	21.44
NS596R	401443	6445501	43.7	39 - 42	Bindaboo Coal Seam	20.4
NS593R	401438	6445499	41	37 - 40	Woods Road Formation	22.6
NS592R	402450	6441865	48	40 - 48	Duralie Road Formation	8.21
GC207R	401130	6441589	48	42 - 48	Waukivory Creek Formation	4.67

Note: BGL = below ground level

A2.11 BASELINE GROUNDWATER LEVEL DATA

A2.11.1 Groundwater Pressure Heads

The vibrating wire piezometer pressure head profiles at NS585, NS246, GC207 and SS256 are displayed in **Figure A-14** and **Figure A-15**, respectively. These plots show pressure head at various sampling depths compared to the expected hydrostatic head profiles. Generally, under pre-mining conditions, pressure heads should plot close to the 45° “hydrostatic line”. Although there is a slight shift from the line in some cases, all data points lie reasonably close to the hydrostatic pressure head line suggesting no significant mining effects have yet been recorded at these locations.

A2.11.2 Spatial Groundwater Level Data

Natural groundwater levels are sustained by rainfall infiltration and are controlled by ground surface topography, geology and surface water elevations. Typically, local groundwater would mound beneath hills and would discharge to incised creeks and rivers. During short events of high surface flow, streams would lose water to the surrounding groundwater system, but during recession groundwater would discharge slowly back into the stream from bank storage. Groundwater flows from elevated to lower lying terrain.

A contour map of inferred groundwater levels has been prepared (**Figure A-16**) for the regional area, based on measurements taken at the SCM, GRL and AGL networks (**Figure A-13**). The SCM measurements are the averages of all data through to 2010 at shallow bores. The GRL measurements are the averages at shallow sites in 2011 (Parsons Brinckerhoff, 2011). The AGL measurements are spot values taken in May 2010 (SRK Consulting, 2010) and average values in the first quarter of 2011 (Parsons Brinckerhoff, 2012). In areas where no data are available, estimates of river and creek water levels have been used to approximate the spatial pattern. No measurements are available in the eastern and western ridge areas.

The direction of groundwater flow in the vicinity of the Stratford Mining Complex is from the south-east to the north-west, and the main groundwater discharge zones are Avondale and Dog Trap Creeks, and the Avon River. A groundwater divide is present in the Craven area (near northing 6442000, **Figure A-16**), which separates the surface catchments and groundwater systems in this part of the Gloucester Basin. South of Craven, groundwater flows generally in a southerly direction and towards Wards River.

The hydraulic gradients are strongly controlled by regional topography with the hills bounding the groundwater flow regime. Gradients flatten appreciably within central parts of the valley due to the natural gradients of watercourses and higher hydraulic conductivity of alluvial sediments associated with the Avondale Creek, Dog Trap Creek and the Avon River.

A2.11.3 Temporal Groundwater Level Data

Monitoring bores have been established in a number of different time frames – generally associated with different stages of development approval. Some bores are off-site (i.e. in Stratford) while others within the mine lease have targeted specific areas during the various operational phases of excavation.

Groundwater levels have been monitored from 1994 at the earliest at locations shown in **Figure A-13**.

Groundwater hydrographs have been grouped into four categories to illustrate possible cause-and-effect relationships with rainfall and mining:

- Coal seam bores (**Figure A-17**);
- Regolith bores (**Figure A-18**);
- Interburden bores (**Figure A-19**); and
- Stratford (village) bores (**Figure A-20**).

The hydrographic plots include the rainfall RMC at the on-site weather station and the starting dates of mining at the BRNOC, Roseville Extended Pit and Roseville West Pit.

The northern coal seam hydrographs (**Figure A-17a**) show a pronounced mining effect at MW6 (north of BRNOC) shortly after mining commenced in 2003, with a drawdown of approximately 8 m from 2007 onwards, this bore responds to weather variations. Bores MW3 and MW4 between the BRNOC and the Roseville Extended Pit show a mild but gradually increasing effect from both the approaching BRNOC and the receding Roseville Extended Pit, and a sharp response at the onset of Roseville West Pit. All bores show responses to rainfall trends.

The southern coal seam hydrographs (**Figure A-17b**) show no response to BRNOC but most have a mild response to Roseville Extended Pit and a sharper response to Roseville West Pit. Responses to weather variations are more subdued than in the north.

All regolith bores (**Figure A-18**) are fairly stable with only mild responses to weather. As bores RB1 and RB2 to the west of the Main Pit show an increasing trend contrary to the rainfall trend, their water levels are likely to be recovering slowly from past mining of the Main Pit. Bore MW9 also has an increasing trend, due probably to enhanced recharge through the adjacent waste emplacement area. Only bores MW9 and MW8 (adjacent to BRNOC) show any effect from BRNOC mining, with drawdowns of about 5 m, and bore RB4 (north of Roseville Extended Pit) is the only one to respond to Roseville mining. Bore RB4 was subsequently removed by mining in 2009.

Interburden bores close to the pits all show a mining response (**Figure A-19**), while the former Griffin and Bramley bores (1.2 km and 2 km respectively from historical [BRNOC and Stratford Main Pit] mining areas) show no mining effects. As bore MW5, with about 10 m drawdown at the commencement of BRNOC, has an almost identical response to MW6 situated in a coal seam, it is likely that MW5 has also intercepted coal. Bore MW7 has a milder 3 m drawdown in 2003. Bore RB3 to the east of the Roseville Extended Pit shows a gradually decline in water level of about 3 m during mining in the Roseville Extended Pit, and a sharp decline of about 4 m when Roseville West Pit commences.

The bores in Stratford Village (**Figure A-20**) have dynamic water level fluctuations of about 2 m, with trends generally in accord with rainfall trends but influenced by local pumping effects. No mining effects have been observed in any privately owned bores in Stratford. An SCPL owned bore at the eastern edge of the village has recorded a mild decline of about 0.5 m from 2003 to 2010.

A2.12 MINE INFLOWS

At the Stratford Mining Complex, records are kept of pumped water volumes from operational pits (BRNOC and Roseville West Pit) and the Roseville Extended Pit. Total pumped volumes are a combination of groundwater inflow combined with rainfall and runoff from the local catchments and waste emplacements, and in some cases water transfers.

Figures A-21 to **A-23** show the equivalent pumping rates at the operational open cuts compared with monthly rainfall. While there is generally good correlation between pumping peaks and rainfall events, the capacity of the pits to hold water will necessarily occasion a delay in the onset of pumping. As a result, the dynamics of pumping are not a good indication of temporal variability in groundwater inflows, but the curves provide an upper limit on groundwater inflow rates.

The trend lines in **Figures A-21** to **A-23** show that pumping rate is about 1 megalitres per day (ML/day) at BRNOC, declining with time; about 0.6 ML/day at Roseville Extended Pit, declining with time; and about 0.3 ML/day at Roseville West Pit but increasing steadily with time.

A2.13 BASELINE GROUNDWATER CHEMISTRY DATA

Table A-6 summarises the EC statistics for laboratory samples analysed from the SCM monitoring network from commencement of sampling to the present day. The median values are generally about 5000 microSiemens per centimetre (µS/cm) in coal (400-7300 µS/cm), about 4500 µS/cm in alluvium and regolith (2200-11700 µS/cm), and about 3500 µS/cm in coal measures interburden (400-7800 µS/cm). Apart from two private bores in Stratford and Bore MW12 (that intercept better quality alluvial waters), most groundwaters are beyond the limit of potable use but on the basis of salinity are suitable for livestock, selective irrigation and other general uses (**Table A-7**).

Table A-6. Electrical Conductivity at SCM Groundwater Monitoring Sites

Bore	Median [µS/cm]	Mean [µS/cm]	Standard Deviation [µS/cm]	Lithology
RB1	8300	8187	1786	Alluvium
RB2	9200	8998	1443	Alluvium
RB3	3930	3754	1248	Wards River Conglomerate
RB4	6550	6323	1817	Alluvium
GW1	4850	4234	1781	Alluvium
GW2	3880	3676	1015	Alluvium
GW3	3395	3597	998	Alluvium
GW4	11700	11303	3651	Alluvium
GW5	3860	4029	1125	Alluvium
GW7	4350	5121	3152	Alluvium
GW8	3850	3706	1027	Wards River Conglomerate
MW1	6100	5450	1471	Roseville Seam
MW2	7338	5919	3647	Bindaboo / Cloverdale / Roseville Seams
MW3	6300	6303	1979	Roseville Seam
MW4	6900	6590	1432	Roseville Seam
MW5	5763	6559	2875	Wards River Conglomerate
MW6	449	989	1011	Roseville Seam
MW7	4090	3911	1506	Wards River Conglomerate
MW8	2400	2422	688	Alluvium

Table A-6. Electrical Conductivity at SCM Groundwater Monitoring Sites (Continued)

Bore	Median [µS/cm]	Mean [µS/cm]	Standard Deviation [µS/cm]	Lithology
MW9	4515	4300	828	Alluvium
MW10	3400	3371	426	Dog Trap Creek Formation
MW11	1276	1273	157	Dog Trap Creek Formation
MW12	437	733	1063	Leloma Formation
Griffin	1600	1599	230	
CD6	4350	4196	820	Roseville Seam
CD9	4170	3903	1217	Alluvium / Regolith
CD10	2240	2806	1193	Alluvium / Regolith
BRWN1	5390	5283	1447	Leloma Formation
Bagnell	1950	1970	198	Leloma Formation
Smith	563	526	171	Leloma Formation
Butler	4050	3976	576	Leloma Formation
Forbes	3530	2325	1245	Leloma Formation
Mitchell	3100	3027	614	Leloma Formation
Glew/Nelson	3595	3502	494	Leloma Formation
Germon	3505	3305	812	Leloma Formation
Hooker	420	425	30	Leloma Formation
Fardell	2600	2449	1362	Leloma Formation
Bramley	7800	7564	860	Wards River Conglomerate
SCPL Bore (Wood St)	6370	6292	906	Leloma Formation

Table A-7. Groundwater Salinity Categories

Potable	Up to 781µS/cm (500 mg/L TDS)+	Suitable for all drinking water and uses.
Marginal Potable	781-2,344 µS/cm (500-1500 mg/L TDS) +	At the upper level this water is at the limit of potable water, but is suitable for watering of livestock, irrigation and other general uses.
Irrigation	2,344-7,813 µS/cm (1500-5000 mg/L TDS) +	At the upper level, this water requires shandying for use as irrigation water or to be suitable for selective irrigation and watering of livestock.
Saline	7,813-21,875 µS/cm (5000-14000 mg/L TDS) +	Generally unsuitable for most uses. It may be suitable for a diminishing range of salt-tolerant livestock up to about 6,500mg/L [~10,150 µS/cm] and some industrial uses.
Highly Saline	> 21,875 µS/cm (14000 mg/L TDS) +	Suitable for coarse industrial processes up to about 20,000 mg/L [~31,000 µS/cm].

+Conversion Factor of 0.64 applied.
Source: MDBC (2005).
mg/L = milligrams per litre.
TDS = total dissolved solids.

The spatial pattern of baseline groundwater salinity is illustrated in **Figure A-24**. This plot consists of median laboratory values at bores in the SCM monitoring network. Best estimates of the sample lithologies are differentiated by symbol, and the magnitude of the concentration is proportional to symbol size. The distribution of salinity is fairly uniform spatially, with the highest value in Avondale Creek alluvium to the south of the SCM, and generally lower values in Stratford closer to the Avon River. There is no clear differentiation between the salinity signatures of different lithologies. In particular, the salinity of alluvial/regolith waters is no better than coal groundwaters.

Groundwater samples taken close to Avondale Creek show generally high salinities in the alluvium and in sub-cropping coal seams. Intermittent seepage of more saline groundwater into the creek has caused gradually increasing salinity of surface water in the downstream direction.

Agricultural use and raw water for drinking are the only beneficial groundwater quality uses. Water quality decline is deemed unacceptable if groundwater extraction causes water quality to decline to a lower beneficial use class. It is clear from **Table A-7** that in the local area most groundwater is neither “potable” nor "marginal potable" in status. Only three bores, all in shallow coal measures interburden, have consistently potable water.

Groundwater in the coal seams is highly mineralized and hard with slightly acidic pH (range 6.2 to 7.0) which is unsuitable for domestic consumption and in some cases unsuitable for stock / irrigation. The total hardness of the coal seam groundwater increases from 300 mg/L to 730 mg/L at depth.

Water quality attributes for all sample groundwaters are summarised in **Table A-8**. Mean salinity (as TDS) is about 3,000 mg/L, while pH averages 6.4.

Table A-8. Water Quality Data at SCM Groundwater Monitoring Sites (July 1981 to December 2010)

Analyte	Unit	Median	Minimum	Maximum	Mean
pH	-	6.7	3.4	8.4	6.4
EC	µS/cm	3,700	425	11,350	4,060
SO_4	mg/L	70	1.7	1,380	158
Ca	mg/L	139	10	1,870	244
Mg	mg/L	50	0.2	238	75.5
Na	mg/L	600	58	2,360	689
K	mg/L	6.5	1.0	22.7	8.1
Cl	mg/L	1,035	73	4,860	1,370
Fe	mg/L	2.2	0.0	110	12.4
Mn	mg/L	0.6	0.0	409	17.1
Zn	mg/L	20	15	550	195
Alkalinity as $CaCO_3$	mg/L	1.0	0.0	350	40.8
TSS	mg/L	14	1.0	3920	377
TDS	mg/L	2,210	200	19,700	3,100
ORP	mV	46.5	6.2	212	60.7
Bicarbonate	mg/L	209	0.0	743	268
Copper (Cu)	mg/L	26	3.0	200	61
Pb	mg/L	0.1	0.0	378	21
P (total)	mg/L	0.3	0.1	312	20

$CaCO_3$ = calcium carbonate.
mV = millivolt.

The median values from commencement of sampling to the present day of the major ions analysed at bores that are monitored routinely are displayed as Schoeller diagrams in **Figure AE-1** for alluvium, **Figure AE-2** for coal seams and in **Figures AE-3** and **AE-4** for interburden (**Attachment AE**). A Schoeller Diagram is a semi-logarithmic plot of the concentrations of the major ionic constituents in groundwater, expressed in milliequivalents per litre. These diagrams have the advantage of showing absolute concentrations at the same time as comparing ionic ratios. If the lines joining adjacent points are parallel from one bore to another, their ionic ratios are the same.

Figure AE-1 shows a similar signature for the two alluvial/regolith bores, with Na+K and Cl as the dominant type. The ionic ratios are almost identical.

Figure AE-2 suggests similar but slightly higher concentrations in coal seam bores as observed in alluvial/regolith bores, with the same Na+K and Cl dominance, but with atypically lower concentrations at site MW6 (at the northern end of Bowens Road North Pit). Ionic ratios are fairly uniform across the sites except for disproportionate lowering in SO_4.

Figure AE-3 shows that the concentrations in interburden bores in the SCPL monitoring network bracket the same range as the alluvium/regolith and coal seam bores. The ionic ratios are uniform at most bores, but sulphate is low in nearly all cases. **Figure AE-4** has a similar pattern for interburden water samples at Stratford but a few bores have anomalous ionic ratios. The same Na+K and Cl dominance is clear.

Parsons Brinckerhoff (2012) has undertaken a substantial water quality assessment for the AGL Gloucester Gas Project based on major ion chemistry, radioactive isotopes and stable isotopes. They found that alluvial groundwater is fresh to brackish, shallow rock groundwater is brackish, and both interburden materials and coal seams contain brackish to slightly saline groundwater. The brackish nature of most samples indicates minimal aquifer recharge from rainfall. The relatively high salinities in alluvium are attributed to high clay content which counters rainfall recharge.

Isotopic dating has revealed that alluvial groundwater is young (less than a few hundred years) while shallow rocks contain water that is several thousand years old (Parsons Brinckerhoff, 2012). They conclude that there can be no more than limited connectivity between the alluvial aquifer and the shallow rock aquifer. Interburden units and coal seams contain groundwater that is much older, in the order of thousands to tens of thousands of years old.

Surface water salinity has been observed to increase as stream flow reduces and groundwater discharge contributions become more prevalent. However, the near-neutral acidity of surface water indicates that baseflow contributions remain small in magnitude (Parsons Brinckerhoff, 2012).

A3 CONCEPTUAL MODEL

A conceptual model of the groundwater regime has been developed based on the review of existing hydrogeological data as described in Section A2, including:

- Gloucester Basin geology mapping (Dungog NSW, 1:100,000 Geological Sheet 9233 [Roberts *et al*., 1991]);
- GCL exploration (geological) data and logs[1];
- NOW Pinneena Groundwater Works Database records;
- Previous hydrogeological assessments/reviews undertaken for the Stratford Mining Complex;
- Water level data from groundwater monitoring programs undertaken at the Stratford Mining Complex and other projects; (e.g. SCPL, 2007; 2008; 2009; 2010; 2011; SRK Consulting, 2010; Parsons Brinckerhoff, 2012; R.W. Corkery & Co. Pty Limited, 2012); and
- Other groundwater investigation testwork (e.g. piezometer installations, pumping and slug/aquifer tests, alluvial boreholes and TEM survey) commissioned by SCPL in 2011.

This assessment has also considered the requirements of the WSP under the *Water Management Act, 2000*.

In addition, this assessment has considered the mapped biophysical strategic agricultural lands defined in the *Draft Upper Hunter Strategic Regional Land Use Plan* (DP&I, 2012).

Based on the above, and consistent with the relevant WSP and conceptual hydrogeological model (and its update) for the AGL Gloucester Gas Project (SRK Consulting, 2010 and Parsons Brinckerhoff, 2012), the data supports two groundwater systems:

- **Fractured Rock groundwater system** - including shallow rock groundwater bearing structures and the Gloucester Coal Measures and underlying Dewrang Group; and
- **Alluvial groundwater system** – including alluvial (narrow channel) sediments of Dog Trap Creek, Avondale Creek and the Avon River.

The conceptual groundwater models for the Project prior to mining and during mining are displayed schematically in **Figure A-25**. The diagrams indicate the dominant recharge and discharge processes acting on the groundwater system under natural conditions, and the effect on the watertable when mining and waste emplacement occur.

1 Refer Enclosure 1.

Recharge to the groundwater systems occurs from rainfall and runoff infiltration, lateral groundwater flow and some leakage from surface water storages and occasionally from streams (e.g. Dog Trap Creek).

Although groundwater levels are sustained by rainfall infiltration, they are controlled by topography, geology and surface water levels in local drainages. Local groundwater tends to mound beneath hills, with ultimate discharge to local drainages and loss by evapotranspiration (ET) through geological outcrops and vegetation where the watertable is near the ground surface (generally less than 2 m to 3 m bgl). The typical depth to water is generally 1-10 m in the vicinity of the Stratford Mining Complex tenements. Greater depths are expected on elevated slopes. Where groundwater levels occur close to surface elevations (e.g. alluvial sediments associated with Avondale Creek), evapotranspiration is a likely occurrence.

During mining, the potentiometric heads in the fractured rock groundwater system will be reduced in the vicinity of the mine, but the watertable will tend to rise beneath emplacement mounds.

The steeply dipping eastern limb of the syncline is made up of complex mixed lithologies and compressed strata with alluvial cover in places. Further to the west, strata become more horizontal and are noticeably coarser. The western limb is not encountered in the mining area.

The dipping coal seams are expected to receive enhanced rainfall recharge where they subcrop or outcrop.

A3.1 HYDRAULIC PROPERTIES

Indicative permeabilities for the various stratigraphic units, summarised in **Table A-9**, have been determined from slug/pumping tests and core measurements conducted by previous studies including Golder Associates (1981, 1982a); Australasian Groundwater and Environmental Consultants Pty Ltd (AGE) (2001); RPS Aquaterra (2011); and Parsons Brinckerhoff (2012). The hydraulic property data collected and reviewed as part of this assessment provide a firm basis for the development of the numerical groundwater model.

Golder Associates undertook a comprehensive groundwater investigation in the area in 1981 and 1982. Although the investigation was centred on the Stratford Main Pit area, it also encompassed the Bowens Road North pit area. A total of 34 rising/falling hydraulic tests and nine pumping tests were undertaken during the 1981 study to determine hydraulic conductivities of the rocks.

Table A-9. Indicative Hydraulic Conductivities of Stratigraphic Units

Unit	Field Horizontal Hydraulic Conductivity Kx (m/day)	Core Horizontal Hydraulic Conductivity Kx (m/day)	Core Vertical Hydraulic Conductivity Kz (m/day)
Alluvium	0.1 - 10		
Leloma Formation	0.05 @40m		
Bindaboo/Cloverdale Seam	0.04 @42m 0.01 @ 270m^	0.07 @ 333m^	
Bowens Road Seam	0.2 - 0.5		
Dog Trap Creek Formation	0.003 - 0.05 @23-50m	8E-5 @20-78m	4E-6 @20-78m
Avon / Triple Seams	0.004 - 0.2 @12-48m		
Waukivory Creek Formation	0.06 @37m	6E-4 @32-53m	2E-4 @32-53m
Mammy Johnsons Formation	0.06 - 0.1	2E-6 @75-131m	2E-7 @75-131m
Weismantel Seam	0.08 - 1.6		
Durallie Road Formation	0.02 @48m 0.04 - 3	2E-6 @144-157m	8E-7 @144-157m
Clareval Seam	0.04 - 0.3		
Deep Coal Seams^	0.09 @ 100m 0.006 to 0.02 @ 300m 0.0005 @ 500m		
Deep Interburden^	4E-5 to 6E-3		

Sources: RPS Aquaterra (2011); Heritage Computing (2009); Golder Associates (1982a);

^ Parsons Brinckerhoff (2012)

m/day = metres per day.

The overburden showed extremely variable hydraulic conductivity, ranging from effectively zero to moderately high. In several boreholes, sharp increases in flow (with depth) were observed. These were interpreted as probably reflecting faulting or closely spaced jointing encountered during drilling. Very little increase in water flow was observed in the floor of the main coal seams. Hydraulic conductivities varied between 0.01 m/day to 2.9 m/day in alluvium. Moderate hydraulic conductivities were observed for some sandstone units.

The pumping tests, each of 72 hours duration, confirmed that the coal seams are the main aquifers. Transmissivities varied between 3.3 square metres per day (m^2/day) and 29 m^2/day and storativities varied between 7.5 x 10^{-5} and 1.1 x 10^{-3}.

AGE (2001) conducted airlift flow testing on seven resource holes in the Bowens Road North pit area. The results indicated that the groundwater inflows from the Bowens Road seam vary from no inflow up to 3 litres per second (L/s). Inflow from overburden typically varied between virtually no flow and 0.01 L/s. Exceptional high inflows (4 L/s) were found occasionally in weathered overburden and coarse grained conglomerate, probably due to localised fracturing of the rocks in vicinity of the tested holes.

The hydraulic conductivity values in **Table A-9** are based mainly on results of the groundwater investigation program undertaken by RPS Aquaterra in 2011 at the Stratford Mining Complex, at locations shown in **Figure A-13**:

- Core testwork - 31 samples from five drill holes [NS497, SS172C, SS181C, SS185C, SS221C];
- Pumping test in the vicinity of Dog Trap Creek [PB1]; and
- Slug tests at five locations.

Recent data has become available from the field groundwater investigation for the AGL Gloucester Gas Project for the Stage 1 Gas Field Development Area, undertaken by Parsons Brinckerhoff (2012).

Overall, field tests have found an hydraulic conductivity for shallow coal generally in the range 0.04 m/day to 0.5 m/day. Deeper coal seams can reduce in hydraulic conductivity down to 10^{-4} m/day. Shallow interburden formations have horizontal hydraulic conductivity values generally in the range 0.003 m/day to 0.1 m/day. Deeper interburden, based on core measurements, has horizontal hydraulic conductivity in the order of 10^{-6} to 10^{-3} m/day and vertical hydraulic conductivity in the order of 10^{-7} to 10^{-4} m/day.

A3.1.1 Core Testwork

The core samples were tested to determine vertical and horizontal hydraulic conductivity. The vertical hydraulic conductivity tests were taken perpendicular to the bedding planes and horizontal hydraulic conductivity was taken parallel to the bedding planes. Care was taken to orient the samples due to the steep dip of bedding planes within the vertical drill holes. Of these, one horizontal and four vertical samples failed under the testing regime. Additional samples were also taken for total porosity.

A summary of the core testwork results is provided in **Table A-10**. These results can be regarded as lower limits for use in model calibration, as cores will not capture the bulk fractured characteristics of a formation. The anisotropy ratio between horizontal hydraulic conductivity (arithmetic mean) and vertical hydraulic conductivity (harmonic mean) varies from 2 to 30.

Table A-10. Summary of Groundwater Investigation Program Core Testwork Results

Unit		Clareval Interburden	Dog Trap Creek Formation	Duralie Road Formation	Mammy Johnsons Formation	Waukivory Creek Formation
Model Layer						
Horizontal	Arithmetic Mean	1.5×10^{-6}	7.5×10^{-5}	3.16×10^{-5}	2.0×10^{-6}	6.3×10^{-4}
	Max	2.48×10^{-6}	5.84×10^{-4}	1.968×10^{-6}	7.37×10^{-6}	2.15×10^{-3}
	Min	6.04×10^{-7}	1.23×10^{-6}	8.42×10^{-7}	1.45×10^{-7}	6.23×10^{-6}
	Sample Count	2	10	8	4	4
Vertical	Harmonic Mean	8.1×10^{-7}	4.1×10^{-6}	1.1×10^{-6}	1.6×10^{-7}	2.2×10^{-4}
	Max	2.00×10^{-5}	1.18×10^{-4}	2.47×10^{-5}	1.59×10^{-7}	2.57×10^{-4}
	Min	4.15×10^{-7}	7.65×10^{-7}	3.18×10^{-7}	1.55×10^{-7}	1.69×10^{-4}
	Count	2	9	7	2	3

Source: RPS Aquaterra (2011)

A3.1.2 Dog Trap Creek Pumping Test

To the north-east of the Project area, on alluvial terraces associated with Dog Trap Creek, three bores (PB1, PBM1, PBM2) were installed 50 m from the creek for a pumping test (**Figure A-9**). PB1 was drilled to 48 m and screened across the Avon Seam from 42 m to 48m. The coal seam was screened and sealed above with a bentonite/cement seal. Two 50 mm PVC monitoring bores were also installed 5 m away from PB1, with PBM1 screened in overburden from 18.5 m to 23 m and PBM2 screened within alluvium associated with Dog Trap Creek from 2.5 m to 4 m depth (**Figure A-9**). A six-day constant rate test at 22 cubic metres per day, and recovery test, was undertaken to establish hydraulic conductivity of the coal seam aquifer and to assess vertical connectivity with the overlying alluvium by monitoring coincident changes in alluvial water levels.

The test was undertaken following heavy rainfall in the preceding week which had resulted in excess surface runoff and a higher than average water level in the nearby Dog Trap Creek. During the pumping test, a recession in stream levels was observed and no rainfall was recorded during the test period. A recession in groundwater levels was also observed within the PBM2 screen within the alluvium and this coincided with the fall in water levels within Dog Trap Creek (**Figure A-26**).

To confirm that the observed recession in PBM2 was not the result of pumping from the deeper coal seam, the test was restarted for a 24 hour period to further test the effect on alluvial water levels due to pumping from the Avon Seam while stream levels in Dog Trap Creek were at normal low levels. No response was seen within this test in PMB2 (**Figure A-27**).

Additional monitoring was undertaken for a three-week period following the coal seam pumping tests to further monitor any potential connection (i.e. recharge) between alluvium and the underlying Avon Seam. Groundwater level loggers were installed within PB1 (Avon Seam) and PBM2 (alluvium). The results are shown in **Figure A-28**, together with rainfall data collected at the SCM meteorological station. The response to a rainfall event was relatively rapid within both the alluvium and Avon Seam. As expected, there is some connection between alluvium and the coal seam which is likely to occur where the Avon Seam subcrops within the extent of Dog Trap Creek or its associated alluvium; however, there is very limited direct vertical hydraulic connection between the coal seam and the alluvium through the overburden.

The pumping test interpretation record is presented in **Figure A-29**.

A3.1.3 Slug Tests

Slug tests (including low-yield short-term pumping) were conducted at five locations as shown in **Figure A-13**. Tests were undertaken to assess the hydraulic conductivity of the selected interburden strata and coal seams. A summary of the results is provided in **Table A-11**.

Table A-11. Summary of Pumping and Slug Test Results

Bore	Depth (m)	Screened Interval (m)	Formation Screened	Calculated Hydraulic Conductivity (m/day)
NS581A	12	6 - 12m	Avon Seam	0.004
NS581B	37.5	31.5 - 37.5	Waukivory Creek Formation	0.06
NS581RB	37.5	31.5 - 37.5	Waukivory Creek Formation	0.06
PBM2	4	2.5 - 4	Dog Trap Creek Alluvium	10
PBM1	24	18.5 - 23	Dog Trap Creek Formation	0.04
PB1	48	42 - 48	Avon Seam	0.22
NS584	37.5	31.5 - 37.5	Dog Trap Creek Formation	0.003
NS596R	42	39 - 42	Bindaboo Seam	0.04
NS593R	40	37 - 40	Leloma Formation	0.05
NS592R	48	38 - 48	Durallie Road Formation	0.02
GC207R	50	44 -50	Dog Trap Creek Formation	0.05

Source: RPS Aquaterra (2011)

Samples of slug test interpretation records are presented in **Figure A-30** to **A-32**. A suite of published analytical methods (Kruseman and de Ridder, 1991) was used by RPS Aquaterra (2011) to analyse the test data from the piezometers. The following methods were used in the analysis:

- Jacob's straight-line method for unsteady flow in a confined aquifer.
- Theis's Recovery method, which is derived for confined aquifers.
- Theis's Distance Drawdown method, which is derived for confined aquifers.
- Bouwer-Rice and Hvorslev solutions, for analysis of falling head slug test data.

Roseville West Pit Extension

Testing localities within the Roseville West Pit Extension area included NS593R and NS596R (**Figure A-13**). Test targets included the Leloma (Woods Road) Formation and the Bindaboo Coal Seam.

Avon North Open Cut

Testing localities within the Avon North Open Cut area included NS584 located just to the northeast of Stratford Main Pit and NS581 to the north of Wenham Cox Road (**Figure A-13**). Slug tests were also conducted on the monitoring bores at the pumping test location on the alluvial floodplain associated with Dog Trap Creek north of Wenham Cox Road (**Figure A-13**).

At NS584, the test target was the Dog Trap Creek Formation. Two holes were drilled with 50 mm PVC installations screened in the Dog Trap Creek sandstone. At NS581, test targets included the Waukivory Creek Formation and the Avon Seam. Two 125 mm holes were drilled with paired 50 mm PVC installations screened in the Waukivory Creek sandstone and overlying Avon Seam. A low yielding short-term (1 hour) constant rate pumping test within the Waukivory Creek Formation and a distance drawdown analysis were undertaken.

Stratford East Open Cut

A single standpipe was installed adjacent to GC207 in the vicinity of Craven (**Figure A-13**) and was screened in the interburden complex within the Dog Trap Creek Formation. Similarly, a single standpipe installation was installed adjacent to the existing SS256R and was screened in the interburden of the Duralie Road Formation.

A3.1.4 Depth Dependence

All field investigations to date have provided estimates of horizontal hydraulic conductivity (K_x) at depths less than 50 m and, apart from core measurements there are no known estimates for vertical hydraulic conductivity (K_z). The field hydraulic conductivities in **Table A-9** are relatively high due to fractured/weathered materials at shallow depth. In general, hydraulic conductivities of the rock strata decrease with depth.

Figure A-33 displays a published depth dependence for Stratford coal seams in the Gloucester Basin to a maximum depth of 900 m (Smith, 2001). There is a linear logarithmic decrease in permeability from a maximum value near surface of about 500 millidarcies (mD) (<0.5 m/day) to a minimum value of 0.01 mD (~10^{-5} m/day) at 900 m depth.

Figure A-34 places the Gloucester Basin coal seam permeability decrease into a broader context by comparing it with Hunter Valley and Sydney Basin lithologies (coal seams, sandstones, sills, interburden) (Tammetta, pers. comm., 2009). There is a distinct decay with depth to 800 m but scatter is substantial at all depths, particularly near ground surface where coal seam hydraulic conductivity can range from 0.001 to 10 m/day.

As the Project open pits would extend to a maximum depth a little less than 200 m below surface, some variation of hydraulic conductivity with depth can be expected in each formation. However, the near-surface hydraulic properties are of most relevance to this investigation.

The hydraulic property measurements and expected variations with depth have been used in the development of the numerical groundwater model as an initial set of hydraulic conductivity values.

A4 GROUNDWATER SIMULATION MODEL

A4.1 MODEL SOFTWARE AND COMPLEXITY

Groundwater modelling has been conducted in accordance with the MDBC Groundwater Flow Modelling Guideline (MDBC, 2001). As this is mostly a generic guide, there are no specific guidelines on special applications such as coal mine modelling.

Under the modelling guideline, the model is best categorised as an Impact Assessment Model of medium complexity. The guide (MDBC, 2001) describes this model type as follows:

> *Impact Assessment model - a moderate complexity model, requiring more data and a better understanding of the groundwater system dynamics, and suitable for predicting the impacts of proposed developments or management policies.*

Numerical modelling has been undertaken using the Groundwater Vistas (Version 6.11) software interface (Environmental Simulations Inc, 2011) in conjunction with MODFLOW-SURFACT (Version 4) distributed commercially by Hydrogeologic, Inc. (Virginia, USA). MODFLOW-SURFACT is an advanced version of the popular MODFLOW code developed by the United States Geological Survey (McDonald and Harbaugh, 1988). MODFLOW is the most widely used code for groundwater modelling and is considered an industry standard.

MODFLOW-SURFACT is a three-dimensional modelling code that is able to simulate variably saturated flow and can handle desaturation and resaturation of multiple aquifers without the “dry cell” problems of Standard-MODFLOW. This is pertinent to the dewatering of layers adjacent to open pit coal mines. Standard-MODFLOW can handle this to some extent, but model cells that are dewatered (reduced below atmospheric pressure) are replaced by “dry cells”.

The model complexity is considered adequate to simulate contrasts in hydraulic properties and hydraulic gradients that may be associated with changes to the groundwater system as a result of the Project.

A4.2 PRIOR MODELLING

A numerical model of the Stratford Main Pit was developed by Golder Associates in 1982, using proprietary finite element software called AFPM that was developed in-house by Golder Associates (1982a, 1982b). A conference paper (Marlon-Lambert, Manoel & Friday, 1979) which describes the development of the software is included in Golder Associates (1982a). The software pre-dates the introduction of the IBM personal computer (circa 1982) and standard MODFLOW groundwater modelling software (circa 1985). The objective of the modelling study was to assess mine water inflows. Anticipated pit inflows were in the range 0.7 to 1.0 ML/day.

An uncalibrated numerical model of the Bowens Road North Project was developed by AGE in 2000, and was reported in January 2001 as Appendix C to the EIS report. The model was developed in Standard-MODFLOW within the PMWIN (version 3) graphic user interface. A full audit of this model was undertaken by Merrick and Dent (2008). The objectives of the modelling study included assessment of potential groundwater inflow rates to the pit, quantification of dewatering requirements, and assessment of impacts on the groundwater resource and users. The stratigraphy was represented by two layers only (overburden and the Bowens Road North coal seam), with no consideration of alluvium. The layers were uniform across the model extent except for increasing elevations at the eastern edge of the pit. The model extent did not include the neighbouring Main Pit or the Roseville Pit, on the basis of expected compartmentalisation by faulting. At the time of modelling, there was limited groundwater level data available. Despite that, a plausible regional groundwater elevation contour map was prepared from seven monitoring bores and six open exploration holes.

Based on coal hydraulic conductivity of 2.4 m/day, the AGE (2001) model predicted pit inflows of about 3 L/s [0.26 ML/day] initially, rising to 13 L/s [1.1 ML/day] and finishing at 11 L/s [0.95 ML/day] at the end of year 7. The only guidance on the plausibility of pit inflow magnitudes at the time was the experience at the Roseville Pit of 10-15 L/s [0.9-1.3 ML/day], and Stratford Main Pit inflows dropping from 25-30 L/s [2.2-2.6 ML/day] initially to a fairly steady 4 L/s [0.35 ML/day].

A model of the DCM 20 km to the south was developed by Heritage Computing (2009) using MODFLOW-SURFACT software. The target coal seams were the Weismantel Seam and the Clareval Seam which occur at the bottom of the stratigraphic sequence at Stratford. The model predicted pit inflows in the order of 0.3 ML/day at the completion of mining, ranging between 0.2 and 1.0 ML/day over the nine years of mining.

A4.3 MODEL EXTENT

The regional model extent was selected for this Project to take into account distributed mining at four open cut pits and, originally, to include the cumulative impacts of CSG production. When the details of the proposed Rocky Hill Coal Project were made available in February 2012 (R.W. Corkery, 2012), the proposed open cut mining operations were shown to be coincident with the northern extent of the model, and therefore have also been included in the cumulative impact assessment.

The model extent, indicated in **Figure A-6** and **Figure A-16**, extends between MGA Eastings 392325 and 407500 and MGA Northings 6435000 and 6452000. The area of coverage is 15.2 km east-west by 17 km north-south, of which 179 square kilometres is active.

A4.4 MODEL LAYERS

Thirteen layers are conceptualised in **Table A-12** for the purpose of numerical modelling. Layers 8-13 are equivalent to layers 2-7 in the Duralie model (Heritage Computing, 2009).

Table A-12. Numerical Model Layers

Layer		Lithology	Geology Key	Lumped Formations
1		**Alluvium**	Qa	
1		**Regolith/Weathered Permian**		
2		**Leloma Formation**	Plc/Pll/Pllj	Crowthers Road Conglomerate / Woods Road Formation
3		**Bindaboo/Cloverdale/Roseville Seams**	Plj	Jilleon Formation
4		**Wards River Conglomerate**	Plw	
5		**Bowens Road Seam**	Plh	Wenhams Formation
6		**Dog Trap Creek Formation**	Plp/Plt	Speldon Formation
7		**Avon / Triple Seams**	Pli	Waukivory Creek Formation
8		**Waukivory Creek Formation**	Ply/Ple	Mammy Johnsons Formation Weismantel Formation
9		**Weismantel Seam**	Ple	Weismantel Formation
10		**Upper Durallie Road Formation**	Pld	
11		**Clareval Seam**	Pld	Durallie Road Formation
12		**Lower Durallie Road Formation**	Pld	
13		**Alum Mountain Volcanics**	Pea	

The top layer comprises alluvium, regolith or weathered overburden in different parts of the model area. The odd-numbered layers represent coal seams targeted by different open cut pits, with interburden lithologies forming the even-numbered layers. The eastern and western limits of the active model area were chosen to coincide with topographic ridgelines and outcropping Alum Mountain Volcanics.

Where multiple seams occur in the one model layer, the layer is given the aggregate thickness of the coal seams/plies. Interburden between the plies is allocated to the overlying sandstone/siltstone aquitard layer.

A4.5 MODEL GEOMETRY

The model domain is discretised into 1.35 million cells (of which 930 thousand are active) comprising 340 rows and 306 columns (**Figure A-35)**. The dimensions of the model cells are uniform at 50 m.

The geometry of the coal seams is defined by the floor elevations of named seams (Bindaboo/ Cloverdale/Roseville, Bowens Road, Avon/Triple, Weismantel and Clareval). The layer thickness is the aggregate of recorded coal thicknesses within the designated groupings.

A comprehensive geological model for the entire groundwater model area was available. Coal ply thicknesses and structure contours for the floor of each model layer were provided by SCPL.

Where layers pinch out or are eroded, the layers must continue laterally in a MODFLOW model and therefore have a notional thickness but are given properties associated with the underlying lithology.

Figure A-35 shows that the sedimentary column has a basal elevation of about -1800 m AHD in the vicinity of Stratford.

Representative model cross-sections through each of the four pits are displayed in **Figure A-36** for west-east profiles and in **Figure A-37** in the south-north direction. The coal layers (black and green) have sudden changes in elevation due to severe dips and faulting, and are clearly synclinal in form.

A4.6 MODEL STRESSES AND BOUNDARY CONDITIONS

The elevated basement forms natural boundaries along the eastern and western edges of the model, approximated as no-flow boundaries due to the exposure of low-permeability rocks of Carboniferous Age.

The northern and southern model edges are arbitrary transects across the valley at distances of 5-6 km from the nearest future mining. No specified boundary conditions are applied here, as the watertable contour map (**Figure A-16**) suggests that lateral flow is primarily parallel to the boundaries. As there will be lateral throughflow in the alluvial sediments, the model relies on "river" cells in layers 1 and 2 to receive groundwater discharge at both northern and southern edges.

As there is a natural groundwater divide near Northing 6441000, the southern model boundary could have been moved farther northward. However, as future Stratford East mining is planned to approach this divide, it was considered prudent to extend the model in order to check if mining effects might cross the divide.

Major and minor streams are established as “river” cells in model Layer 1 (and occasionally Layer 2, depending on local ground elevations) using the MODFLOW RIV package (**Figure A-35a**). The RIV package allows water exchange in either direction between the stream and the groundwater system, unless the river stage is set equal to the bottom elevation of the streambed layer in the model river. This has been done for minor streams so that these cells will accept baseflow when the watertable breaches the bed elevation of the stream, but they will never provide a source of water for the groundwater system. The river conductances vary from 25 to 100 m^2/day[2].

River cells along the Avon River are assigned water levels that are 0.5 m below topographic surface. The bottom of the river cells is varied linearly from a depth of 0.5 m in the upper reaches to 2.0 m in the lower reaches.

Drain cells (i.e. river cells with stage equal to the bottom elevation of the streambed layer) are assigned head values 0.1 m below topographic surface. Based on observations made in the field, the river stages for Dog Trap Creek and Avondale Creek are defined as 2 m below topographic surface, and the streambed elevation is set at 0.5 m below the stage.

The Stratford East Dam and the Return Water Dam also are represented as "river" cells.

“Drain” cells using the MODFLOW DRN package are used to represent mining in Layers 3, 5, 7, 9 and 11. Invert levels are generally 0.1 m above the floor of the lowest mined coal seam, and 0.1 m below base levels for layers overlying the mined seam (to avoid artificial perched conditions with SURFACT software). The drain conductance value was set at 1,000 m^2/day to virtually eliminate any resistance to flow.

Rainfall infiltration has been imposed as a percentage of actual rainfall (for transient calibration) or long-term average rainfall (for prediction simulations) across four zones (**Figure A-34**):

1. Alluvium associated with drainage channels;
2. Alluvium associated with broader floodplains;
3. Regolith; and
4. Elevated Volcanics.

The recharge rates were determined during model calibration.

[2] Leakage coefficient approximately 0.05 to 0.2 d^{-1}.

In the vicinity of the Stratford Mining Complex, there is no historical groundwater production other than stock and domestic use. While this occurs at the Stratford bores, and will affect the character of the monitored groundwater hydrographs, the usage is too small and too irregular for inclusion in the model. Large-scale groundwater pumping associated with CSG production in the Gloucester Valley is included in one of the prediction simulations to assess cumulative impacts. Rather than impose specified pumping rates, the model has applied conventional drain cells with inverts set at one of two target water depressurisation levels that are required to allow gas to flow.

Evapotranspiration is applied uniformly using MODFLOW's linear function, with a maximum rate of 4 x 10-4 m/day (about 146 millimetres per annum [mm/annum]) and an extinction depth of 2 m.

A4.7 HYDRAULIC CONDUCTIVITY ZONE CONFIGURATION

Hydraulic conductivity in the vicinity of the Stratford Mining Complex was initially discretised into 17 unique zones to allow for reducing hydraulic conductivity with depth, as illustrated by field and laboratory measurements in **Figure A-33** and **Figure A-34**. Hydraulic conductivity zone 1 represents alluvial deposits in the vicinity of surface water features. Hydraulic conductivity zones 2 to 7 represent the interburden rock material surrounding the coal seams. The remaining hydraulic conductivity zones, 8 to 17, represent the coal seams.

Within the rock and coal model layers, hydraulic conductivities were assumed to decrease with depth in 100 m increments (**Table A-13**). The entries in this table are based on the following formulas for K in m/day units and depth in metres below ground surface:

- Rock K = 0.0057 exp(-0.025 x depth).
- Coal K = 0.4211 exp(-0.014 x depth).

The shallower rock and coal hydraulic conductivities are based on site-specific hydraulic conductivity measurements. In the absence of hydraulic conductivity measurements with depth, minimum rock and coal hydraulic conductivities were assumed to be 1×10^{-7} m/day and 1×10^{-6} m/day, respectively. For configuration purposes, initial vertical hydraulic conductivity was assumed to be one-tenth of horizontal hydraulic conductivity.

The individual horizontal and vertical hydraulic conductivity zone values were adjusted during model calibration, at which time additional zones were introduced for finer resolution spatially.

Table A-13. Hydraulic Conductivity Zone Descriptions and Initial Values

Zone	Description	Kx [m/day]	Kz [m/day]
1	Alluvium	1.00e+000	1.00e-001
2	Rock: 0 to 100 m depth	5.00e-003	5.00e-004
3	Rock: 100 to 200 m depth	4.07e-005	4.07e-006
4	Rock: 200 to 300 m depth	6.72e-006	6.72e-007
5	Rock: 300 to 400 m depth	1.11e-006	1.11e-007
6	Rock: 400 to 500 m depth	3.04e-007	3.04e-008
7	Rock: 500 m plus depth	1.00e-007	1.00e-008
8	Coal: 0 to 100 m depth	2.20e-001	2.20e-002
9	Coal: 100 to 200 m depth	5.43e-002	5.43e-002
10	Coal: 200 to 300 m depth	1.34e-002	1.34e-003
11	Coal: 300 to 400 m depth	3.30e-003	3.30e-004
12	Coal: 400 to 500 m depth	8.14e-004	8.14e-005
13	Coal: 500 to 600 m depth	2.01e-004	2.01e-005
14	Coal: 600 to 700 m depth	4.95e-005	4.95e-006
15	Coal: 700 to 800 m depth	1.22e-005	1.22e-006
16	Coal: 800 to 900 m depth	3.01e-006	3.01e-007
17	Coal: 900 m plus depth	1.00e-006	1.00e-007

A4.8 MODEL VARIANTS

The modelling approach has necessitated the development of five model variants:

A. *Steady-State calibration model*.
Calibration of shallow aquifer permeabilities against the inferred recent groundwater levels in **Figure A-16**.

B. *Transient calibration model*.
Thorough calibration of groundwater system properties against hydrographic responses at Project monitoring bores (**Figures A-17** to **A-20**) for dynamic rainfall recharge and static stream water levels.

C. *Transient prediction model*.
Simulation of the annual progression of open cut mining, with prediction of potential impacts of mine development on the groundwater regime (particularly stream-aquifer interaction, alluvium-coal interaction and groundwater dependent ecosystems) and prediction of mine inflow rates. Two versions of the model were developed:

1) Project open cut mining (excluding neighbouring operations); and
2) Project open cut mining with CSG production and the proposed Rocky Hill Coal Project open cut mining to assess the cumulative impacts of the Project in association with other major stresses.

D. *Transient recovery model*.
Simulation of dynamic groundwater levels for the final landform and evolving pit voids (Project only).

E. *Steady-State recovery model*.
Simulation of equilibrium groundwater levels for the final landform and final void water levels (Project only).

A4.9 STEADY-STATE CALIBRATION

The model was set up and initially run in steady-state mode to replicate the broad groundwater elevation and hydraulic gradient spatial patterns shown in **Figure A-16**, inferred from field measurements and drainage controls.

Calibration was performed against 39 shallow head targets averaged at each site over the monitoring record to 2010, concentrated near past and current mining and in Stratford.

Automated calibration using PEST software was done iteratively both before and after transient calibration, initially on the full model and subsequently on a sub-model that circumscribed the monitoring network. The simulated watertable contours are shown in **Figure A-38a** for comparison with the inferred actual pattern in **Figure A-16**.

This preliminary model reproduced the broad features of the groundwater system, in particular the groundwater divide and the primary groundwater flow directions.

A4.10 TRANSIENT CALIBRATION

Calibration was conducted on model variant B for the time period January 2003 to July 2010 for 90 monthly stress periods[3]. The starting date precedes the commencement of mining at the BRNOC in March 2003, and the duration of the calibration period includes commencement of the Roseville Extended Pit in June 2006 and the Roseville West Pit in June 2009.

Initial heads were provided by preliminary steady-state simulation.

In all, 1,145 target heads were established for 39 sites. Calibration was conducted manually. A separate verification process was not conducted as the full length of mine monitoring records was required for calibration of hydrographs exhibiting mining effects.

Head targets were allocated to layer 1 (12 sites; 370 data points), layer 2 (12 sites; 165 data points), layer 3 (8 sites; 415 data points), layer 4 (5 sites; 127 data points) and layer 6 (2 sites; 68 data points) - all equally weighted.

[3] A stress period is the timeframe in the model when all hydrological stresses (e.g. rain recharge, river stage, etc.) remain constant.

Pit inflow limits for BRNOC, Roseville Extended Pit and Roseville West Pit were also taken into consideration during calibration. The upper limits on pit inflows are indicated in **Figures A-21** to **A-23**.

Where aquifer properties differ from the initial values in **Table A-13**, the modified or introduced values are listed in **Table A-14**. Full distributions and databases for hydraulic and storage properties are given in **Attachment AA**. Shallow coal seams were found to have horizontal hydraulic conductivities (Kx) ranging from 0.04 to 1 m/day, in good agreement with prior field estimates. Shallow vertical hydraulic conductivities (Kz) range from 0.01 to 0.1 m/day.

Table A-14. Calibrated Aquifer Properties

Zone	Description	Kx [m/day]	Kz [m/day]	Sy [-]	S [-]
1	Colluvium/Regolith	0.2	2.0e-003	0.01	-
18	Spoil (Roseville Pit)	1	1	0.1	5.0e-003
19	Alluvium (Channels)	10	1	0.2	-
20	Alluvium (Flood Plain)	0.2	2.0e-003	0.05	-
21	Western Co-Disposal	0.01	1.0e-004	0.01	-
26	Colluvium/Regolith (Village)	2.35	0.041	Zone 1	-
2	Rock: 0 to 100 m depth	6.78e-003	7.47e-004	5.0e-003	1.0e-004
32	Leloma Formation	1.0e-005	7.15e-004	5.0e-003	1.0e-004
33	Leloma Formation (Village)	6.78e-005	1.12e-003	5.0e-003	1.0e-004
8	Coal: 0 to 100 m (AN, SE)	0.05	0.01	0.01	5.0e-004
23	Coal: 0 to 100 m (BRN)	0.4	0.05	0.01	1.0e-003
27	Coal: 0 to 100 m (BRN)	1	0.1	0.01	1.0e-003
28	Coal: 0 to 100 m (R)	0.04	0.01	0.01	1.0e-003
9	Coal: 100 to 200 m (AN, SE)	0.02	0.01	5.0e-003	1.0e-004
10	Coal: 200 to 300 m (SE)	1.28e-004	1.0e-003	5.0e-003	1.0e-004
11	Coal: 300 to 400 m (SE)	2.47e-005	2.99e-004	5.0e-003	1.0e-004

Note: AN = Avon North pit; SE = Stratford East pit; BRN = Bowens Road North pit; R = Roseville pits; Sy = specific yield; S = storage coefficient

Rainfall recharge is applied to five distinct zones, as shown in Attachment AA. The adopted values for rainfall recharge expressed as percentages (%) of rainfall recorded at Craven (Station 060042) are:

- Flood Plain Alluvium [Zone 2]: 8%
- Channel Alluvium [Zone 3]: 8%
- Colluvium / Regolith [Zone 1]: 1%
- Western Co-Disposal Area [Zone 5]: 3%
- Hills [Zone 4]: 0.25%

Open cut drain cells were activated in the model wherever pit floor contours breached the top of a coal seam layer (Layer 5 for the BRNOC; Layer 3 for the Roseville Extended Pit), and were deactivated when backfilling restored the ground level above the roof of the model seam. As the pits retained low elevations (well below natural surface) throughout the calibration period, no time-varying changes were made for spoil properties (hydraulic conductivity and recharge). The rising water level in the Stratford Main Pit was simulated by a gradually rising drain invert level up to a maximum of 75.3 m AHD at June 2010. Drain conductance was set at 1000 m^2/day for each pit.

A4.10.1 Transient Calibration Performance

The simulated pit inflows illustrated in **Figure A-39** for the BRNOC and in **Figure A-40** for the combined Roseville pits, are consistent with recorded pit pumping rates, which include sources of water other than groundwater. The recorded pumped volumes are a combination of groundwater inflow, rainfall runoff, seepage from waste emplacements and (in some cases) water transfers. The large peaks represent surface water inflow from pit runoff and direct rainfall. The lower continuous values are more representative of the groundwater inflow component. The simulated groundwater inflows are not meant to fit the "recorded trend" but should have a magnitude similar to the lowest pumping rates.

The simulated pit inflow shown in **Figure A-41** for the Stratford Main Pit is consistent with rates reported in Golder Associates (1982b) and AGE (2001). For the calibration period, the average simulated rates are 0.28 ML/day for the BRNOC, 0.26 ML/day for the combined Roseville pits and 0.37 ML/day for the Main Pit.

A scattergram of simulated versus measured heads in **Figure A-42** demonstrates good agreement across the whole range of measurements. There is no bias towards overestimation or underestimation.

The overall performance of the transient calibration is quantified by a number of statistics in **Table A-15**. The key statistic is 7.8% Scaled Root Mean Square (SRMS), which is below the target 10% SRMS suggested in the MDBC flow model guidelines (MDBC, 2001).

Sites MW1-4 and MW6 to the immediate west of the BRNOC are allocated to Layer 3 in the model, but their observed hydrographic responses are more consistent with those of Layer 4.

Table A-15. Transient Calibration Performance

Calibration Statistics	Value
Number of Data (n)	1,144
Root Mean Square (RMS) (m)	2.6
SRMS (%)	7.8
Average residual (m)	0.3
Absolute average residual (m)	2.1

As the real responses are transitional between Layer 3 and Layer 4, it is likely that the sites are responding to dewatering of coal plies whose elevation would be within Layer 3 in reality but are aggregated in Layer 4 in the model. This is an unavoidable consequence of using discrete layers in the model to represent all-interburden (Layer 3) and all-coal (Layer 4) lithologies. The best match of the mining-induced water level trends at these sites is achieved by weighting the Layer 3 (80%) and Layer 4 (20%) simulated levels. This degrades the calibration statistics a little to 8.3 % SRMS and 2.7 m RMS.

The ability of the model to replicate observed groundwater hydrographs is reported in full in **Attachment AB**. For illustration, **Figures A-43** to **A-46** show comparisons at representative sites within the Stratford Mining Complex monitoring network for bores screened in coal (**Figure A-43**), regolith (**Figure A-44**), interburden (**Figure A-45**) and for two Stratford bores (**Figure A-46**). Model water level trends and absolute elevations, in the majority of cases, are consistent with the observed water levels.

A4.10.2 Transient Water Balance

The instantaneous transient water balance across the entire model area is summarised in **Table A-16** at the end of the calibration period (June 2010). The total inflow (recharge) to the groundwater system was approximately 21 ML/day at that time, fairly evenly split between leakage from the rivers and creeks into the aquifer (55%) and rainfall recharge (45%). The leakage from all streams is simulated to be about 11 ML/day. There are no boundary inflows in the model.

Groundwater baseflow to the streams is the dominant discharge mechanism, accounting for 61.5% of the total outflow. Next in order of importance is evapotranspiration (35%). The computed inflow to all mines active at that time (0.78 ML/day) is about 3.5% of the total groundwater discharge over the model area.

At the end of the calibration period (July 2010), discharge exceeded recharge by a little less than 1 ML/day.

Table A-16. Simulated Water Balance for the Transient Calibration Model at the End of the Calibration Period

Component	Groundwater Inflow (Recharge) (ML/day)	Groundwater Outflow (Discharge) (ML/day)
Rainfall Recharge	9.3	-
Evapotranspiration	-	7.6
Rivers/Creeks	11.3	13.2
Mines	-	0.78
Boundary Flow	0	0
TOTAL	**20.6**	**21.6**
Storage	**0.9 LOSS**	
Discrepancy (%)	**0.1**	

A4.10.3 Transient Sensitivity Analysis

Sensitivity analysis has been conducted on a number of attributes of the groundwater system to identify key parameters, through observing the impact they have on calibration statistics. The investigated parameters were:

- global horizontal hydraulic conductivity (Kx) of coal zones;
- global vertical hydraulic conductivity (Kz) of coal zones;
- host interburden (Zone 2 Kx) at the Stratford East pit; and
- rainfall recharge rate in the hills.

The results are summarised in **Table A-17**. Global increase in coal horizontal hydraulic conductivity by a factor of 10 causes a severe disruption to calibration; however, an increase in the vertical value gives a slight improvement. There is also a slight improvement in calibration by increasing the rainfall recharge through the hills from 0.25% to 2.5%. Increasing the connectivity between the Stratford East Dam and the Stratford East Pit through the intervening interburden causes a noticeable degradation in calibration performance, although it would still be regarded as an acceptable calibration.

Table A-17. Calibration Sensitivity Analysis

Parameter	Change	% SRMS	mRMS	Average residual (m)
BASE		7.9	2.6	0.38
Global Coal Kx	x 10	15.4	5.1	2.3
Global Coal Kz	x 10	7.6	2.5	0.28
Stratford East Interburden Kx [Base 6.8e-3]	x 10	8.9	2.9	0.25
Hills Recharge [Base 0.25%]	x 10	7.7	2.5	0.33

A5 SCENARIO ANALYSIS

Two model versions were considered for predictive scenario analysis:

A. Stratford Mining Complex (SMC) open cut mining (excluding neighbouring operations);

B. SMC open cut mining with AGL Gloucester Gas Project CSG production and the proposed Rocky Hill Coal Project open cut mining, to assess the cumulative impacts of the Project in association with other major stresses.

A5.1 MINE SCHEDULE

Using the hydraulic and storage properties found during transient calibration, the model was run in transient mode from July 2010 to June 2024 in annual steps for both Model A ("base case" model) and Model B ("CSG model"). The Model A Project is taken to commence in July 2013 (stress period 94) and finish in June 2024 (stress period 104). Given the relatively short duration of Project mining, the lag in placement of backfill, and the time required for backfill to wet up, no time-varying change was made in spoil properties or spoil recharge. As was done during the calibration period, open cut drain cells were activated according to design pit floor contours and were deactivated in line with progressive backfilling.

The progression of mining in the model was applied consistent with the general arrangement snapshots for the Project presented in Section 2 in the Main Report of the EIS. **Attachment AC** summarises the stress period setup in the model and the sequencing of open cut operations, backfilling, and use of voids as water storages.

Four open cut pits are simulated in parallel, with floors in Layer 3 (Roseville), Layer 5 (Bowens Road North), Layer 7 (Avon North) and Layer 11 (Stratford East). Both Avon North and Stratford East open cuts commence in 2013-2014 (stress period 94) in the model. The Bowens Road North pit and the Main Pit are assumed to be backfilled after mid-2019 (during stress period 100). The Roseville, Avon North and Stratford East pits have residual voids at the end of the Project.

The rising water levels in the water storages due to natural inflows, transfers and placement of rejects, were taken as the median water levels for the 123 climate realisations simulated by Gilbert & Associates (Appendix B of the EIS). The water level in the Main Pit was assumed to rise to a final elevation of 89 m AHD in mid-2019 (stress period 99). It was simulated by a drain feature during the calibration period and initially by a constant head boundary during prediction to allow for the possibility of flux reversal (i.e. at high free water levels, it was anticipated that the Main Pit could leak water back to the groundwater system). As this did not occur, drain features were reinstated during the prediction period.

The water level in the Bowens Road North Pit was assumed to rise to a maximum elevation of 39.6 m AHD in mid-2016 (stress period 96) and then settle at 31 m AHD in mid-2019 (close to model layer floor) (stress period 99). The water level in the Avon North Pit was assumed to rise to a final elevation of 78.8 m AHD at the end of the Project in 2024 (stress period 104).

For Model A, the only time-varying stress in the prediction model is mining. Rainfall recharge and stream stages were held at static levels from 2010 to 2024 to prevent confusion between weather and mining stresses when examining hydrographic responses.

A5.2 WATER BALANCE

Simulated water balances for the entire model extent have been averaged over the 11 years of proposed Project life (stress periods 94 to 104) and are examined in **Table A-18**.

Table A-18 compares the Project averages with simulated values at the commencement of the Project (end of stress period 93, June 2013), considering only SMC mining. An increase in mine inflow of about 0.3 ML/day is expected, on average. This increase in inflow coincides with a reduction in net baseflow of 0.2 ML/day and a reduction in evapotranspiration by 0.3 ML/day. On the whole, less groundwater is taken from storage.

Table A-18. Simulated Net Water Balance Changes Due to the Project

Component	Project Start (ML/day)	Project Average (ML/day)	Difference (ML/day)	Change (%)
Rainfall Recharge	8.8	8.8	0.0	0.0
Evapotranspiration	-7.3	-7.0	-0.3	-4.5
Rivers/Creeks	-1.6	-1.4	-0.2	-14
Mines	-1.0	-1.3	0.3	27
Boundary Flow	0.0	0.0	0.0	0.0
Storage	1.1 LOSS	0.9 LOSS	0.2	26

A5.3 PREDICTED PIT INFLOW

The time-varying pit inflows predicted by the model since mining commenced at the Bowens Road North pit in 2003 are illustrated in **Figure A-47** for each of the four operating pits and the Stratford Main Pit water storage. The average and maximum inflow rates are listed in **Table A-19**.

The Roseville West Pit Extension is expected to attract the highest inflow with an average of about 0.5 ML/day, while Stratford East Open Cut should receive the least (about 0.1 ML/day). The combined pit inflows (**Figure A-48**) are expected to peak around 1.3 ML/day, with a minimum of about 0.7 ML/day at the end of the Project.

Table A-19. Predicted Pit Inflows

Pit	Project Average (ML/day)	Project Maximum (ML/day)
BRNOC	0.22	0.43
Roseville West Pit Extension	0.50	0.69
Avon North Open Cut	0.25	0.32
Stratford East Open Cut	0.11	0.17
Stratford Main Pit	0.11	0.25

A5.4 PREDICTED BASEFLOW CHANGES

Stream-aquifer water exchanges with alluvium have been examined for Dog Trap Creek, Avondale Creek and THE Avon River since mining commenced at the BRNOC in 2003. The predicted fluxes are shown in **Figure A-49**. Only during the calibration period (2003-2010) was rainfall varied in the model. Stream stages were held constant at all times.

Only in the Avon River is there an occasional switch from a predominantly gaining system to a losing system. On average, the Dog Trap and Avondale Creeks have a net gaining status (i.e. with some baseflow component). The baseflows are estimated to be about 0.4 ML/day (Dog Trap Creek) and about 0.2 ML/day (Avondale Creek) on average.

Project mining is too far away from Avon River for any discernible effect on net baseflow for that stream. The changes in baseflow at the other two steams are illustrated in **Figure A-50**. Dog Trap Creek has an average baseflow reduction of 0.07 ML/day during the Project; it peaks at a little over 0.08 ML/day but becomes less when the BRNOC is backfilled in 2019. Avondale Creek has a complicated pattern. The change in baseflow varies from a peak reduction of 0.17 ML/day to a maximum gain of about 0.05 ML/day. Overall, there is an average net reduction in baseflow of about 0.02 ML/day.

The reason for the complicated Avondale Creek pattern is elucidated in **Figure A-51**, which shows the baseflows partitioned between four reaches of similar length from north to south. The northern reach initially leaks more water (negative baseflow) to the underlying aquifer when the active Roseville pit is close. As mining moves to the south, the amount of leakage reduces in the northern reach and increases in the upper middle reach. As mining moves farther south, the lower middle reach is affected gradually. The southern reach shows a slight downwards trend in baseflow as the Stratford East Open Cut approaches from north to south, with a more pronounced effect from 2022 onwards.

A5.5 CUMULATIVE IMPACTS

Model B considers the cumulative effects of SMC open cut mining, AGL Gloucester Gas Project CSG production and Rocky Hill Coal Project open cut mining. Outlines of the lease areas are shown in **Figure A-52**.

The AGL Gloucester Gas Project has current Stage 1 approval for 110 CSG wells within the outline in **Figure A-52** at depths greater than 150 m. The Rocky Hill Coal Project plans to conduct open cut mining in a number of pits: Main Pit to floor -65 m AHD; two sub-pits within the Main Pit; Bowen Road 2 Pit to floor +25 m AHD; Avon Pit to floor +25 m AHD; and Weismantel Pit to floor +50 m AHD. As the sequencing of the wells and pits is unknown, a conservative cumulative assessment has been done by assuming all stresses are active continuously for the 11 years of Project mining.

For the Rocky Hill Coal Project, the pits have been simulated as "drain" cells down to model layer 5 (Main Pit and Bowen Road 2 Pit), layer 7 (Avon Pit) and layer 9 (Weismantel Pit).

For the AGL Gloucester Gas Project, the CSG wells have been simulated as stacked blanket drains[4] from model layer 3 down to model layer 11. Coal depths less than 150 m have been excluded. The active drain cells (for the SMC Project and the AGL Gloucester Gas Project) in each layer are shown in **Figure A-53**. Due to the strong dip of the strata, the active area extends farther to the east for older target coal seams.

Initial cumulative impacts were conducted without the Rocky Hill Coal Project and with four CSG scenarios:

- either zero or 40 m pressure head above the roof of a target coal seam; and
- including or excluding the SMC MLs.

The average groundwater inflow rates to the SMC pits and the CSG produced water are summarised in **Table A-20**.

Table A-20 shows that the expected (extreme case) production of CSG water will range from 4.4 ML/day to 6.6 ML/day on average over 11 years (assuming all wells are active). The pressure head required to induce gas flow has an effect of about 15% on produced water for a 40 m range in required pressure head. If CSG wells are active over the SMC area in parallel production, the SMC pit inflows would reduce by 0.4-0.5 ML/day on average, which is almost 50% of expected inflows. If no CSG activities occur within the SMC lease areas during the 11 years of the Project, the pit inflows would reduce by a little over 0.1 ML/day (about 10-15% lower).

Cumulative drawdown impacts are addressed in Section A6.1.8.

[4] Pervasive continuous drain cells are applied in each coal seam model layer (below 150 m depth).

Table A-20. Simulated Water Make for Various CSG Scenarios

	Base Case (ML/day)	Excluding SMC, Zero Pressure Head (ML/day)	Excluding SMC, 40m Pressure Head (ML/day)	Including SMC, Zero Pressure Head (ML/day)	Including SMC, 40m Pressure Head (ML/day)
BRNOC	0.21	0.15	0.17	0.06	0.07
Roseville West Pit Extension	0.50	0.44	0.45	0.30	0.36
Avon North Open Cut	0.23	0.21	0.21	0.10	0.12
Stratford East Open Cut	0.10	0.09	0.11	0.06	0.07
Total Pit Inflow	**1.04**	**0.89**	**0.94**	**0.52**	**0.62**
CSG Northern Zone	0	3.95	3.24	3.70	3.06
CSG Central Zone	0	-	-	1.88	1.62
CSG Southern Zone	0	1.23	1.10	1.03	0.93
Total CSG Produced Water		**5.2**	**4.3**	**6.6**	**5.6**
Pit Inflow Reduction		**0.16**	**0.11**	**0.53**	**0.44**

A5.6 SENSITIVITY ANALYSIS

As the Stratford East pit was estimated to receive the least groundwater inflow (about 0.1 ML/day), a series of sensitivity runs were conducted to assess the uncertainty in pit inflow for possible variations in rainfall recharge (to the adjacent hills), coal seam hydraulic conductivity (Kx and Kz) and the overburden hydraulic conductivity separating the pit from the Stratford East Dam. The results are shown in **Figure A-54**.

The magnitude of the pit inflow is very sensitive to increases in coal seam and overburden horizontal hydraulic conductivity. However, as the calibration performance is degraded for these perturbations, they are unlikely to be realised (see Section A4.10.3 and **Table A-17)**. Pit inflow is also very sensitive to much higher rain recharge (10% of rainfall) but sensitivity to 2.5% of rainfall is slight (no more than 0.05 ML/day extra). Sensitivity to coal seam vertical hydraulic conductivity is very low.

A5.7 POST-MINING EQUILIBRIUM

A final void water balance was prepared by Gilbert & Associates (Appendix B of the EIS) using a rainfall-runoff model. Estimates of groundwater inflow over time required as inputs to the model were provided by conducting a transient groundwater recovery simulation for 200 years with the three voids (Roseville, Avon North and Stratford East) treated as highly permeable water bearing material (K = 1000 m/day; Sy = 1.0) accepting 100% rainfall with open water evaporation rates in place of evapotranspiration.

The results of the post-mining estimates of groundwater inflows are presented in **Table A-21**.

Table A-21. Post-mining Transient Simulation Results – Input to Rainfall-Runoff Model

Year	Roseville Void	Roseville Void	Avon North Void	Avon North Void	Stratford East Void	Stratford East Void
	Water Level (m AHD)	Inflow (ML/day)	Water Level (m AHD)	Inflow (ML/day)	Water Level (m AHD)	Inflow (ML/day)
5	75.0	0.75	83.3	0.29	56.7	0.45
10	80.6	0.74	86.0	0.30	62.9	0.33
15	85.5	0.67	87.9	0.31	66.9	0.31
20	91.3	0.59	90.0	0.31	70.6	0.31
25	98.9	0.40	92.5	0.30	75.3	0.27
30	103.7	0.35	94.3	0.30	79.1	0.32
40	106.1	0.27	95.5	0.30	81.8	0.35
50	107.8	0.20	96.5	0.30	84.0	0.35
75	108.9	0.15	97.2	0.30	85.7	0.35
100	109.7	0.12	97.8	0.30	87.1	0.35
125	110.5	0.09	98.5	0.29	88.7	0.34
150	111.1	0.06	99.1	0.29	90.2	0.34
200	111.6	0.04	99.6	0.29	91.4	0.34

The groundwater recovery in each model layer at four representative sites adjacent to the three voids and between the Roseville and Bowens Road North pits is illustrated in **Figure A-55**. Substantial recovery is apparent after about 40 years.

Appendix B of the EIS provides estimates of equilibrium final void water levels. A steady-state groundwater simulation that has been run with these final levels shows that each void remains a permanent and localised groundwater sink with total inflows of about 0.9 ML/day partitioned between Roseville West (0.77 ML/day), Avon North (0.03 ML/day) and Stratford East (0.11 ML/day). The relatively high final inflow rates are due mainly to enhanced recharge through waste rock emplacements at a rate of 5% of rainfall.

The predicted long-term equilibrium watertable pattern is displayed in **Figure A-56**. Comparison is made with the simulated pattern at the end of the calibration period (June 2010). The patterns are generally similar, with lower heads at the three voids and higher heads around the Stratford Main Pit.

A6 IMPACTS ON THE GROUNDWATER RESOURCE

A6.1 POTENTIAL IMPACTS ON GROUNDWATER

A6.1.1 Changes in Hydraulic Properties

There would be a change in hydraulic properties over the mine footprint where mine waste rock infills the excavations down to the floors of the mined coal seams, and in the waste rock out-of-pit emplacements. As mine waste rock would have a higher hydraulic conductivity than any natural material in this area, with the possible exception of alluvium, there would be associated reductions in hydraulic gradients in accordance with Darcy's Law. As one increases, the other must decrease to maintain the same flow.

A flattening of hydraulic gradients in the mine waste rock material is expected. Also, rainfall recharge is expected to be higher in the mine waste rock than in any natural local material. This accounts for the relatively high equilibrium groundwater inflows to the final voids noted in Section A5.7:

- Total inflow: about 0.9 ML/day;
- Roseville West Pit Extension inflow: 0.77 ML/day;
- Avon North Open Cut inflow 0.03 ML/day; and
- Stratford East Open Cut inflow: 0.11 ML/day.

A6.1.2 Changes in Groundwater Flow and Quality

As mining progresses, the active voids would act as groundwater sinks. This would cause a temporary change in groundwater flow direction, in places reversal of direction, until mining is completed and the groundwater system recovers to a new equilibrium (**Figure A-56**). The final groundwater flow pattern, as shown in **Figure A-56**, is similar regionally to the pre-Project pattern, apart from localised changes in the vicinity of Stratford Mining Complex operations. The post-mining steady-state groundwater simulation has demonstrated that each void remains a permanent groundwater sink.

The quality of the inflow water during mining will be a mixture of the qualities of the waters in source lithologies, primarily coal and coal measures. After mining is completed, the geochemistry of waste rock would become a major contributor to void water chemistry (see Section A6.1.3).

The chemical characteristics of groundwater have been assessed in Section A2.13. It was found that, apart from two Stratford bores and Bore MW12, most groundwaters are beyond the limit of potable use but on the basis of salinity are suitable for livestock, selective irrigation and other general uses (**Table A-7**). Not much difference was found between the baseline salinities of different formations. The median EC in the coal samples was found to be only 10% higher than for alluvial/regolith samples, which in turn was about 25% higher than coal measures interburden samples (3500 µS/cm).

The spatial pattern of baseline groundwater salinity (i.e. measured EC) was illustrated in **Figure A-24**. The distribution of salinity was found to be fairly uniform spatially, with the highest value in Avondale Creek alluvium to the south of the SCM, and generally lower values in Stratford. There is no clear differentiation between the salinity signatures of different lithologies. In particular, the salinity of alluvial/regolith waters was found to be no better than coal groundwaters.

Given the similarity of salinity for the various source waters, no appreciable change in groundwater salinity is expected as a consequence of mining.

Over time, the salinity in the final voids will increase through evaporative concentration. As long as the voids remain as groundwater sinks, as is predicted, there will be no deleterious effect on the beneficial uses of any groundwater sources.

Appendix B of the EIS includes predictions of salinity evolution in each of the three final voids. Final void salinity is generally predicted to increase slowly with time, reaching about 9,000 µS/cm at Avon North, about 12,000 µS/cm at Roseville West and about 6,000 µS/cm at Stratford East after 200 years (Appendix B of the EIS). Given the long time frame, and the radially focussed groundwater flow direction, the surrounding groundwater quality would therefore not be affected by the water contained within the final void after mining.

A6.1.3 Geochemistry

Geochemical investigation undertaken in Appendix L of the EIS (Environmental Geochemistry International Pty Ltd [EGI}, 2012) has concluded that the overburden and interburden materials in the proposed pit expansion areas are expected to be non-acid forming at the Bowens Road North pit, the Roseville West pit and the Avon North pit. However, waste rock materials are expected to be potentially acid forming (PAF) at the Stratford East pit.

In addition, no significant elemental enrichment is expected apart from sulphur, and negligible mobilisation of metals/metalloids is anticipated due to near-neutral pH conditions (Appendix L of the EIS).

EGI (2012) has recommended that PAF waste be segregated and selectively handled, with placement in-pit or in out-of-pit engineered PAF waste cells.

The rejects from the Project will be disposed in accordance with the approved Life of Mine Rejects Disposal Plan. The rejects during the Project are expected to have lower acid generating potential than those currently being generated (Appendix L of the EIS).

Based on these results, it is expected that use of the existing mine waste segregation and handling practices, and rejects disposal protocols, would be sufficient to maintain adequate control over acid rock drainage risk on-site.

In consideration of the above, there would be negligible impacts to groundwater quality (either directly or via final pit voids) as a result of PAF material.

A6.1.4 Pit Inflows

Up to the end of mining, there would be a continuous loss of groundwater from the fractured rock to the mining void. A minor amount of water would be drawn in from the regolith and the thin veneer of floodplain sediments.

The predicted groundwater inflows are graphed in **Figure A-47**.

The year-by-year expected pit inflows (without mitigating effects from CSG production) are listed in **Table A-22**. The analysis of cumulative effects in Section A5.5 indicates that the Project inflows could be reduced by a maximum of 0.5 ML/day if CSG activities are coincident with SMC mining.

Table A-22. Predicted Pit Inflows for Each Open Cut [ML/day]

Year	Bowens Road North	Roseville West	Avon North	Stratford East	Total
1	0.29	0.69	0.23	0.11	**1.32**
2	0.40	0.61	0.23	0.11	**1.35**
3	0.40	0.43	0.22	0.13	**1.18**
4	0.42	0.49	0.24	0.12	**1.27**
5	0.43	0.50	0.23	0.11	**1.27**
6	0.43	0.48	0.32	0.09	**1.32**
7	0.00	0.50	0.28	0.09	**0.87**
8	0.00	0.46	0.27	0.10	**0.83**
9	0.00	0.44	0.23	0.07	**0.74**
10	0.00	0.43	0.23	0.17	**0.83**
11	0.00	0.46	0.20	0.08	**0.74**

A6.1.5 Alluvium

The Project open cuts would not be located within 40 m of Avondale Creek or Dog Trap Creek. In addition, no direct pumping of water from alluvial sediments is proposed for the Project.

Approved mining and proposed mining will pass through an area classified as Quaternary Alluvium on the geological map (**Figure A-8**). However, the TEM survey results and the cross-section alluvial transect holes (**Figure A-9**) demonstrate that the alluvial sediments are primarily confined to the alignment of the drainage line (i.e. Dog Trap Creek) and are less likely to be associated with the topographic highs mapped at the regional scale (i.e. some mapped areas are more likely to be regolith). In addition, no deep alluvium with favourable subsoil properties (i.e. with the potential for use as rehabilitation material) was identified within the proposed Project open cut mining areas despite attempts in the regionally mapped alluvial/colluvial areas with the use of 3 m depth soil pits as part of the Agricultural Resource Assessment (McKenzie, 2012) (Appendix K of the EIS).

As there is only one groundwater licence with a total entitlement of 20 ML/annum for the Avon River Water Source, the mapped Quaternary Alluvium (other than the alluvium identified by the TEM survey along Dog Trap Creek and Avondale Creek, and the alluvium along the channel of the Avon River) are not significant alluvial water sources.

Water can be lost from the alluvium/regolith groundwater source by three mechanisms:

- enhanced leakage from the alluvium/regolith to the underlying fractured rock;
- interruption of rainfall recharge to excavated alluvium/regolith; and
- direct excavation of alluvium/regolith materials as part of the mine pit.

As mining progresses, an increase in natural leakage of groundwater from the alluvium/regolith to the underlying fractured rock would be expected. This has been examined in the model for the mapped Quaternary Alluvium intersections with the Roseville West pit and the Avon North pit, and is estimated to be about 33 ML/annum (0.09 ML/day). Of this amount, the TEM-identified Dog Trap Creek alluvium would account for about 6 ML/annum on average over the life of the Project. The Dog Trap Creek alluvium would lose additional water to the underburden in Project years 1 to 8, after which time the alluvium would gain more water from beneath (relative to Project commencement), due to rising water levels as mining moves to the south.

The removal of alluvium/regolith during mining will reduce rainfall recharge temporarily by about 144 ML over the life of the Project. This is equivalent to about 13 ML/annum (0.036 ML/day), assuming 8% infiltration over an area of about 2.6×10^5 square metres. After mining has finished, recharge will resume through waste rock infill.

The direct loss of water from storage due to excavation of alluvium/regolith is estimated to be about 31 ML over the life of the Project. This is equivalent to about 3 ML/annum (0.085 ML/day) assuming 2 m saturated thickness and 10% porosity.

A6.1.6 Fractured Rock

There is not yet any separate water sharing plan for the fractured rock groundwater system.

Up to the end of mining, there would be a continuous loss of water from the fractured rock groundwater system to the mining void. The combined pit inflows (Figure A-48) are expected to peak around 1.3 ML/day, with a minimum of about 0.7 ML/day at the end of the Project.

The average combined pit inflow over the life of the Project is predicted to be about 1.1 ML/day (390 ML/annum) (**Table A-22**). All but about 1.5% (6 ML/annum) of this water will be derived from the fractured rock groundwater source. The predicted flows from this source are expected to reduce during post-mining recovery to about 0.6 ML/day (**Table A-21**).

A6.1.7 Potential Impacts on Registered Production Bores

Locally, there is little reliance on groundwater bores as a source of water as agricultural enterprises make use of surface water sources. Within 5 km of any proposed pit, there are only 12 private bores other than those on SCM land. There are 11 bores in Stratford and one bore located to the south (GW079759). The private bores are licensed for stock and domestic use.

Figure A-57 shows the drawdown magnitude and pattern for the watertable being accessed by the private bores. Drawdowns are naturally limited to the east by outcropping volcanics. The 1 m drawdown threshhold does not reach the bores in Stratford or the other private bore to the south.

The impact on the water level in each privately owned bore is expected to be negligible.

Where end-of-mining drawdowns exceed 1 m, the drawdown extents are approximately:

- 0.8 km to the west of Roseville West Pit Extension;
- 1.6 km to the south of Roseville West Pit Extension;
- 0.2 km to the north of Avon North Open Cut;
- 0.7 km to the west of Avon North Open Cut;
- 1.0 km to the east of Avon North Open Cut;
- 0.3 km to the south of Avon North Open Cut;

- 0.1 km to the north of Stratford East Open Cut;
- 0.8 km to the west of Stratford East Open Cut;
- 0.8 km to the south of Stratford East Open Cut; and
- 0.1 km to the north of Stratford East Open Cut.

The predicted regional drawdowns in each of the target coal seam layers (2, 3, 5, 7 and 11) are presented in **Attachment AD**. The Layer 3 drawdowns are very similar to the predicted watertable drawdowns. For deeper layers the drawdown extents are similar, except that the effect of Roseville West mining dies off rapidly below Layer 3, and the effect of Avon North mining dies off rapidly below Layer 7.

A6.1.8 Potential Cumulative Impacts

A conservative assessment of the cumulative effects of the Project, the AGL Gloucester Gas Project CSG production and the proposed Rocky Hill Coal Project open cut mining has been undertaken.

Figure A-58 shows the cumulative drawdown magnitude and pattern for the watertable being accessed by private bores for one of the CSG scenarios (namely, zero pressure head and broad deployment of CSG wells including the SMC MLs), with coincident mining at the SMC and the proposed Rocky Hill Coal Project.

While drawdowns are naturally limited to the east by outcropping volcanics, the extents of the 1 m drawdown contours are much broader. CSG activity would cause pronounced drawdown in the watertable between the Project and Stratford. Nevertheless, the predicted drawdowns at the Stratford bores are less than 1 m for bores in the northern half and 1-2 m for the southern half. There would be no impact on the other private bore to the south, given that drawdown is generally limited to the natural groundwater divide and the southern private bore (GW079759) lies to the south of the divide.

The predicted cumulative drawdowns in each of the target coal seam layers are presented in **Attachment AD**. The Layer 3 drawdowns are very similar to the predicted watertable drawdowns. Deeper layers show a pronounced line of strong drawdown trending north-south centred approximately on the Roseville Pit. However, the western extent is tightly constrained by reducing coal seam hydraulic conductivity as the seams dip to the west.

Based on the modeling results, cumulative effects are expected to be substantially greater than would be produced by the Project acting alone.

A6.1.9 Effects on Mapped Biophysical Strategic Agricultural Land

The *Draft Stage 1 Aquifer Interference Policy* (DTIRIS, 2012) and the *Draft Upper Hunter Strategic Regional Land Use Plan* (DP&I, 2012) were released in early March 2012. As the Project open cut mining areas (nearest being the Roseville West Pit Extension) are more than 2,000 m from the nearest biophysical strategic agricultural land mapped along the Avon River (**Figure A-59**), the conditions of the *Draft Stage 1 Aquifer Interference Policy* have not been considered further.

Notwithstanding, **Figure A-57** (Project alone) and **Figure A-58** (Cumulative) demonstrates that the predicted watertable drawdown contours at the end of the Project would not extend as far as the nearest mapped biophysical strategic agricultural land.

A6.2 POTENTIAL IMPACTS ON SURFACE WATERBODIES

A6.2.1 Changes in Water Balance

The main local drainage systems associated with the Project area are Dog Trap Creek, Avondale Creek and Avon River. The stream-aquifer interaction status of these streams has been examined in Section A5.4 and in **Figures A-49** to **Figure A-51**.

Project mining is too far away from Avon River for any discernible effect on that stream.

Dog Trap Creek would continue as a gaining stream (i.e. with some baseflow component) and would have an average baseflow reduction of about 0.07 ML/day during the Project. The baseflow reduction would peak at a little over 0.08 ML/day and would become progressively less (i.e. reducing to <0.05 ML/day over time) when the BRNOC is used as a water storage and ultimately backfilled with waste rock in 2019 (i.e. when the system recovery commences).

Avondale Creek would have a complicated pattern of changes in baseflow that would vary from a peak reduction of less than 0.2 ML/day to a gain in baseflow of about 0.05 ML/day. Overall, an average net reduction in baseflow of about 0.02 ML/day is expected. The variation from reduced baseflow to gaining baseflow is illustrated in **Figure A-51**, which shows the baseflows partitioned between four reaches of similar length from north to south. The predicted behaviour is readily explained by considering the proximity of various creek reaches to active mining as the BRNOC, Roseville West Pit Extension and Stratford East Open Cut pits progress to the south.

The predicted decreases and increases in baseflow would have a negligible effect on natural stream flow.

The small predicted drawdown which extends to the south across the catchment divide would have negligible impact on the Karuah River Water Source (**Figure A-57**).

A6.2.2 Changes in Surface Water Quality

Overall, there is predicted to be a slight reduction in baseflow of about 0.1 ML/day to Dog Trap Creek and Avondale Creek over the life of the Project and no effect at Avon River.

As the reductions in baseflow would occur close to where target coal seams are subcropping, the reductions in baseflow would mean a lower contribution of coal seam waters to flow in the two creeks. The median EC in coal samples has been found to be about 10% higher than for alluvial/regolith samples. It follows that the baseflow waters can be expected to be slightly fresher. However, the change in salinity is unlikely to be measureable.

A6.2.3 Effects on Surface Ecosystems

Given the localised disturbance of open pit mining, and the demonstration of inconsequential changes in stream baseflow, no effects on surface ecosystems are anticipated in relation to mining-induced changes to the water system.

Parsons Brinckerhoff (2012), in an independent assessment for the AGL Gloucester Gas Project, noted that there are *no known wetlands, lakes or other surface features that are indicative of shallow groundwater processes and possible groundwater dependent ecosystems*. Furthermore, they note that the brackish-saline nature of groundwater baseflow is unlikely to be conducive to the sustenance of groundwater dependent ecosystems.

A6.3 PROPOSED GROUNDWATER MONITORING PROGRAM

The proposed groundwater monitoring program for the Project is summarised in **Table A-23** and described below. The groundwater monitoring program should augment the existing SCPL groundwater monitoring program and utilise the results of other mine groundwater monitoring programs in the vicinity of the Project (i.e. the AGL Gloucester Gas Project and the proposed Rocky Hill Coal Project). The groundwater monitoring program should comply with the *Murray-Darling Basin Groundwater Quality Sampling Guidelines* (MDBC, 1997).

The groundwater monitoring program should monitor groundwater conditions for changes as a result of mining, and should include consideration of aquifer definition and interactions, strata hydraulic properties, expected drawdown extent and groundwater quality.

The results of the groundwater monitoring program should be used to validate modelling predictions.

Table A-23. Proposed Groundwater Monitoring Program

Parameter	Location	Timing
Piezometers (Groundwater Levels – m AHD)	Existing monitoring network (SCPL and surrounding mines/projects).	Quarterly for Project life.
	Additional Fractured Rock groundwater system monitoring bores (west of pits).	Years 1-11 and 2 years post-mining.
	Additional bore installations in the mine waste rock emplacement behind the advancing open cut.	Progressive over the Project life.
Groundwater Quality (pH, dissolved oxygen [DO], EC, TDS, Fe, aluminium [Al], arsenic [As], molybdenum [Mg], Mo, selenium [Se], Ca, Na, Cl, SO_4)	At piezometers above (except vibrating wire installations).	Quarterly for Project Life.
Mine Water Balance	Measurement of volumes extracted from the open cut sumps, pumped water, coal moisture, etc.	Annual for Project life.

A6.3.1 Monitoring Piezometers

As mining progresses, the existing SCPL network of piezometer installations should be augmented near the locations marked on **Figure A-60** as sites F1 to F7. Sites F1 to F3 are selected as monitors on the watertable elevation in waste rock infilling the Roseville West Pit, the Avon North Open Cut and the Stratford East Open Cut. These piezometers will allow assessment of the waste rock hydraulic conductivity and the rainfall recharge rate through the infill material.

Sites F4 to F7 are selected to the west of the three pits where end-of mining groundwater drawdowns are anticipated.

Site F4 is midway between the Roseville West Pit and the most easterly monitoring bore near Stratford. This piezometer should be screened in the Roseville Seam (model layer 3) so that it will provide an early warning of effects approaching users in Stratford in case they exceed model predictions.

Sites F5 to F7 are all in predicted drawdown areas associated with the Stratford East Open Cut. All piezometers should be screened no higher than the Bowens Road Seam (model layer 5). Ideally, site F6 should be a vibrating wire installation with piezometers placed in each of the major coal seams (model layers 3, 5, 7, 9 and 11).

The timing for installation should be after final rehabilitation at sites F1-F3 and in advance of excavation at the same northing for sites F4 (Roseville West Pit Extension) and F5-F7 (Stratford East Open Cut) as mining progresses.

The final location of piezometers should include consideration of site characteristics, their location relevant to the mine plan, access and site inspection.

Water level measurements should be automated with daily or more frequent recordings and should continue for at least two years following mining.

A6.3.2 Groundwater Quality

The groundwater monitoring network should be sampled for water quality on a regular basis during mining, and for at least two years following mining. Groundwater quality samples should also be taken during drilling of any new/future piezometer or hydrogeological investigation bores.

Groundwater quality monitoring should include, but not necessarily be limited to, analysis of the following parameters: pH, DO, EC, TDS, Fe, Al, As, Mg, Mo, Se, Ca, Na, Cl and SO4. Analysis should be undertaken at a NATA accredited laboratory. Water quality data should be evaluated as part of the Annual Environmental Management Report (AEMR) process and should aim to identify any potential mining related impacts.

A6.3.3 Mine Water Balance

Water balances should be conducted continuously, accounting for all monitored volumes (including pit groundwater inflows/pumping records) and should be reported in the AEMR.

The water balance should be reviewed annually to confirm groundwater transmission characteristics and modelling predictions. Monitoring results which indicate anomalous/high groundwater inflows should be investigated. If anomalous/high groundwater inflows are detected, SCPL should notify and consult with the relevant regulator regarding further courses of action.

The Project water management system is discussed further in the Surface Water Assessment (Appendix B of the EIS).

A7 CLIMATE CHANGE AND GROUNDWATER

The effects of climate change on groundwater are projected to be negative in some places on earth, but positive in other places. In the Netherlands, for example, beneficial effects are anticipated (Kamps et al., 2008). There it is expected that coastal watertables will rise, but evapotranspiration will reduce in response to the adaptation of vegetation to higher levels of carbon dioxide. Modelling shows more pronounced seasonal watertable fluctuations by accounting for vegetation feedback mechanisms (Kamps et al., 2008). Plants are expected to have a lower water demand under higher carbon dioxide levels due to production of more biomass, increased leaf area index, and a shorter time to reach the saturation point for carbon demand (Kamps et al., 2008).

In New Hampshire USA, on the other hand, negative effects on the watertable are expected due to the onset of spring recharge two to four weeks earlier (Mack, 2008). This shift will allow a longer period for evapotranspiration prior to summer months, at which time groundwater availability is likely to decrease.

The modelling of climate change effects needs to take into account complex vegetation and hydrologic feedback mechanisms, coupled surface water and groundwater interactions, and inter-annual temporal variations. Very few modelling studies have been conducted so far. Hunt et al. (2008) reported on the difficulties to be overcome in doing comprehensive modelling using newly released integrated GSFLOW software (MODFLOW plus PRMS).

Order of magnitude estimates can be found by ignoring feedback mechanisms and changing the currently calibrated rain infiltration percentages. However, more intense rainfall events would be expected to increase fast runoff and lead to a reduction in infiltration. This should be taken into account to allow for short-term temporal variations.

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

The approach taken for this assessment has been to conduct a transient simulation for the calibration period and the prediction period for rainfall infiltration reduced by 20%.

If the climate change effects had occurred during the calibration period, the calibration performance statistics would have deteriorated slightly from 7.86% RMS (base case) to 7.95 % RMS and 2.58 m RMS (base case) to 2.61 m RMS. This means that the model is not sensitive to this level of change and any resulting effects would lie within the envelope of uncertainty for base case modelling.

The effect of the postulated climate change on pit inflow has been assessed for one pit (Stratford East Open Cut). It was found that the average reduction in pit inflow over the life of the Project would be about 2% for 20% less recharge from rainfall. This is illustrated in **Figure A-54**. The simulated reduction in pit inflow is due to reduced groundwater levels adjacent to the active void during mining.

A8 MANAGEMENT AND MITIGATION MEASURES

SCPL should implement the proposed groundwater monitoring programme outlined in Section A6.3.

The numerical groundwater model developed as part of this groundwater assessment should be used as a management tool for validating the predicted groundwater impacts throughout the Project life. The results of the groundwater monitoring programme (Section A6.3) should be used to assess progressive development, verification and refinement of the numerical model. Revised outputs from the numerical model should be reported in subsequent relevant groundwater assessments over the life of the Project.

A8.1 GROUNDWATER USERS

The numerical modelling indicates that the drawdown effects on groundwater users in the vicinity of the mine are not likely to be significant (i.e. less than 1 m) and would not materially affect the existing or potential future beneficial use of groundwater (refer to Section A6.1.7). Notwithstanding the above, it is recommended that a comprehensive groundwater monitoring programme (Section A6.3) be established to monitor the groundwater effects of the Project (including triggers for investigation), and to enable contingency measures to be implemented in the event that agreed trigger levels are exceeded.

In the event that a complaint is received in relation to depressurisation of a privately owned bore, well or spring by local groundwater users, the relevant data set should be reviewed by SCPL as part of a preliminary evaluation to determine if further investigation, notification and mitigation is required.

A8.2 GROUNDWATER LICENSING

Water licensing requirements including consideration of water management principles and access licence dealing principles are addressed in detail in the Water Licensing Addendum (Attachment 5) to the EIS.

The Project has the potential to intercept groundwater from two water sources associated with fractured rock and alluvium. Groundwater extraction from the fractured rock aquifer is not currently covered by any water sharing plan. In that case, the *Water Act, 1912* is the relevant Act for approval of groundwater extraction. The relevant alluvial source is the *Lower North Coast Unregulated and Alluvial Sources 2009*.

The predicted annual groundwater volumes required to be licensed over the life of the Project are summarised in **Table A-24**. The estimates for alluvium are justified in Section A6.1.5.

Table A-24. Project Groundwater Licensing Summary

Groundwater System	Water Sharing Plan	Water Source	Predicted Average and Maximum Annual Inflow Volumes requiring Licensing [ML/annum]			
			BRNOC^	RWPE	ANOC	SEOC
Fractured Rock	None	None	Av. 152 Max. 163	Av. 188 Max. 261	Av. 92 Max. 119	Av. 38 Max. 57
Alluvium	Lower North Coast Unregulated and Alluvial Sources 2009	Avon River Water Source	Max. 6+	Max. 14#	Max. 34@	Nil

^ Until backfilled.

+ No more than 6 ML/annum from Dog Trap Creek alluvium; after year 8 the alluvium will gain water.

The regolith / floodplain alluvial veneer will provide about 2 ML/annum from extra leakage to fractured rock, 10 ML/annum from reduced rainfall recharge, and 2.2 ML/annum in excavated sediments.

@ The regolith / floodplain alluvial veneer will provide about 31 ML/annum from extra leakage to fractured rock, 2.8 ML/annum from reduced rainfall recharge, and 0.6 ML/annum in excavated sediments.

BRNOC = Bowens Road North Open Cut; RWPE = Roseville West Pit Extension; ANOC = Avon North Open Cut;
SEOC = Stratford East Open Cut.

GCL currently holds a combined total of 1,021 ML volumetric licence allocation under Part 5 of the *Water Act, 1912* for the operations at the Stratford Mining Complex which is greater than the predicted maximum for all Project open cut mining areas combined (i.e. approximately 600 ML).

While negligible drawdown in the aquifers of the alluvial groundwater system and negligible impact on groundwater levels or groundwater yield for groundwater users with privately owned bores in the alluvial groundwater system are predicted, the numerical model has accounted for water that could be lost from the alluvium/regolith groundwater source.

There is only one known groundwater licence with a total entitlement of 20 ML/annum for the Avon River Water Source (DWE, 2009). Notwithstanding, GCL currently holds a combined total of 140 megalitres per unit volumetric licence allocations under the *Water Management Act, 2000* for unregulated rivers in the Avon River Water Source, which is greater than the predicted maximum inflows from the alluvial groundwater system for all Project open cut mining areas combined (i.e. 54 ML).

A9 MODEL LIMITATIONS

Although MODFLOW-SURFACT is capable of simulating unsaturated conditions, the focus in this study has been on the saturated part of the groundwater system. Nevertheless, MODFLOW-SURFACT will report groundwater heads (equivalent to negative pore pressures) in dry portions of model layers.

The model has adopted uniform rainfall recharge across five zones. As more data are gathered, the spatial distributions of aquifer properties can be refined.

There is substantial faulting through the study area. The model has not represented the faulting explicitly but has honoured the structural geometry by complying with the stratigraphic picks in the geological resource model. In effect, the model assumes that coal seams "roll over" a fault, rather than suffering dislocation. If discontinuity occurs in reality, the model will overestimate drawdown extent, as drawdown impacts could be compartmentalised.

This model has implemented declining hydraulic conductivity with depth in a discrete number of depth ranges. Separate depth functions were applied initially for the interburden as a group and for coal seams as another group. Subsequently, some fine-tuning of hydraulic conductivity values was done at shallow depths during calibration. As strata dips are often severe (of order 45^o), there can be sudden reductions in hydraulic conductivity from east to west along any layer. This has resulted in fairly sharp limits to predicted drawdown extents.

As lower pit inflows can be expected as coal seam hydraulic conductivity reduces with depth, the predicted inflows for the deeper pits could be underestimated if the applied hydraulic conductivity is too low.

At this stage, there is no hydrographic evidence for hydraulic conductivity reduction with depth, but this can be expected as mining proceeds to greater depths. Vibrating wire piezometers have been installed as part of this study to provide information on deep groundwater responses to mining.

A10 CONCLUSIONS

In the vicinity of the Stratford Mining Complex, there is little reliance on groundwater bores as a source of water, as agricultural enterprises predominantly rely on surface water sources which are more abundant and generally better quality. Within 5 km of proposed Project open cut mining operations, there are 12 private bores other than those on land owned by SCPL. There are 11 bores in Stratford and one bore to the south (GW079759). The private bores are licensed for stock and domestic use.

Groundwater is found within two groundwater systems:

- **Fractured Rock groundwater system** - including shallow rock groundwater bearing structures and the Gloucester Basin coal measures of Permian age; and
- **Alluvial groundwater system –** including alluvial (narrow channel) sediments of Dog Trap Creek, Avondale Creek and Avon River.

The Stratford Coal Mine commenced operations in 1995 and the earliest groundwater monitoring dates from 1994. The groundwater monitoring network was expanded in 2003 and subsequent years to coincide with the commencement of mining at the BRNOC.

Mining is conducted currently at the BRNOC, and the Roseville West Pit, with backfilling of the Roseville Extended Pit ongoing. Mining has been completed at the Stratford Main Pit and the Roseville Pit. CSG production is scheduled to commence shortly by AGL for the approved AGL Gloucester Gas Project, and GRL is currently investigating and seeking approval for a new open cut coal mining operation to the north at the proposed Rocky Hill Coal Project.

The Project includes continuation of mining at the BRNOC and the Roseville West Pit Extension, with new excavations in the Avon North and Stratford East Open Cuts.

Based on analysis of field hydrographic data, there is clear evidence of a mining effect on some of the groundwater hydrographs in regolith, interburden rocks and coal seams, but no discernible effect on the alluvial groundwater system. There is no field evidence of current mining effects on the private bores in Stratford. The simulation results indicate that future mining will have minimal effect on water levels in the private bores in Stratford, well within the range of fluctuations experienced under dry to wet weather conditions.

Groundwater sinks have developed in the voids formed by current mining, which have locally altered natural groundwater flow directions.

Numerical modelling has been undertaken to provide a basis for the groundwater assessment for this Project and to quantify the likelihood and magnitude of potential drawdown and water quality impacts.

Based on the numerical groundwater modelling, there is expected to be:

- negligible groundwater drawdown in the Alluvial sediments;
- negligible impact on groundwater levels or groundwater yield for groundwater users with privately owned bores in any groundwater system;
- substantial reduction in potentiometric head in the Fractured Rock groundwater system in the near vicinity of the Project;
- a maximum drawdown extent of 1.6 km from the Roseville West Pit Extension at the end of mining;
- a maximum drawdown extent of 1.0 km from the Avon North Open Cut at the end of mining;
- a maximum drawdown extent of 0.8 km from the Stratford East Open Cut at the end of mining;
- no effect on the nearest Biophysical Strategic Agricultural Land along the Avon River, west of Stratford;
- negligible reduction in natural baseflow to surface stream systems (i.e. Dog Trap Creek, Avondale Creek and the Avon River);
- total pit inflows ranging between approximately 0.7 ML/day and 1.3 ML/day during the Project open cut operations;
- a final combined pit inflow in the order of 0.7 ML/day at the completion of mining (Year 11) reducing to about 0.6 ML/day once the final void water level reaches equilibrium;
- an average combined pit inflow of 1.0 ML/day during the 11 years of the Project; and
- negligible change in groundwater quality as a result of mining in the short-term and in the long-term.

Cumulative effects are expected to be substantially greater than would be produced by the Project acting alone. CSG activity would cause pronounced drawdown in the watertable between the Project and Stratford. Nevertheless, the predicted drawdowns at the Stratford privately owned bores are less than 1 m for bores in the northern half and 1-2 m for the southern half. There would be no impact on the other known private bore located within 5 km of the Stratford Mining Complex.

The potential impacts of mining on surface water resources, other than those assessed within this report, are assessed in Appendix B of the EIS.

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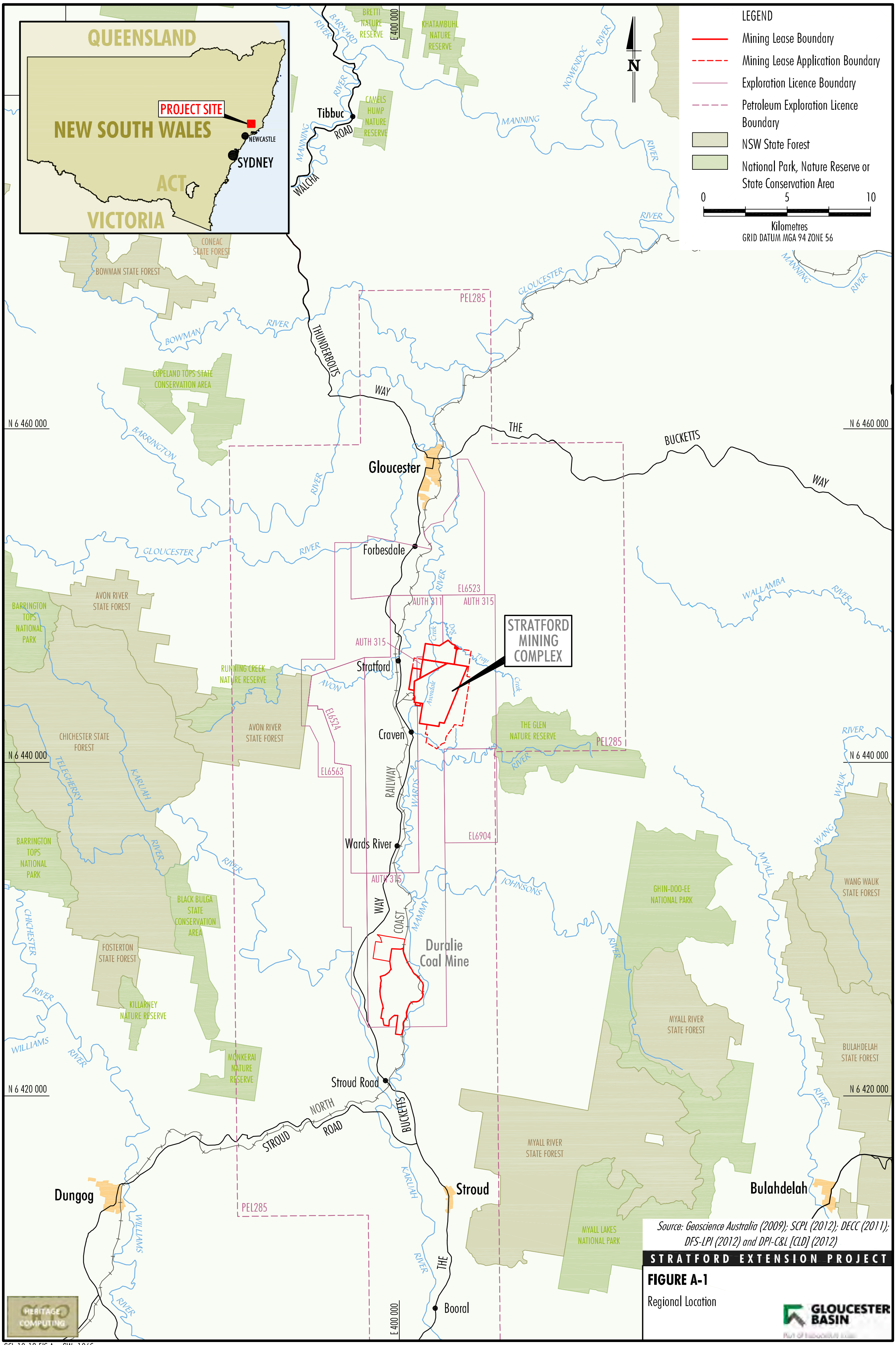
ILLUSTRATIONS

Figures A-1 to A-60



STRATFORD EXTENSION PROJECT

FIGURE A-1

Regional Location

GCL-10-12 EIS App GW_106C

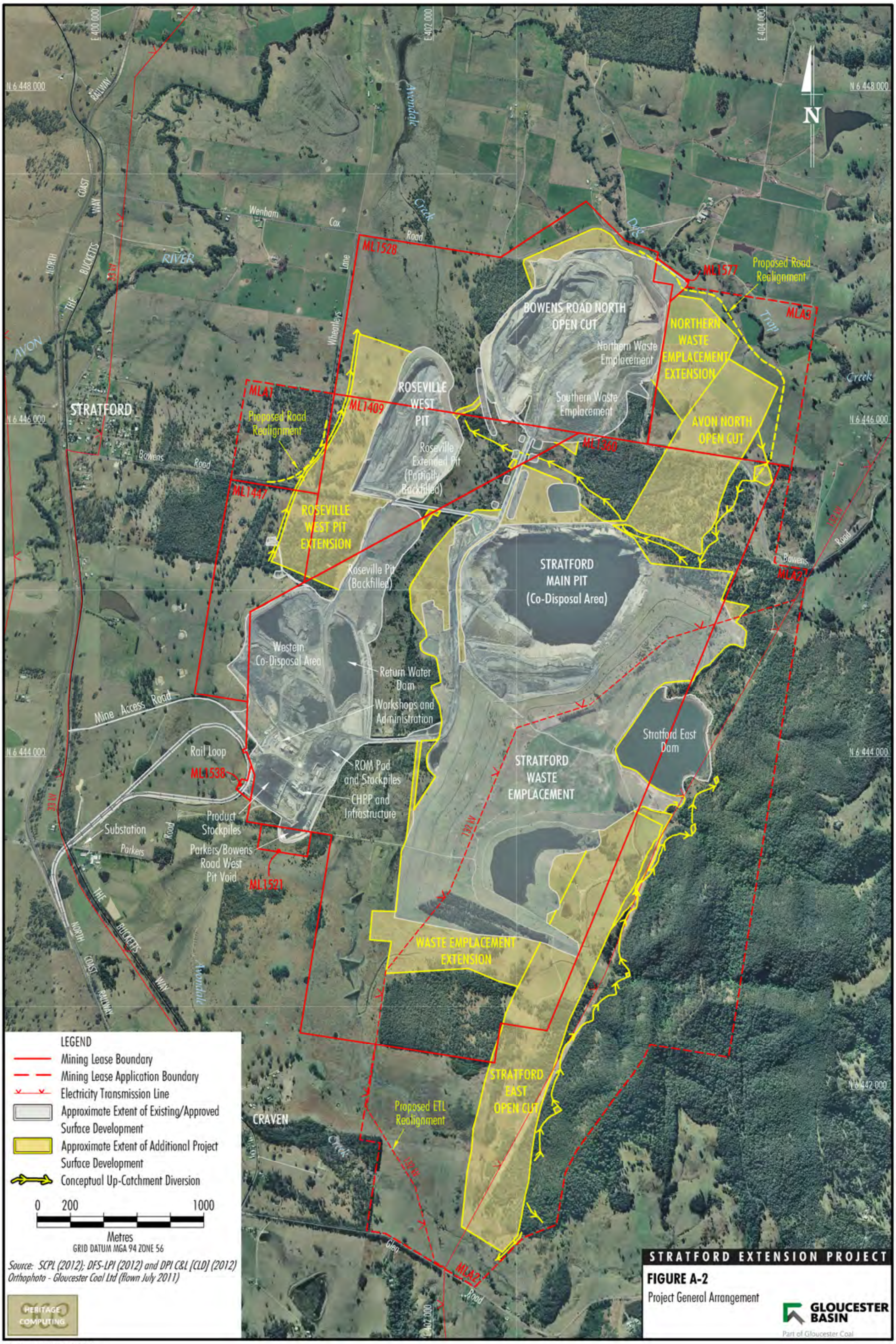
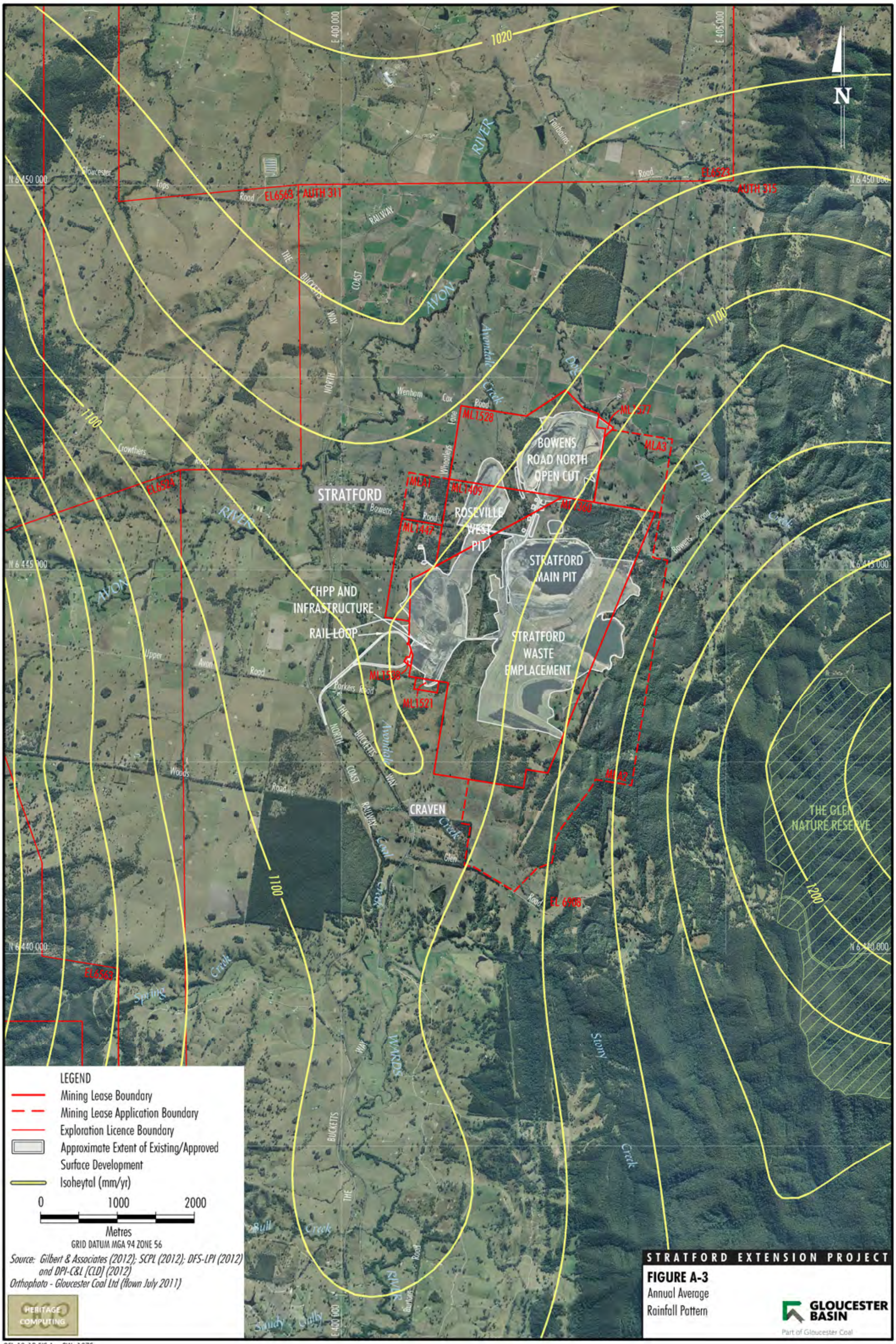


FIGURE A-2
Project General Arrangement

GCL-10-12 EIS App GW_105D



STRATFORD EXTENSION PROJECT

FIGURE A-3
Annual Average Rainfall Pattern

GCL-10-12 EIS App GW_107C

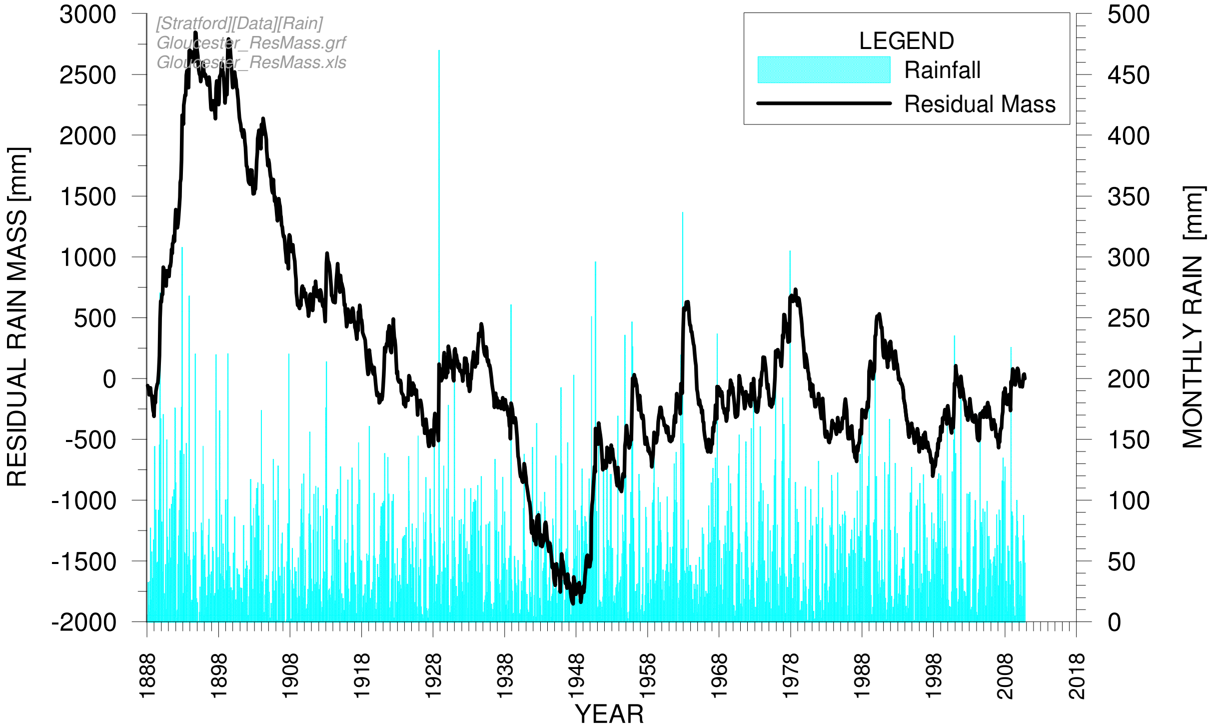


Figure A-4 Rainfall Residual Mass Curve for Gloucester Post Office (since 1888)

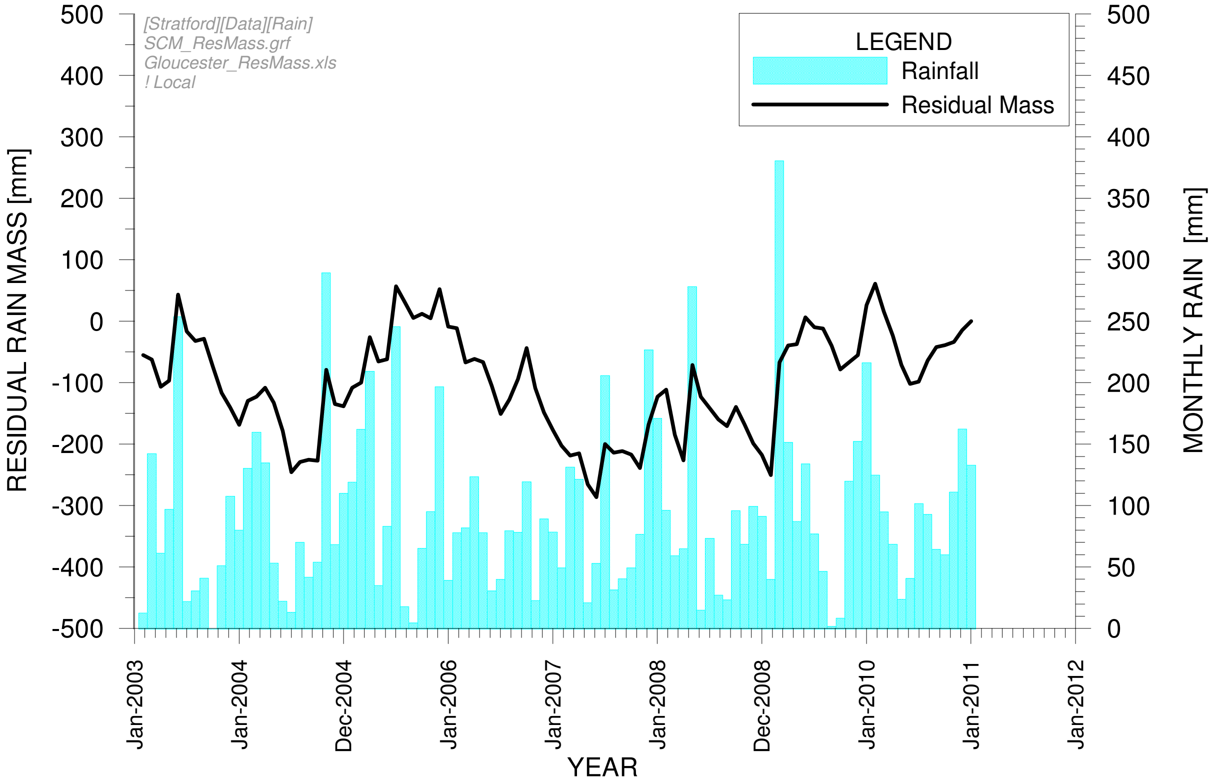


Figure A-5 Rainfall Residual Mass Curve for Stratford Coal Mine Meteorological Station

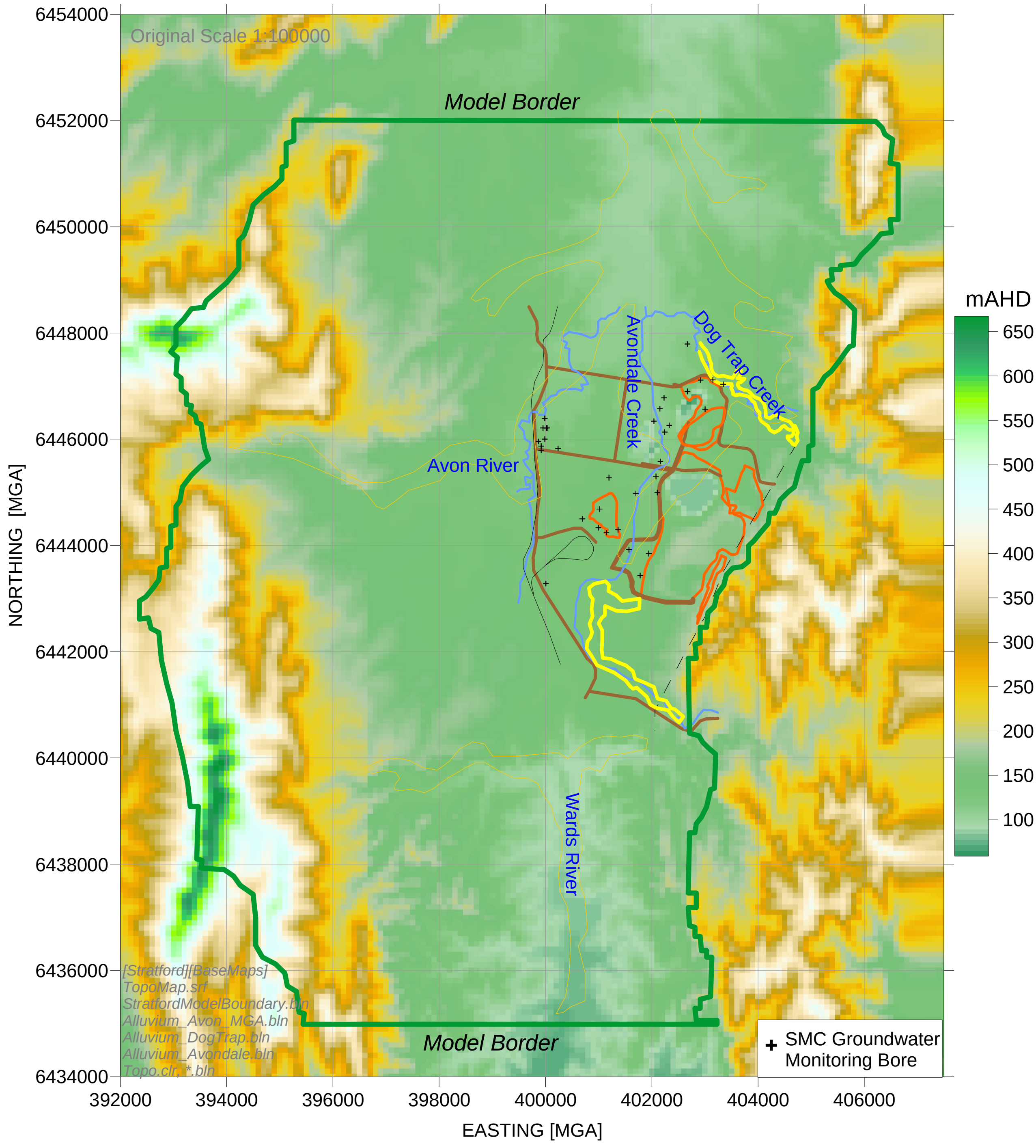


Figure A-6 Regional Topography and Model Extent

[The thin orange outlines show the extents of alluvium as they appear on published geological maps; the thick yellow outlines mark the main channels detected by a TEM survey]

BASIN	PERIOD	GROUP	SUB-GROUP	FORMATION	COAL SEAMS
GLOUCESTER	PERMIAN	GLOUCESTER COAL MEASURES	CRAVEN	Crowthers Road	[*Conglomerate*]
				Woods Road (Leloma)	*Linden, Marker (M6,M7[2]), Bindaboo[1,2], Deards[1,2]*
				Bucketts Way (Jilleon)	*Cloverdale[1,2], Roseville[1,2], Marker (M3, M8, M1)[1]*
				Wards River	[*Conglomerate*]
				Wenham	*Bowens Road[1,2], Bowens Road Lower[1]*
			SPELDON FORMATION		
			AVON	*Dog Trap Creek*	*Glenview, Marker 2*
				Waukivory Creek	*Avon[1,2], Triple[1], Rombo, Glen Road, Valley View, Parkers Road*
		DEWRANG GROUP		*Mammy Johnsons*	*Mammy Johnsons*
				Weismantel	*Weismantel*
				Duralie Road	*Cheer-up[2], Clareval[2]*
		ALUM MOUNTAIN VOLCANICS			

[1] Coal reserves currently/previously mined at the Stratford Mining Complex
[2] Coal reserves to be mined by the Project

Source: Tamplin Resources (2010), Stratford Coal (1994) and SCPL (2012)

STRATFORD EXTENSION PROJECT

FIGURE A-7

Stratigraphic Units of the Development Application Area

GLOUCESTER BASIN
Part of Gloucester Coal

GCL-10-02 EIS AppGW_004F

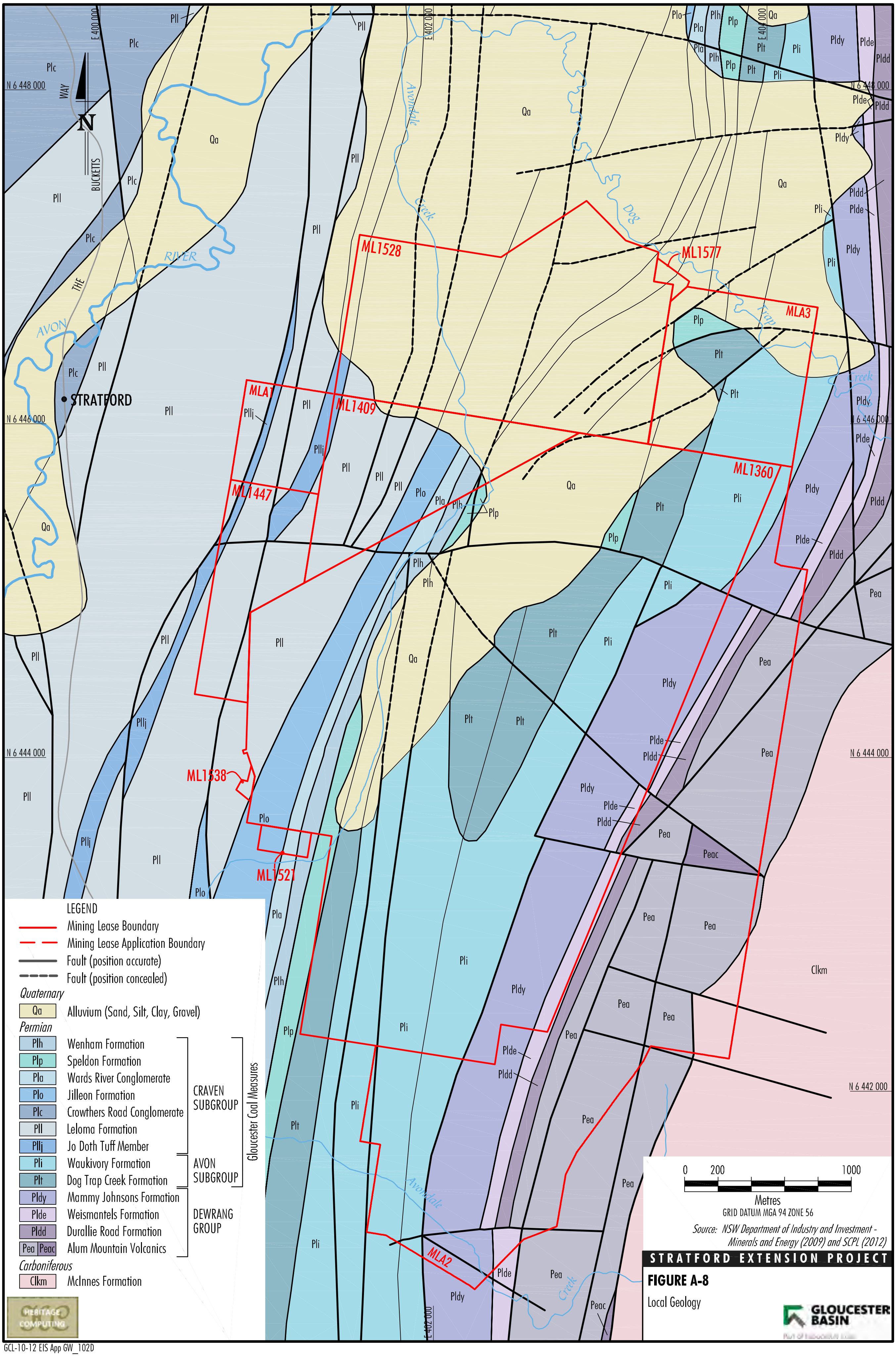
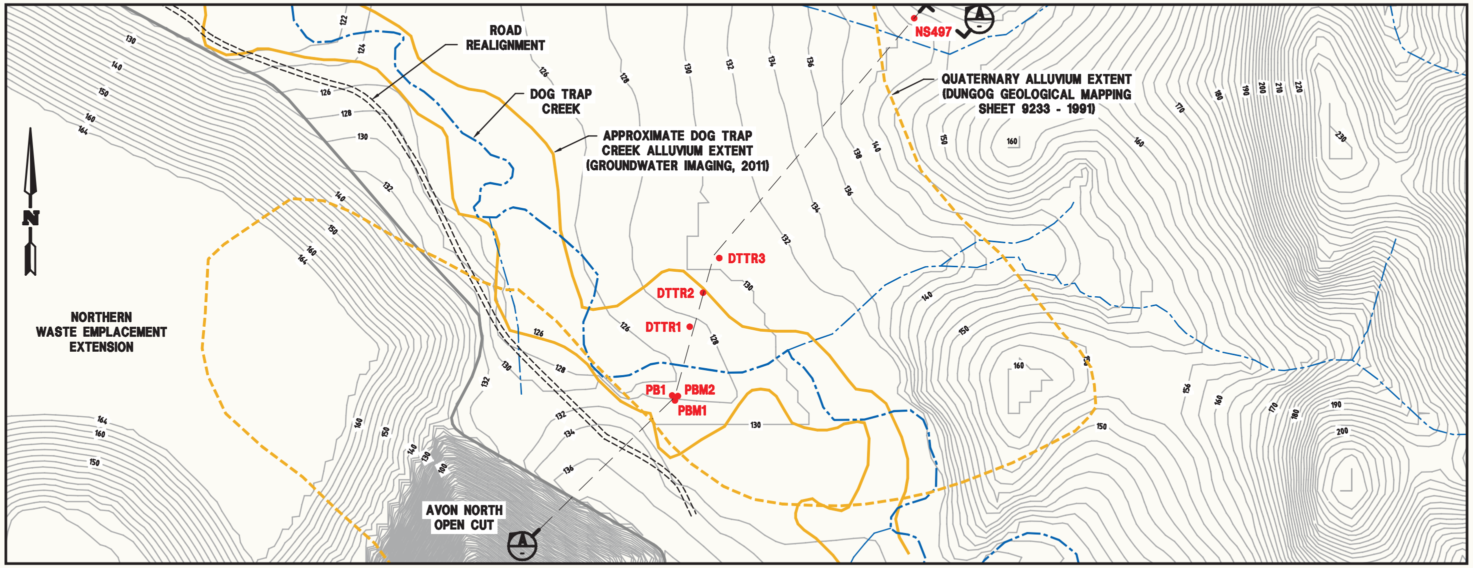


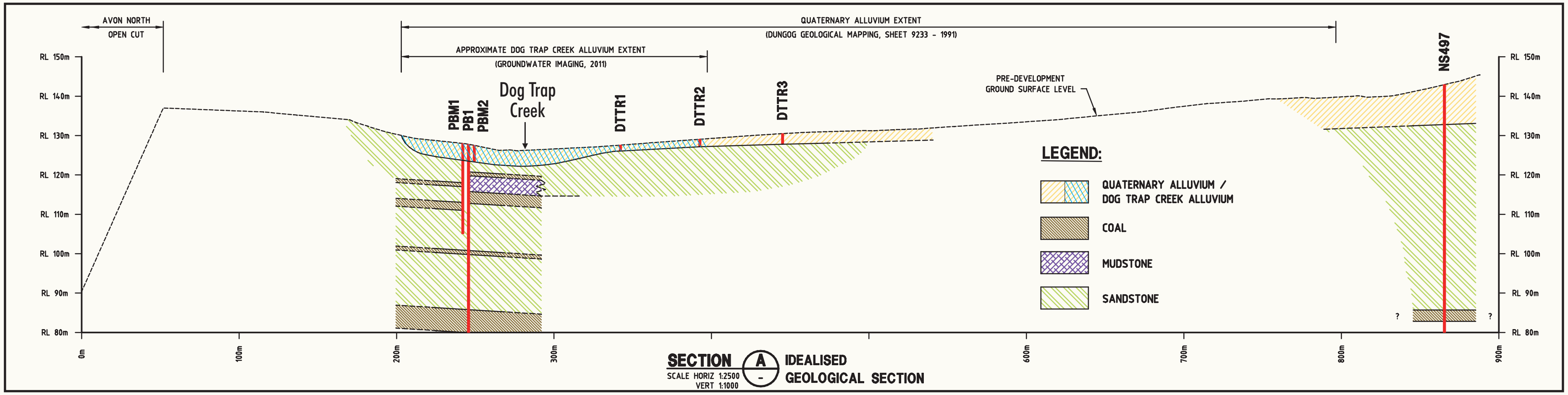
FIGURE A-8

Local Geology



Source: Allan Watson Associates (2011)

Dog Trap Creek Alluvium - Plan View



Source: Allan Watson Associates (2011)

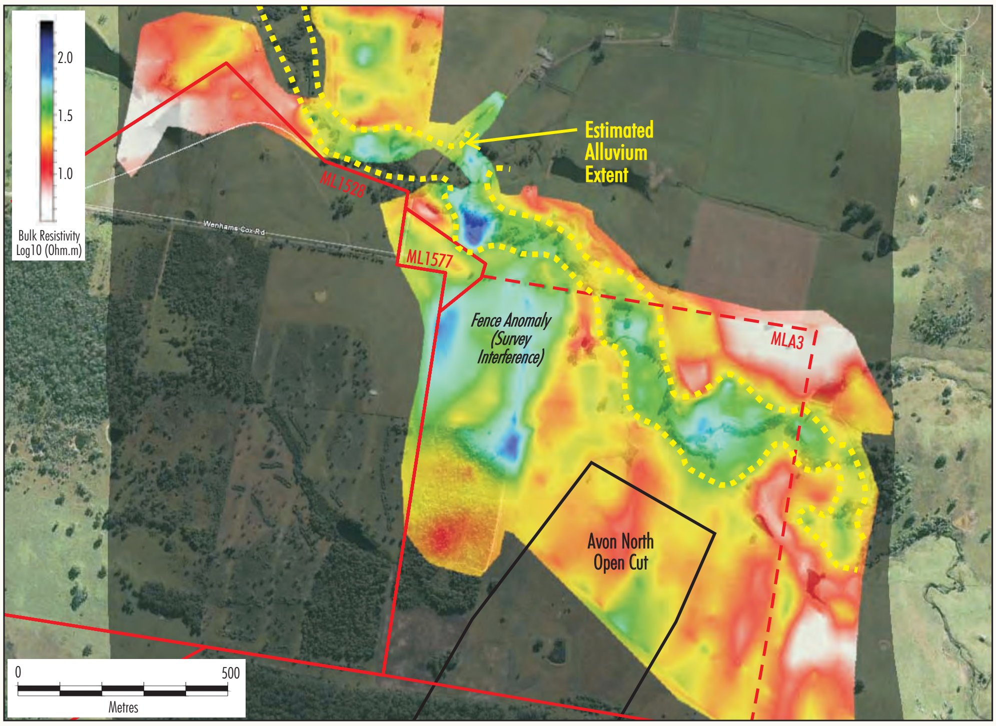
Dog Trap Creek Alluvium - Section

STRATFORD EXTENSION PROJECT

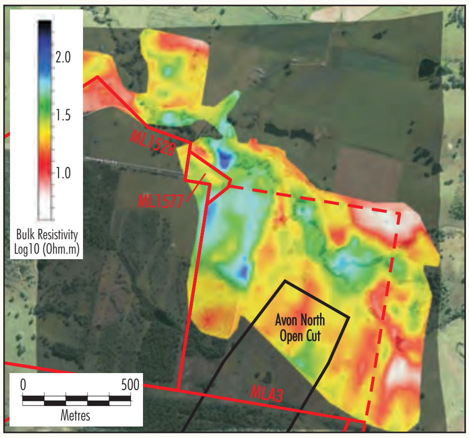
FIGURE A-9

Transect of Alluvial Bores across Dog Trap Creek

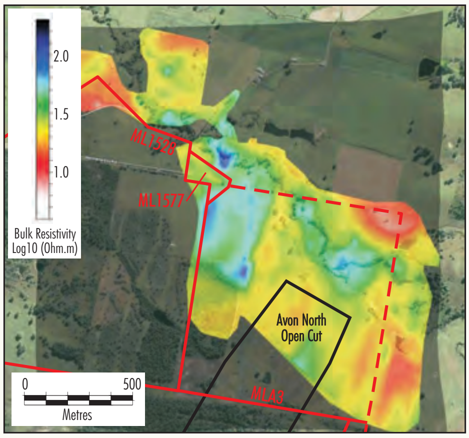
GLOUCESTER BASIN
Part of Gloucester Coal



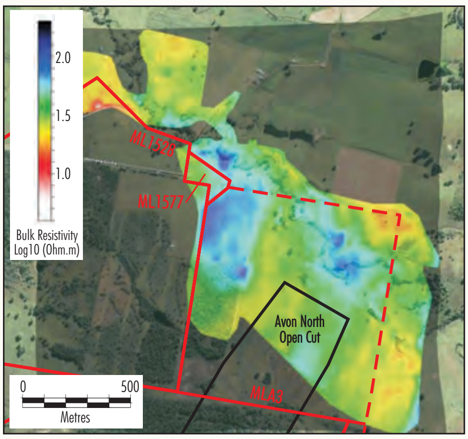
TEM Results @ 1m Depth (Including Estimated Alluvium Extent)



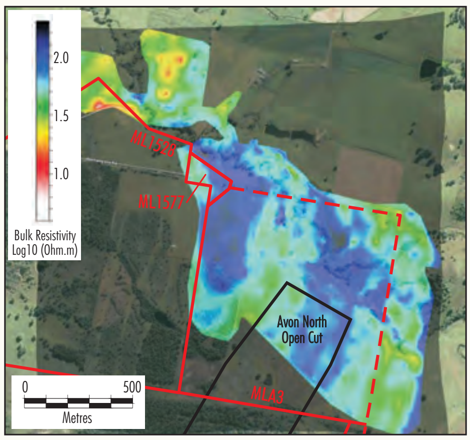
TEM Results @ 3m Depth



TEM Results @ 7m Depth



TEM Results @ 12m Depth



TEM Results @ 20m Depth

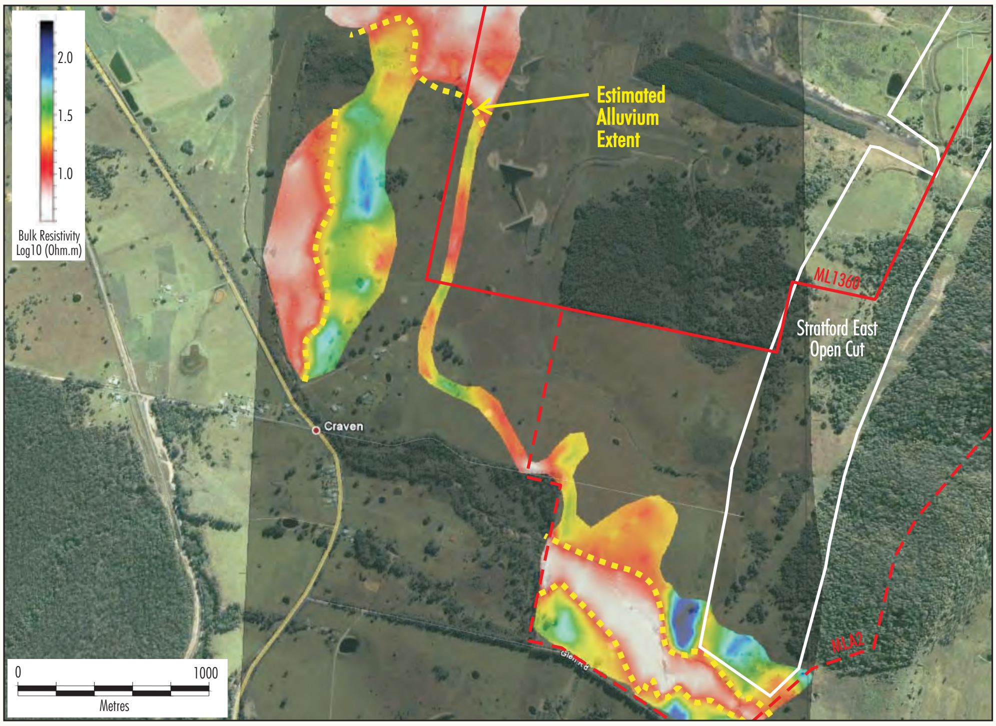
Source: Groundwater Imaging (2012)

Mining Lease Boundary
Mining Lease Application Boundary

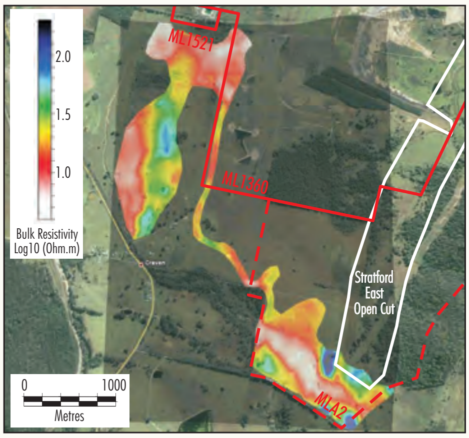
STRATFORD EXTENSION PROJECT

FIGURE A-10
TEM Survey Results
Dog Trap Creek

GLOUCESTER BASIN
Part of Gloucester Coal



TEM Results @ 1m Depth (Including Estimated Alluvium Extent)



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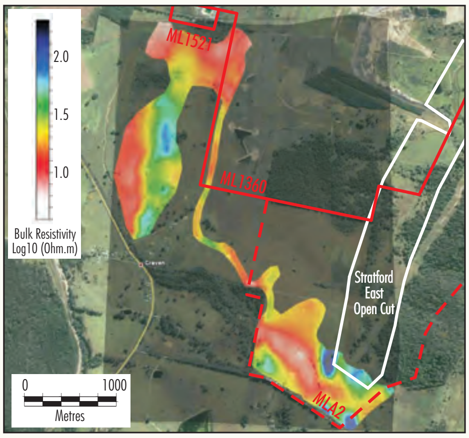
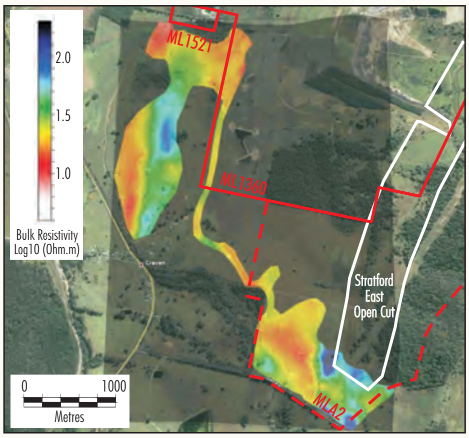
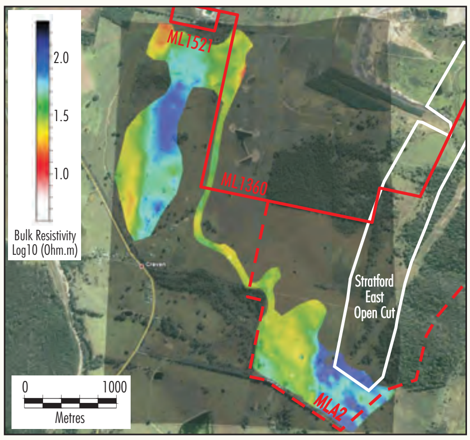


TEM Results @ 7m Depth



TEM Results @ 12m Depth



TEM Results @ 20m Depth

Source: Groundwater Imaging (2012)

Mining Lease Boundary
Mining Lease Application Boundary

STRATFORD EXTENSION PROJECT

FIGURE A-11

TEM Survey Results
Avondale Creek

GLOUCESTER BASIN
Part of Gloucester Coal

HERITAGE COMPUTING

GCL-10-02 EIS AppGW_002D

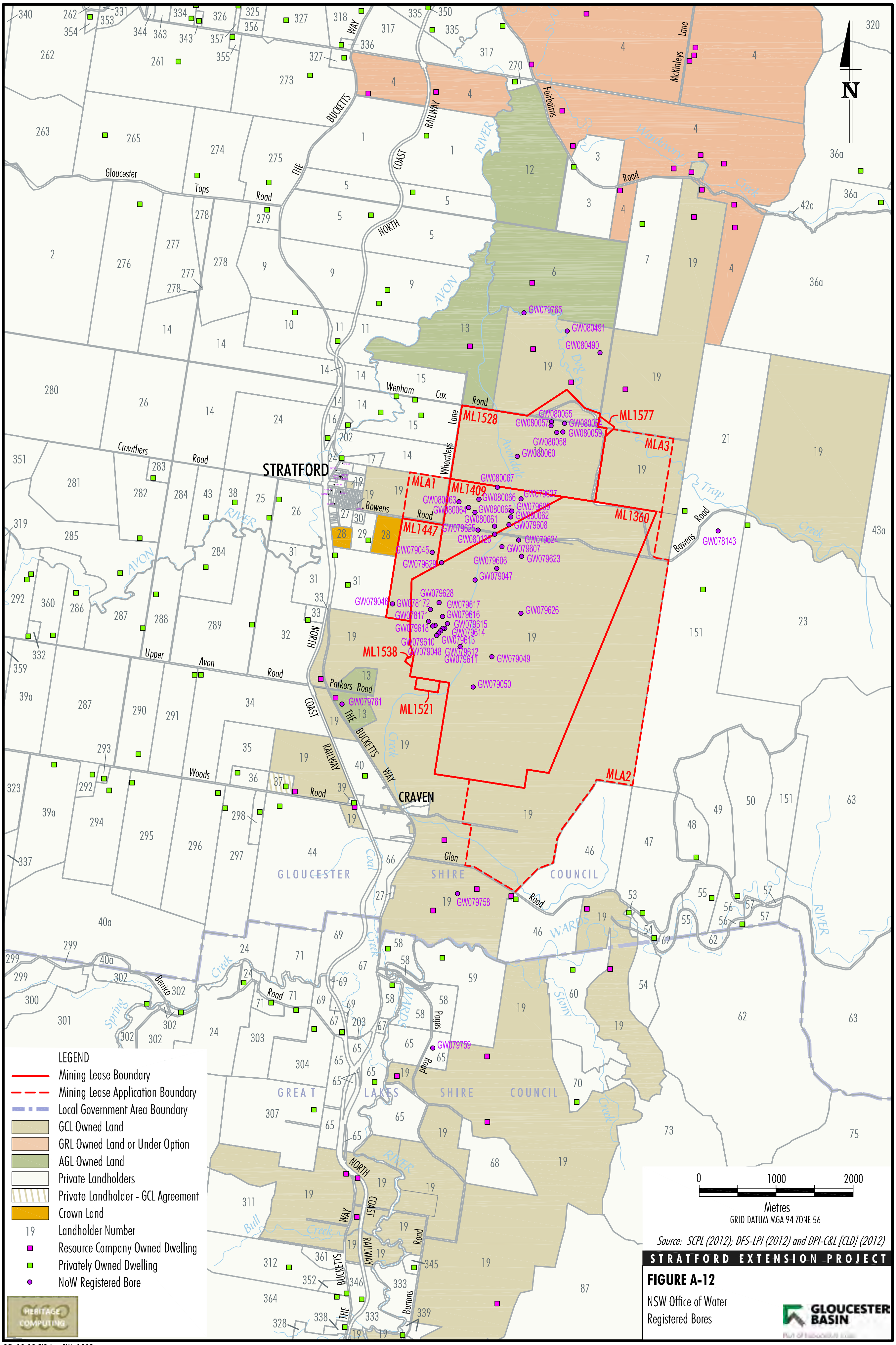


FIGURE A-12
NSW Office of Water Registered Bores

GCL-10-12 EIS App GW_109C

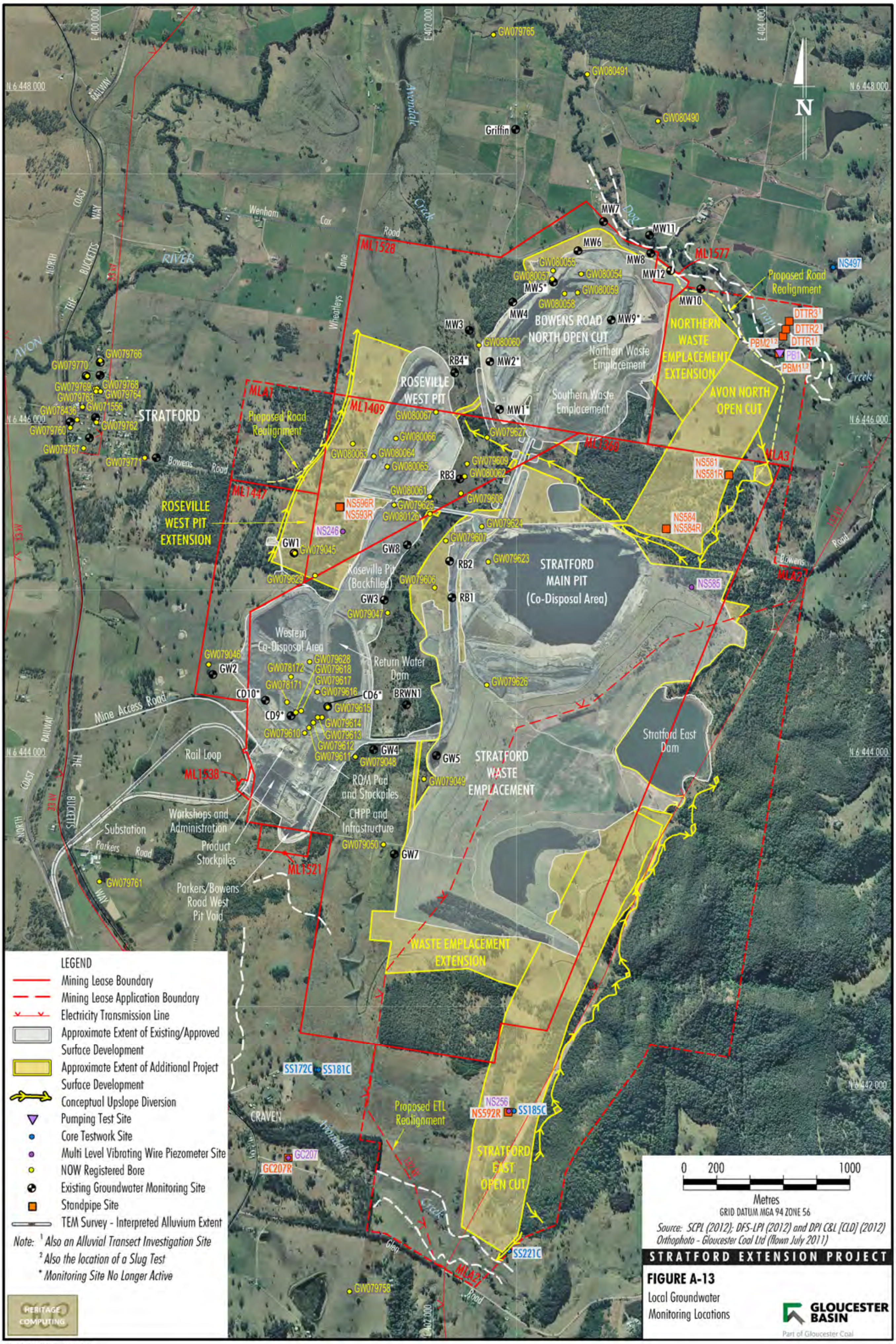
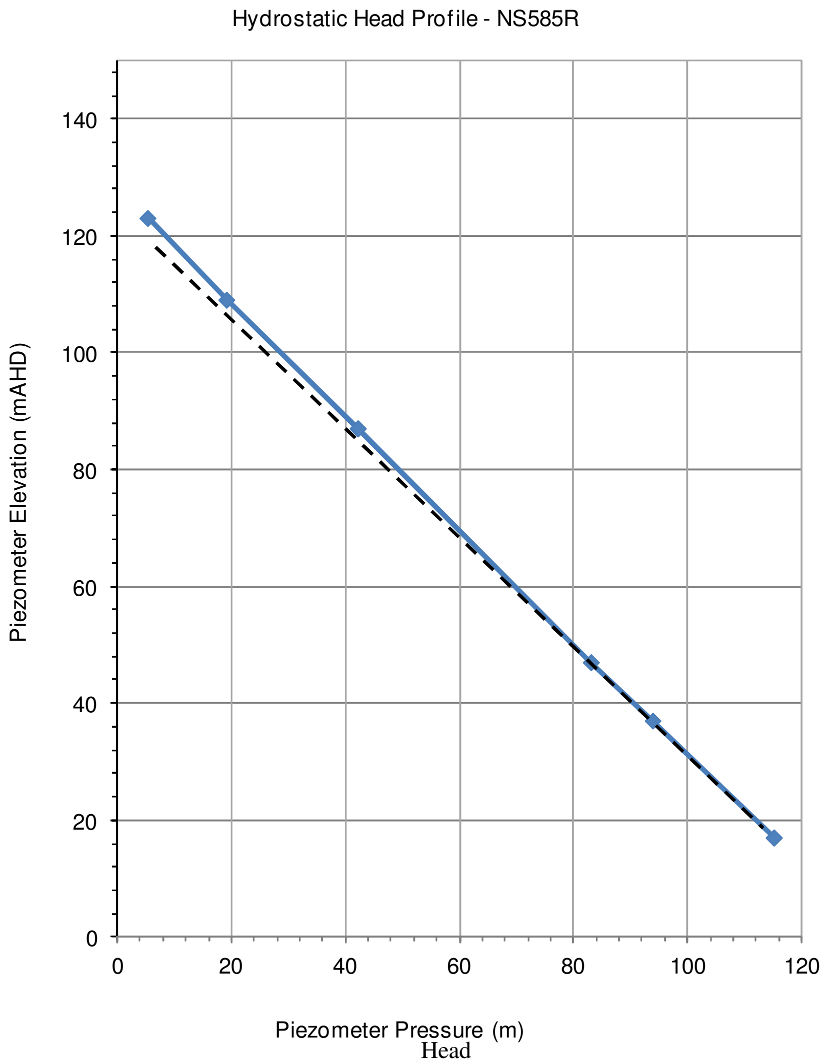


FIGURE A-13

Local Groundwater Monitoring Locations

GCL-10-12 EIS App GW_101L



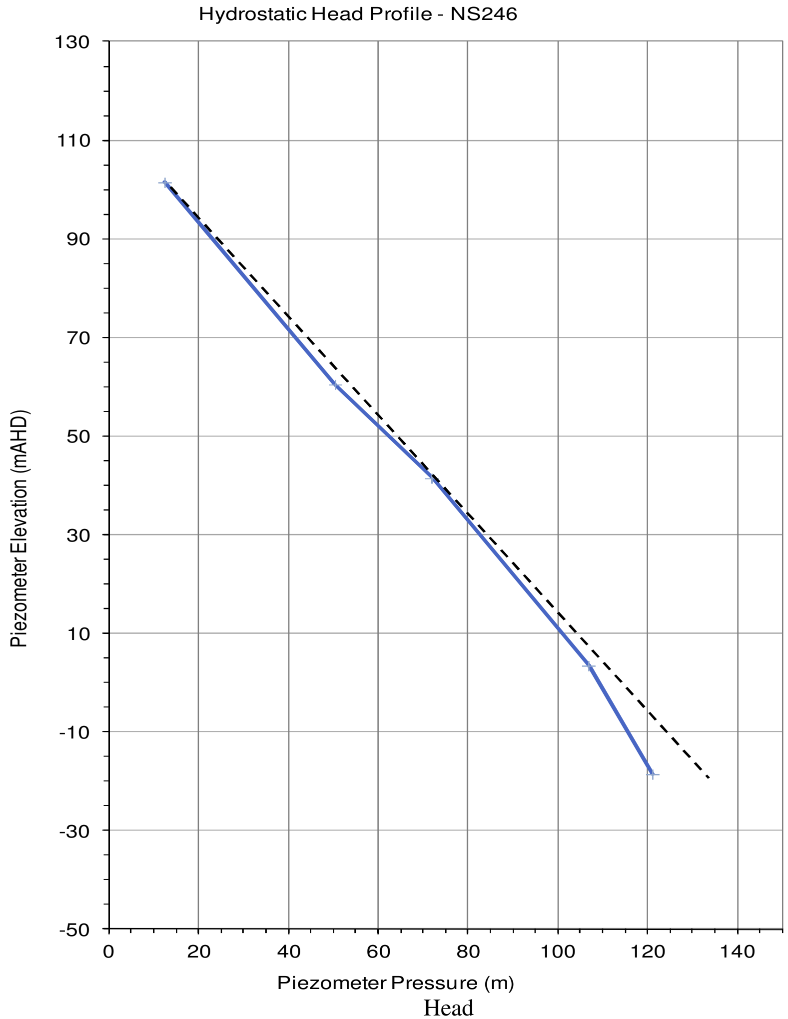


Figure A-14 Multi-level Vibrating Wire Groundwater Piezometer Hydrostatic Plots for NS585 and NS246

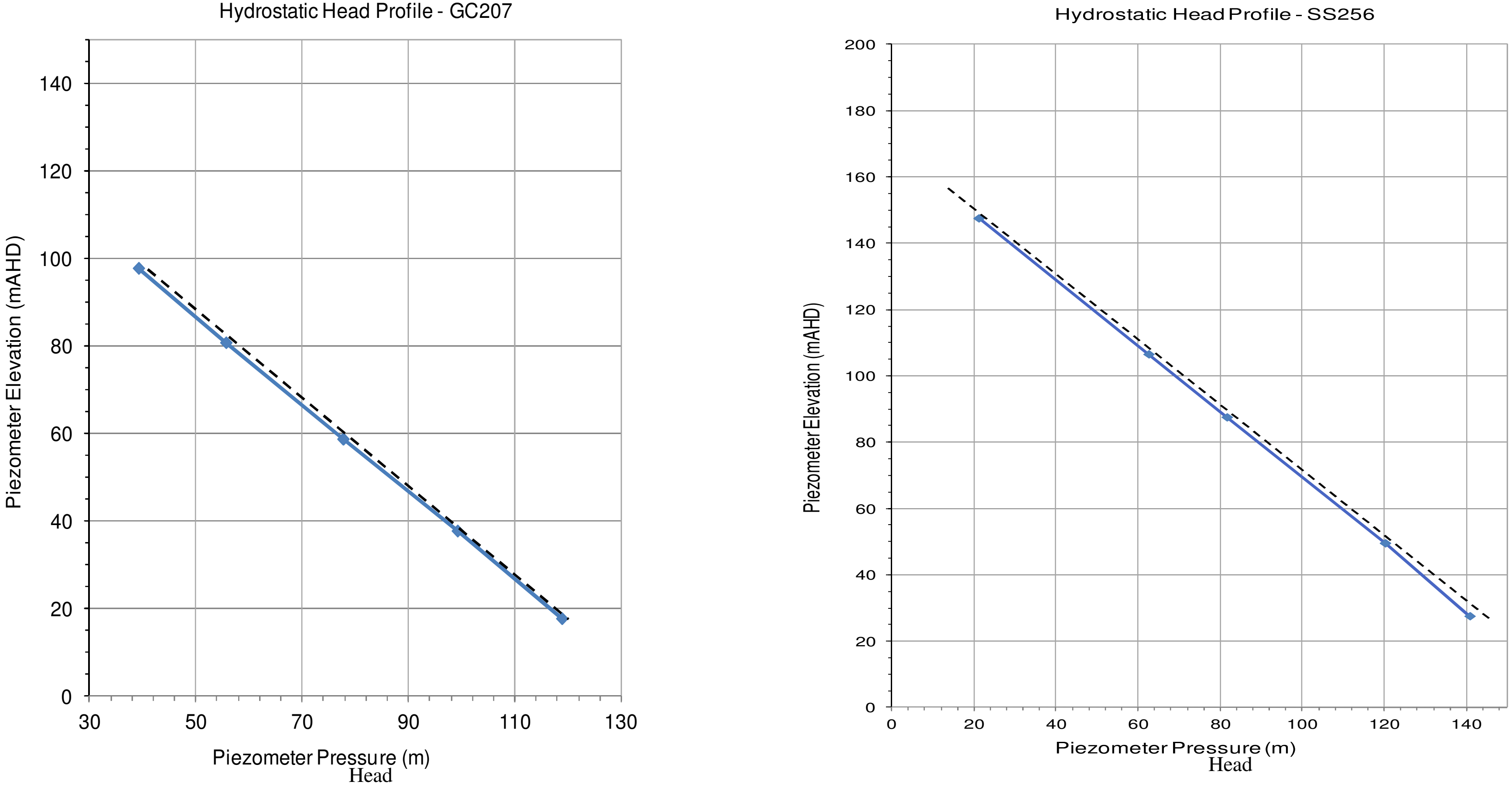


Figure A-15 Multi-level Vibrating Wire Groundwater Piezometer Hydrostatic Plots for GC207 and SS256

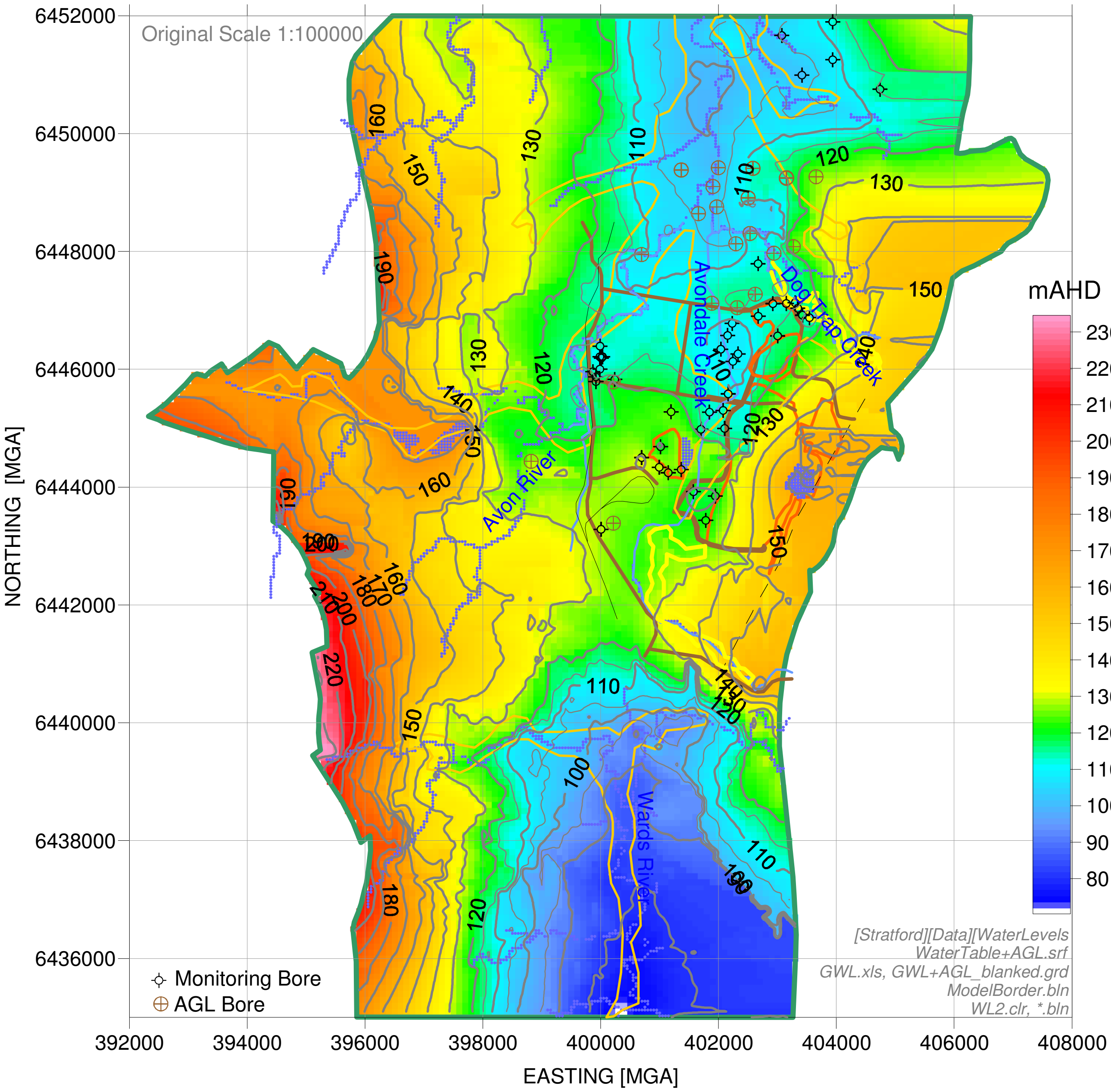
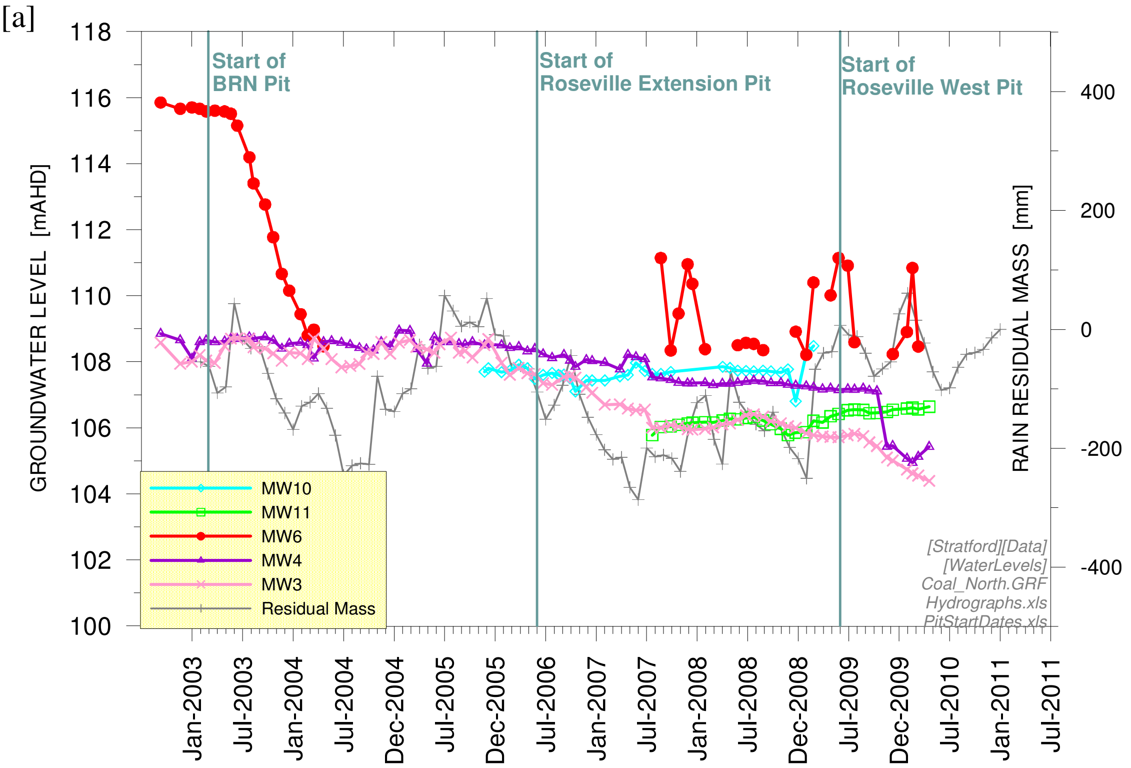


Figure A-16 Inferred Regional Shallow Groundwater Elevations [mAHD]



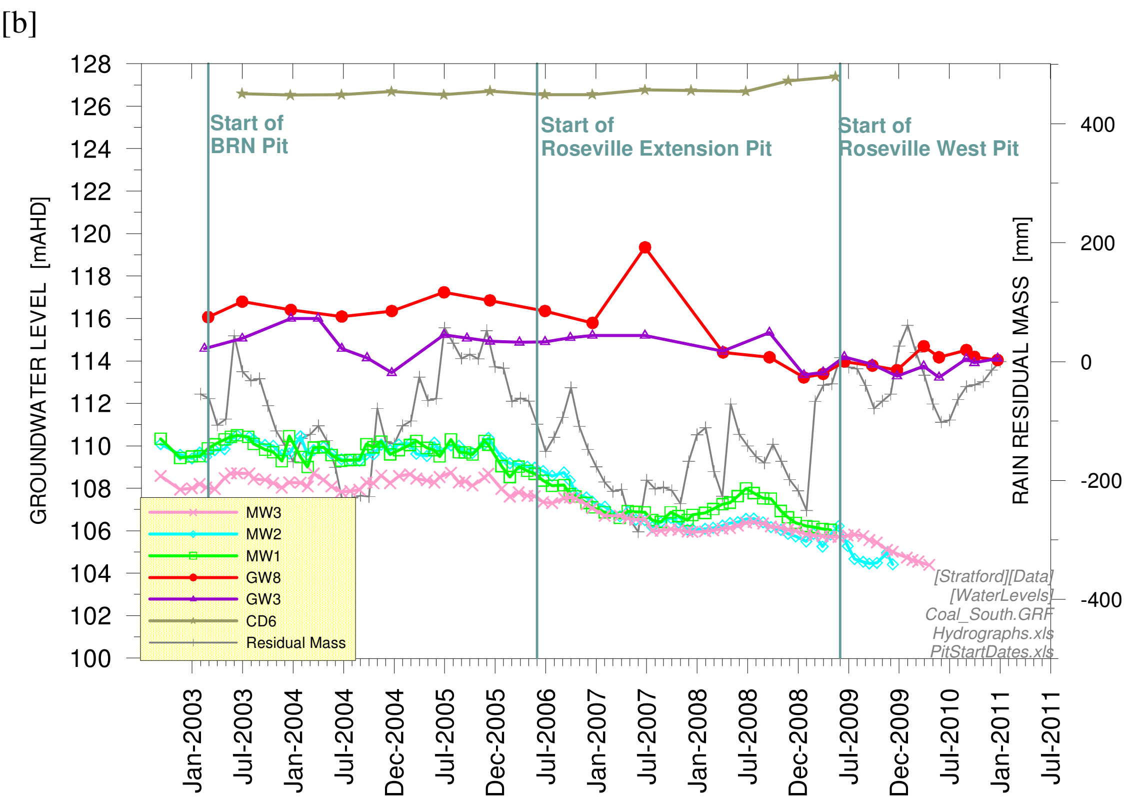
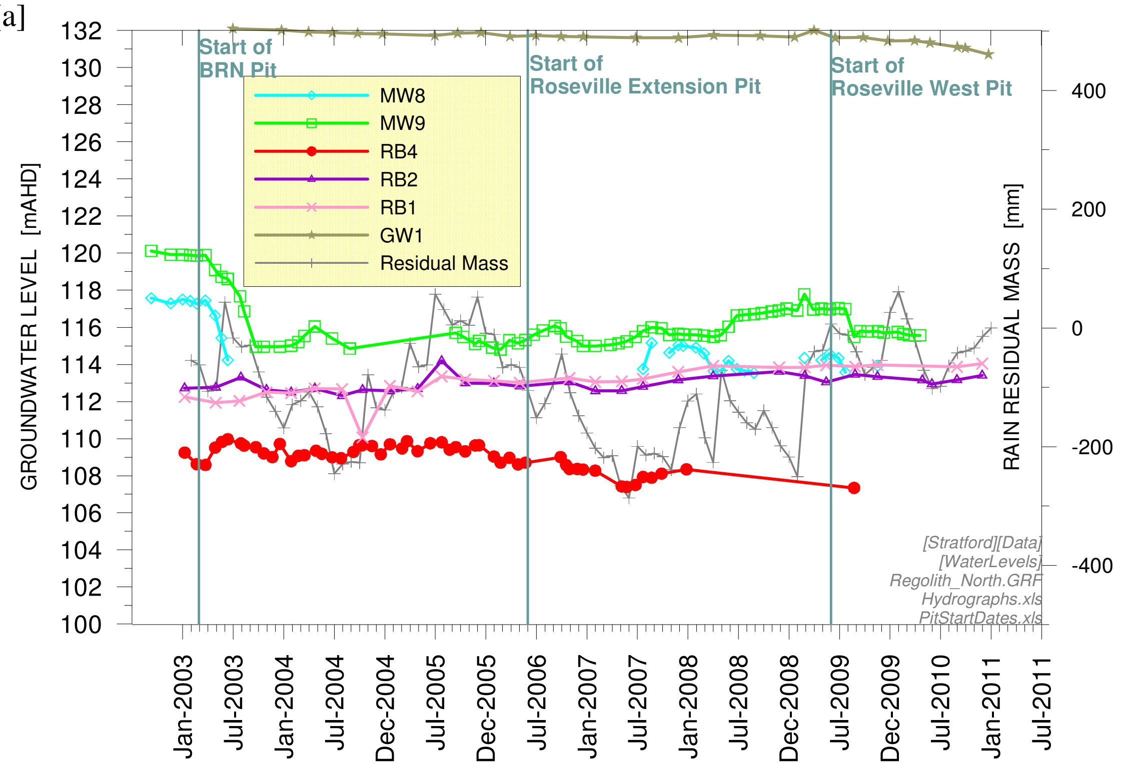


Figure A-17 Groundwater Hydrographs in Coal Seams: [a] north; [b] south

[a]



[b]

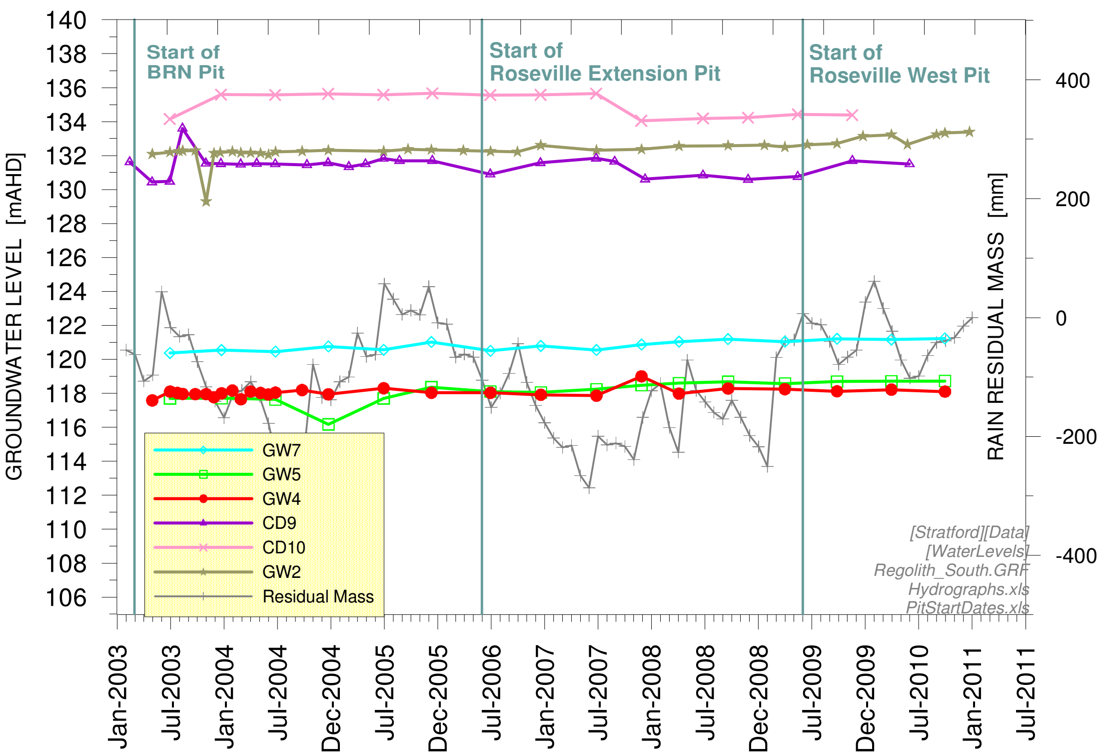
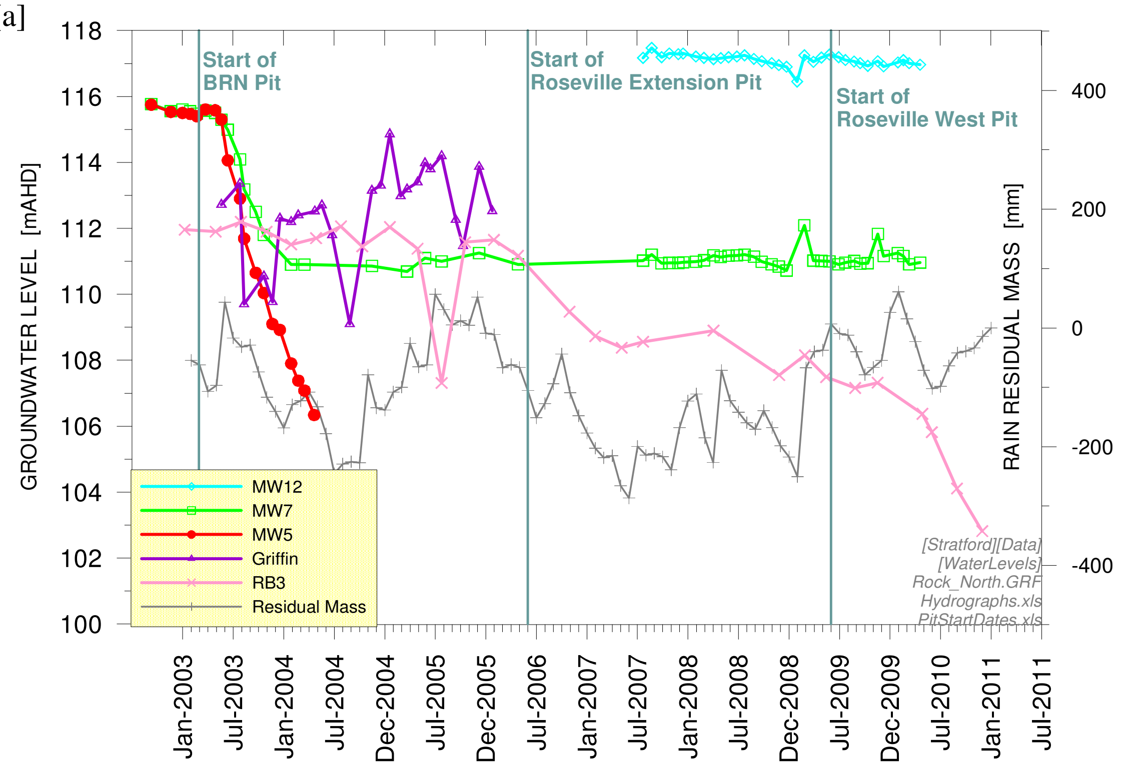


Figure A-18 Groundwater Hydrographs in Regolith: [a] north; [b] south

[a]



[b]

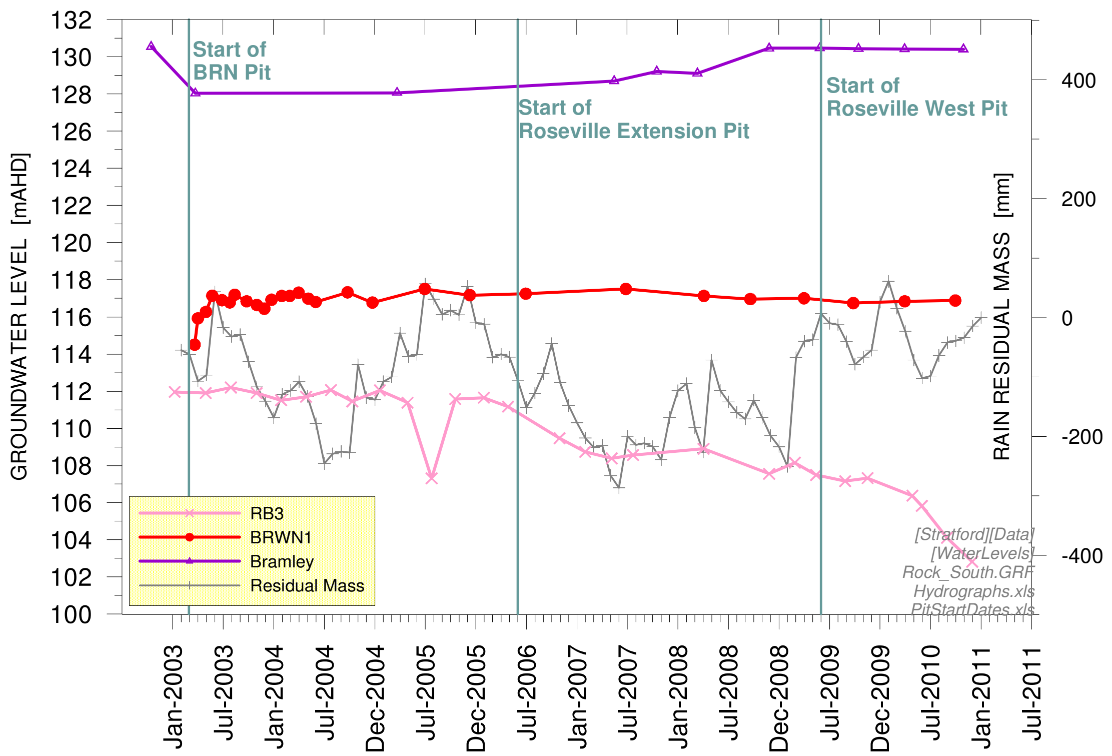
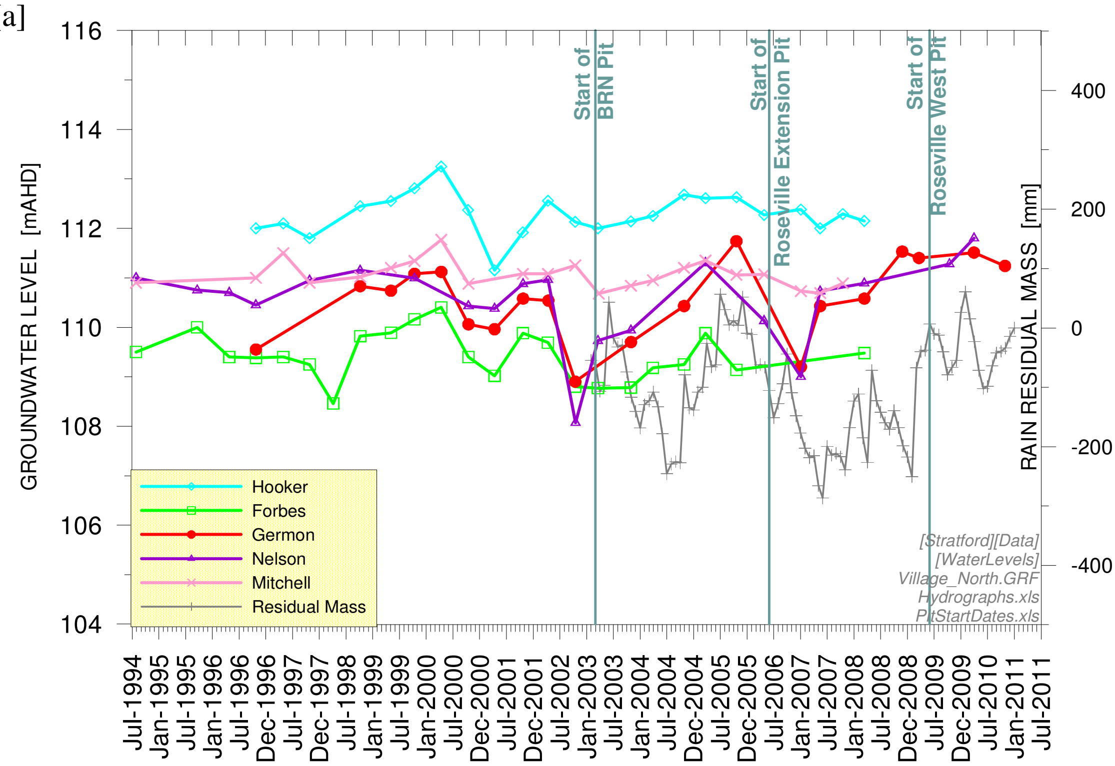


Figure A-19 Groundwater Hydrographs in Interburden: [a] north; [b] south

[a]



[b]

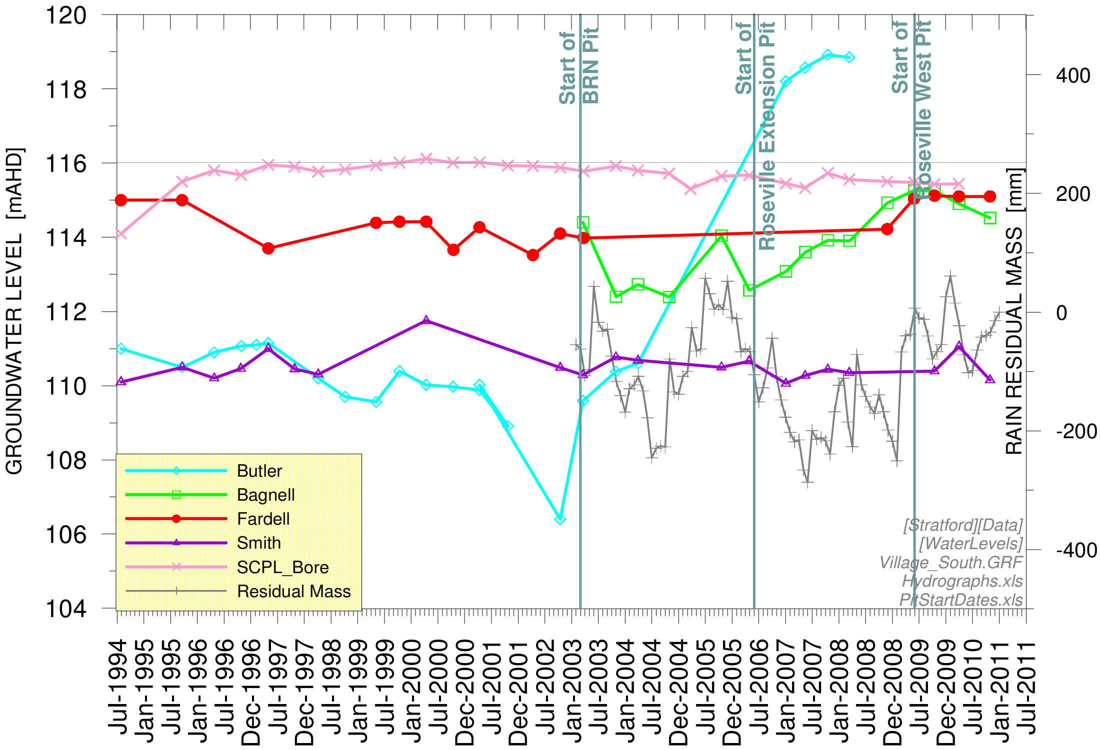


Figure A-20 Groundwater Hydrographs at Stratford Village: [a] north; [b] south

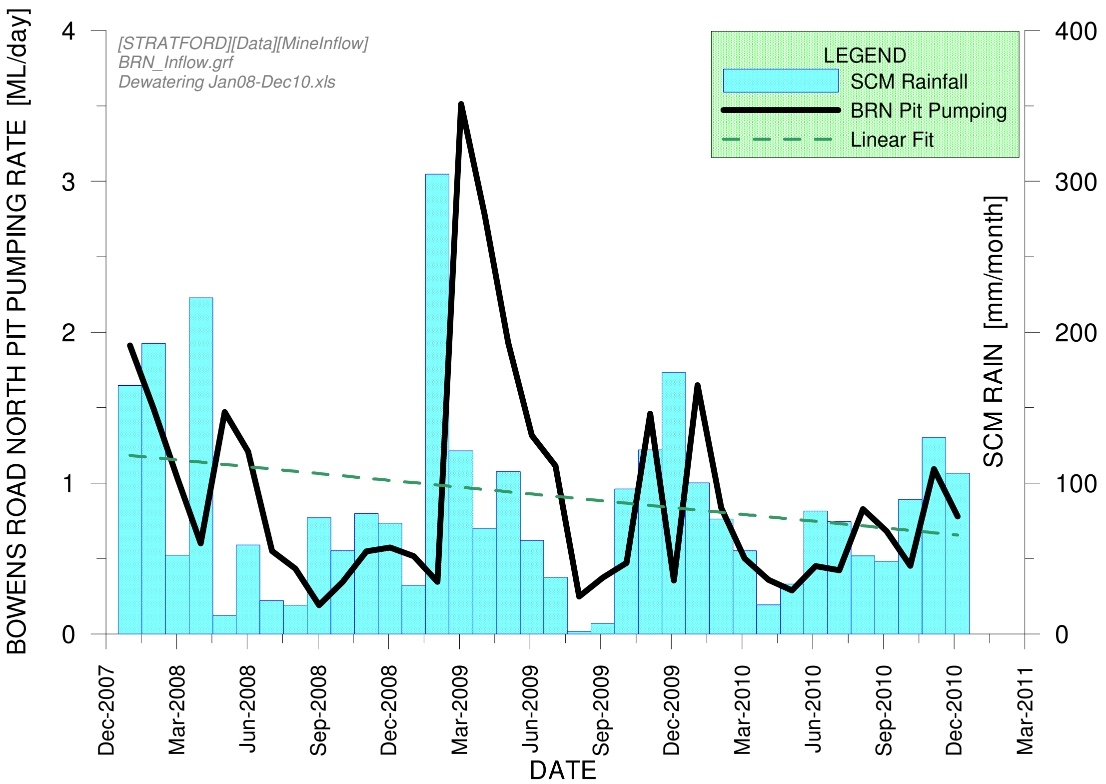


Figure A-21 Recorded Pumping Rates from the Bowens Road North Pit [ML/day]

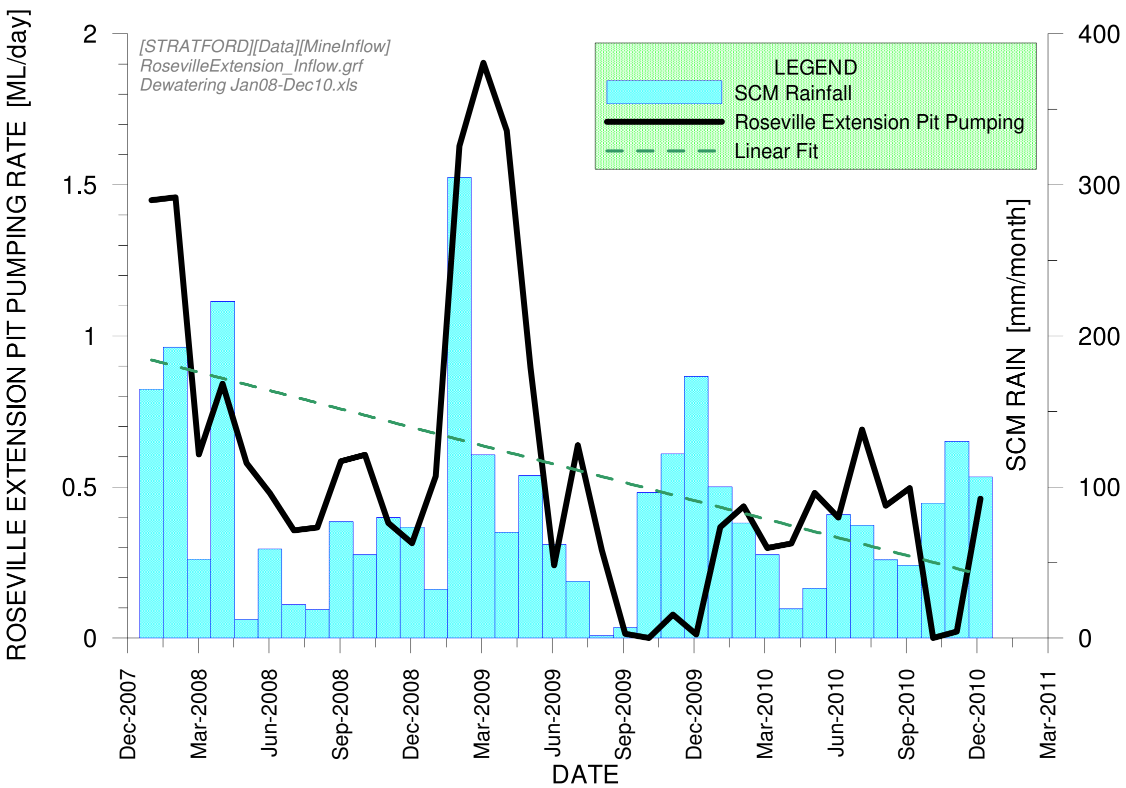


Figure A-22 Recorded Pumping Rates from the Roseville Extension Pit [ML/day]

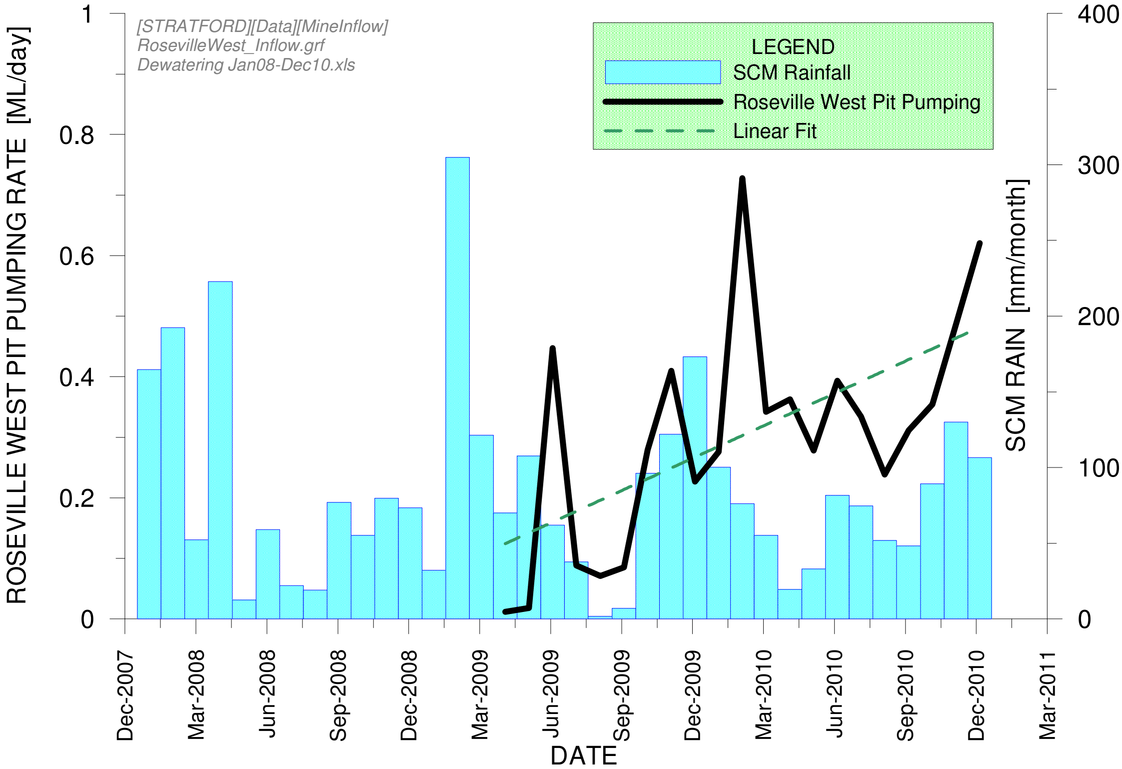


Figure A-23 Recorded Pumping Rates from the Roseville West Pit [ML/day]

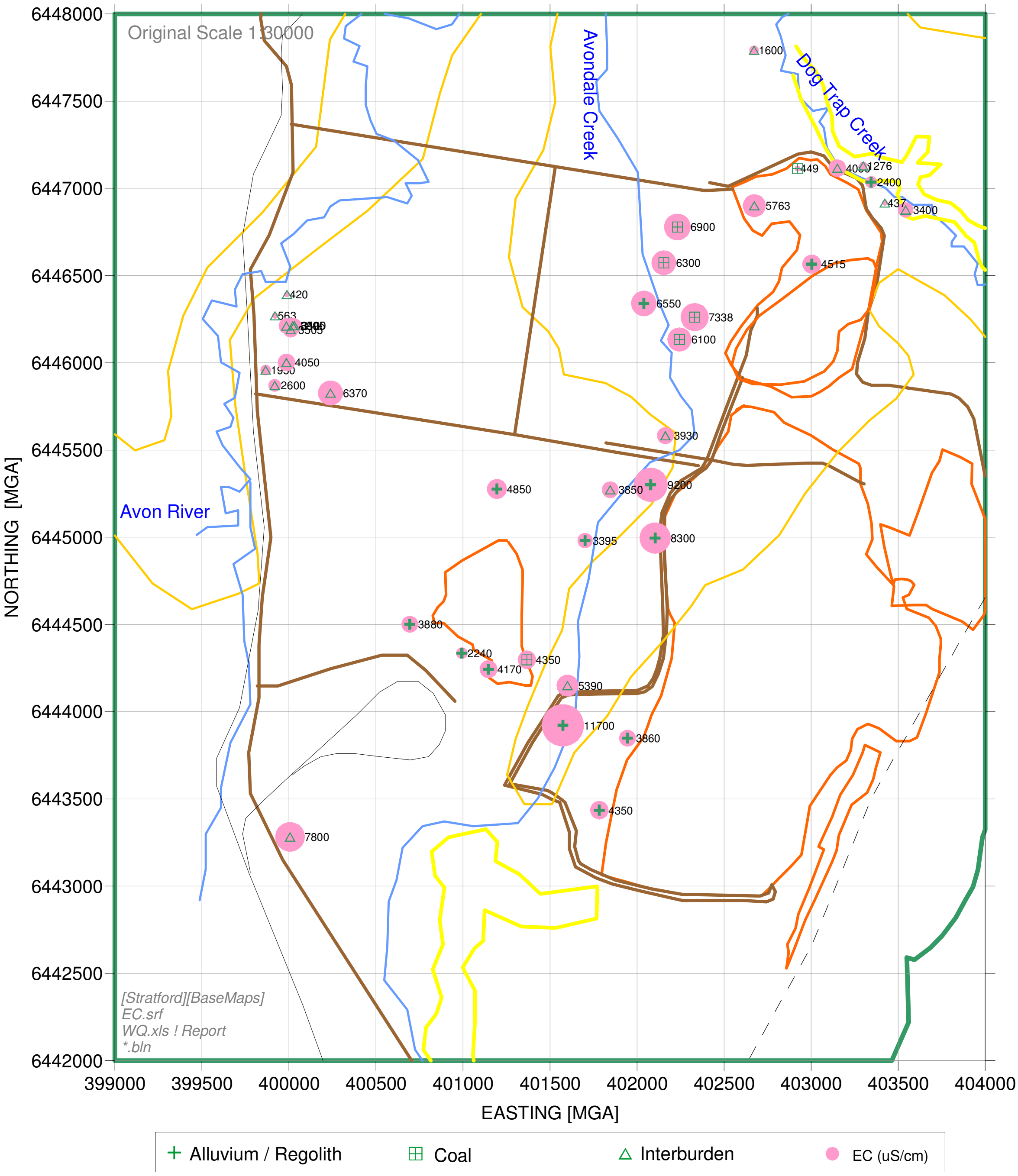


Figure A-24 Spatial Distribution of Groundwater Electrical Conductivity [µS/cm]

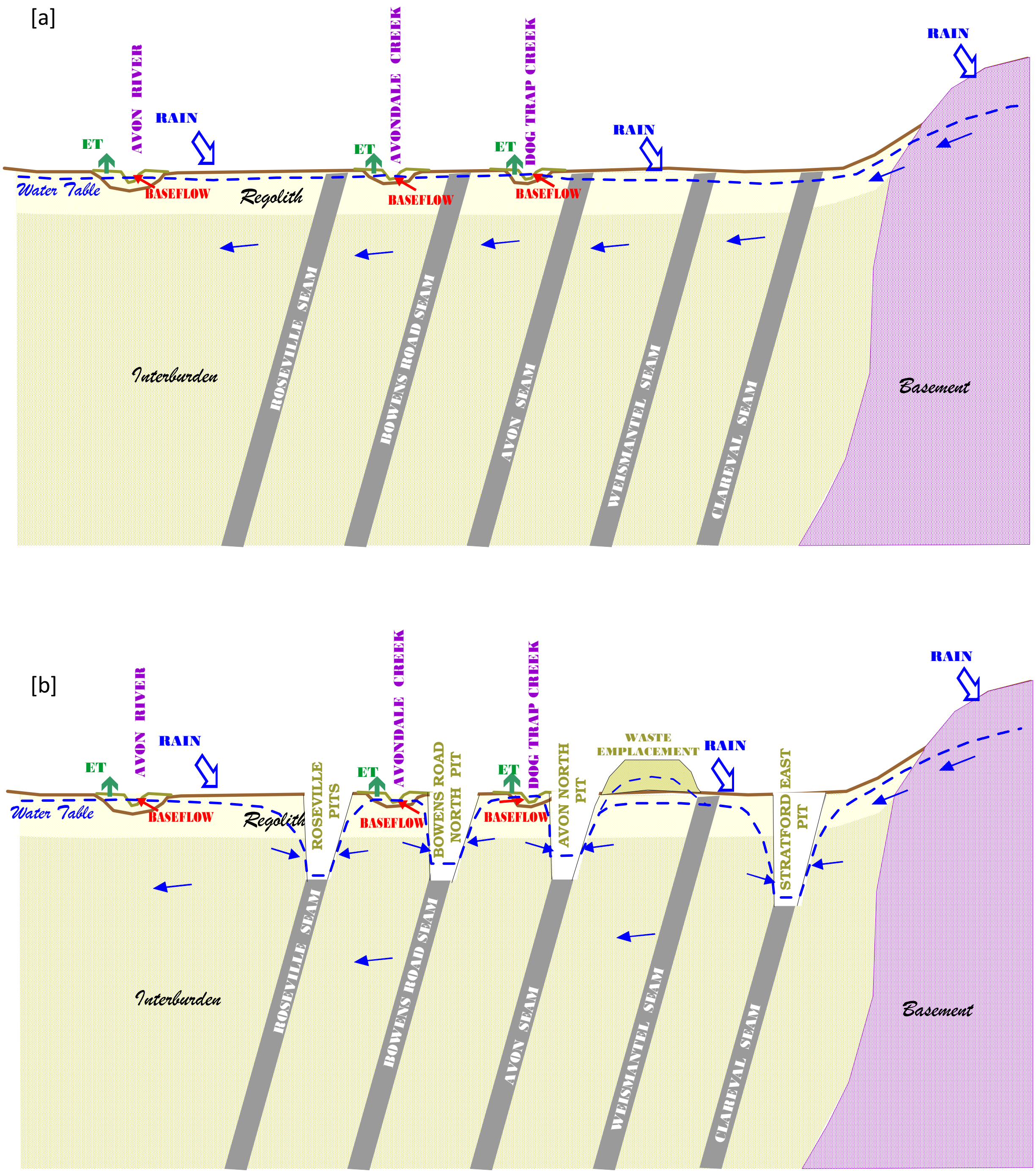


Figure A-25 Conceptual Groundwater Models [a] Natural conditions; [b] During mining.

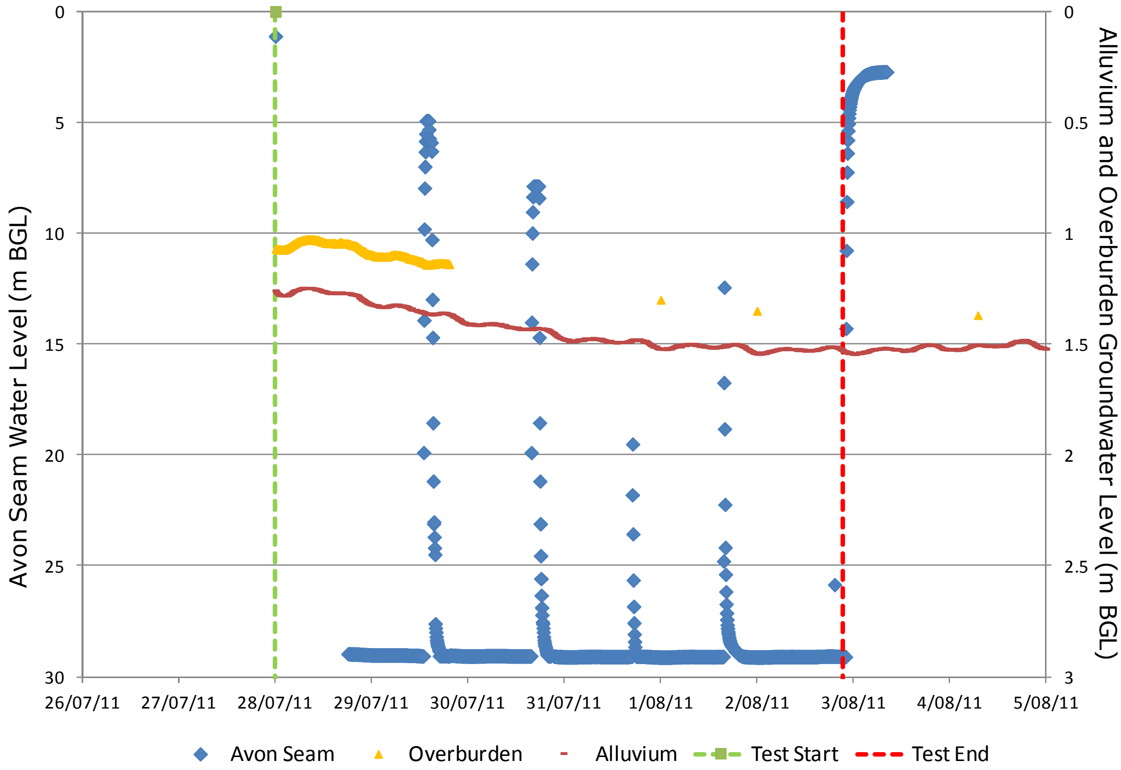


Figure A-26 Pumping Test at Dog Trap Creek (Source RPS Aquaterra, 2011)

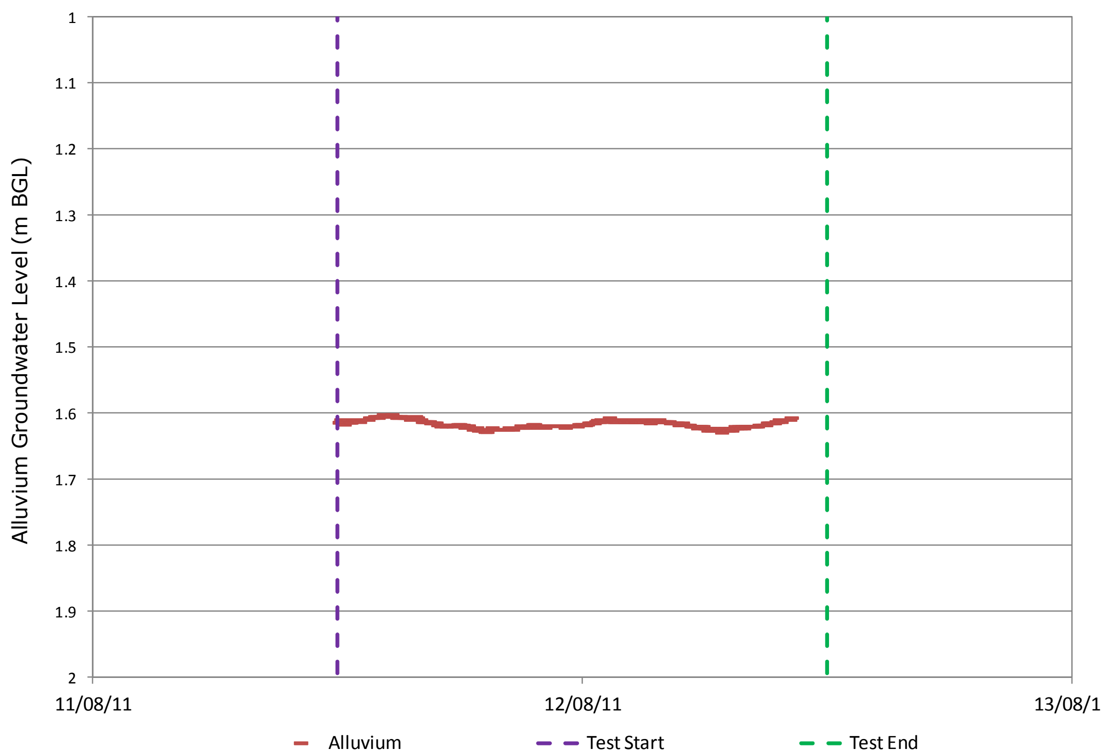


Figure A-27 Pumping Test Restart at Dog Trap Creek (Source RPS Aquaterra, 2011)

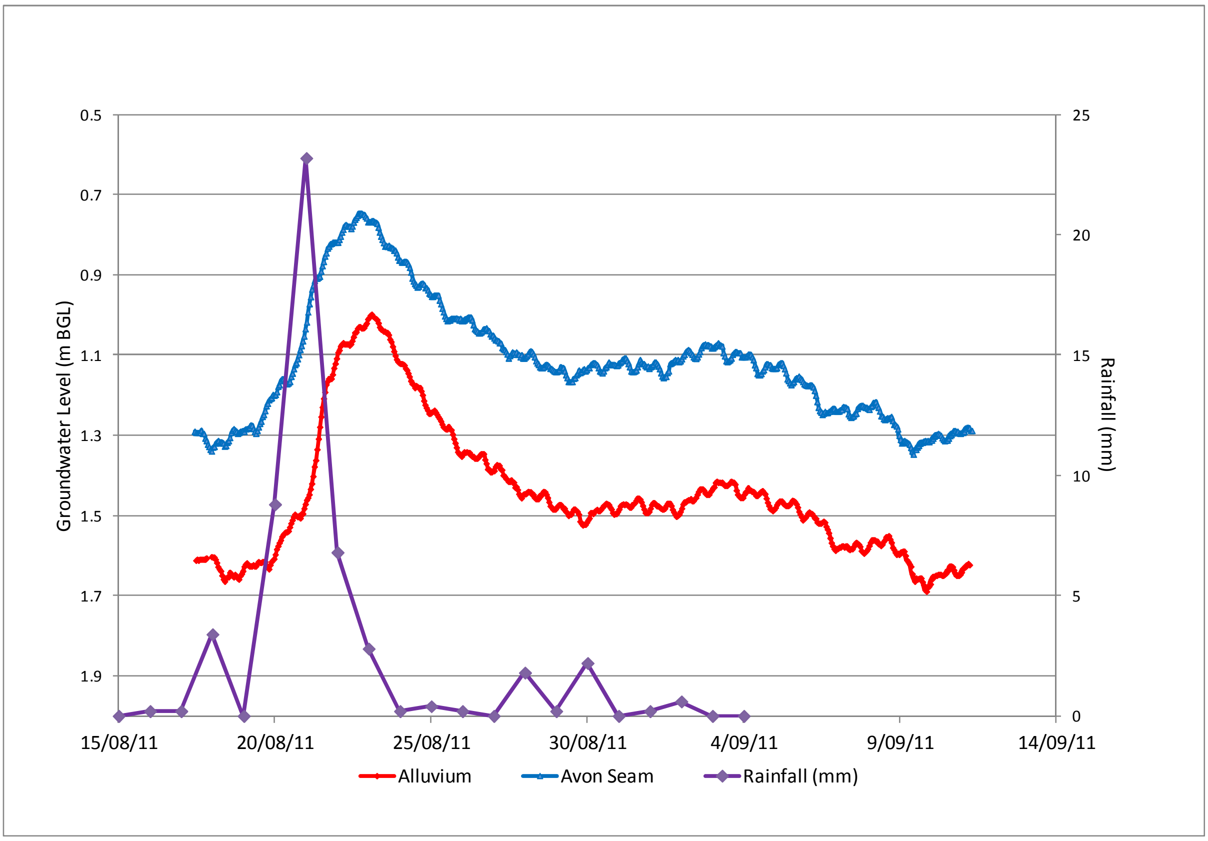
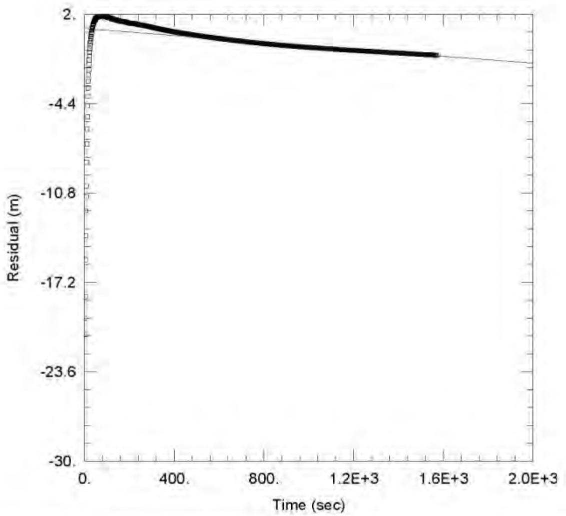


Figure A-28 Monitoring at Dog Trap Creek - (Source RPS Aquaterra, 2011)



WELL TEST ANALYSIS

Data Set: C:\GCL\PB1 Pump Test Drawdown.aqt
Date: 09/15/11 Time: 08:12:14

PROJECT INFORMATION

Company: GCL
Client: GCL
Project: S146
Location: Stratford
Test Well: PB1

WELL DATA

Pumping Wells

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

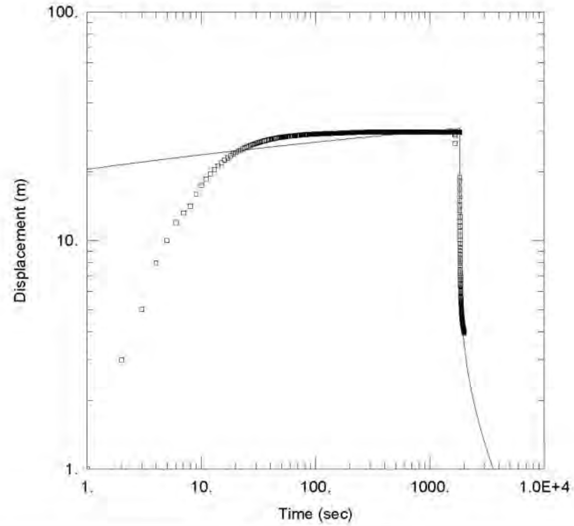
Observation Wells

Well Name	X (m)	Y (m)
□ New Well	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1.435 m^2/day
Kz/Kr = 0.5
S = 1.0E-10
b = 10. m



WELL TEST ANALYSIS

Data Set: C:\GCL\PB1 Pump Test and Recovery.aqt
Date: 09/15/11 Time: 08:13:43

PROJECT INFORMATION

Company: GCL
Client: GCL
Project: S146
Location: Stratford
Test Well: PB1

WELL DATA

Pumping Wells

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

Observation Wells

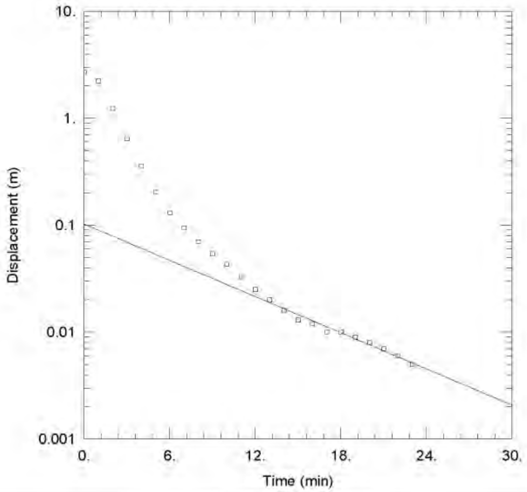
Well Name	X (m)	Y (m)
□ New Well	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1.233 m^2/day
Kz/Kr = 0.1
S = 3.121E-9
b = 6. m

Figure A-29 Groundwater Investigation – Pumping Test (PB1) Drawdown and Recovery (Source RPS Aquaterra, 2011)



WELL TEST ANALYSIS

Data Set: C:\GCL\NS593R.aqt
Date: 09/15/11 Time: 06:52:24

PROJECT INFORMATION

Company: GCL
Client: GCL
Project: S146
Location: Stratford
Test Well: NS593R

AQUIFER DATA

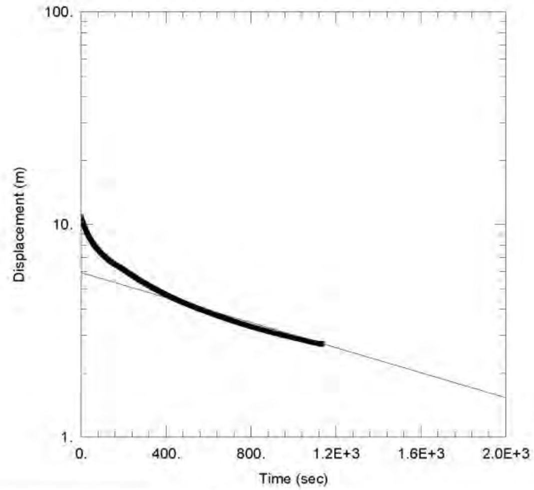
Saturated Thickness: 6. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (New Well)

Initial Displacement: 2.7 m
Total Well Penetration Depth: 29. m
Casing Radius: 0.025 m
Static Water Column Height: 25. m
Screen Length: 6. m
Well Radius: 0.025 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined Solution Method: Bouwer-Rice
K = 0.05191 m/day y0 = 0.1023 m



WELL TEST ANALYSIS

Data Set: C:\GCL\NS596R.aqt
Date: 09/15/11 Time: 06:55:39

PROJECT INFORMATION

Company: GCL
Client: GCL
Project: S146
Location: Stratford
Test Well: NS596R

AQUIFER DATA

Saturated Thickness: 6. m Anisotropy Ratio (Kz/Kr): 0.1

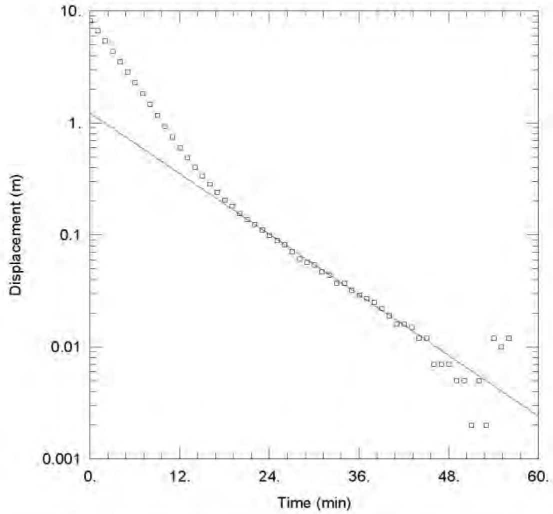
WELL DATA (New Well)

Initial Displacement: 10.93 m
Total Well Penetration Depth: 42. m
Casing Radius: 0.025 m
Static Water Column Height: 20. m
Screen Length: 3. m
Well Radius: 0.025 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Unconfined Solution Method: Hvorslev
K = 0.04043 m/day y0 = 5.936 m

Figure A-30 Groundwater Investigation – Slug Test Results 1 (Source RPS Aquaterra, 2011)



WELL TEST ANALYSIS

Data Set: C:\GCL\NS592R.aqt
Date: 09/15/11 Time: 06:49:36

PROJECT INFORMATION

Company: GCL
Client: GCL
Project: S146
Location: Stratford
Test Well: NS592R

AQUIFER DATA

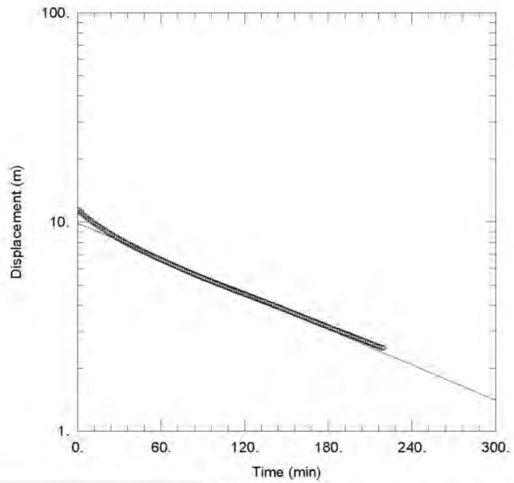
Saturated Thickness: 10. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (New Well)

Initial Displacement: 8.183 m
Total Well Penetration Depth: 48. m
Casing Radius: 0.025 m
Static Water Column Height: 40. m
Screen Length: 10. m
Well Radius: 0.025 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 0.02476 m/day
y0 = 1.226 m



WELL TEST ANALYSIS

Data Set: C:\GCL\NS583.aqt
Date: 09/15/11 Time: 07:00:07

PROJECT INFORMATION

Company: GCL
Client: GCL
Project: S146
Location: Stratford
Test Well: NS583

AQUIFER DATA

Saturated Thickness: 6. m Anisotropy Ratio (Kz/Kr): 1.

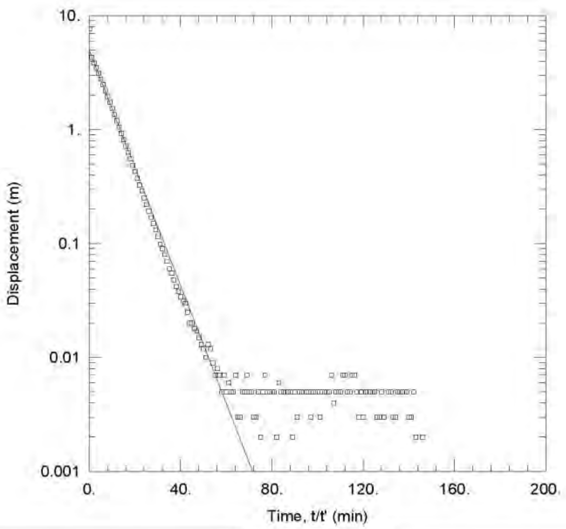
WELL DATA (New Well)

Initial Displacement: 11.4 m
Total Well Penetration Depth: 37. m
Casing Radius: 0.025 m
Static Water Column Height: 25.5 m
Screen Length: 6. m
Well Radius: 0.025 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Confined
Solution Method: Hvorslev
K = 0.002584 m/day
y0 = 9.87 m

Figure A-31 Groundwater Investigation – Slug Test Results 2 (Source RPS Aquaterra, 2011)



WELL TEST ANALYSIS

Data Set: C:\GCL\GC207R.aqt
Date: 09/15/11 Time: 06:46:53

PROJECT INFORMATION

Company: GCL
Client: GCL
Project: S146
Location: Stratford
Test Well: GC207R

AQUIFER DATA

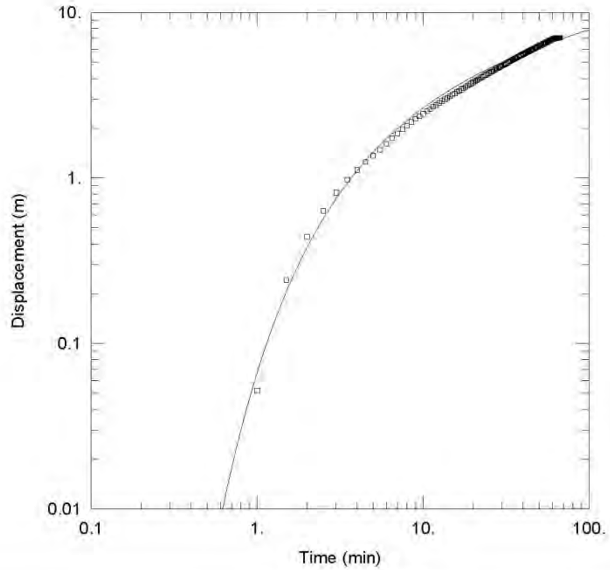
Saturated Thickness: 6. m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (New Well)

Initial Displacement: 7.7 m Static Water Column Height: 42.3 m
Total Well Penetration Depth: 50. m Screen Length: 6. m
Casing Radius: 0.025 m Well Radius: 0.025 m

SOLUTION

Aquifer Model: Confined Solution Method: Hvorslev
K = 0.04734 m/day y0 = 4.973 m



WELL TEST ANALYSIS

Data Set: C:\GCL\NS581B.aqt
Date: 09/15/11 Time: 07:43:26

PROJECT INFORMATION

Company: GCL
Client: GCL
Project: S146
Location: Stratford
Test Well: NS581B

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
New Well	0	5

Observation Wells

Well Name	X (m)	Y (m)
▫ New Well	0	12

SOLUTION

Aquifer Model: Confined Solution Method: Theis
T = 0.3311 m^2/day S = 4.59E-5
Kz/Kr = 0.5 b = 6. m

Figure A-32 Groundwater Investigation – Slug Test Results 3 (Source RPS Aquaterra, 2011)

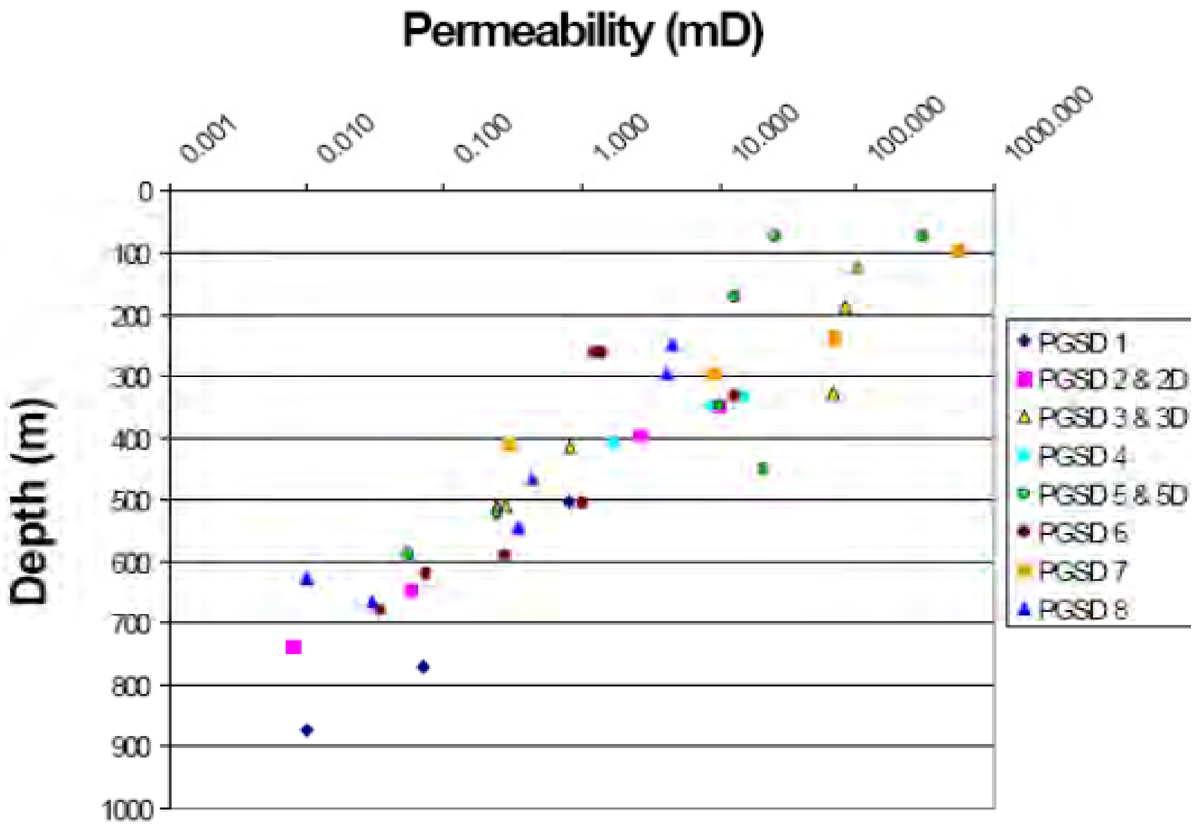


Figure A-33. Intrinsic Permeability Measurements of Coal Seams at Stratford in the Gloucester Basin [Source: Smith, 2001]

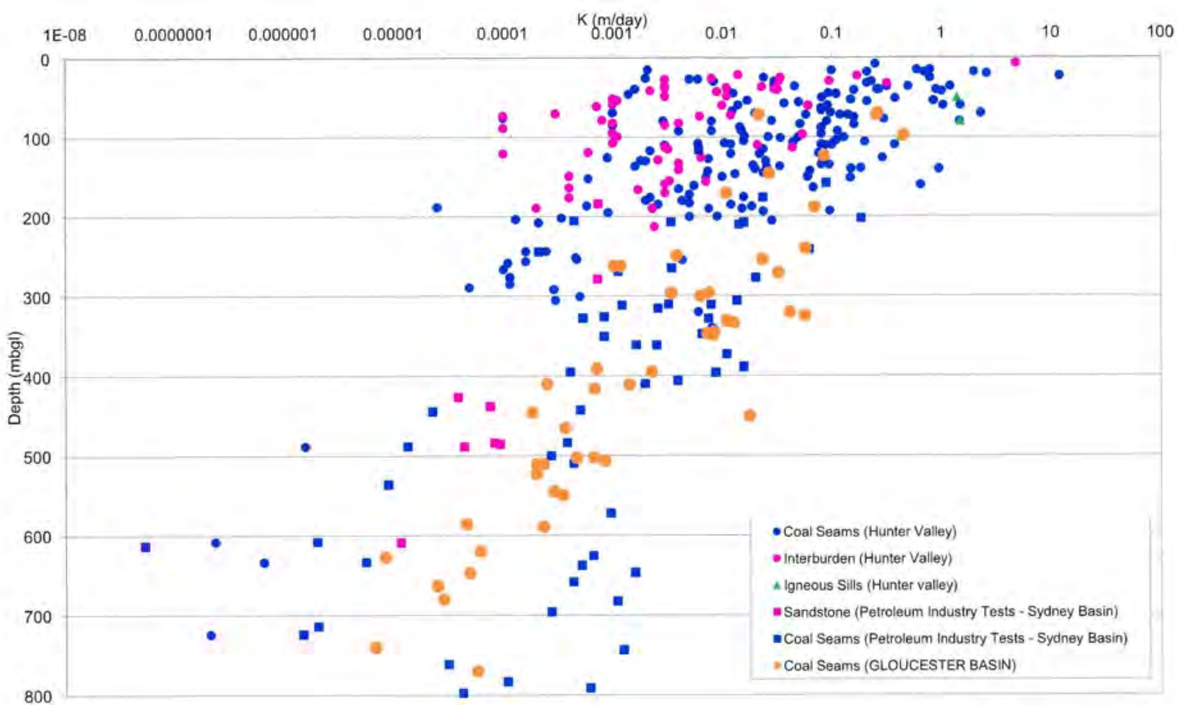


Figure A-34. Comparative Hydraulic Conductivity Measurements in the Gloucester Basin, Sydney Basin and Hunter Valley [Source: Tammetta, 2009]

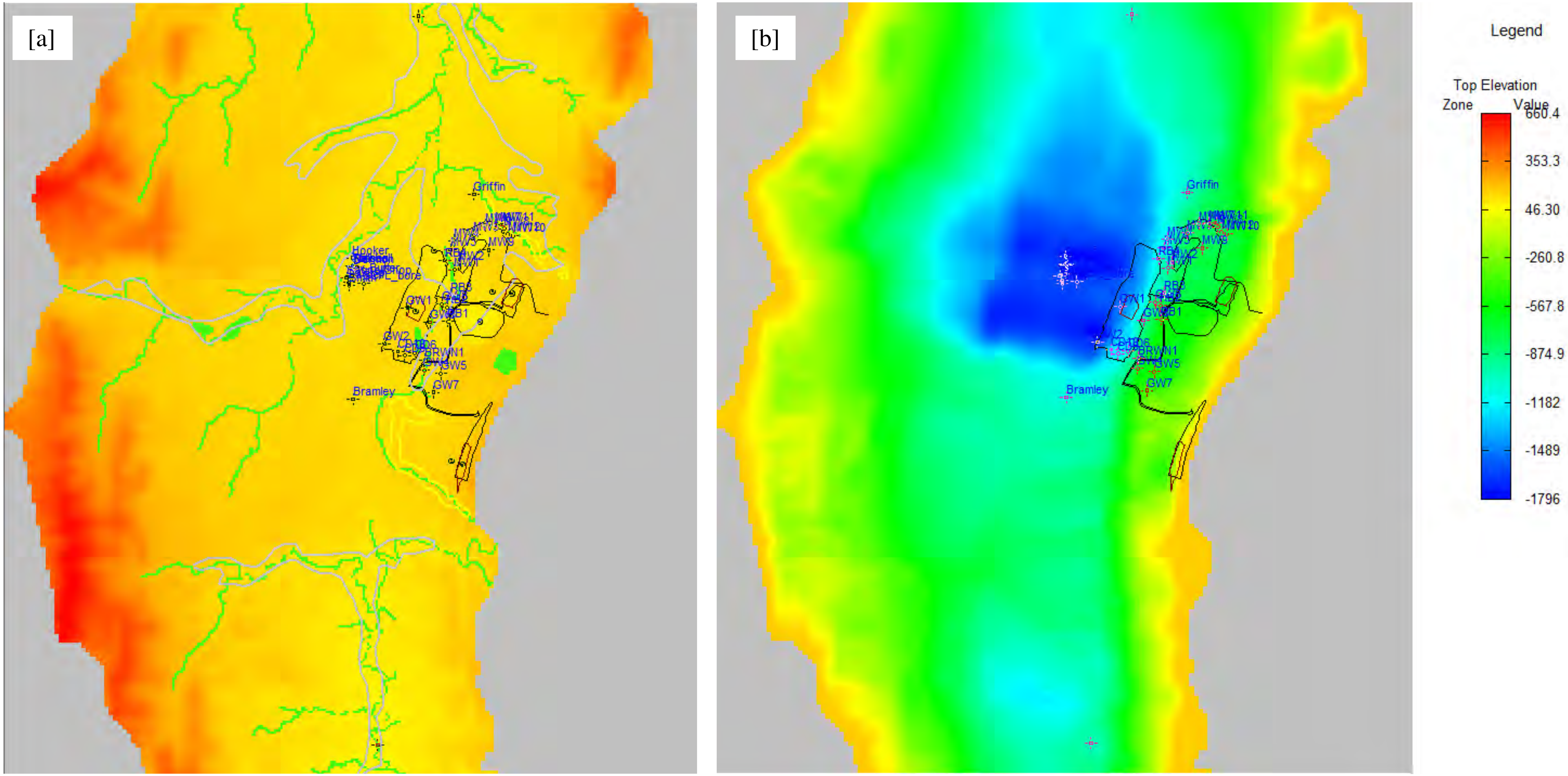
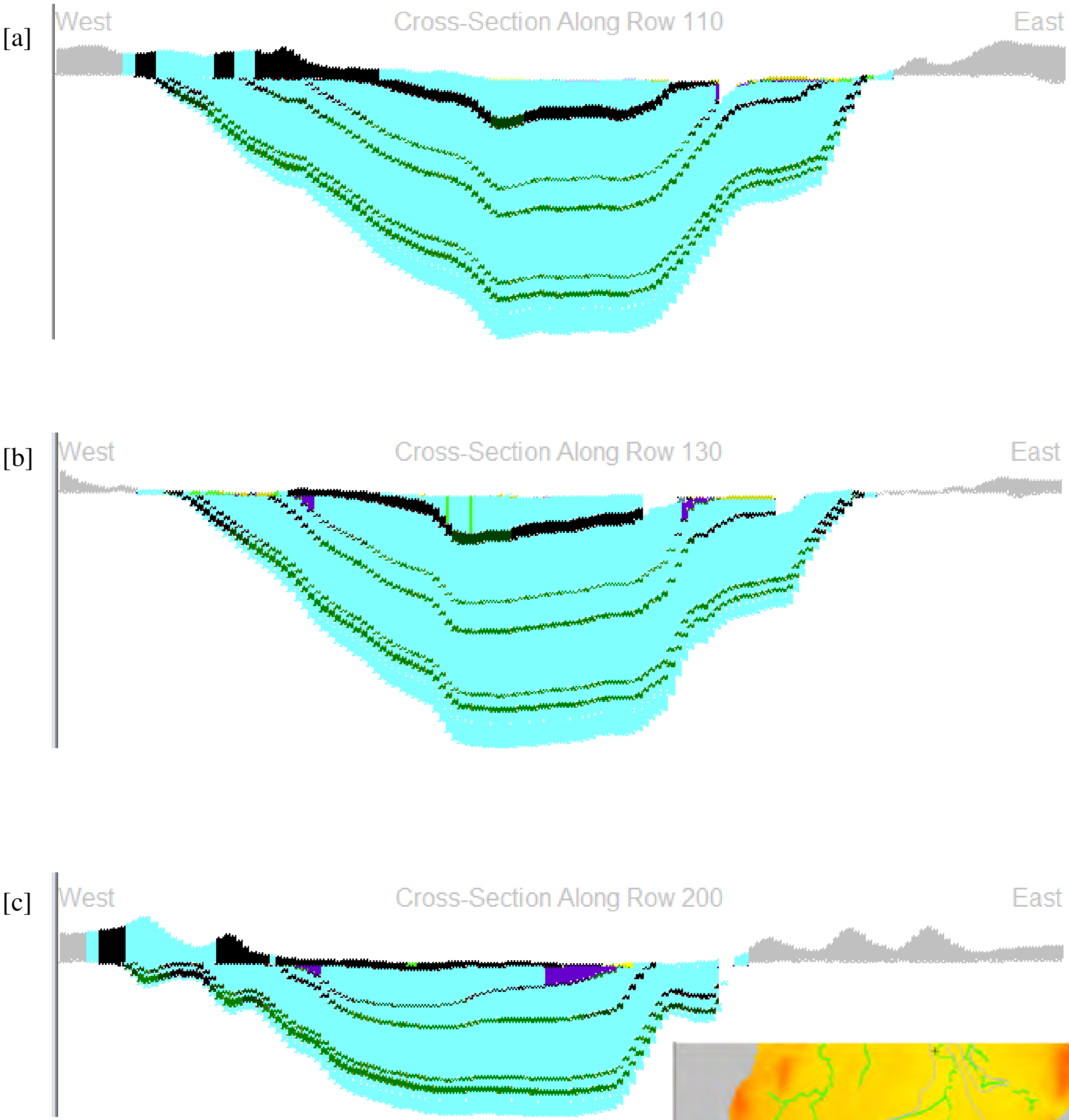


Figure A-35. Active Model Extent Showing [a] Layer 1 Land Surface Topography and Boundary Conditions, and [b] Elevations for the Top of Layer 13 [mAHD]



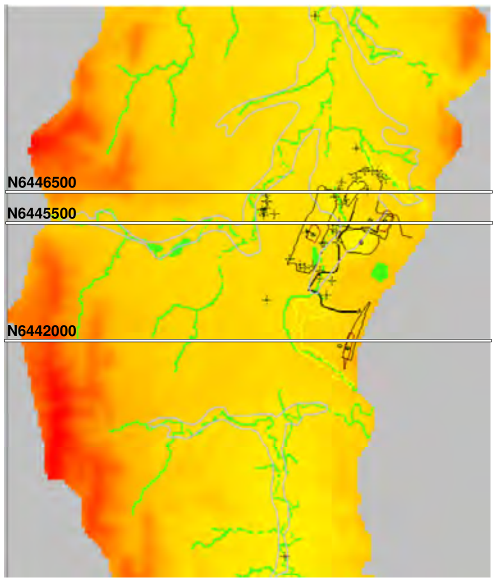
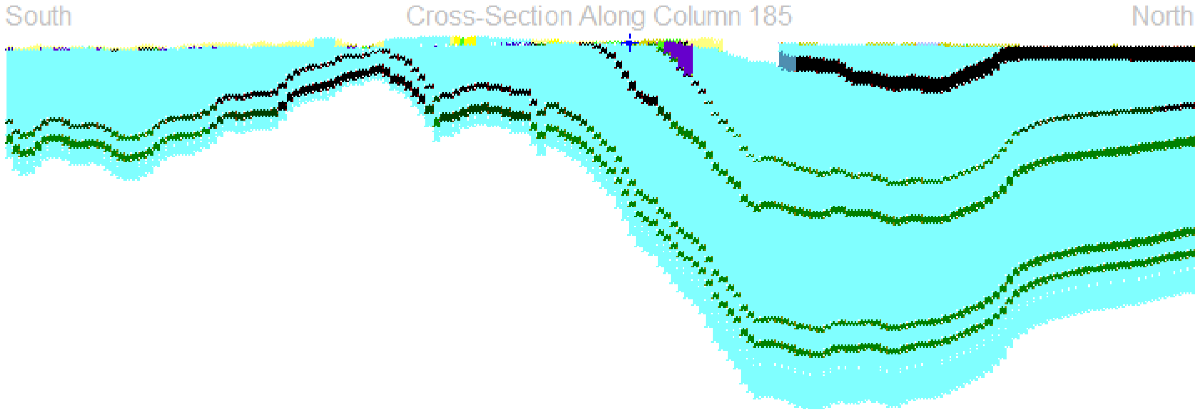
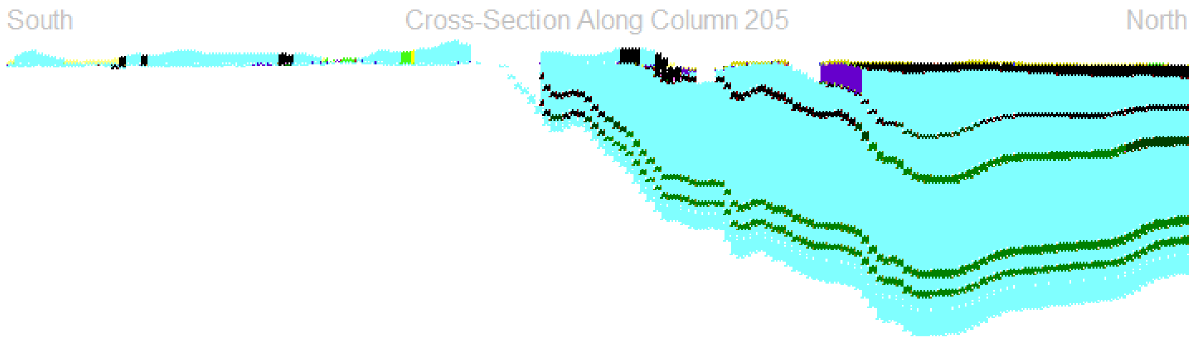


Figure A-36. Representative West-East Model Cross-Sections through [a] Bowens Road North Pit (Northing 6446500); [b] Roseville and Avon North Pits (Northing 6445500); and [c] Stratford East Pit (Northing 6442000)

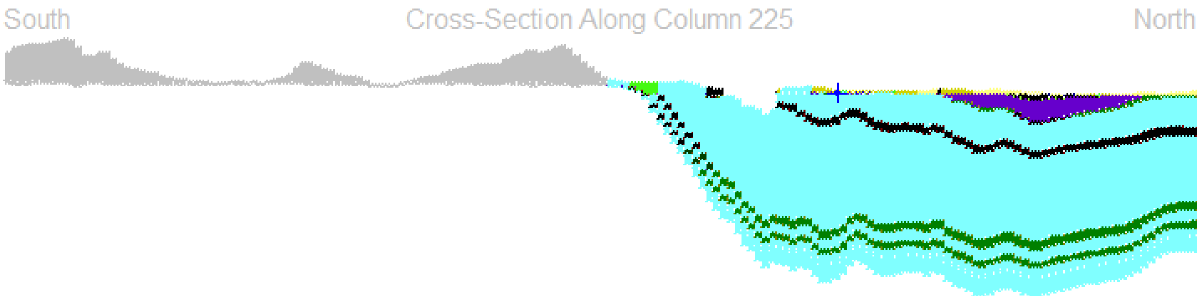
[a]



[b]



[c]



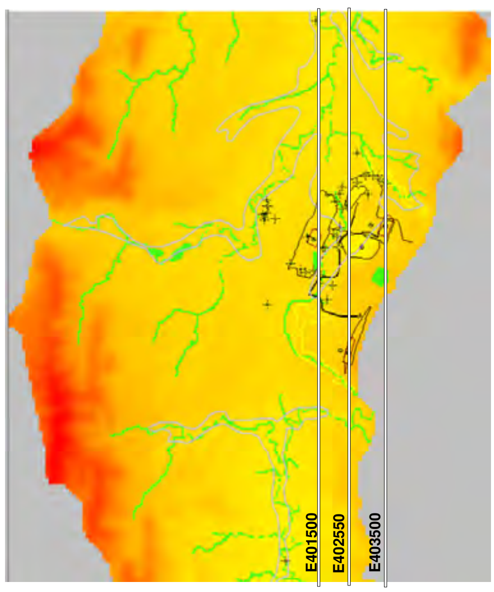


Figure A-37. Representative South-North Model Cross-Sections through [a] Roseville West Pit (Easting 401500); [b] Bowens Road North, Stratford Main and Stratford East Pits (Easting 402550); and [c] Avon North Pit and Stratford East Dam (Easting 403500)

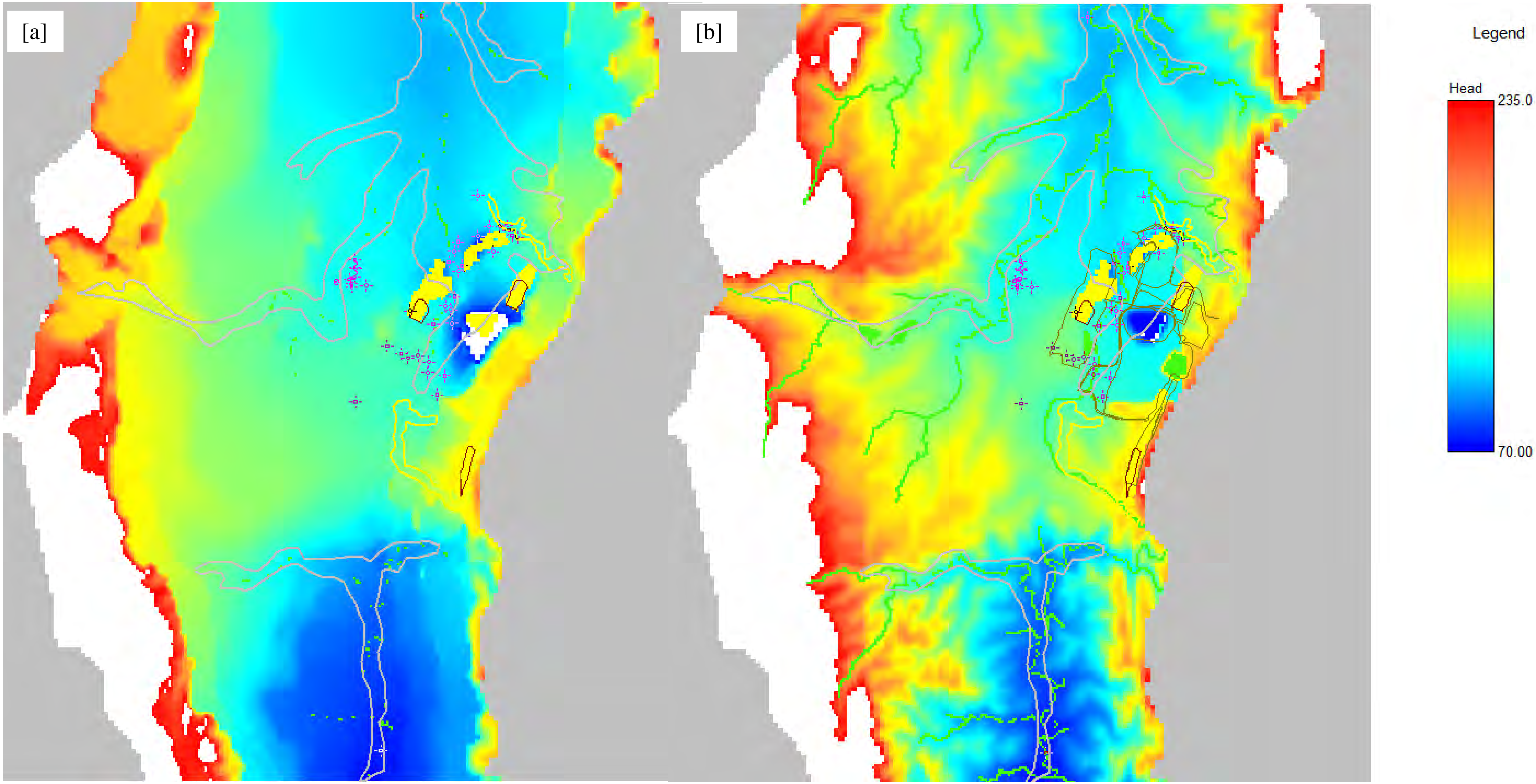


Figure A-38. Simulated Layer 1 Watertable Elevations at [a] Steady State; [b] End of Transient Calibration Period (June 2010) [mAHD]

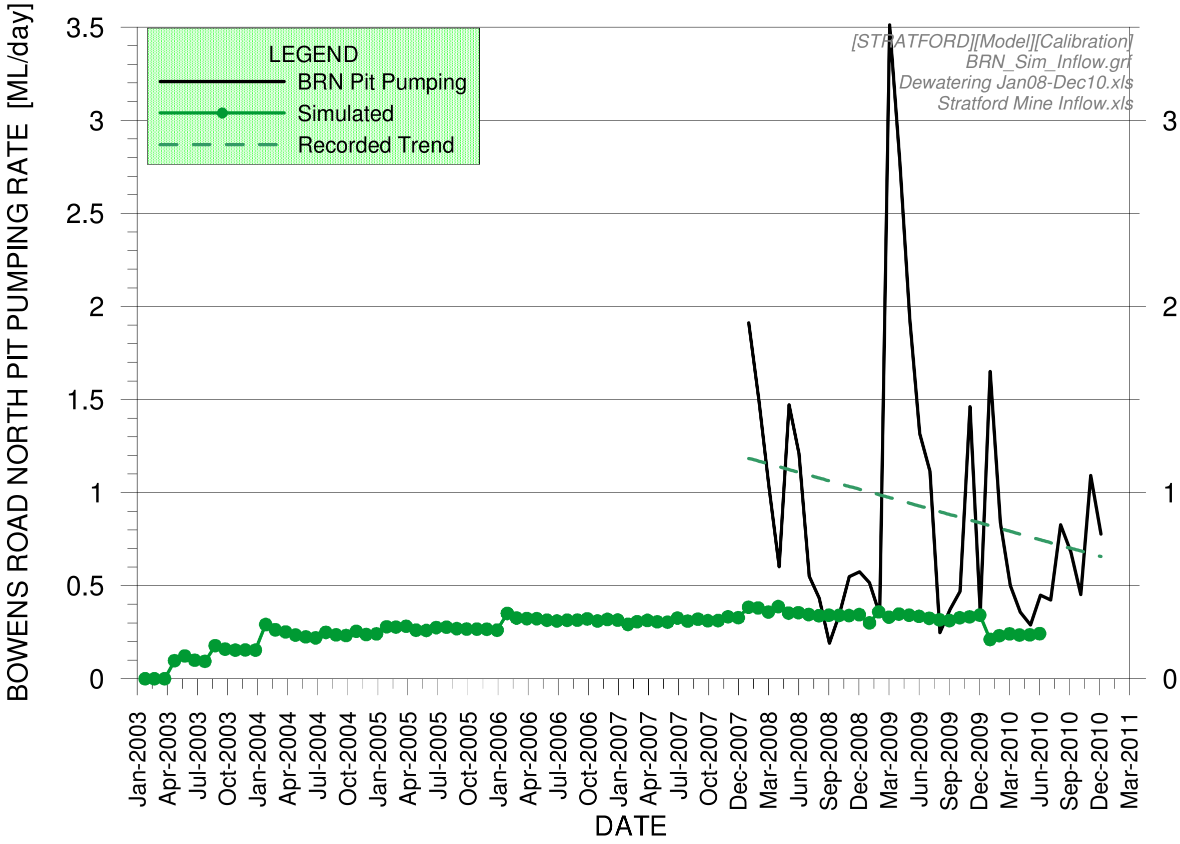


Figure A-39. Bowens Road North Pit Inflow Simulated during the Calibration Period

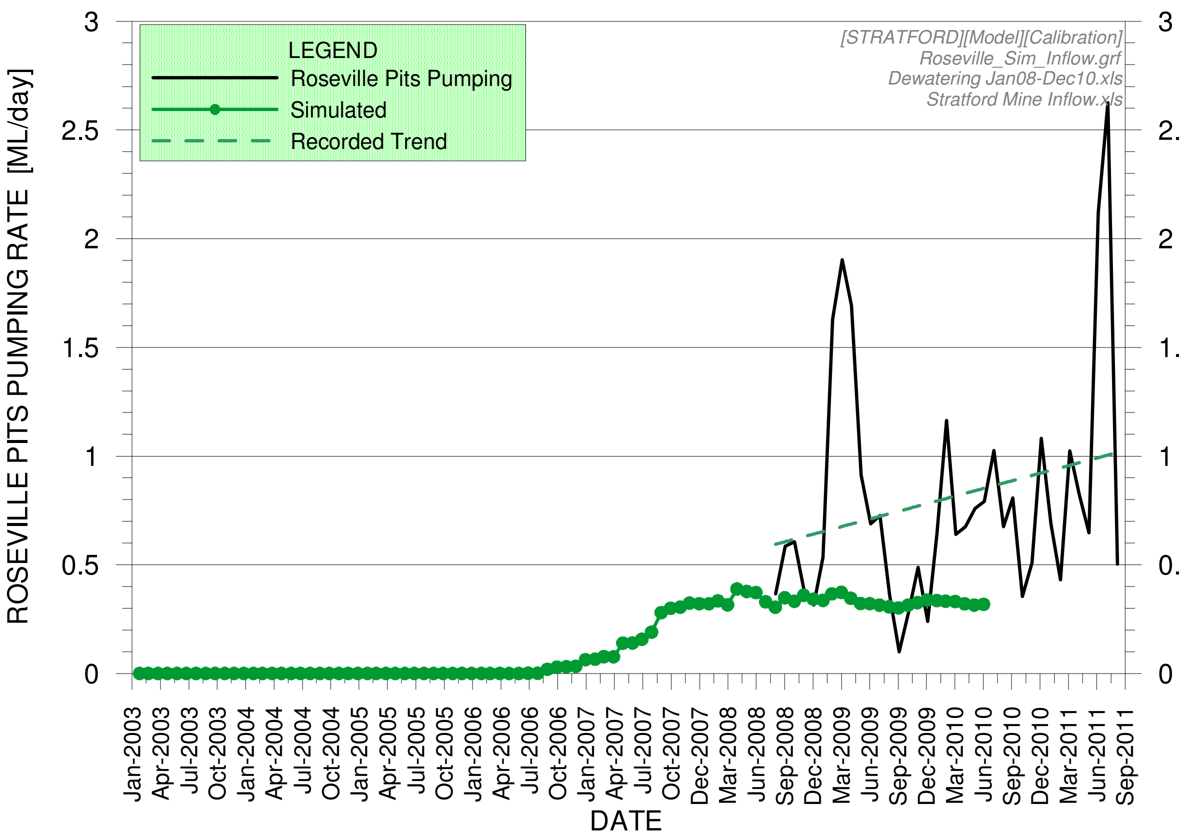


Figure A-40. Combined Roseville Pits Inflow Simulated during the Calibration Period

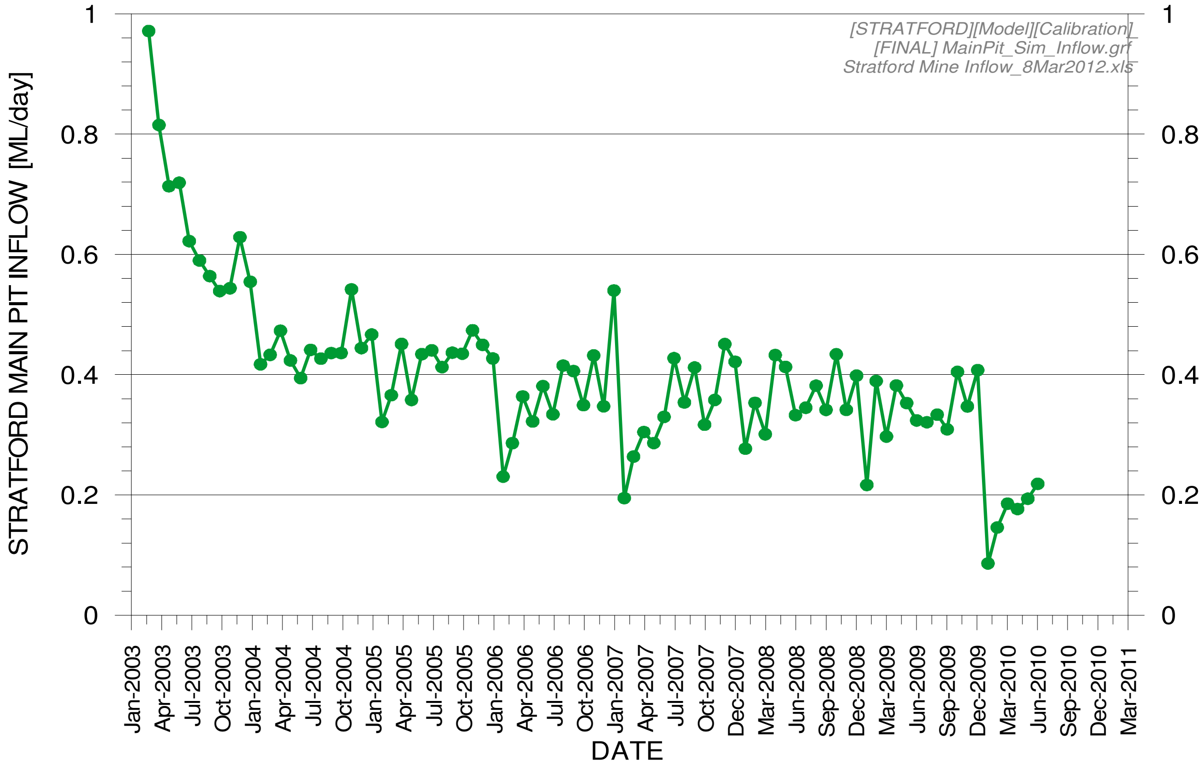


Figure A-41. Stratford Main Pit Inflow Simulated during the Calibration Period

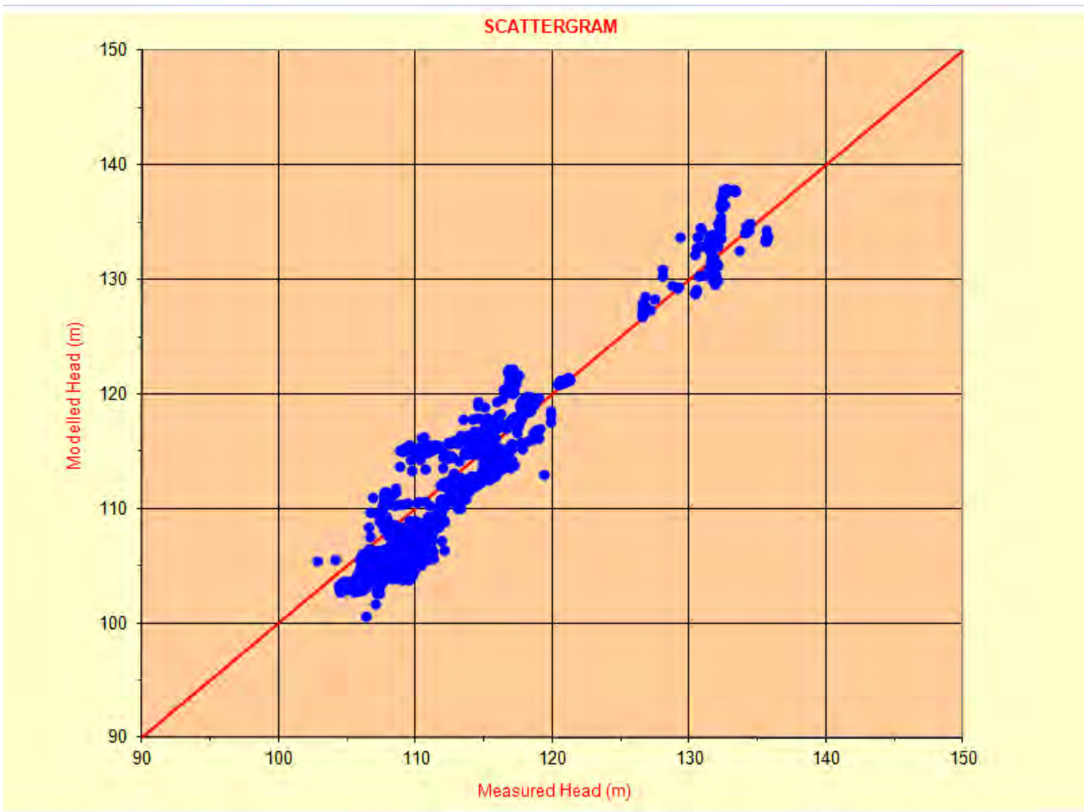
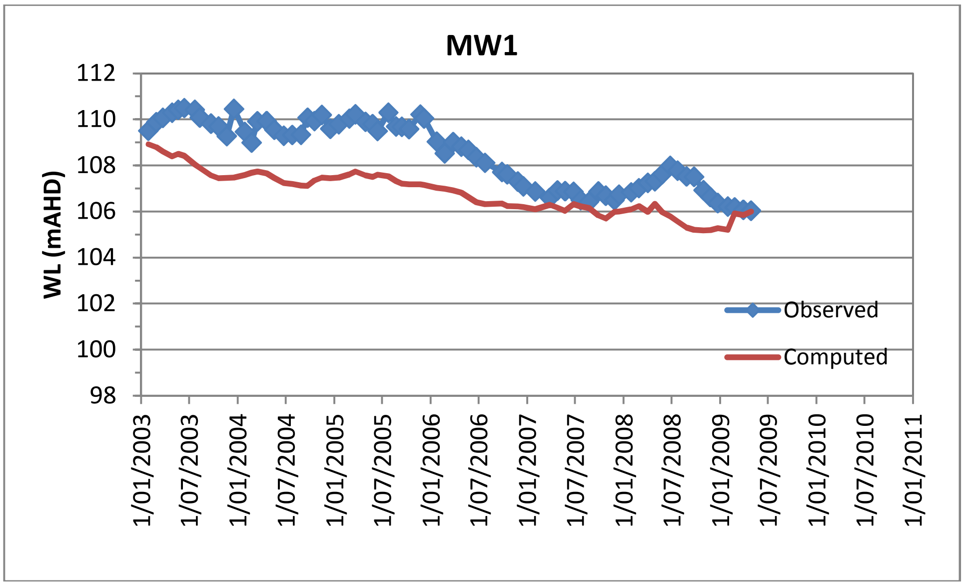


Figure A-42. Scattergram of Simulated and Measured Heads for Transient Calibration



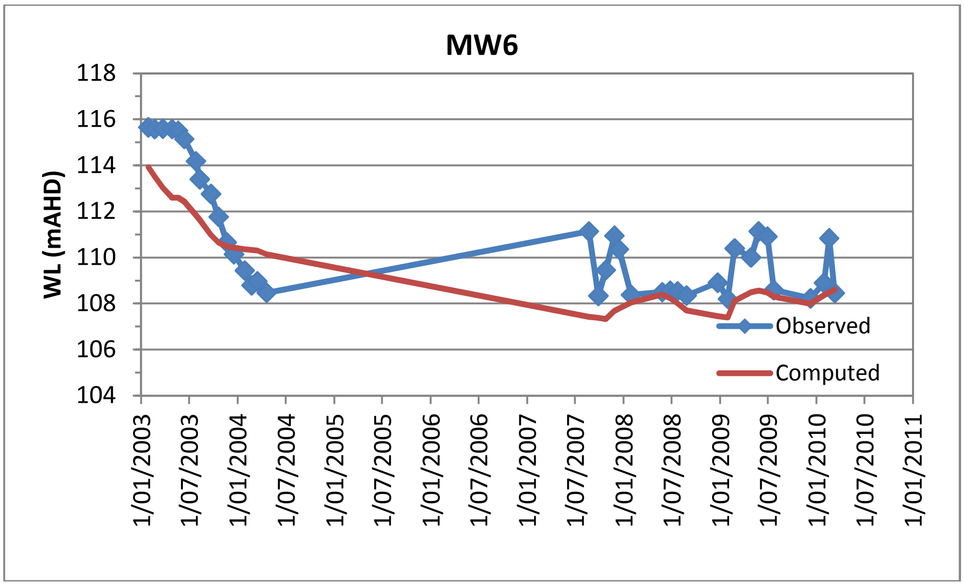
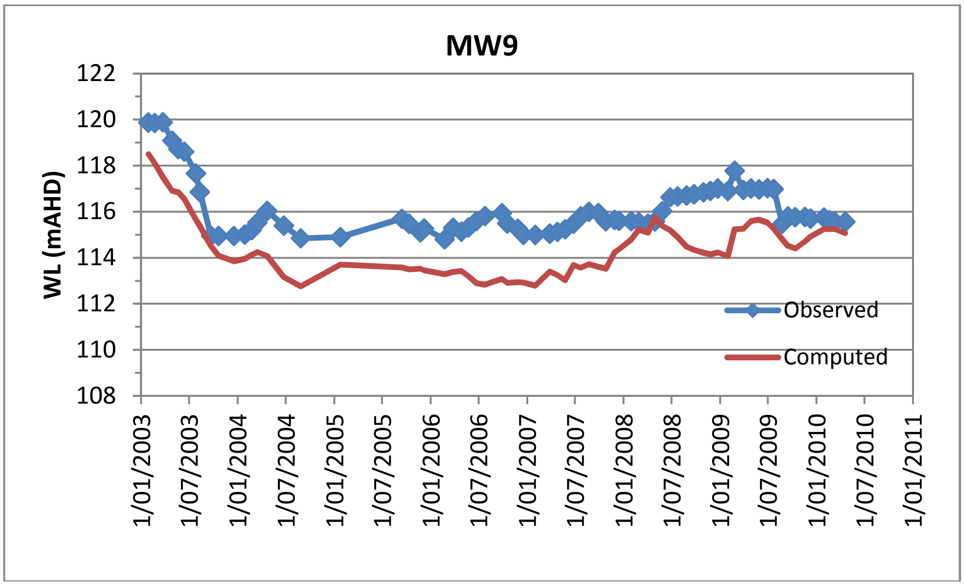


Figure A-43. Representative Simulated and Measured Hydrographs at Bores Screened in Coal [MW1 and MW6]



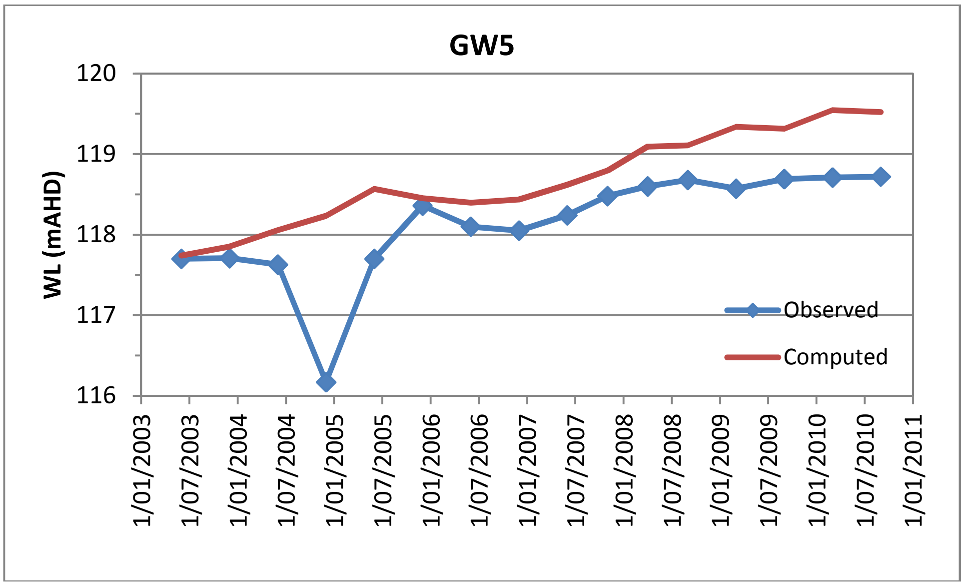
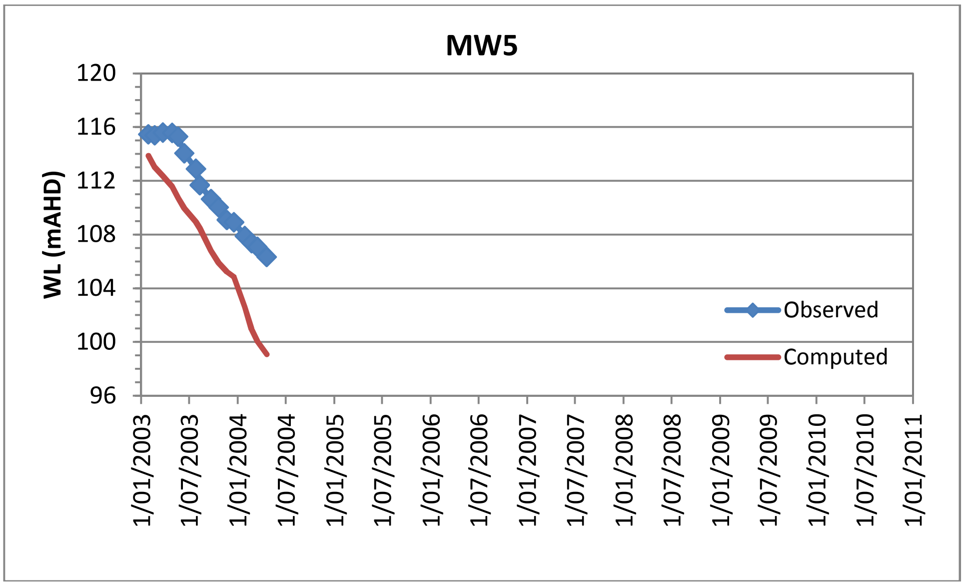


Figure A-44. Representative Simulated and Measured Hydrographs at Bores Screened in Regolith [MW9 and GW5]



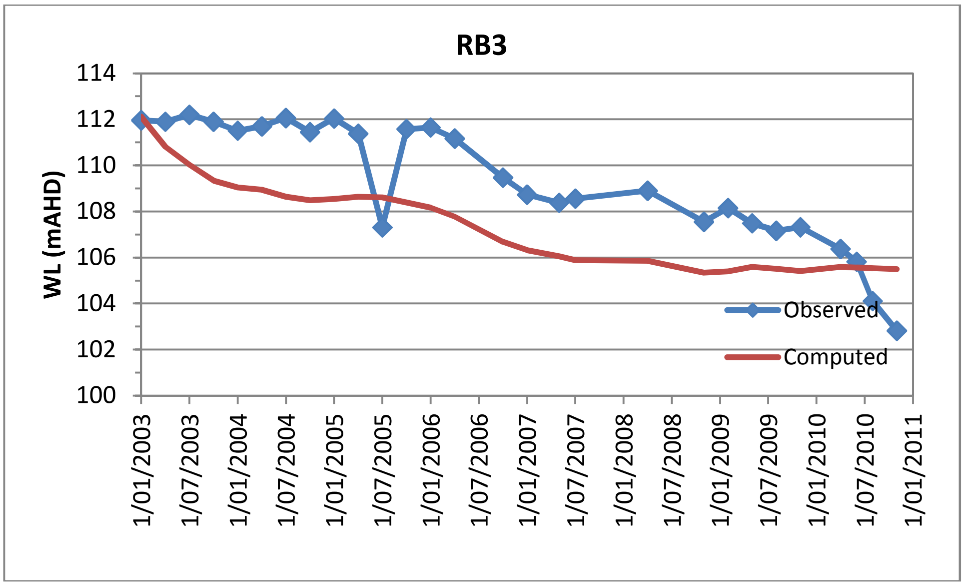
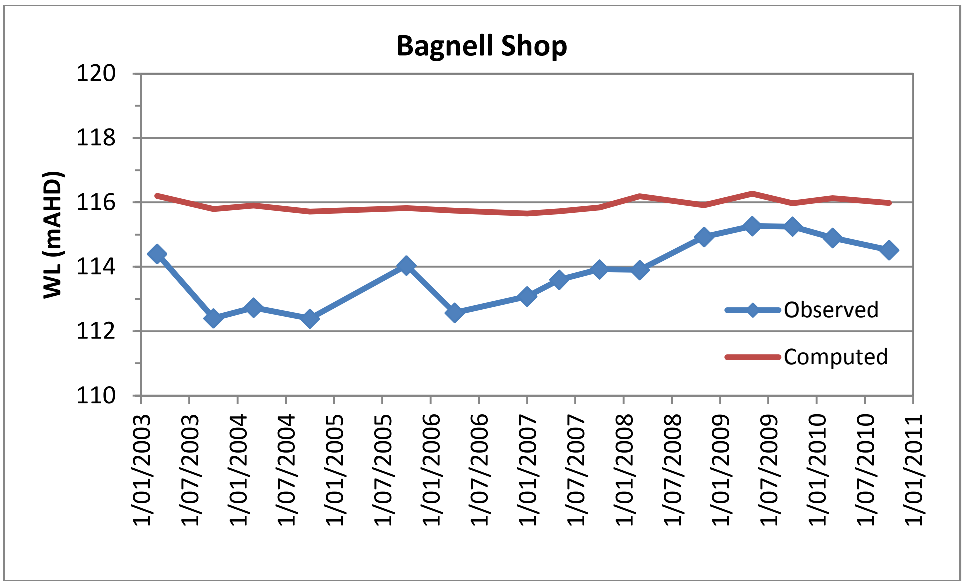


Figure A-45. Representative Simulated and Measured Hydrographs at Bores Screened in Interburden [MW5 and RB3]



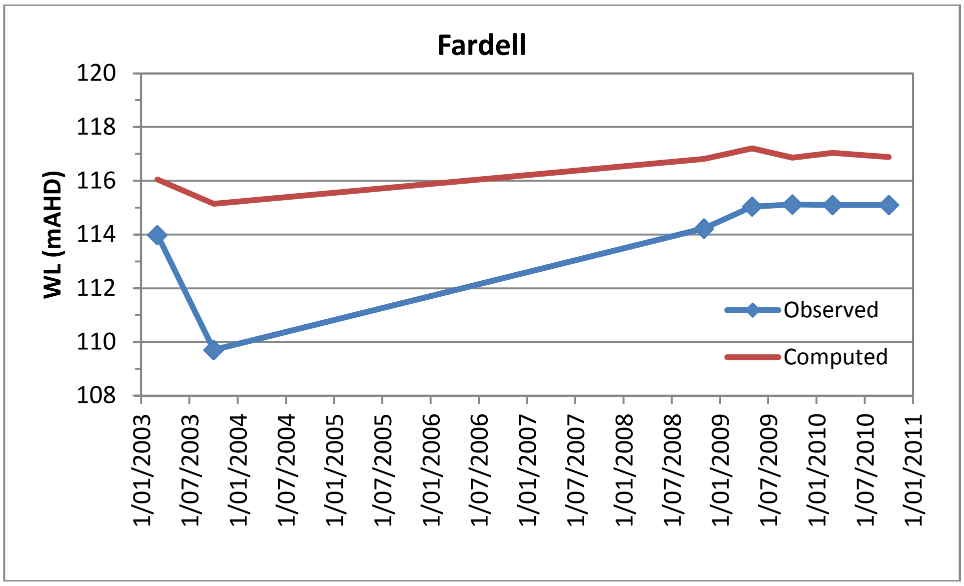


Figure A-46. Representative Simulated and Measured Hydrographs at Stratford Village [Bagnell and Fardell]

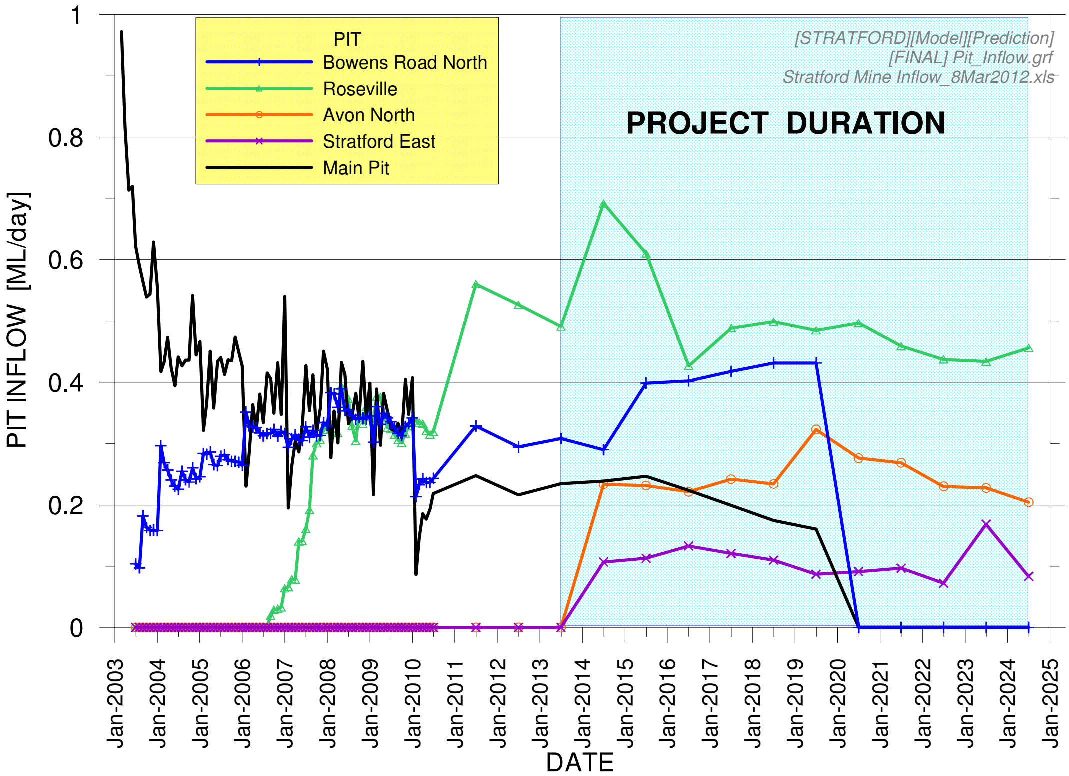


Figure A-47. Simulated Groundwater Inflow to Each Pit

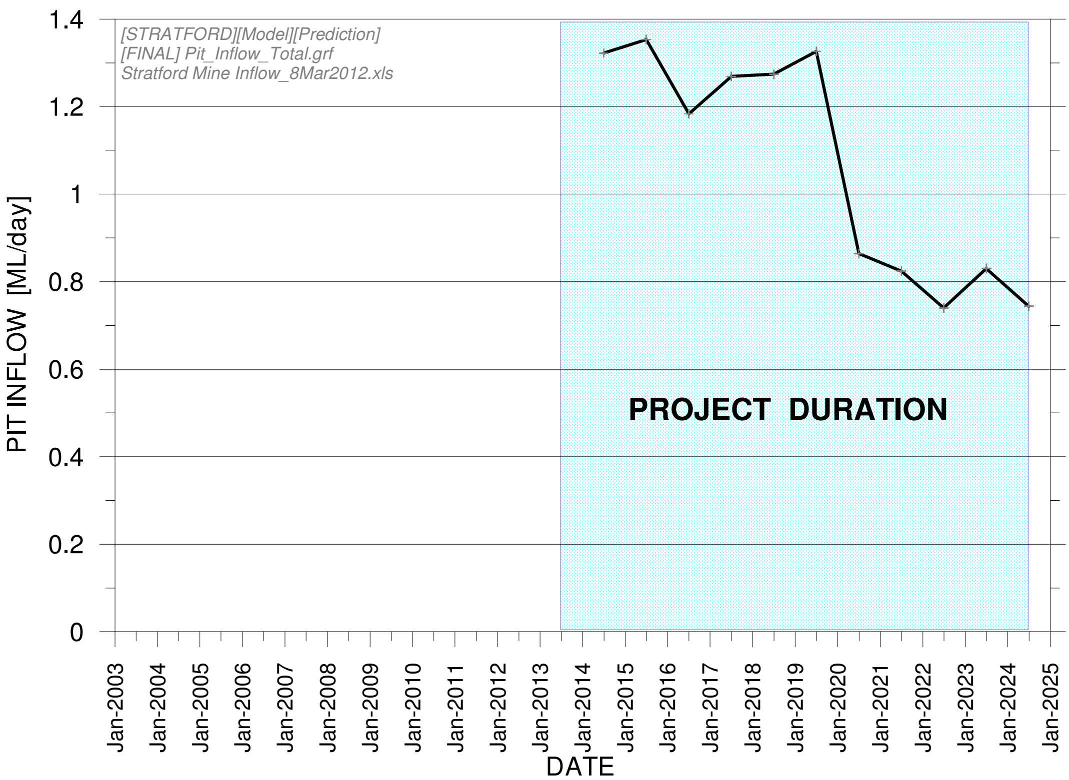


Figure A-48. Simulated Total Groundwater Inflow to Bowens Road North, Roseville, Avon North and Stratford East Pits during the Project

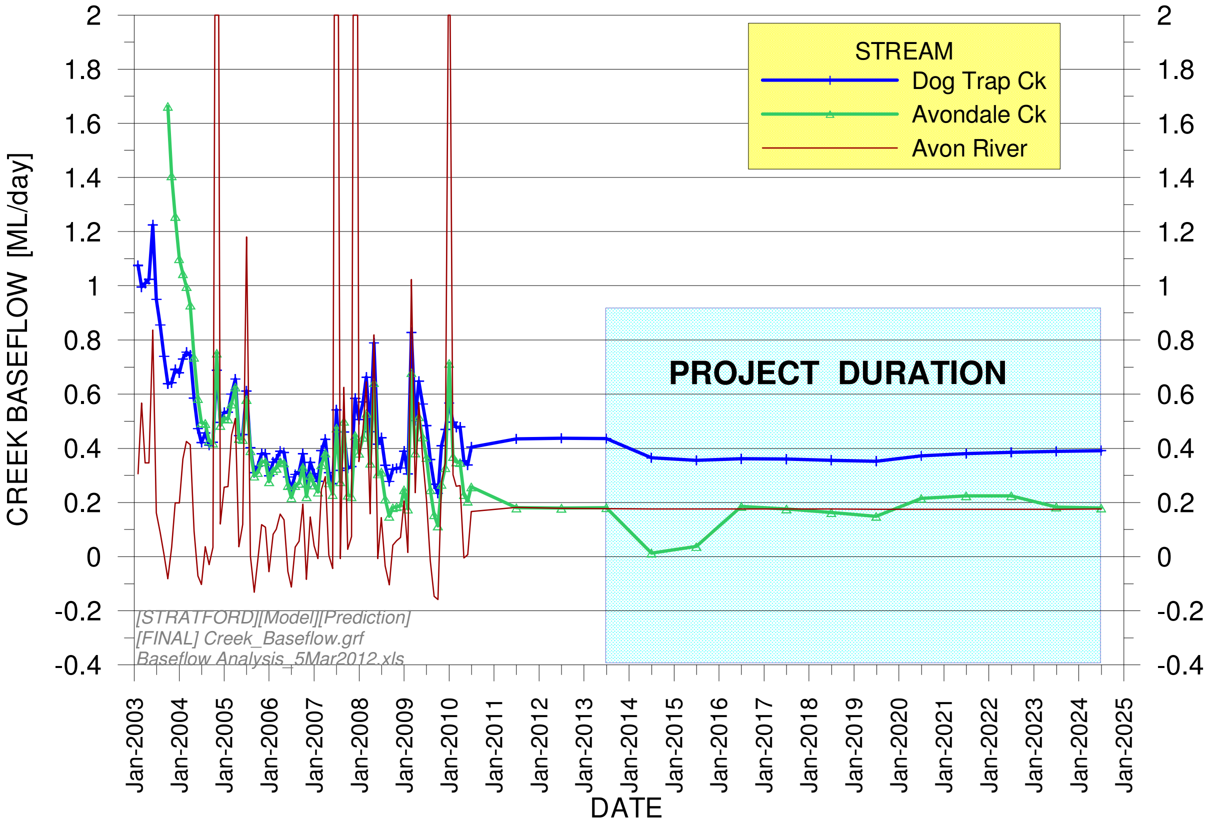


Figure A-49. Simulated Stream-Aquifer Exchanges for Dog Trap Creek, Avondale Creek and Avon River

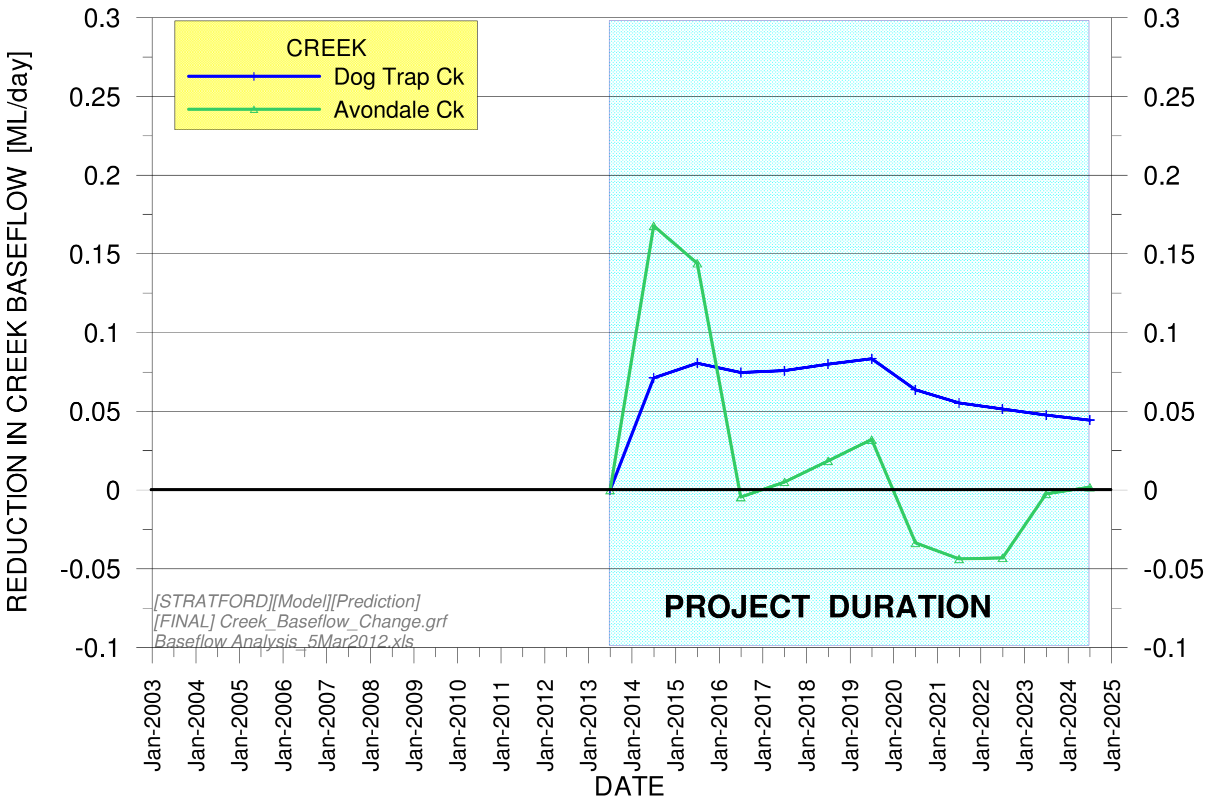


Figure A-50. Simulated Reduction in Baseflow to Dog Trap Creek and Avondale Creek during the Project

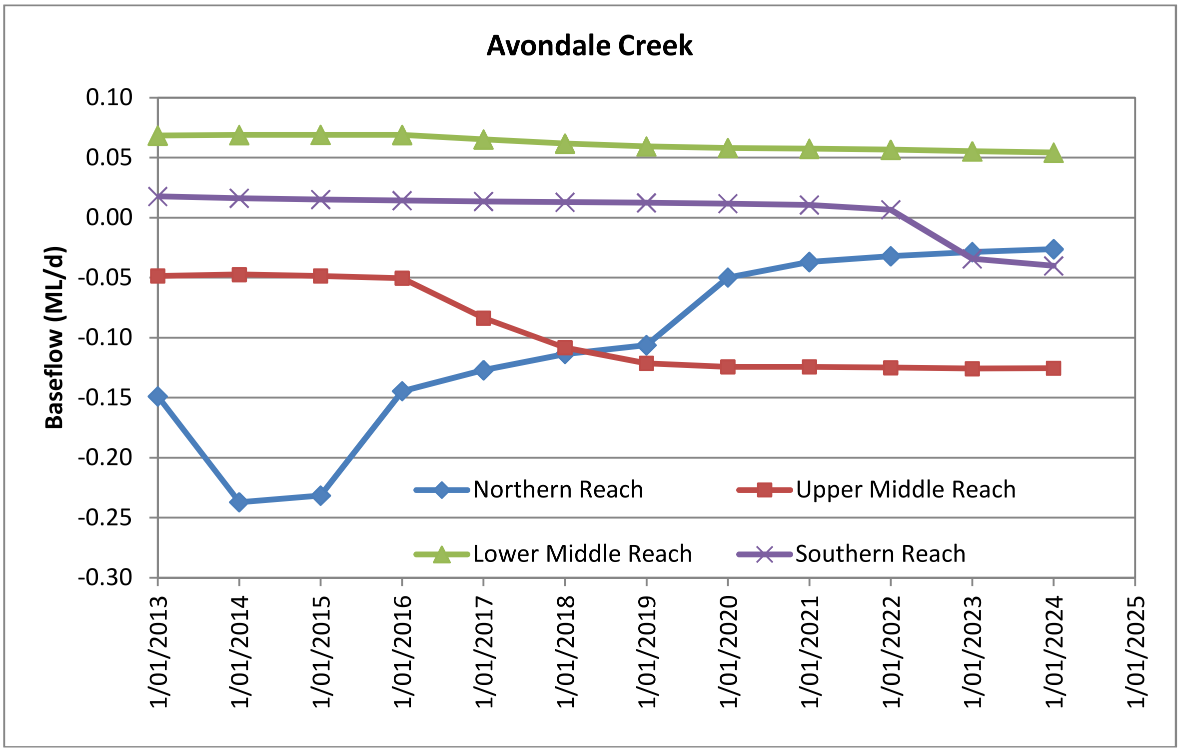


Figure A-51. Simulated Changes in Baseflow to Avondale Creek Reaches during the Project

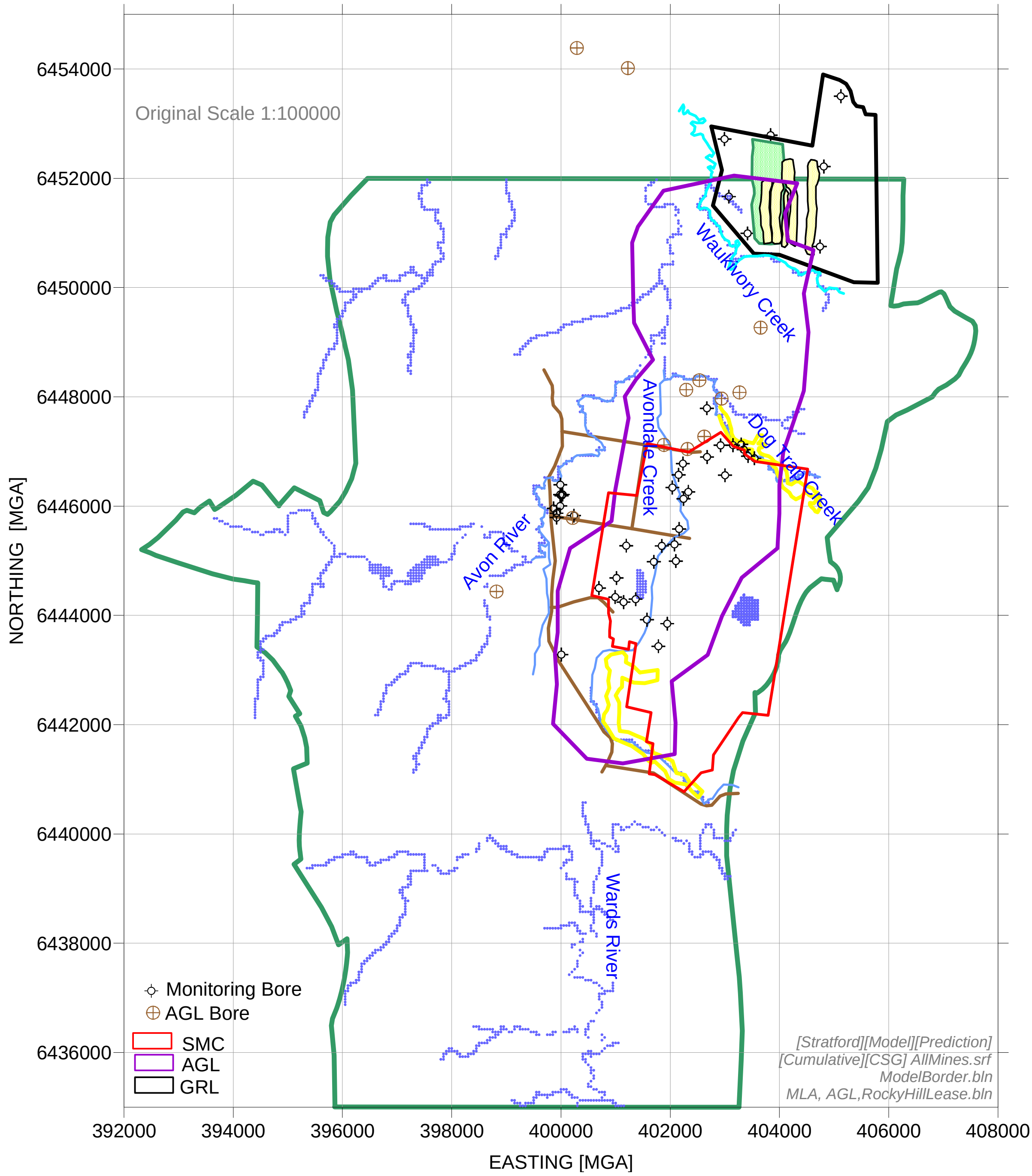


Figure A-52. Lease Areas for Cumulative Impact Assessment

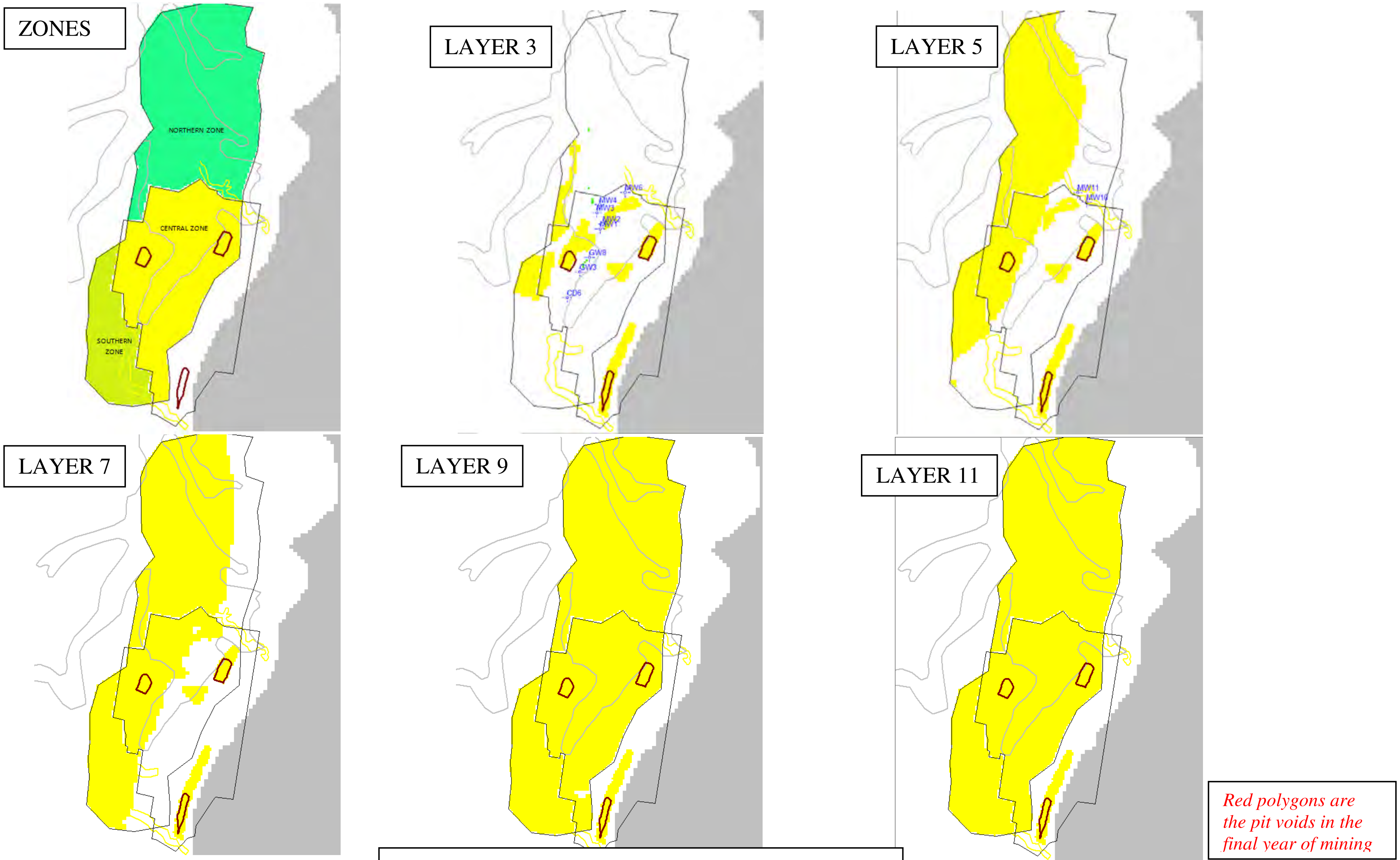


Figure A-53. Activated CSG and SMC Drain Cells

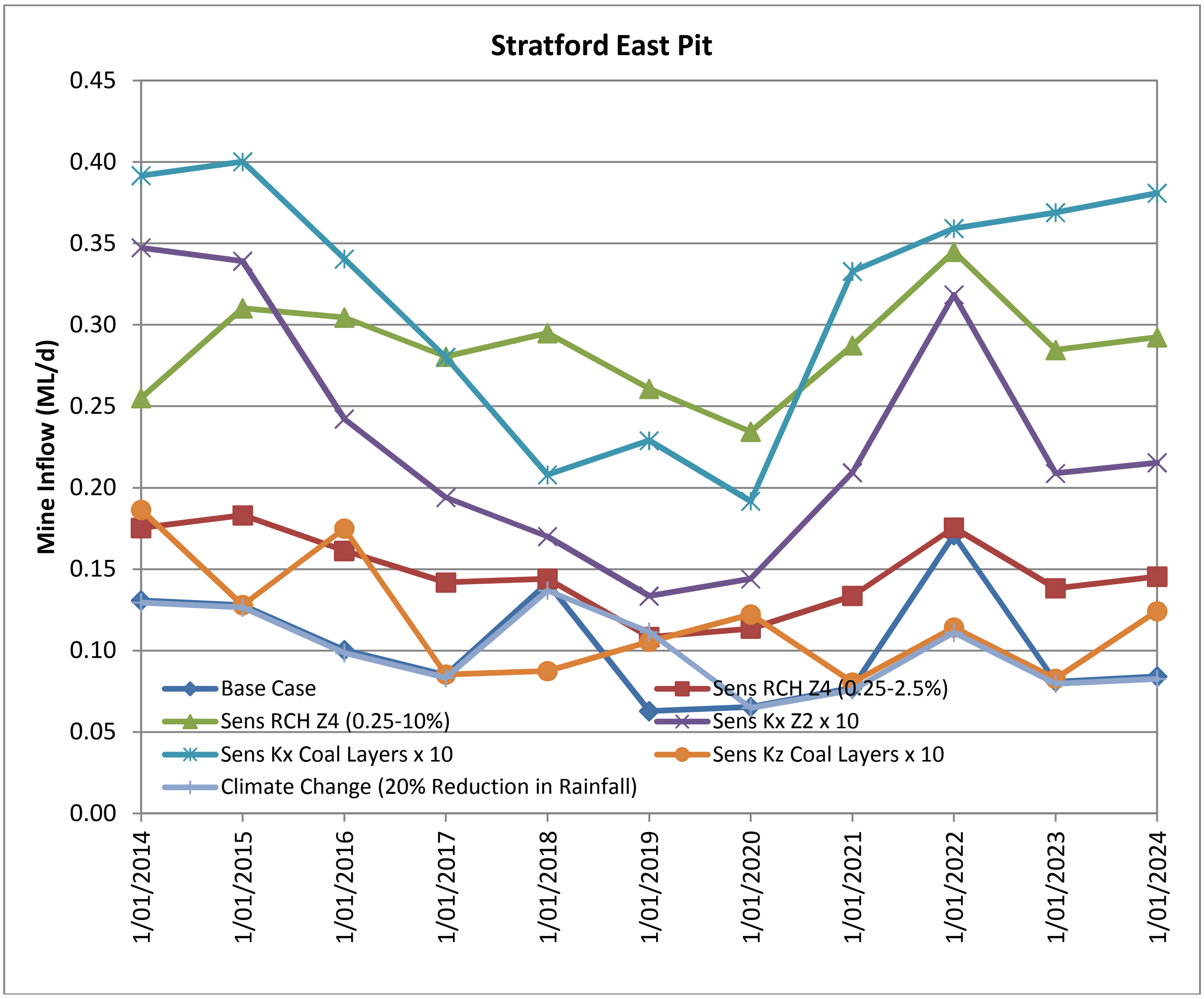


Figure A-54. Sensitivity Analysis for Stratford East Pit Inflow

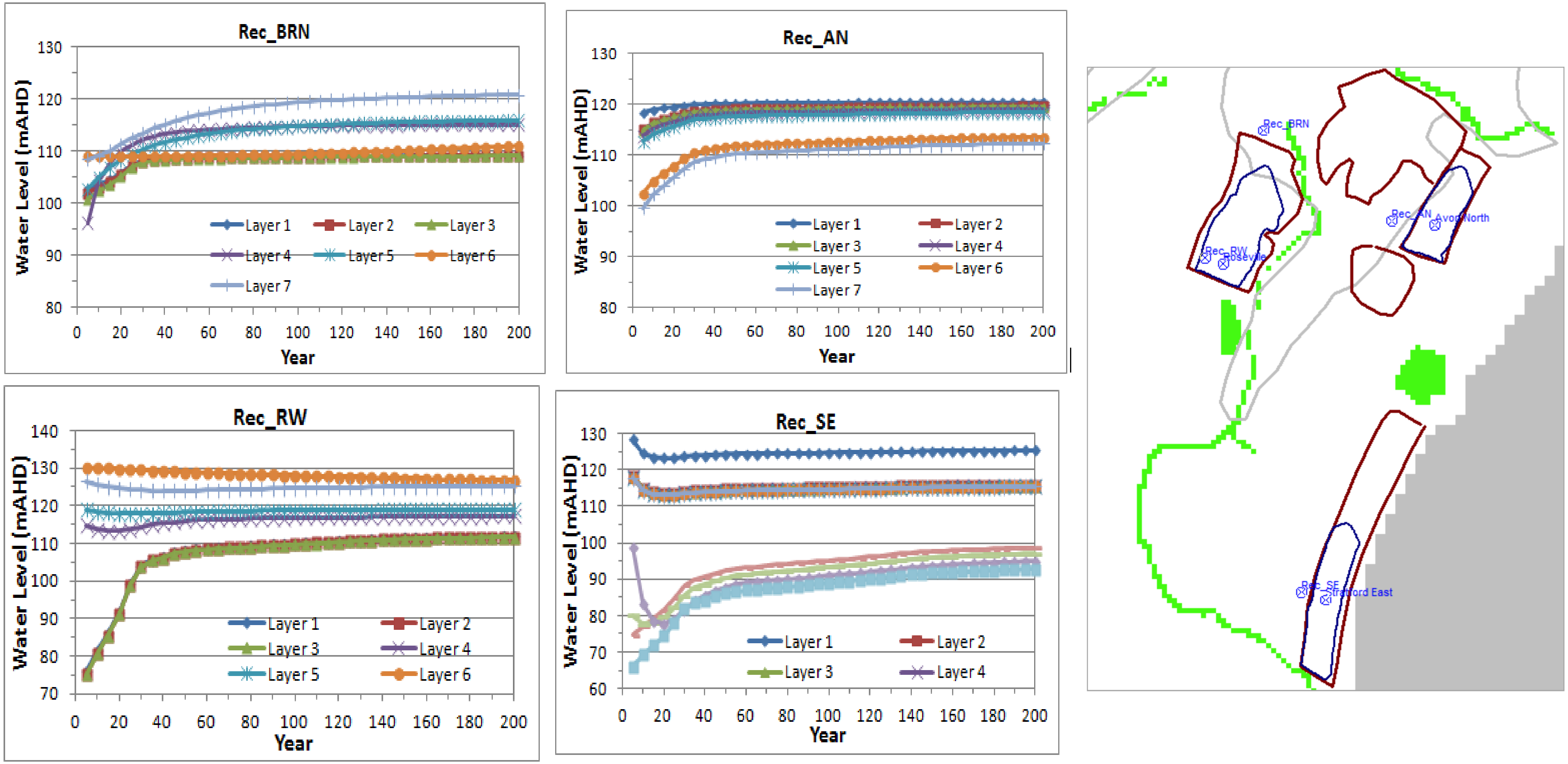


Figure A-55. Recovery Groundwater Hydrographs at Representative Sites

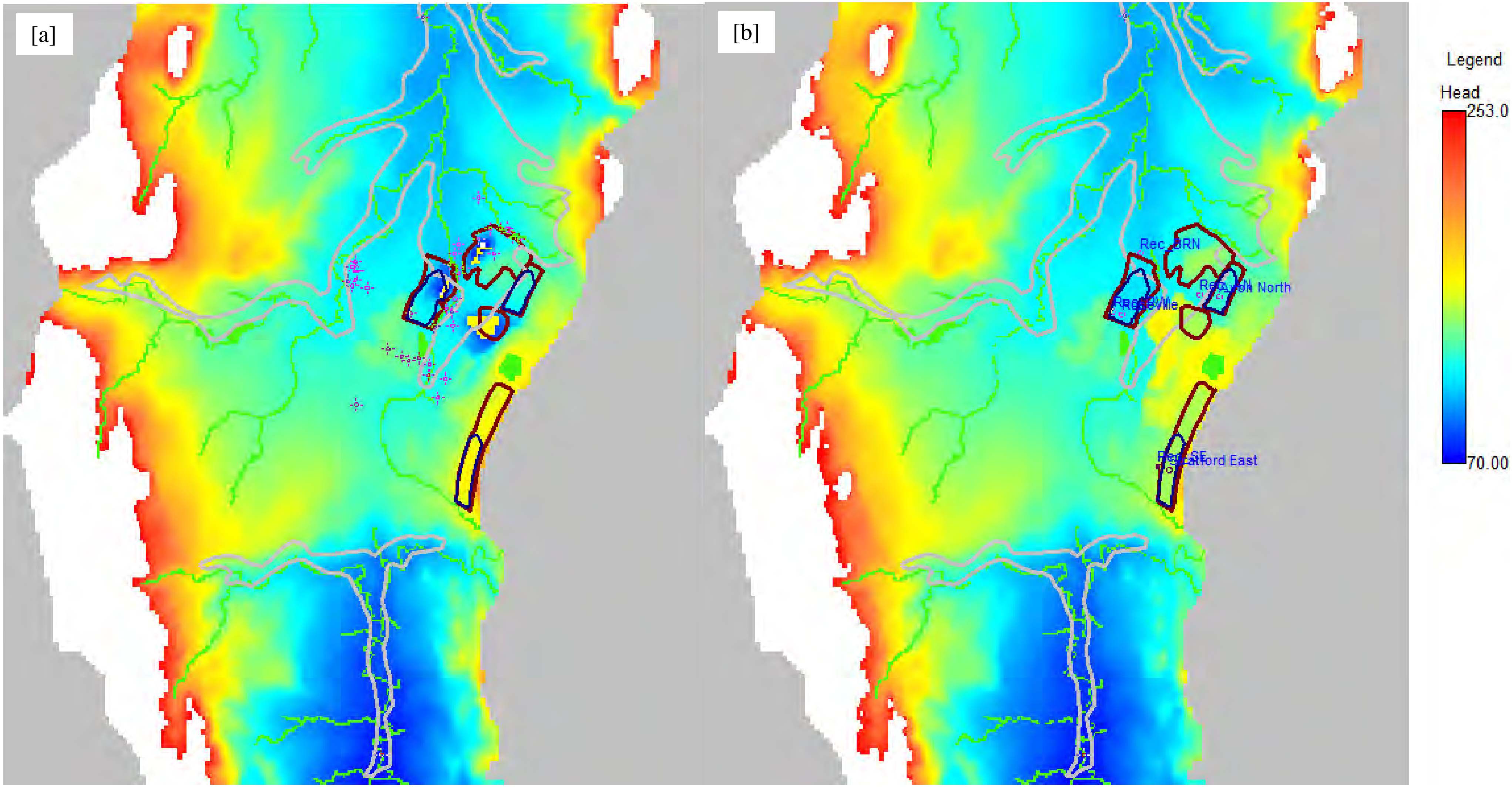


Figure A-56. Simulated Layer 1 Watertable Elevations at [a] End of Transient Calibration Period (June 2010); [b] Post-Mining Final Equilibrium [mAHD]

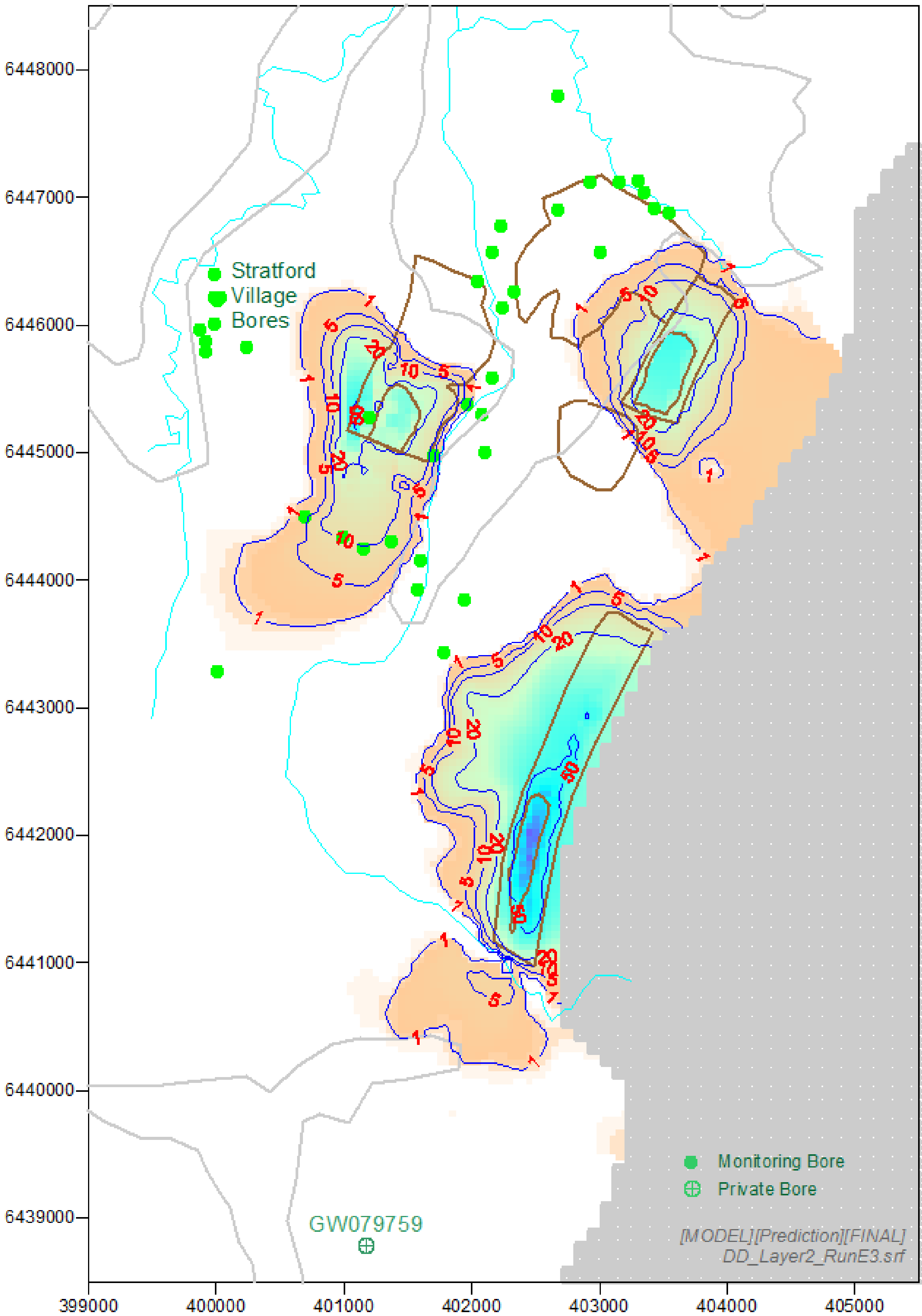


Figure A-57. Predicted Watertable Drawdown Contours at the end of the Project [m]

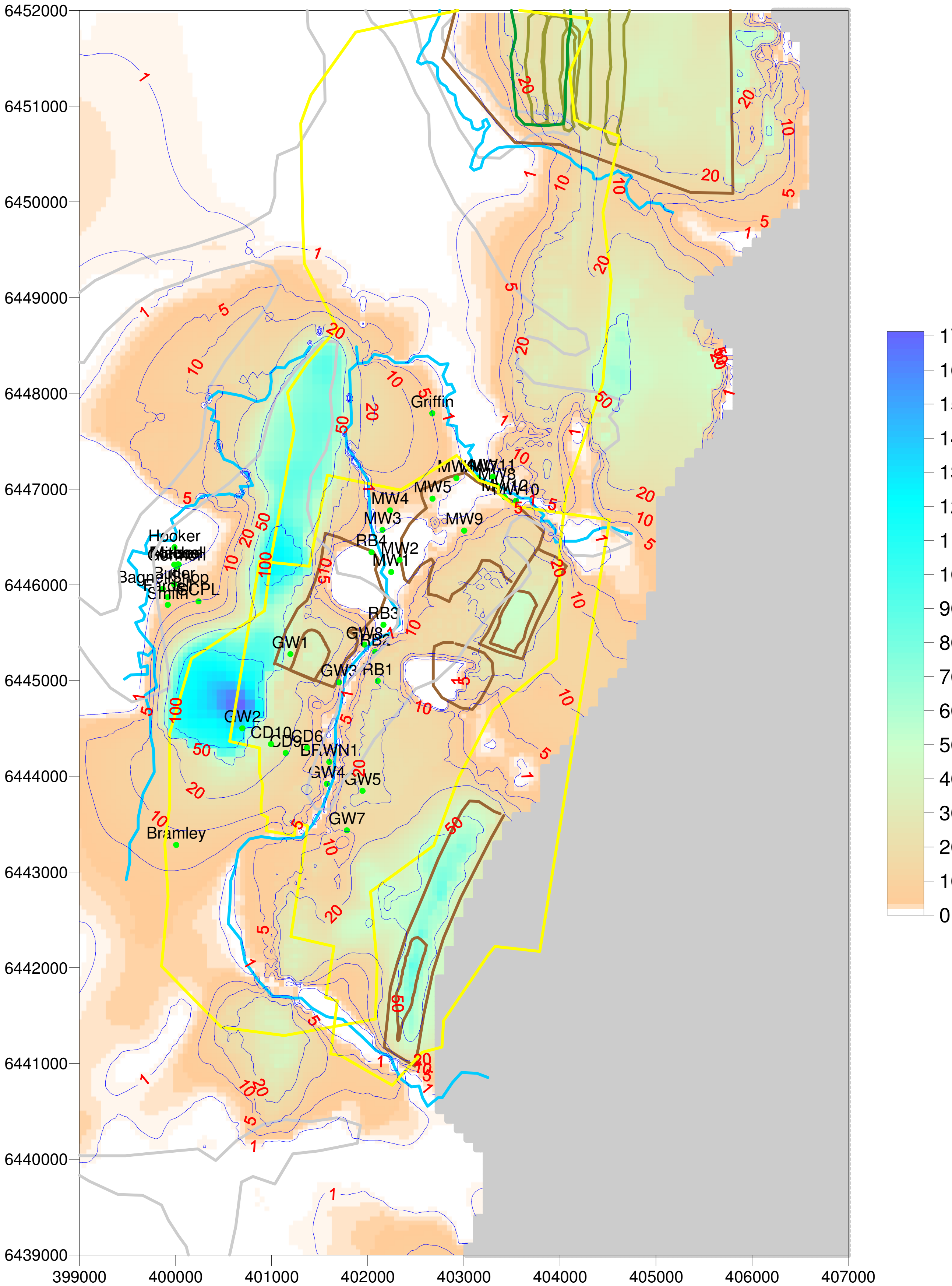
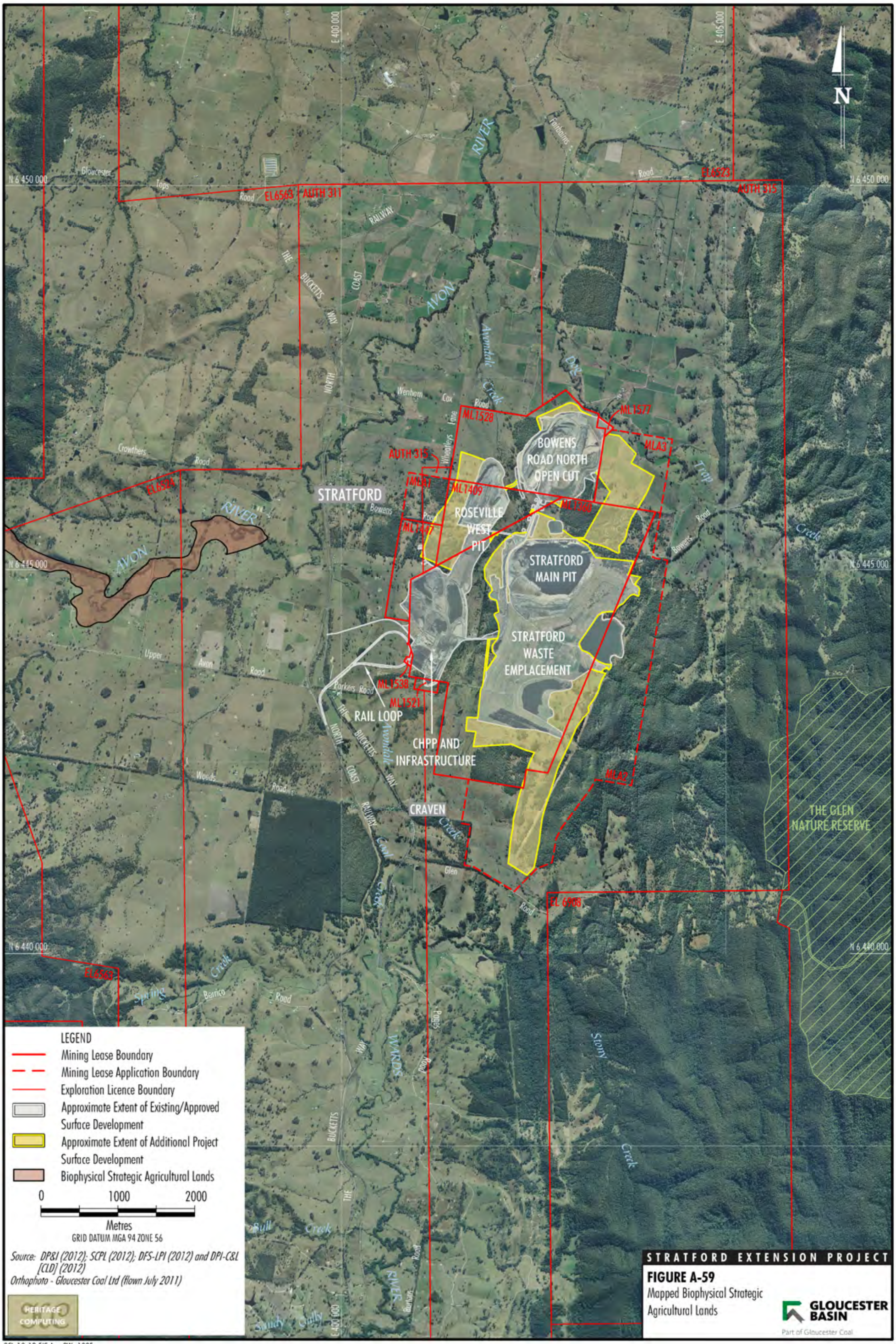


Figure A-58. Predicted Watertable Drawdown Contours Resulting from the Cumulative Effects of All Three Projects at 2024 [m]



STRATFORD EXTENSION PROJECT

FIGURE A-59
Mapped Biophysical Strategic Agricultural Lands

GCL-10-12 EIS App GW_108E

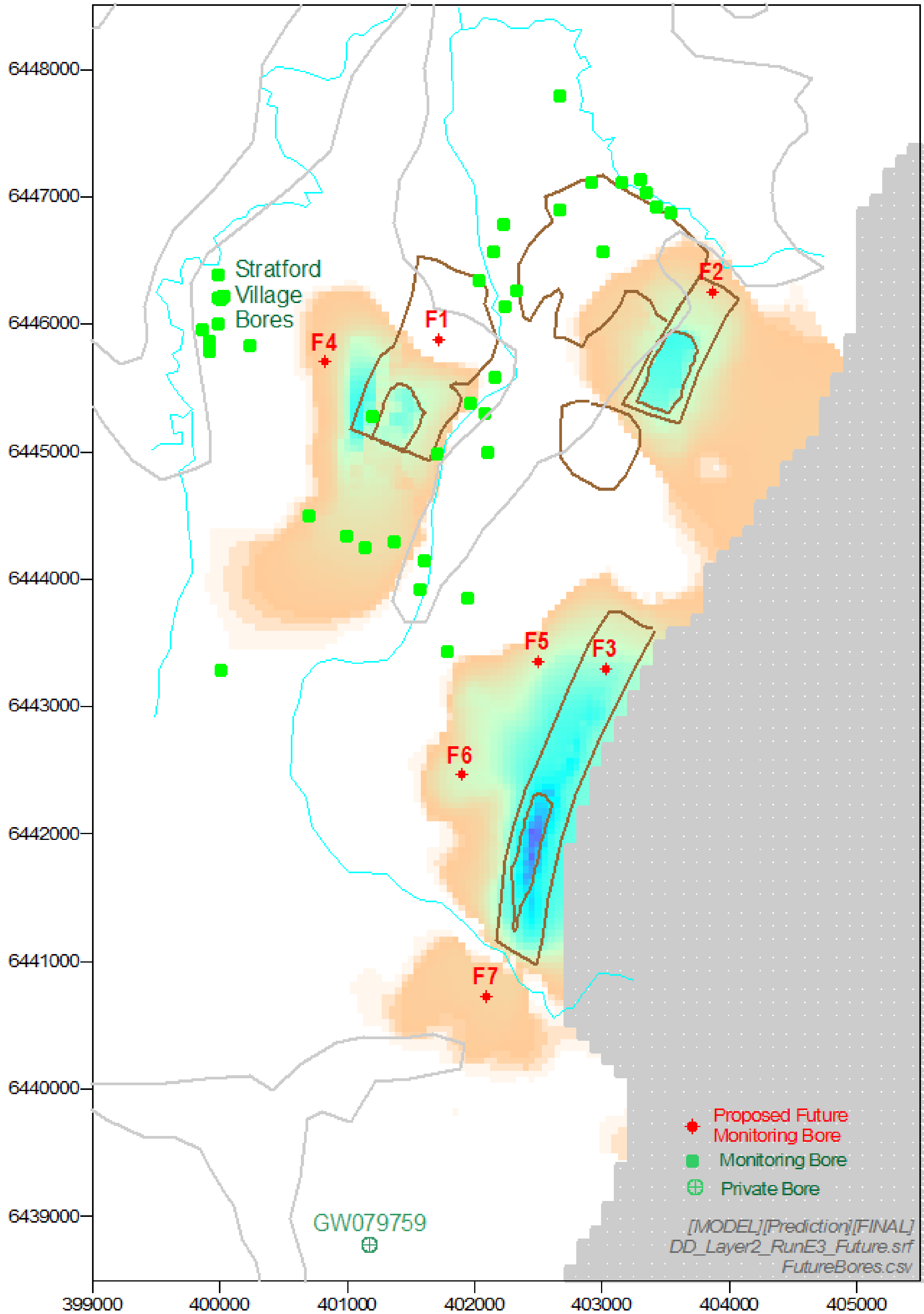


Figure A-60. Proposed Expansion of the Groundwater Monitoring Network

ATTACHMENTS

AA to AE

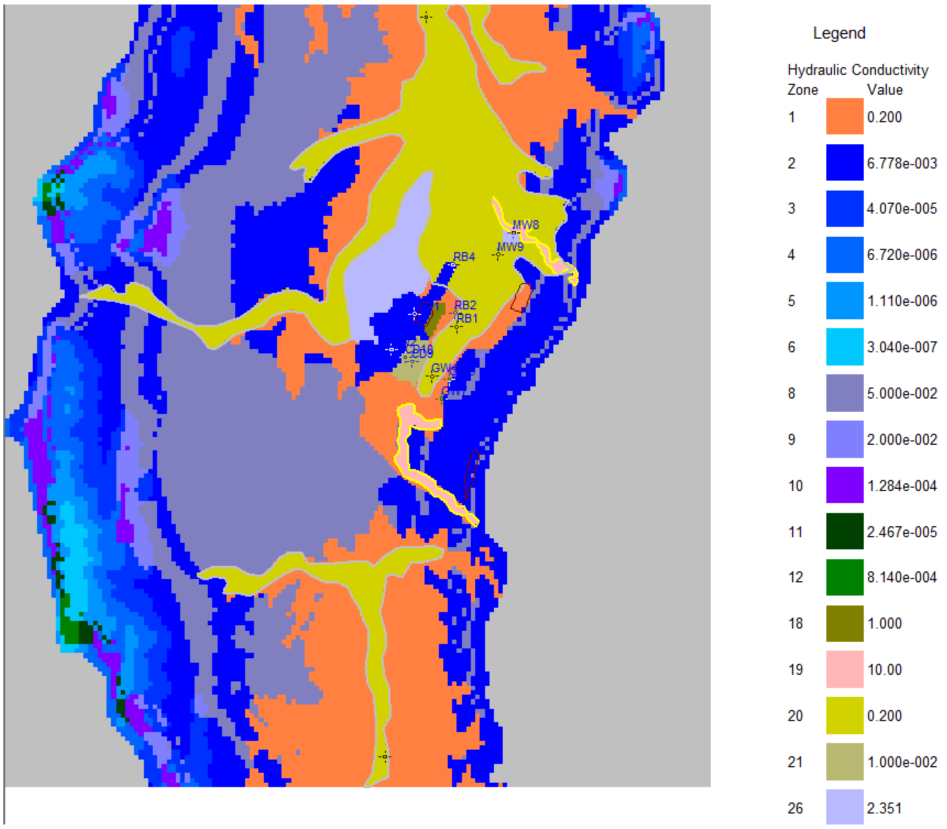
ATTACHMENT AA

Calibrated Hydraulic Conductivity [m/day]

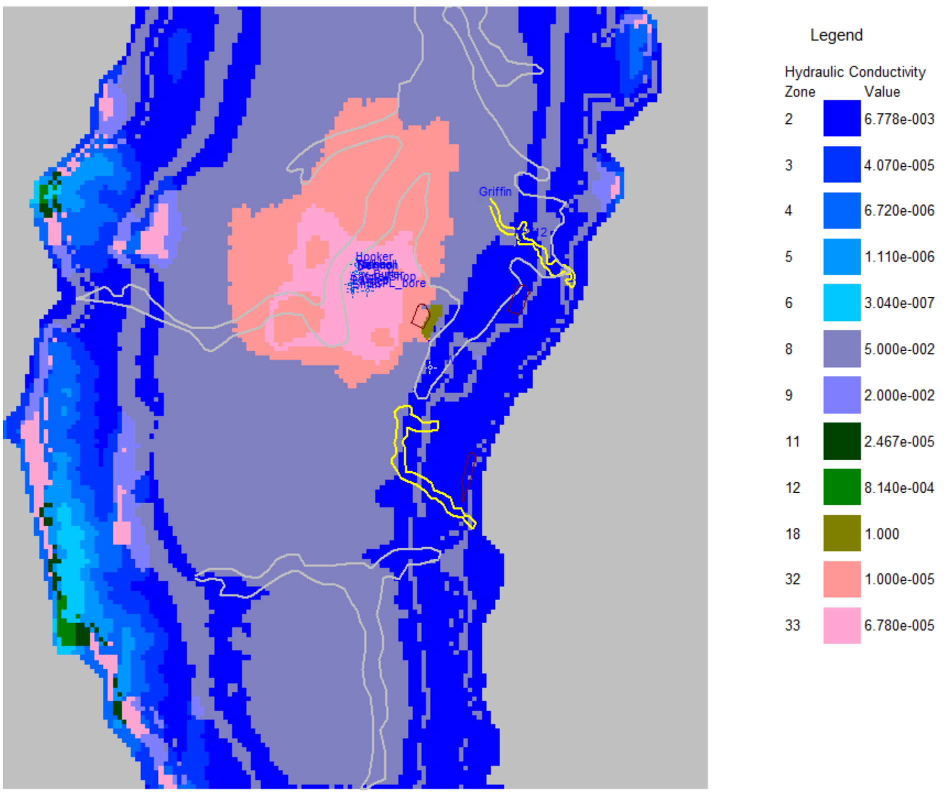
Specific Yield [-], Storage Coefficient [-]

and Rainfall Recharge Distributions

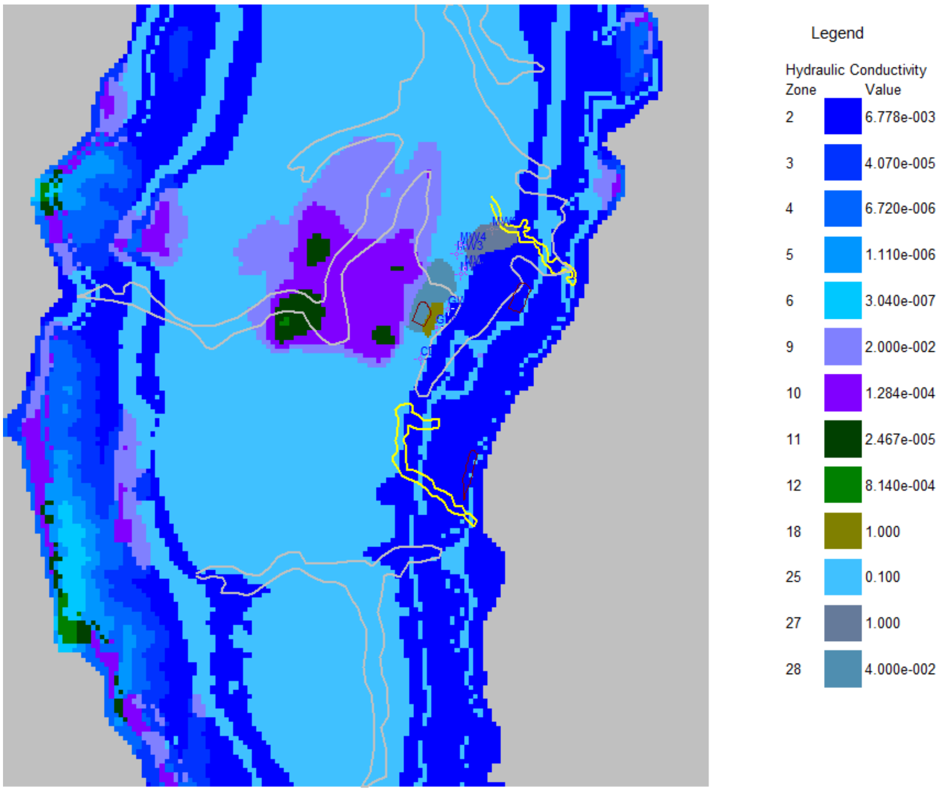
LAYER 1



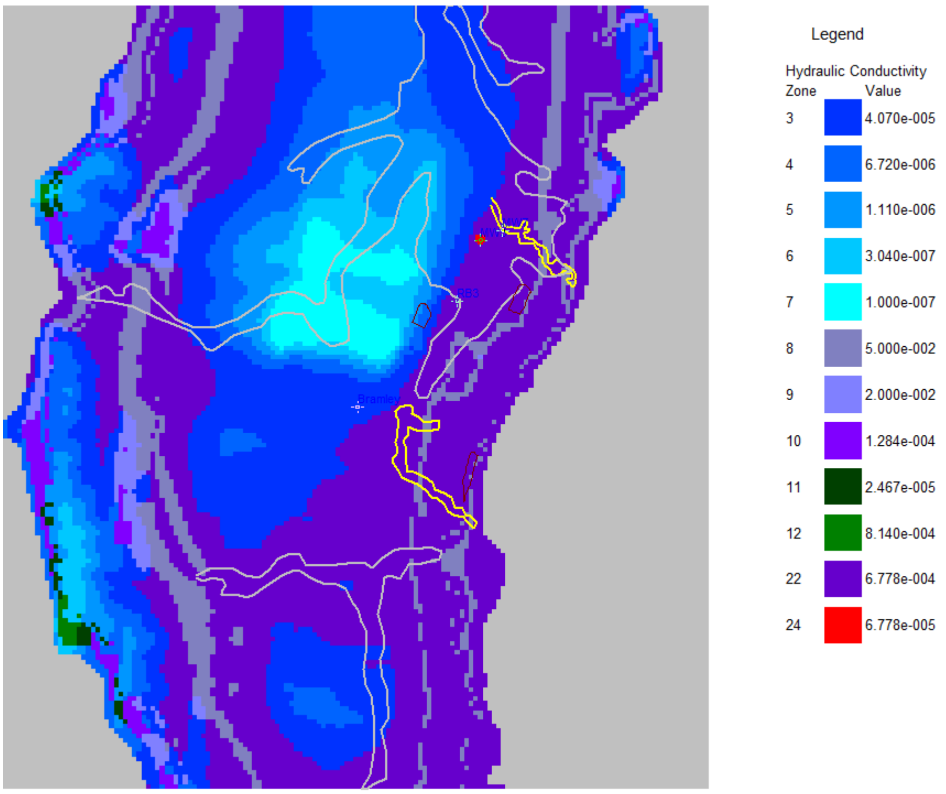
LAYER 2



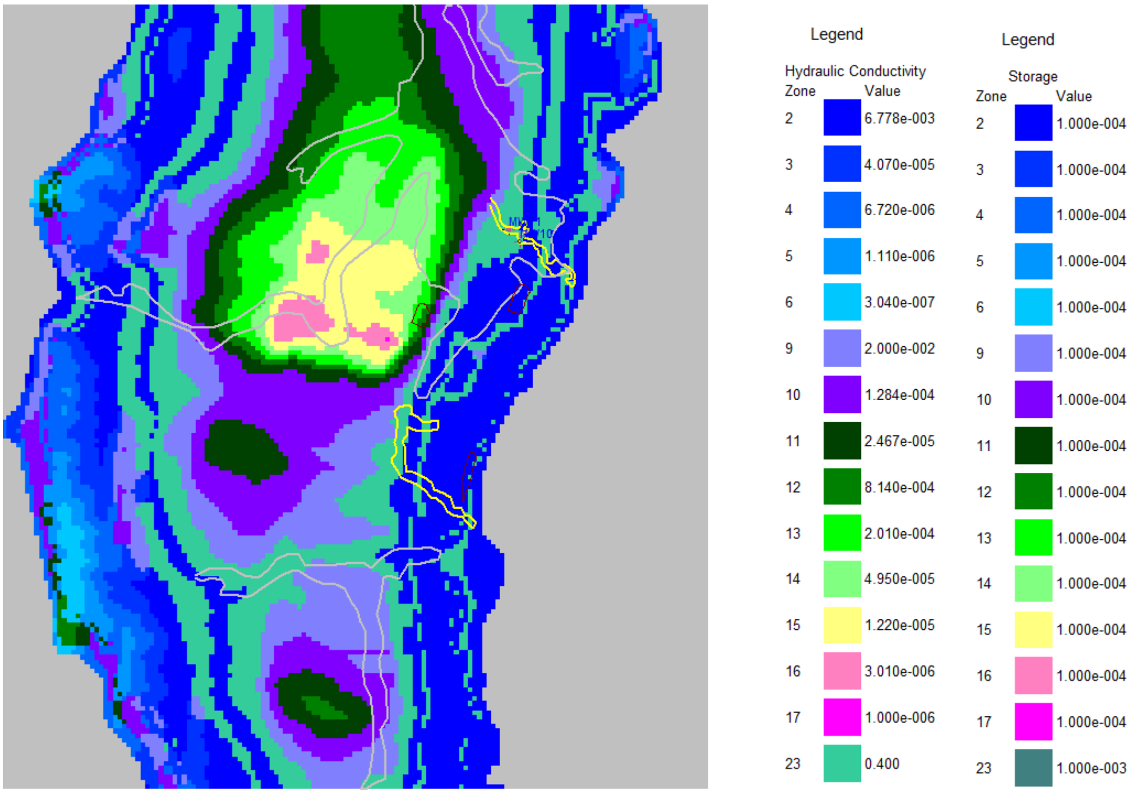
LAYER 3



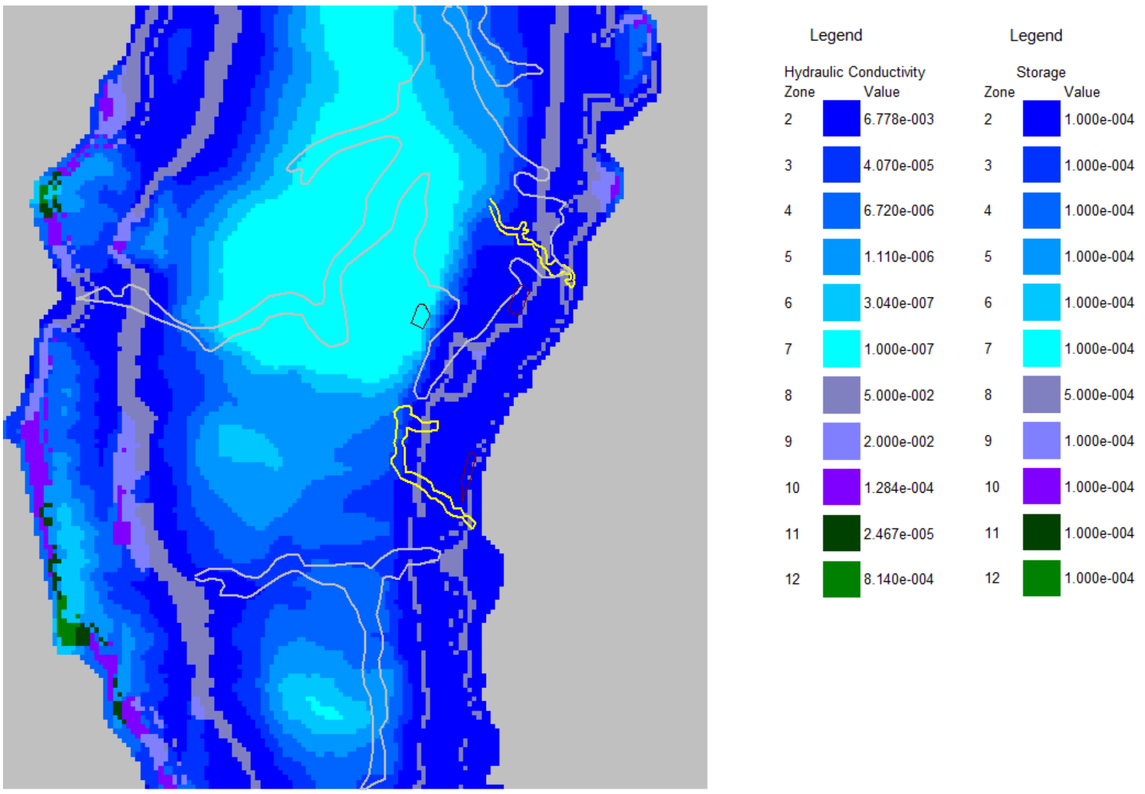
LAYER 4



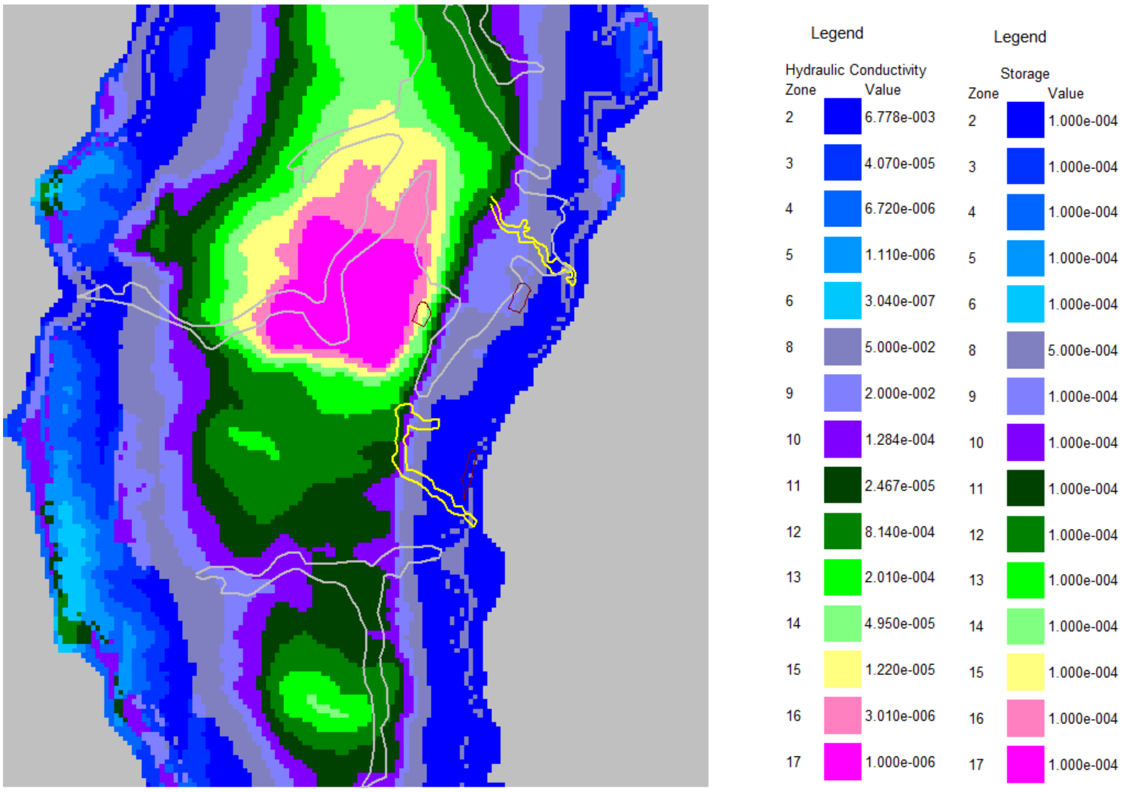
LAYER 5



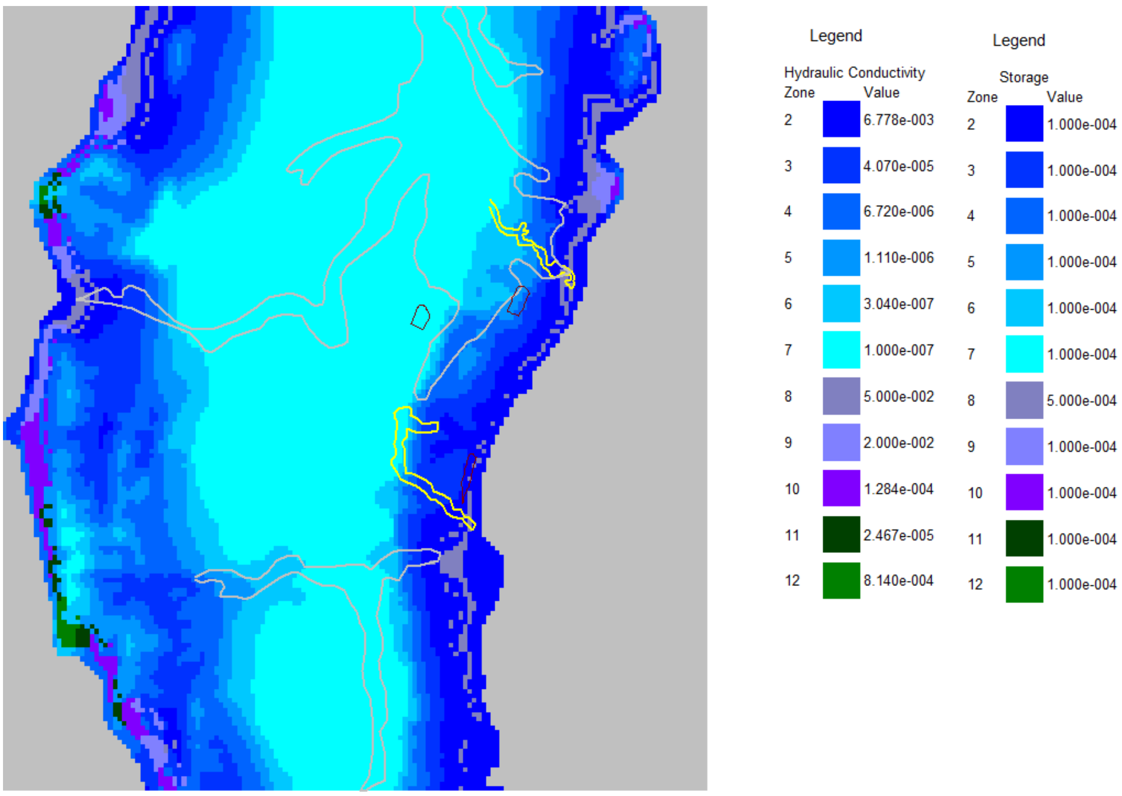
LAYER 6



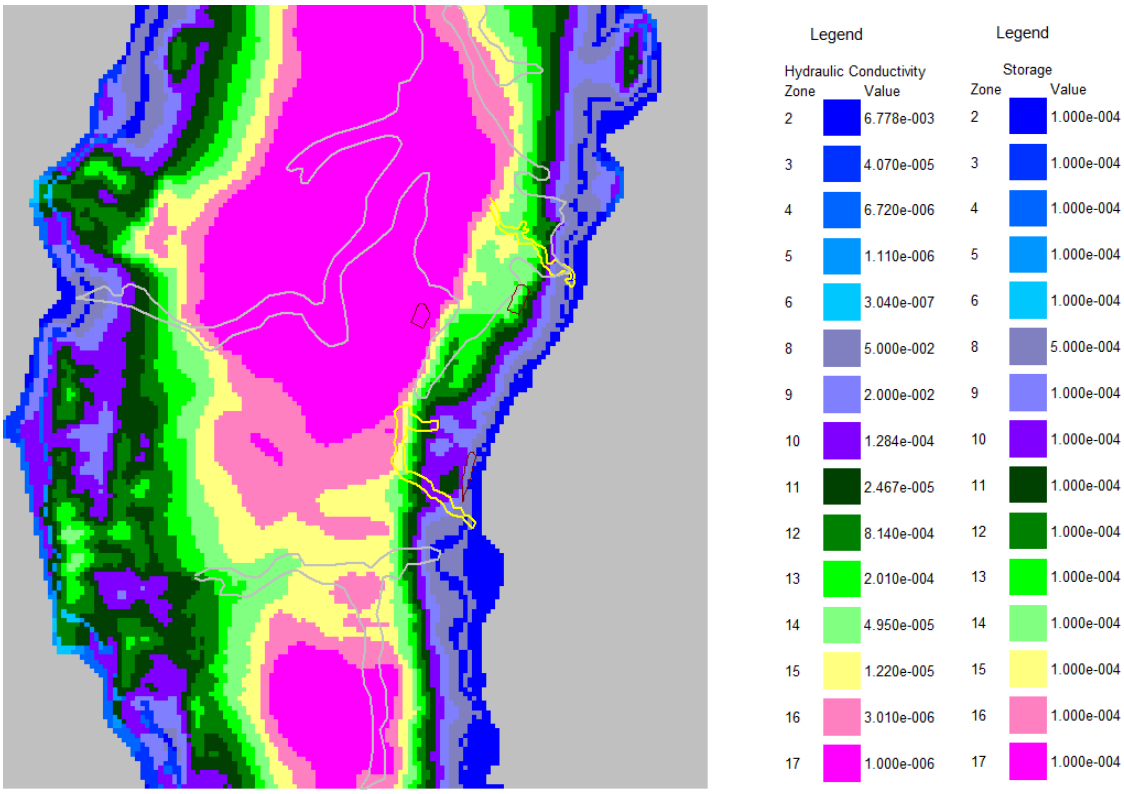
LAYER 7



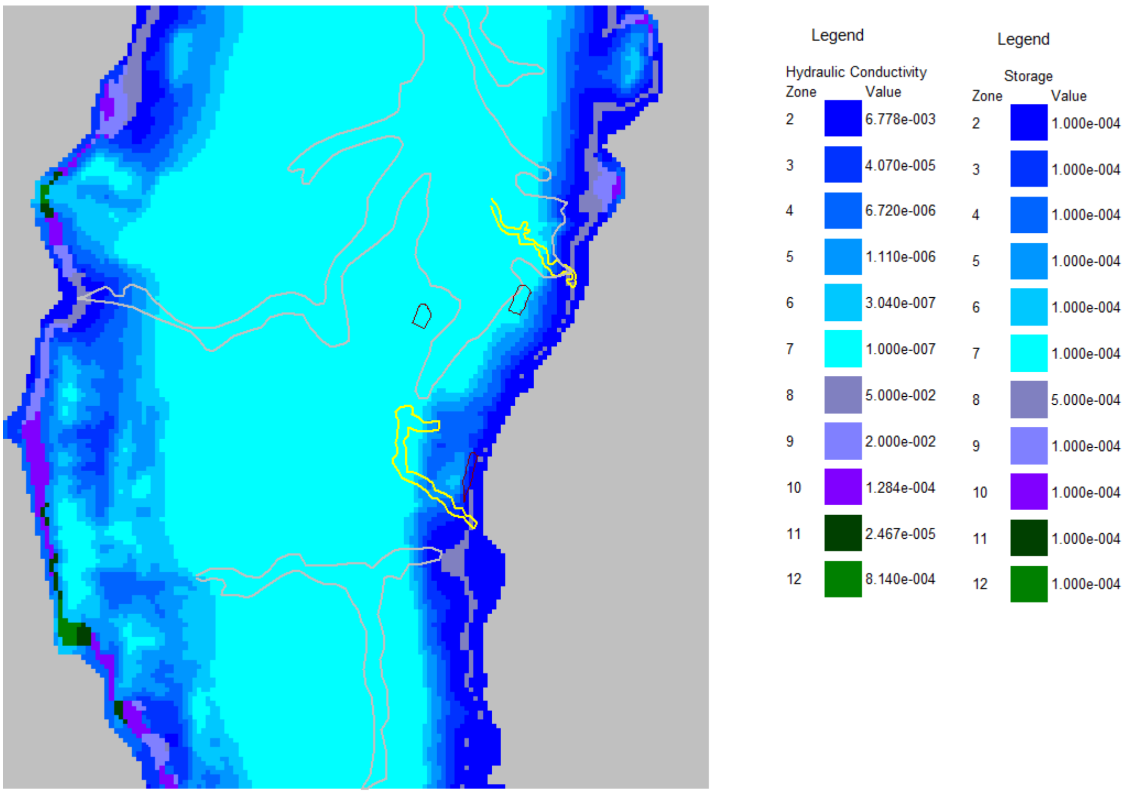
LAYER 8



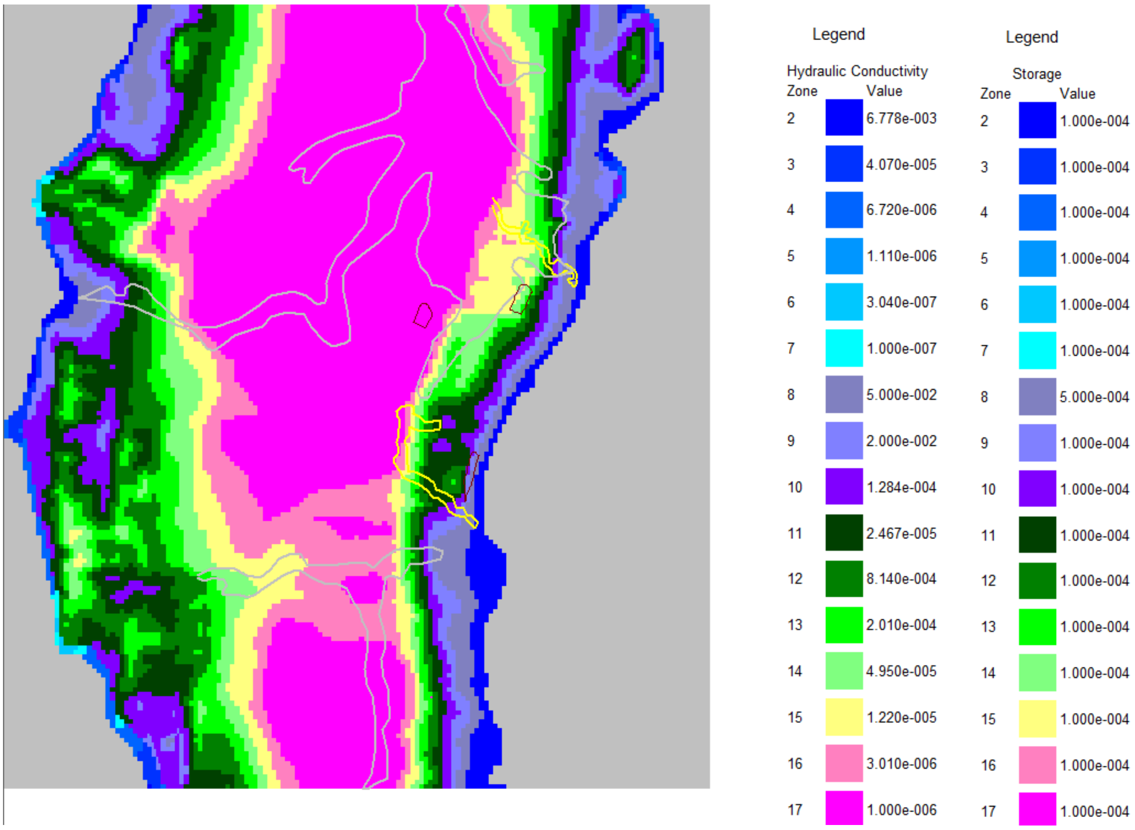
LAYER 9



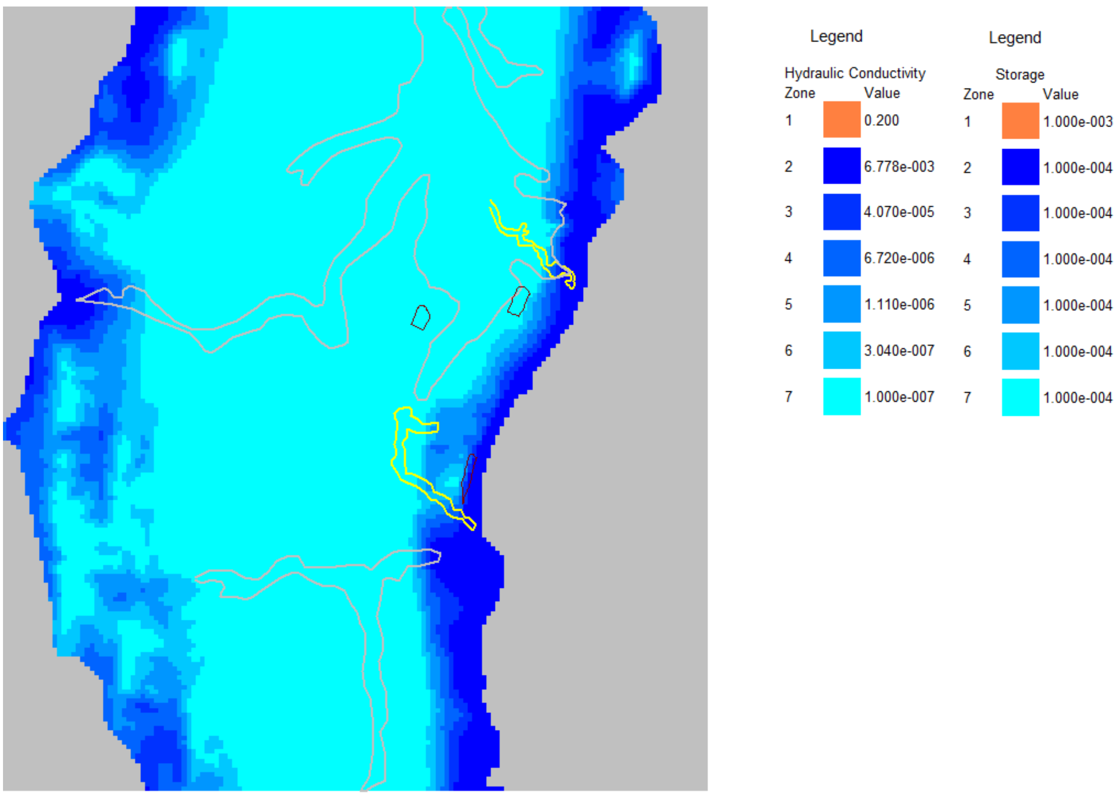
LAYER 10



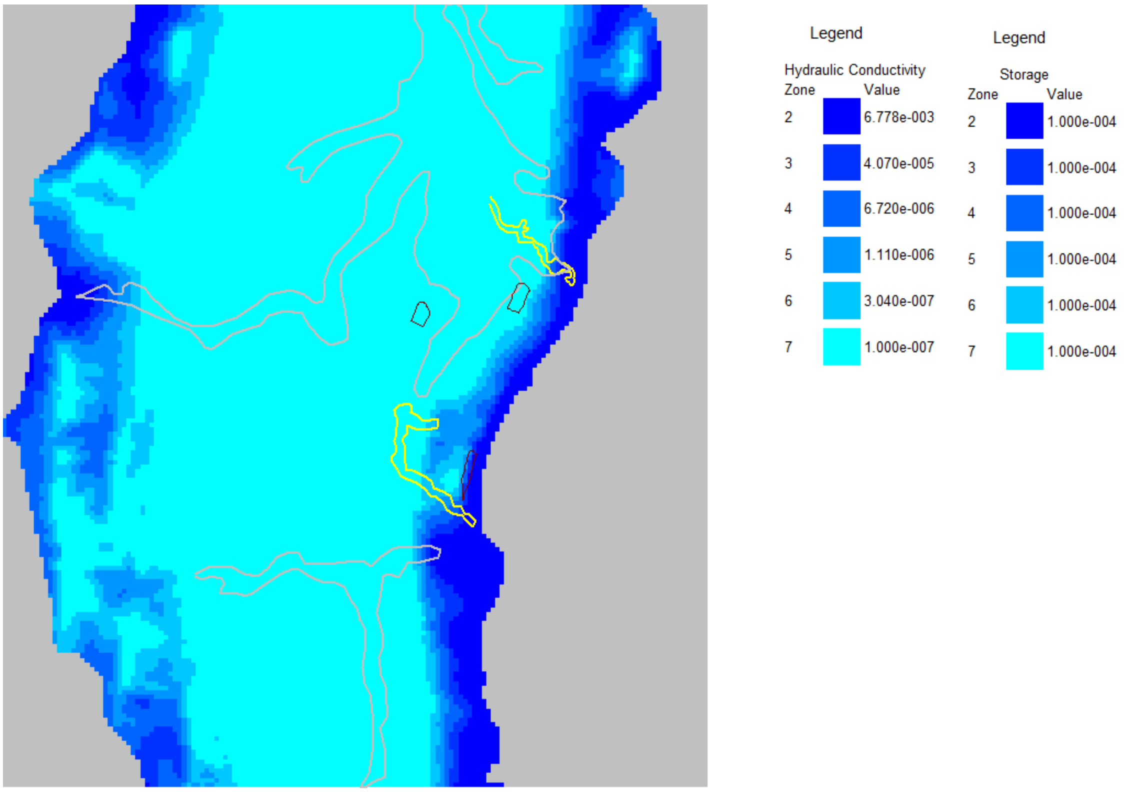
LAYER 11



LAYER 12



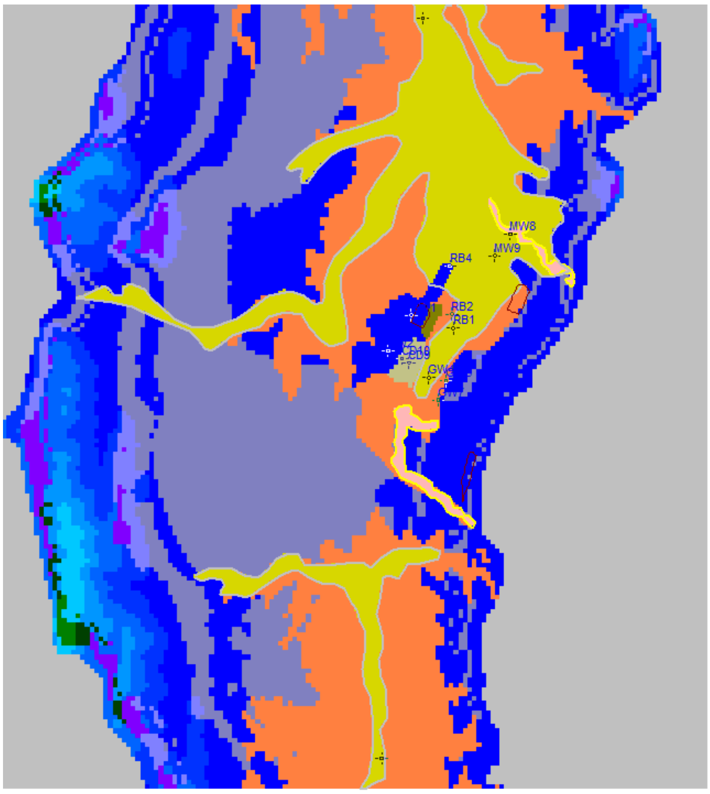
LAYER 13


Legend
Hydraulic Conductivity
Zone Value
2 6.778e-003
3 4.070e-005
4 6.720e-006
5 1.110e-006
6 3.040e-007
7 1.000e-007
Legend
Storage
Zone Value
2 1.000e-004
3 1.000e-004
4 1.000e-004
5 1.000e-004
6 1.000e-004
7 1.000e-004

HYDRAULIC CONDUCTIVITY DATABASE

K_Zone	Kx	Ky	Kz
1	2.00E-01	2.00E-01	2.00E-03
2	6.78E-03	6.78E-03	7.47E-04
3	4.07E-05	4.07E-05	4.07E-06
4	6.72E-06	6.72E-06	6.72E-07
5	1.11E-06	1.11E-06	1.11E-06
6	3.04E-07	3.04E-07	3.04E-08
7	1.00E-07	1.00E-07	1.00E-08
8	5.00E-02	5.00E-02	1.00E-02
9	2.00E-02	2.00E-02	1.00E-02
10	1.28E-04	1.28E-04	1.00E-03
11	2.47E-05	2.47E-05	2.99E-04
12	8.14E-04	8.14E-04	8.14E-05
13	2.01E-04	2.01E-04	2.01E-05
14	4.95E-05	4.95E-05	4.95E-06
15	1.22E-05	1.22E-05	1.22E-06
16	3.01E-06	3.01E-06	3.01E-07
17	1.00E-06	1.00E-06	1.00E-07
18	1.00E+00	1.00E+00	1.00E+00
19	1.00E+01	1.00E+01	1.00E+00
20	2.00E-01	2.00E-01	2.00E-03
21	1.00E-02	1.00E-02	1.00E-04
22	6.78E-04	6.78E-04	3.47E-05
23	4.00E-01	4.00E-01	5.00E-02
24	6.78E-05	6.78E-05	7.47E-07
25	1.00E-01	1.00E-01	5.00E-02
26	2.35E+00	2.35E+00	4.13E-02
27	1.00E+00	1.00E+00	1.00E-01
28	4.00E-02	4.00E-02	1.00E-02
32	1.00E-05	1.00E-05	7.15E-04
33	6.78E-05	6.78E-05	1.12E-03

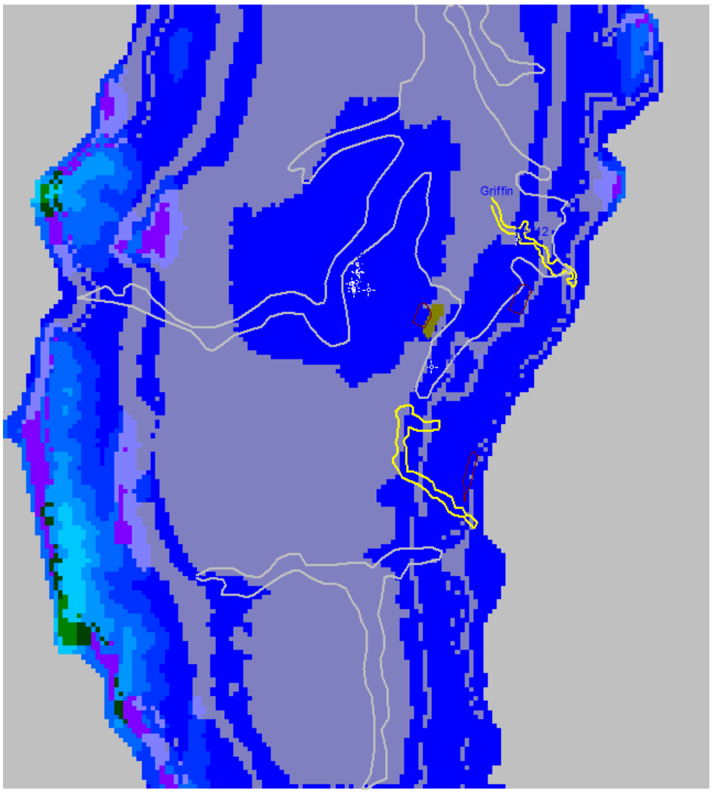
LAYER 1 STORAGE COEFFICIENT



Legend

Zone	Storage Value	
1	1.000e-003	Sy = 0.01
2	1.000e-004	Sy = 0.005
3	1.000e-004	Sy = 0.005
4	1.000e-004	Sy = 0.005
5	1.000e-004	Sy = 0.005
6	1.000e-004	Sy = 0.005
8	5.000e-004	Sy = 0.01
9	1.000e-004	Sy = 0.005
10	1.000e-004	Sy = 0.005
11	1.000e-004	Sy = 0.005
12	1.000e-004	Sy = 0.005
18	5.000e-003	Sy = 0.1
19	1.000e-003	Sy = 0.2
20	1.000e-003	Sy = 0.05
21	1.000e-004	Sy = 0.01

LAYER 2 STORAGE COEFFICIENT

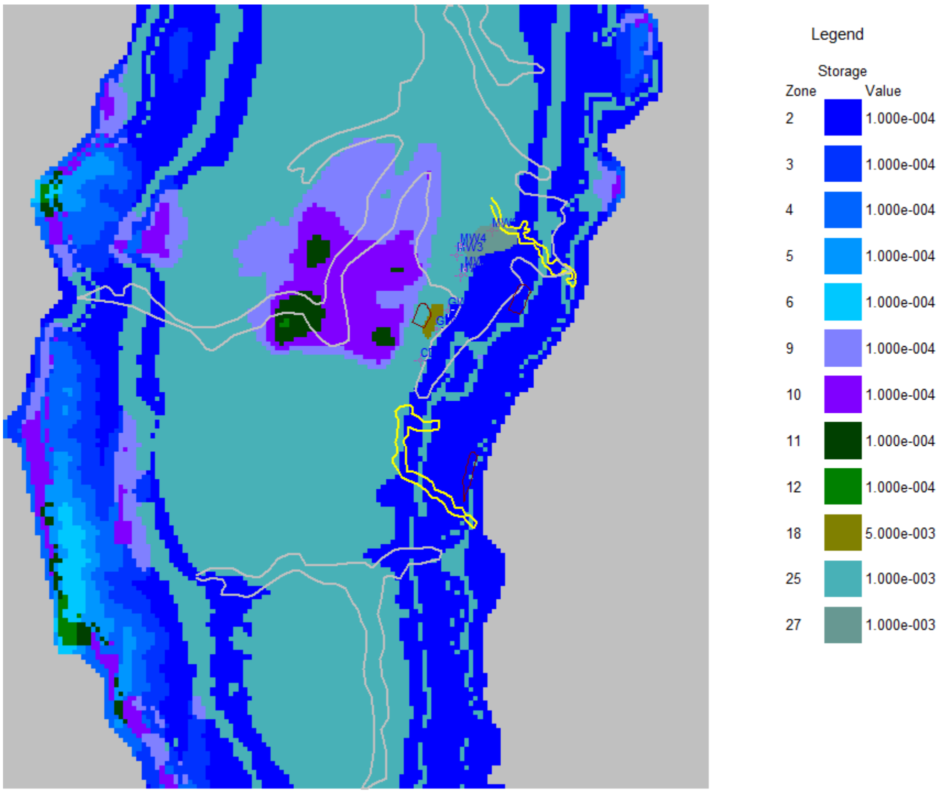


Legend

Zone	Storage Value	
2	1.000e-004	Sy = 0.005
3	1.000e-004	
4	1.000e-004	
5	1.000e-004	
6	1.000e-004	
8	5.000e-004	Sy = 0.01
9	1.000e-004	
10	1.000e-004	
11	1.000e-004	
12	1.000e-004	
18	5.000e-003	Sy = 0.1

Sy = 0.005 for other zones

LAYER 3 STORAGE COEFFICIENT



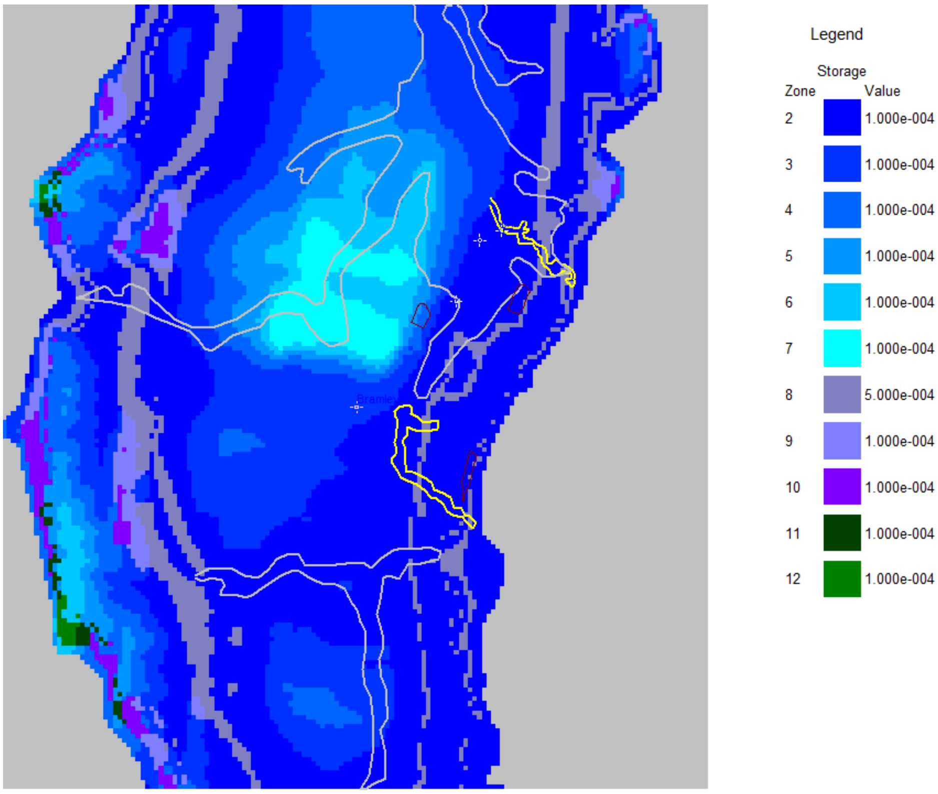
Sy = 0.1

Sy = 0.01

Sy = 0.01

Sy = 0.005 for other zones

LAYER 4 STORAGE COEFFICIENT



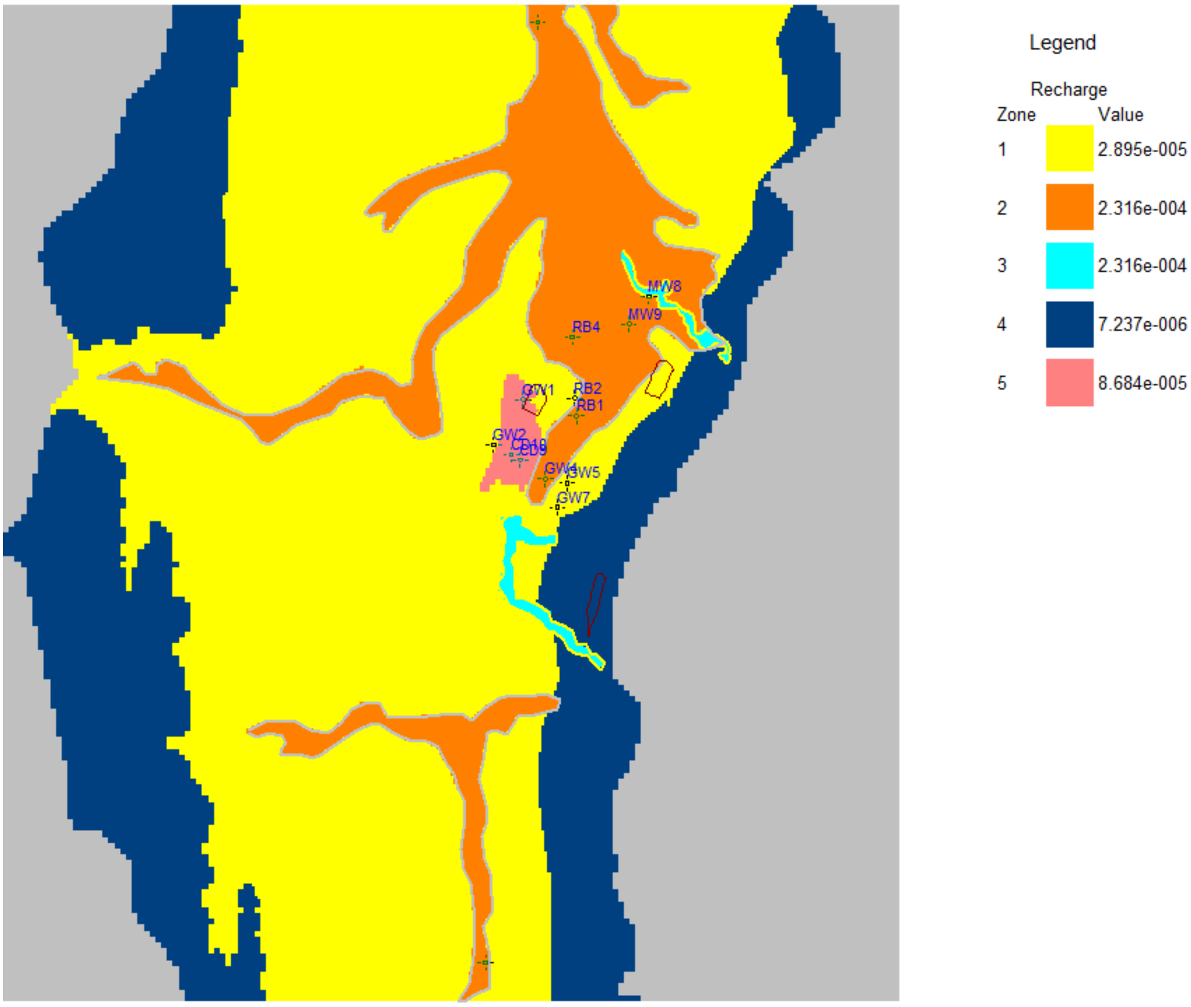
Sy = 0.01

Sy = 0.005 for other zones

STORAGE DATABASE

S_Zone	S	Sy
1	1.0E-03	1.0E-02
2	1.0E-04	5.0E-03
3	1.0E-04	5.0E-03
4	1.0E-04	5.0E-03
5	1.0E-04	5.0E-03
6	1.0E-04	5.0E-03
7	1.0E-04	5.0E-03
8	5.0E-04	1.0E-02
9	1.0E-04	5.0E-03
10	1.0E-04	5.0E-03
11	1.0E-04	5.0E-03
12	1.0E-04	5.0E-03
13	1.0E-04	5.0E-03
14	1.0E-04	5.0E-03
15	1.0E-04	5.0E-03
16	1.0E-04	5.0E-03
17	1.0E-04	5.0E-03
18	5.0E-03	1.0E-01
19	1.0E-03	2.0E-01
20	1.0E-03	5.0E-02
21	1.0E-04	1.0E-02
23	1.0E-03	1.0E-02
25	1.0E-03	1.0E-02
27	1.0E-03	1.0E-02

AVERAGE RAINFALL RECHARGE [m/day]

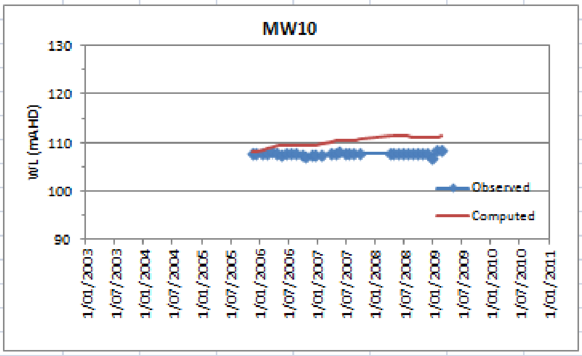


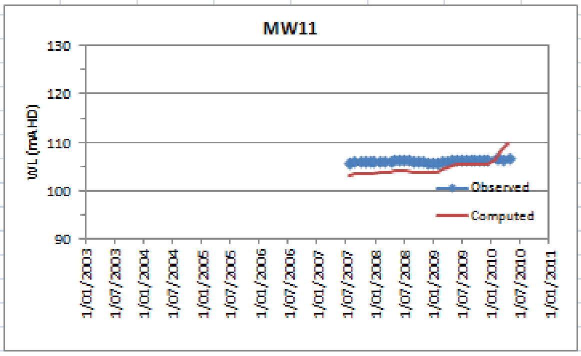
ATTACHMENT AB

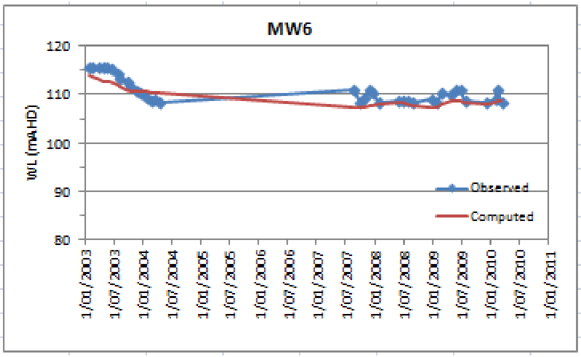
Hydrographic Calibration

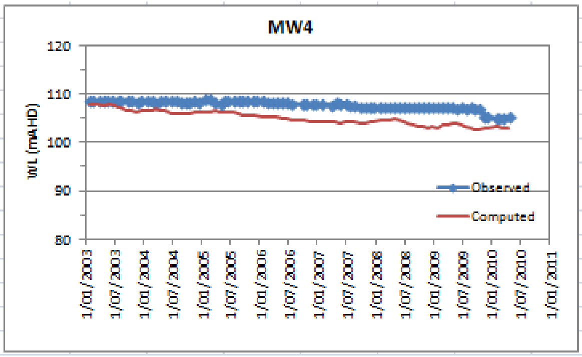
BORES SCREENED IN COAL

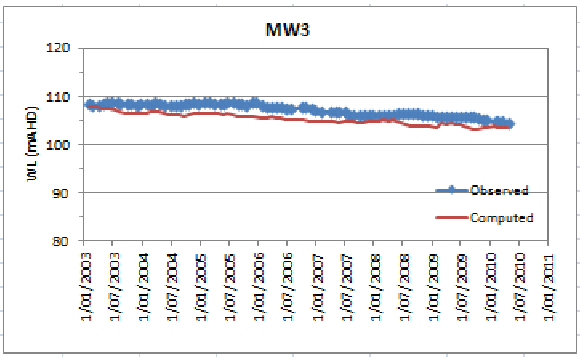
[Ordered North to South]

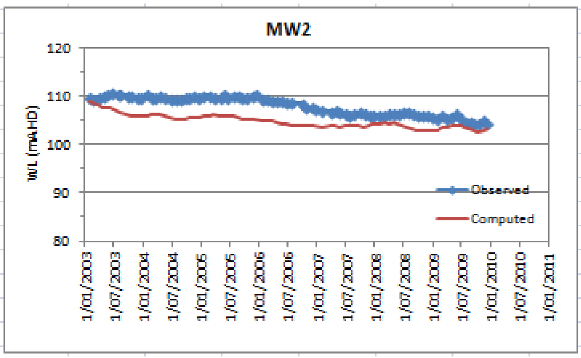






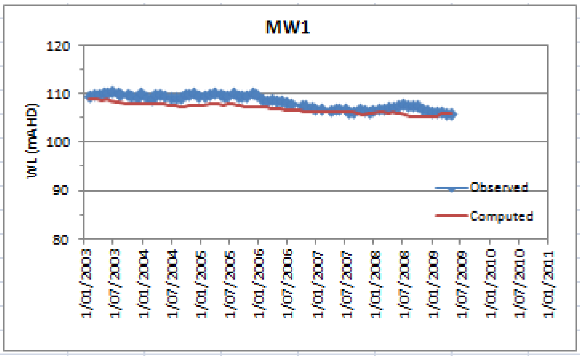


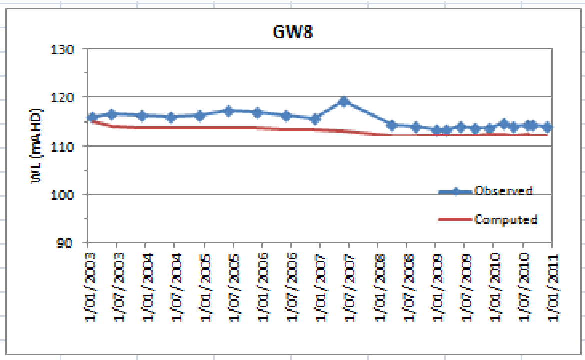


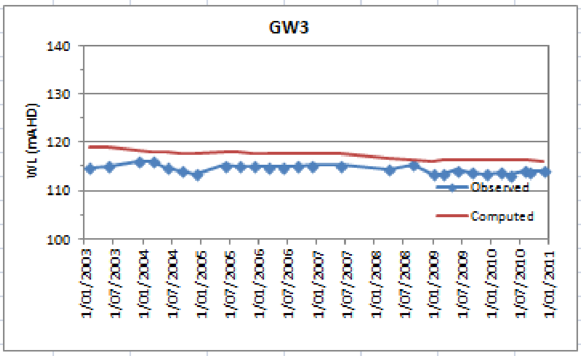


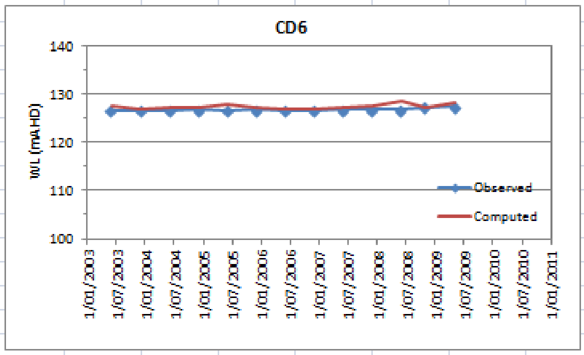
BORES SCREENED IN COAL

[Ordered North to South]



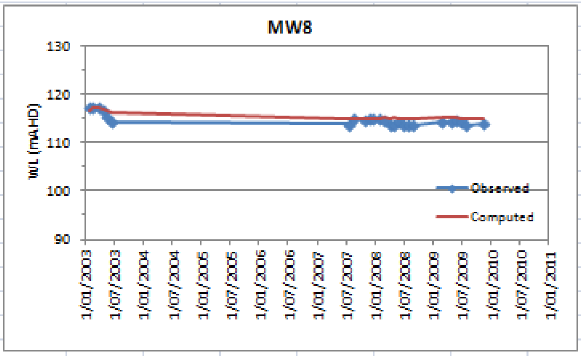


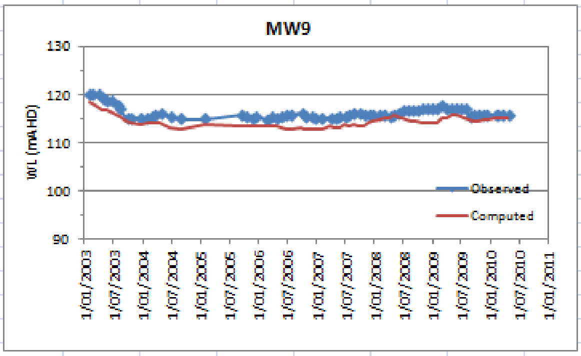


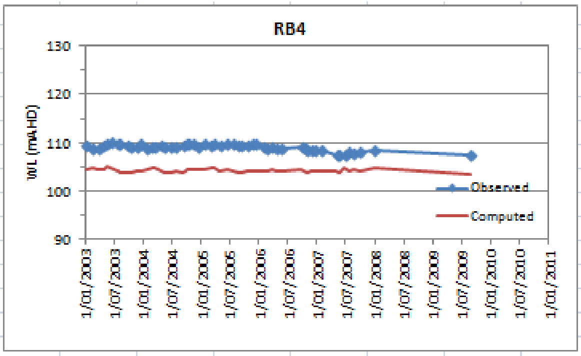


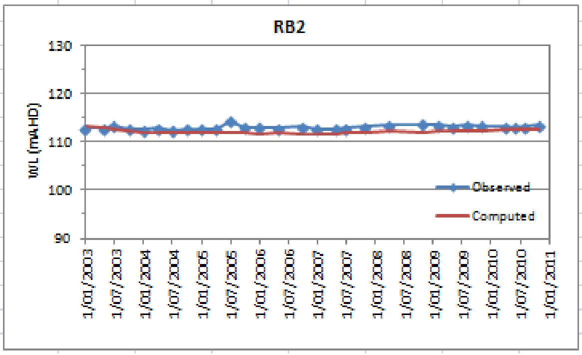
BORES SCREENED IN REGOLITH

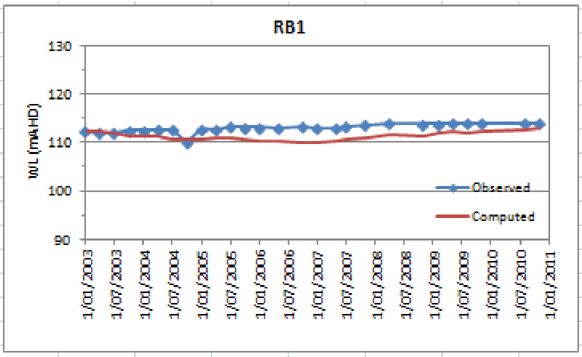
[Ordered North to South]

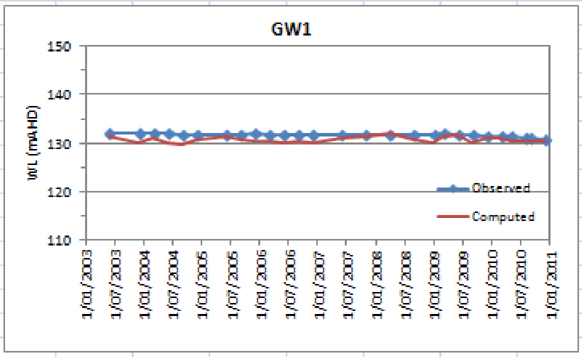






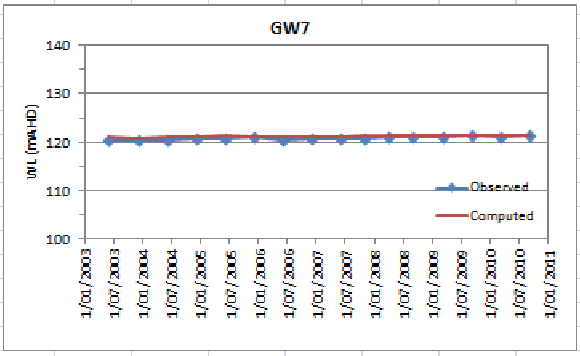


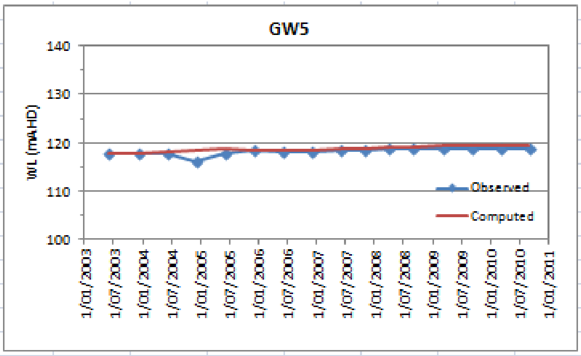


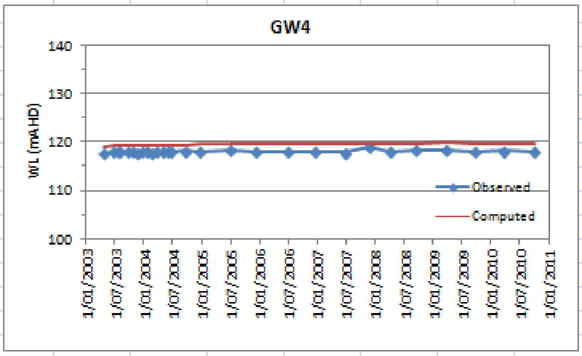


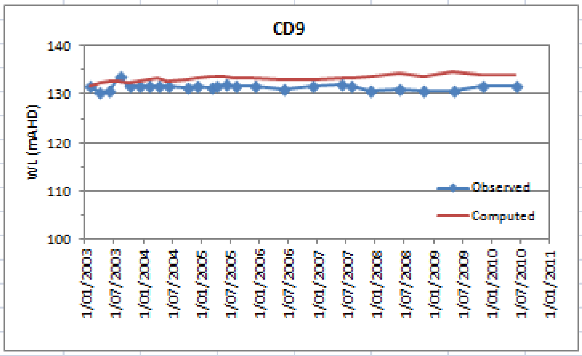
BORES SCREENED IN REGOLITH

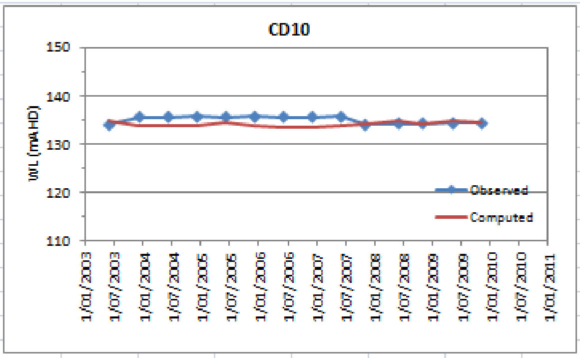
[Ordered North to South]

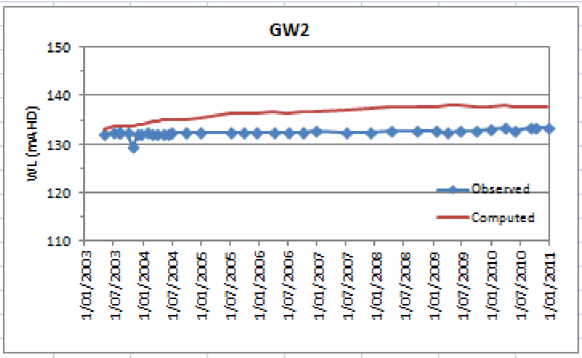






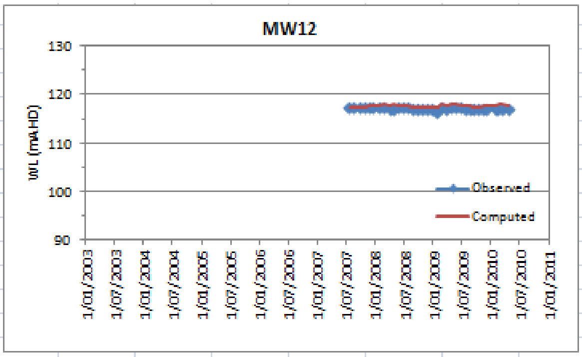


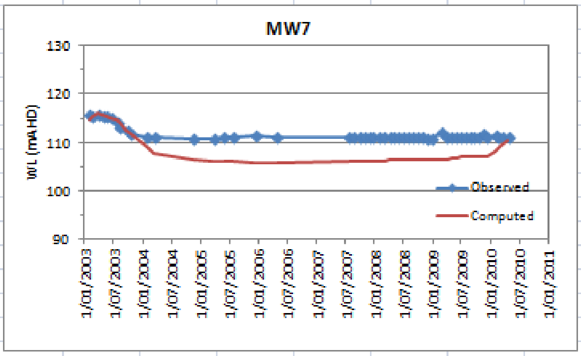


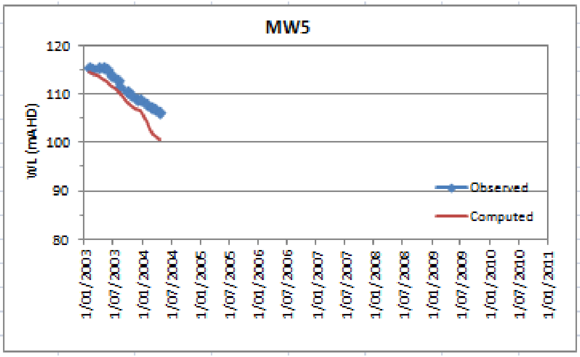


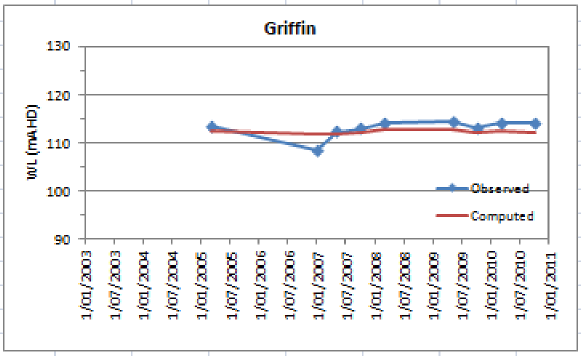
BORES SCREENED IN INTERBURDEN

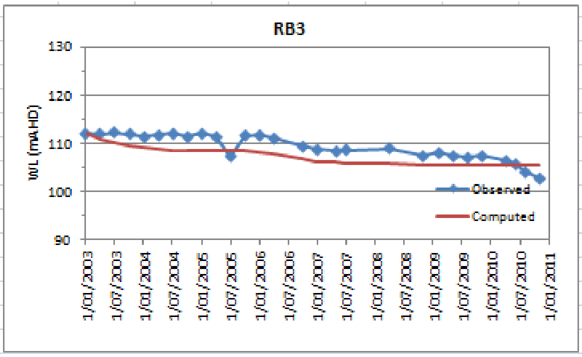
[Ordered North to South]

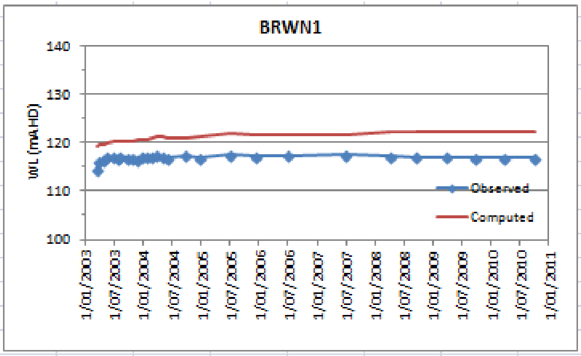


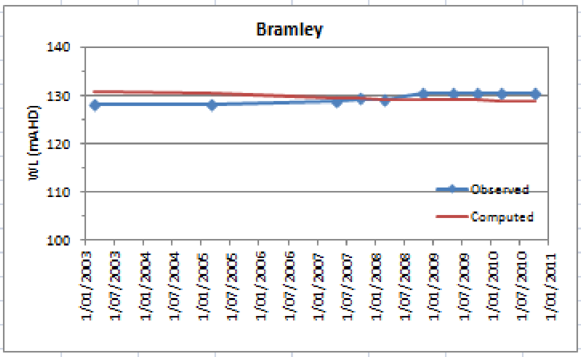






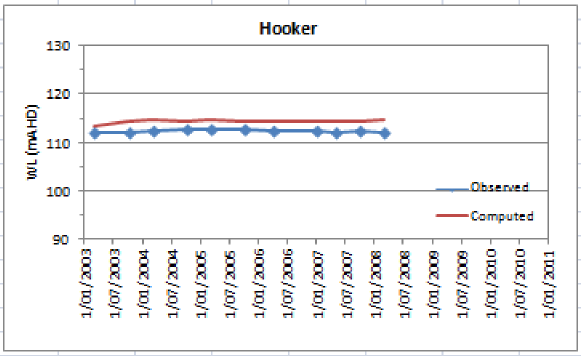


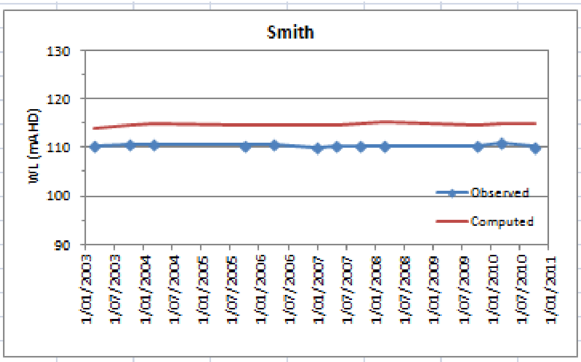


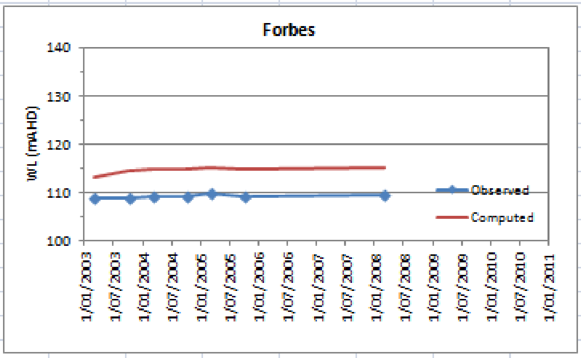


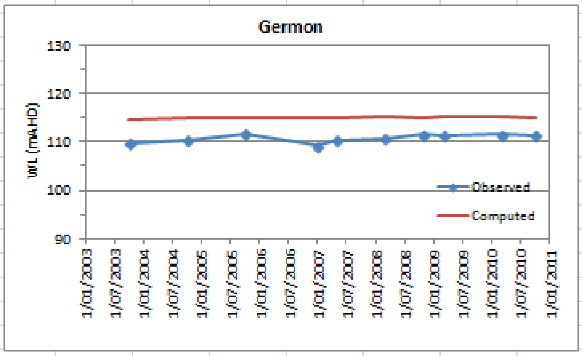
STRATFORD VILLAGE BORES

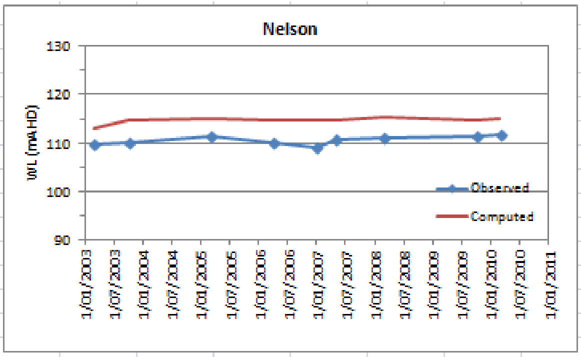
[Ordered North to South]

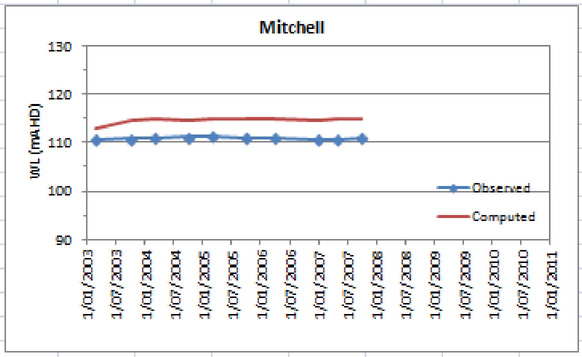






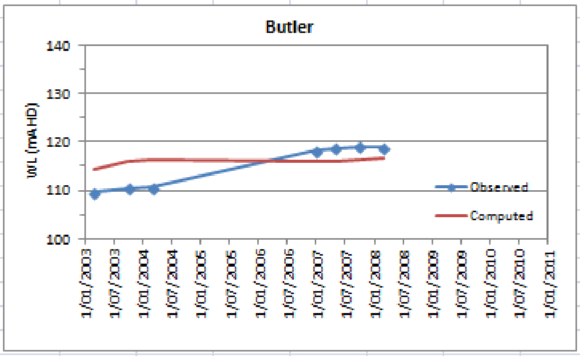


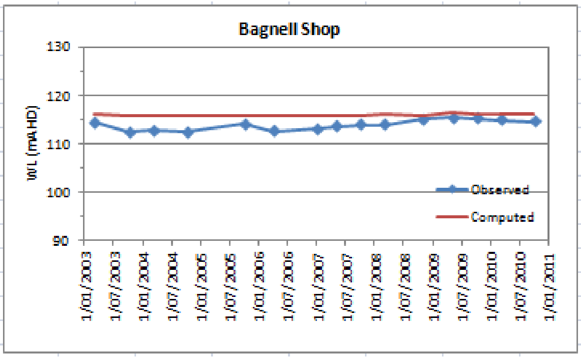


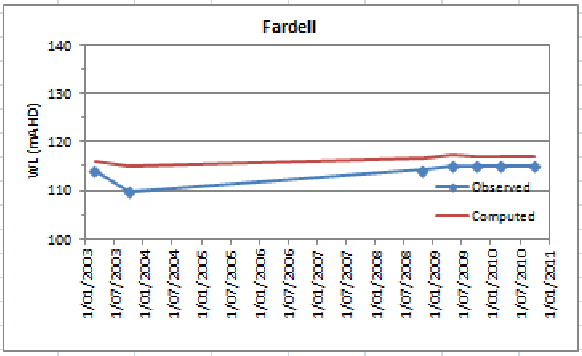


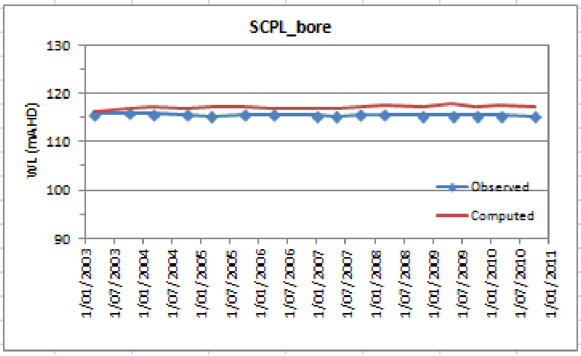
STRATFORD VILLAGE BORES

[Ordered North to South]









ATTACHMENT AC

Model Stress Period Setup

Table AC-1. Model Stress Period Setup

Model Purpose	Model Type	Stress Period	Start Date	End Date	Period Length	Timing of Operation				
						BRNOC Layer 5	Roseville West Pit Extension Layer 3	Stratford Main Pit Layer 7	Avon North Open Cut Layer 7	Stratford East Open Cut Layer 11
CALIBRATION	Transient	1	Jan-03	Jan-03	Monthly			Water Storage (DRN Cells)		
	Transient	2	Feb-03	Feb-03	Monthly					
	Transient	3	Mar-03	Mar-03	Monthly					
	Transient	4	Apr-03	Apr-03	Monthly	Open Cut				
	Transient	5	May-03	May-03	Monthly					
	Transient	6	Jun-03	Jun-03	Monthly					
	Transient	7	Jul-03	Jul-03	Monthly					
	Transient	8	Aug-03	Aug-03	Monthly					
	Transient	9	Sep-03	Sep-03	Monthly					
	Transient	10	Oct-03	Oct-03	Monthly					
	Transient	11	Nov-03	Nov-03	Monthly					
	Transient	12	Dec-03	Dec-03	Monthly					
	Transient	13	Jan-04	Jan-04	Monthly					
	Transient	14	Feb-04	Feb-04	Monthly					
	Transient	15	Mar-04	Mar-04	Monthly					
	Transient	16	Apr-04	Apr-04	Monthly					
	Transient	17	May-04	May-04	Monthly					
	Transient	18	Jun-04	Jun-04	Monthly					
	Transient	19	Jul-04	Jul-04	Monthly					
	Transient	20	Aug-04	Aug-04	Monthly					
	Transient	21	Sep-04	Sep-04	Monthly					
	Transient	22	Oct-04	Oct-04	Monthly					
	Transient	23	Nov-04	Nov-04	Monthly					
	Transient	24	Dec-04	Dec-04	Monthly					
	Transient	25	Jan-05	Jan-05	Monthly					
	Transient	26	Feb-05	Feb-05	Monthly					

	Transient	27	Mar-05	Mar-05	Monthly					
	Transient	28	Apr-05	Apr-05	Monthly					
	Transient	29	May-05	May-05	Monthly					
	Transient	30	Jun-05	Jun-05	Monthly					
	Transient	31	Jul-05	Jul-05	Monthly					
	Transient	32	Aug-05	Aug-05	Monthly					
	Transient	33	Sep-05	Sep-05	Monthly					
	Transient	34	Oct-05	Oct-05	Monthly					
	Transient	35	Nov-05	Nov-05	Monthly					
	Transient	36	Dec-05	Dec-05	Monthly					
	Transient	37	Jan-06	Jan-06	Monthly					
	Transient	38	Feb-06	Feb-06	Monthly					
	Transient	39	Mar-06	Mar-06	Monthly					
	Transient	40	Apr-06	Apr-06	Monthly					
	Transient	41	May-06	May-06	Monthly					
	Transient	42	Jun-06	Jun-06	Monthly					
	Transient	43	Jul-06	Jul-06	Monthly					
	Transient	44	Aug-06	Aug-06	Monthly					
	Transient	45	Sep-06	Sep-06	Monthly					
	Transient	46	Oct-06	Oct-06	Monthly					
	Transient	47	Nov-06	Nov-06	Monthly					
	Transient	48	Dec-06	Dec-06	Monthly					
	Transient	49	Jan-07	Jan-07	Monthly		Open Cut			
	Transient	50	Feb-07	Feb-07	Monthly					
	Transient	51	Mar-07	Mar-07	Monthly					
	Transient	52	Apr-07	Apr-07	Monthly					
	Transient	53	May-07	May-07	Monthly					
	Transient	54	Jun-07	Jun-07	Monthly					
	Transient	55	Jul-07	Jul-07	Monthly					
	Transient	56	Aug-07	Aug-07	Monthly					
	Transient	57	Sep-07	Sep-07	Monthly					

	Transient	58	Oct-07	Oct-07	Monthly					
	Transient	59	Nov-07	Nov-07	Monthly					
	Transient	60	Dec-07	Dec-07	Monthly					
	Transient	61	Jan-08	Jan-08	Monthly					
	Transient	62	Feb-08	Feb-08	Monthly					
	Transient	63	Mar-08	Mar-08	Monthly					
	Transient	64	Apr-08	Apr-08	Monthly					
	Transient	65	May-08	May-08	Monthly					
	Transient	66	Jun-08	Jun-08	Monthly					
	Transient	67	Jul-08	Jul-08	Monthly					
	Transient	68	Aug-08	Aug-08	Monthly					
	Transient	69	Sep-08	Sep-08	Monthly					
	Transient	70	Oct-08	Oct-08	Monthly					
	Transient	71	Nov-08	Nov-08	Monthly					
	Transient	72	Dec-08	Dec-08	Monthly					
	Transient	73	Jan-09	Jan-09	Monthly					
	Transient	74	Feb-09	Feb-09	Monthly					
	Transient	75	Mar-09	Mar-09	Monthly					
	Transient	76	Apr-09	Apr-09	Monthly					
	Transient	77	May-09	May-09	Monthly					
	Transient	78	Jun-09	Jun-09	Monthly					
	Transient	79	Jul-09	Jul-09	Monthly					
	Transient	80	Aug-09	Aug-09	Monthly					
	Transient	81	Sep-09	Sep-09	Monthly					
	Transient	82	Oct-09	Oct-09	Monthly					
	Transient	83	Nov-09	Nov-09	Monthly					
	Transient	84	Dec-09	Dec-09	Monthly					
	Transient	85	Jan-10	Jan-10	Monthly					
	Transient	86	Feb-10	Feb-10	Monthly					
	Transient	87	Mar-10	Mar-10	Monthly					
	Transient	88	Apr-10	Apr-10	Monthly					

	Transient	89	May-10	May-10	Monthly					
	Transient	90	Jun-10	Jun-10	Monthly					
	Transient	91	Jul-10	Jun-11	Yearly					
	Transient	92	Jul-11	Jun-12	Yearly					
	Transient	93	Jul-12	Jun-13	Yearly					
	Transient	**94^**	Jul-13	Jun-14	Yearly					
	Transient	**95**	Jul-14	Jun-15	Yearly			Water Storage (DRN Cells)		
	Transient	**96**	Jul-15	Jun-16	Yearly				Open Cut	
PREDICTION	Transient	**97**	Jul-16	Jun-17	Yearly	Water Storage (DRN Cells)				
	Transient	**98**	Jul-17	Jun-18	Yearly					
	Transient	**99**	Jul-18	Jun-19	Yearly					Open Cut
	Transient	**100**	Jul-19	Jun-20	Yearly					
	Transient	**101**	Jul-20	Jun-21	Yearly				Water Storage (DRN Cells)	
	Transient	**102**	Jul-21	Jun-22	Yearly	Backfilled		Backfilled		
	Transient	**103**	Jul-22	Jun-23	Yearly					
	Transient	**104**	Jul-23	Jun-24	Yearly					
Recovery	Transient	105			200 Years	Back-filled	Open Void	Back-filled	Open Void	Open Void

^ The Project period runs from stress period 94 to stress period 104

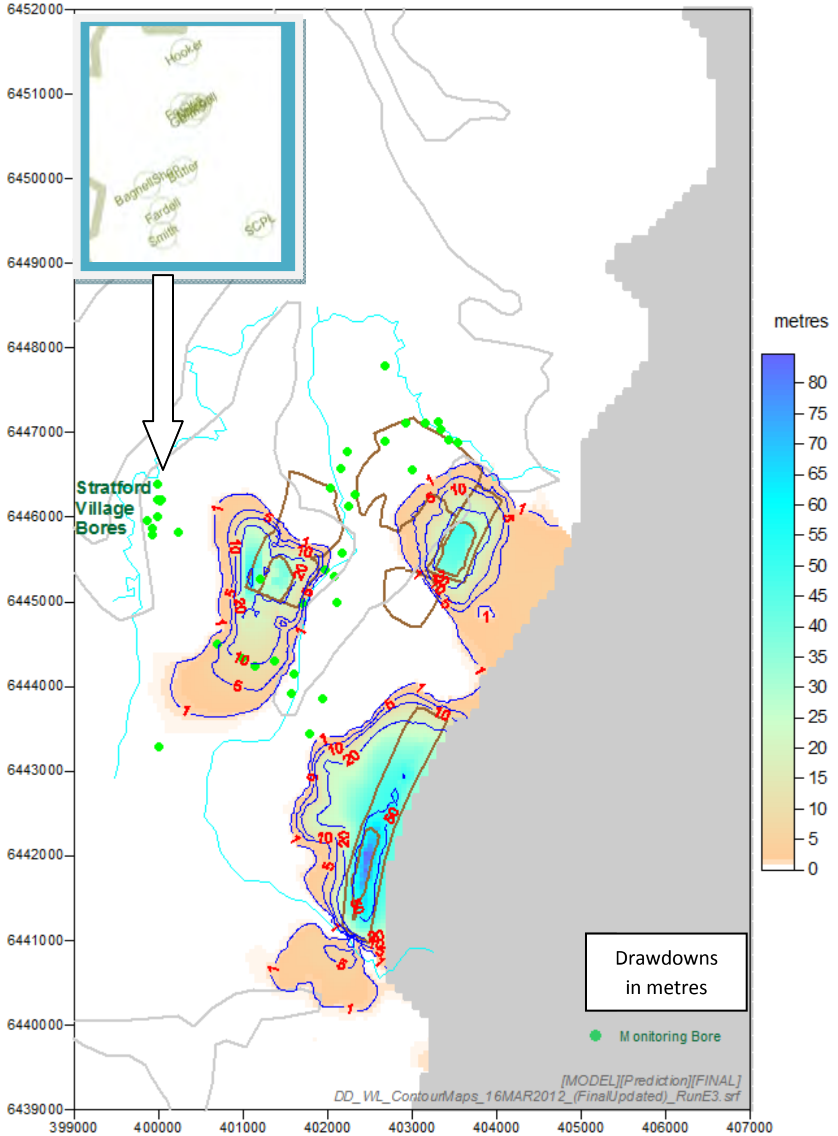
ATTACHMENT AD

Predicted Groundwater Drawdown (m) Contour Maps for Layers 2, 3, 5, 7 and 11 from 2013 to 2024:

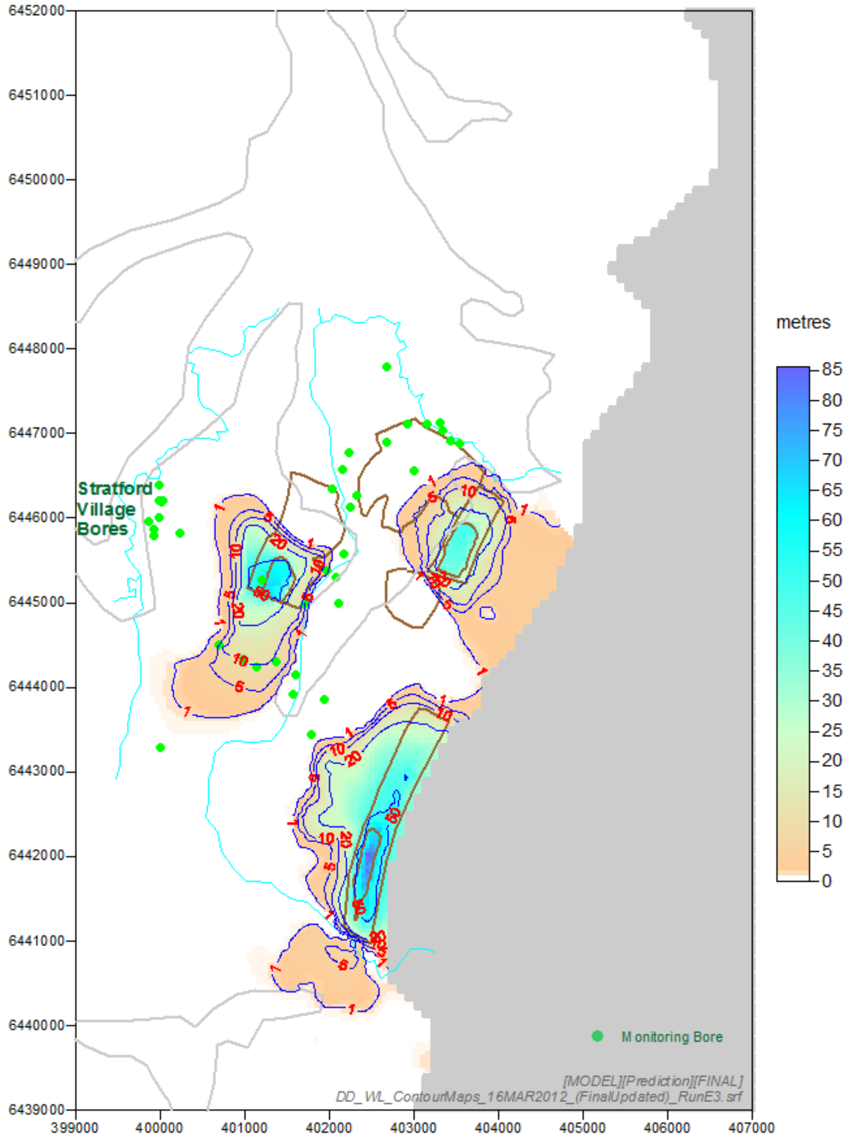
(1) Project Only

(2) Cumulative Projects

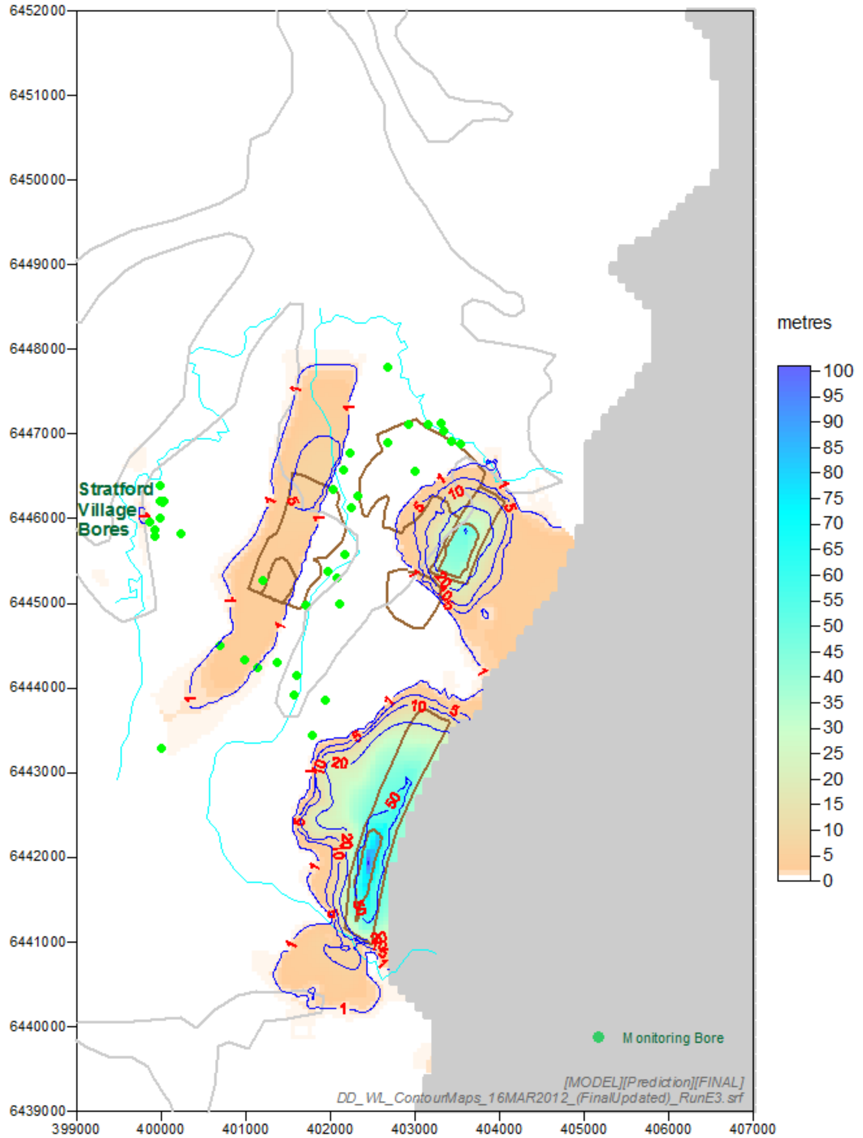
PROJECT ONLY - LAYER 2



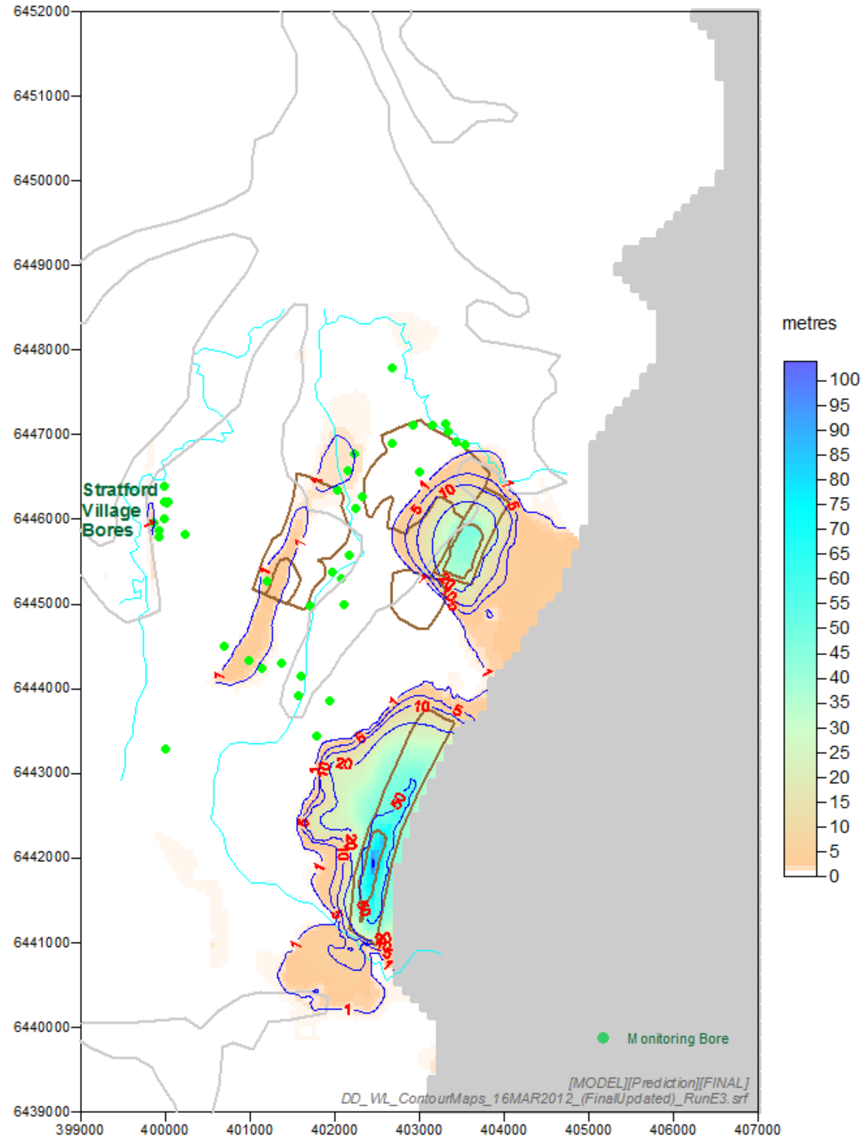
PROJECT ONLY - LAYER 3



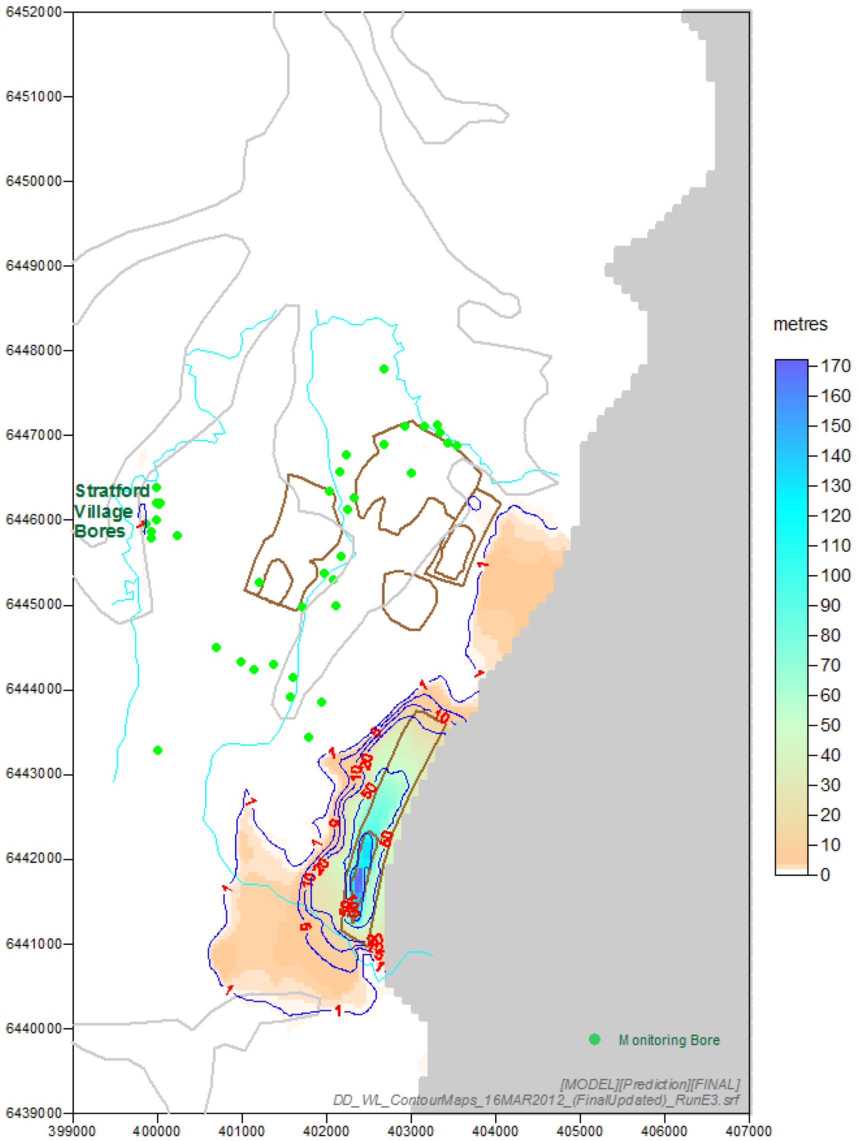
PROJECT ONLY - LAYER 5



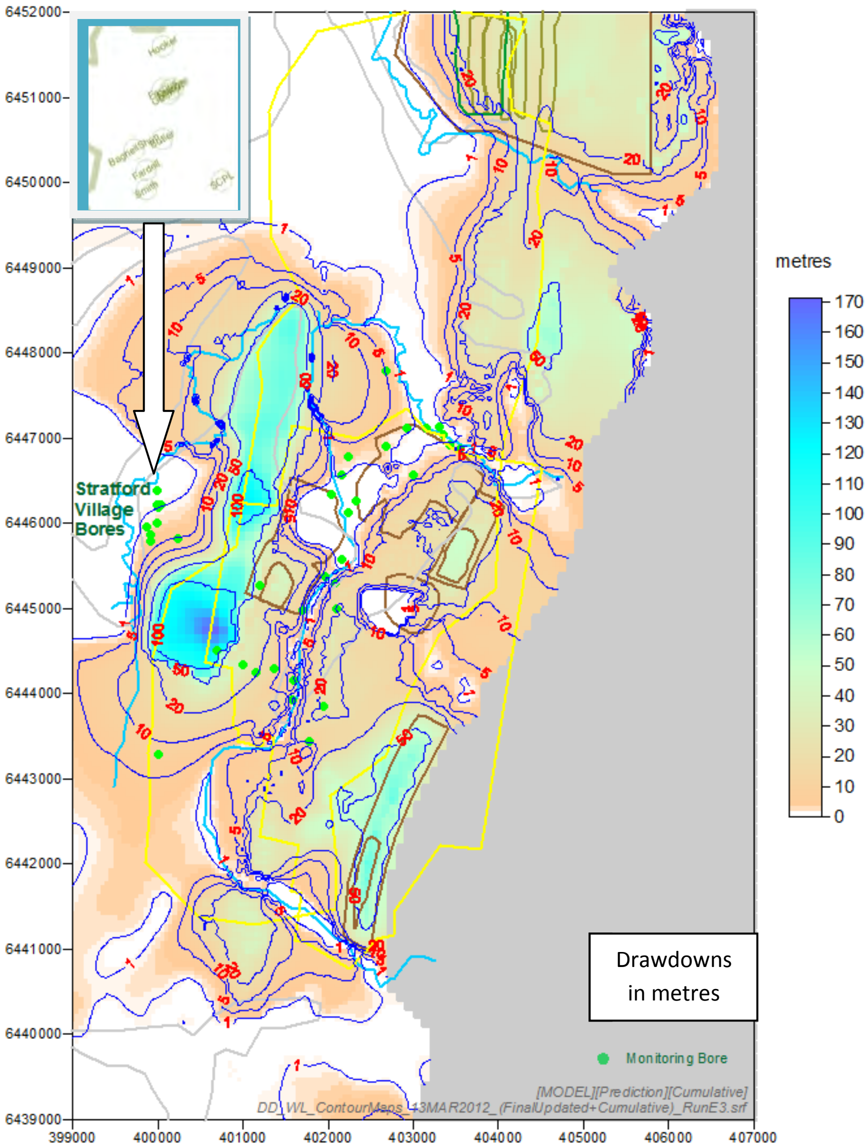
PROJECT ONLY - LAYER 7



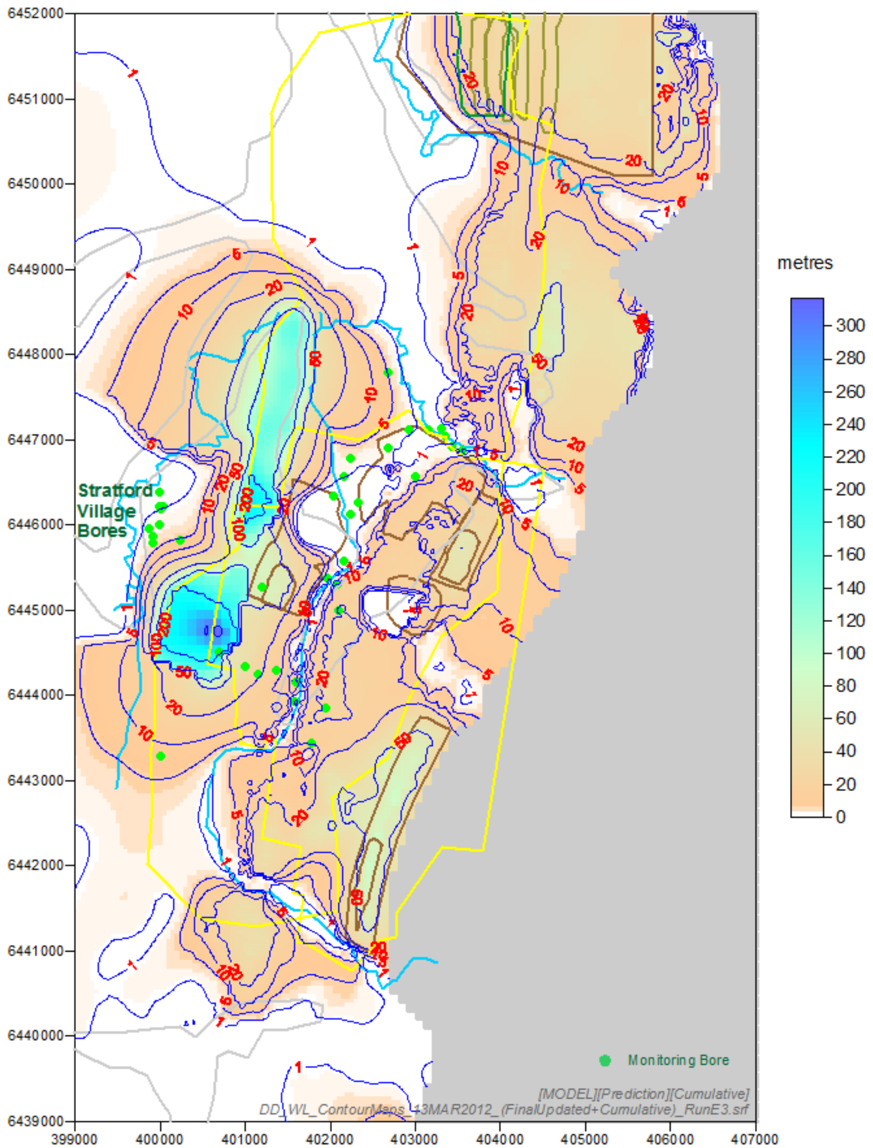
PROJECT ONLY - LAYER 11



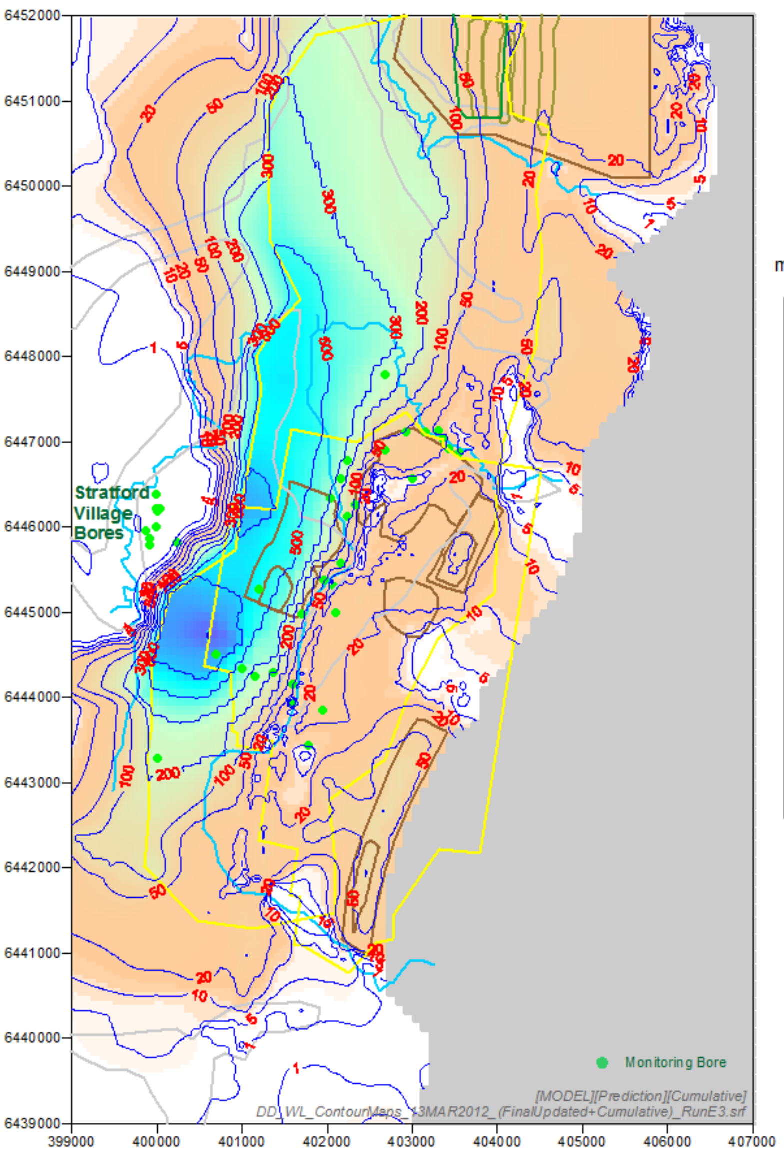
CUMULATIVE PROJECTS - LAYER 2



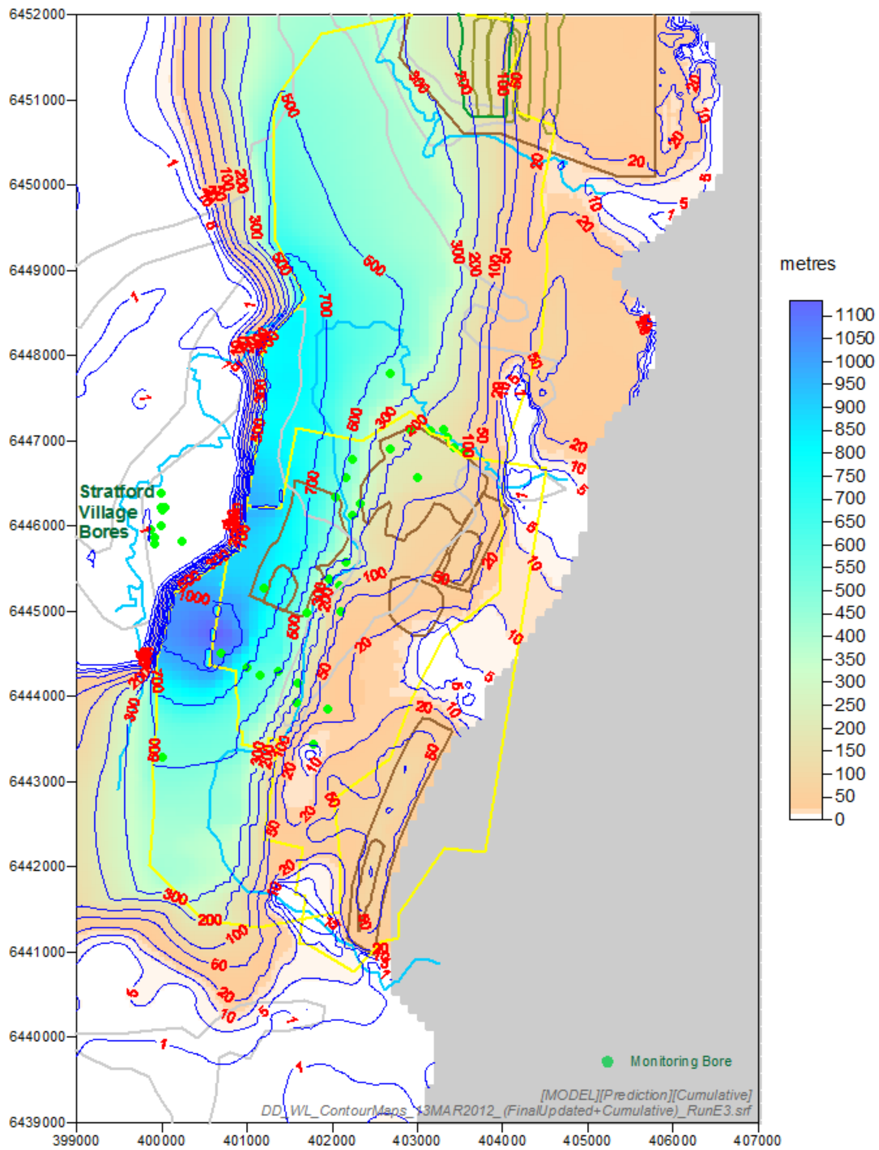
CUMULATIVE PROJECTS - LAYER 3



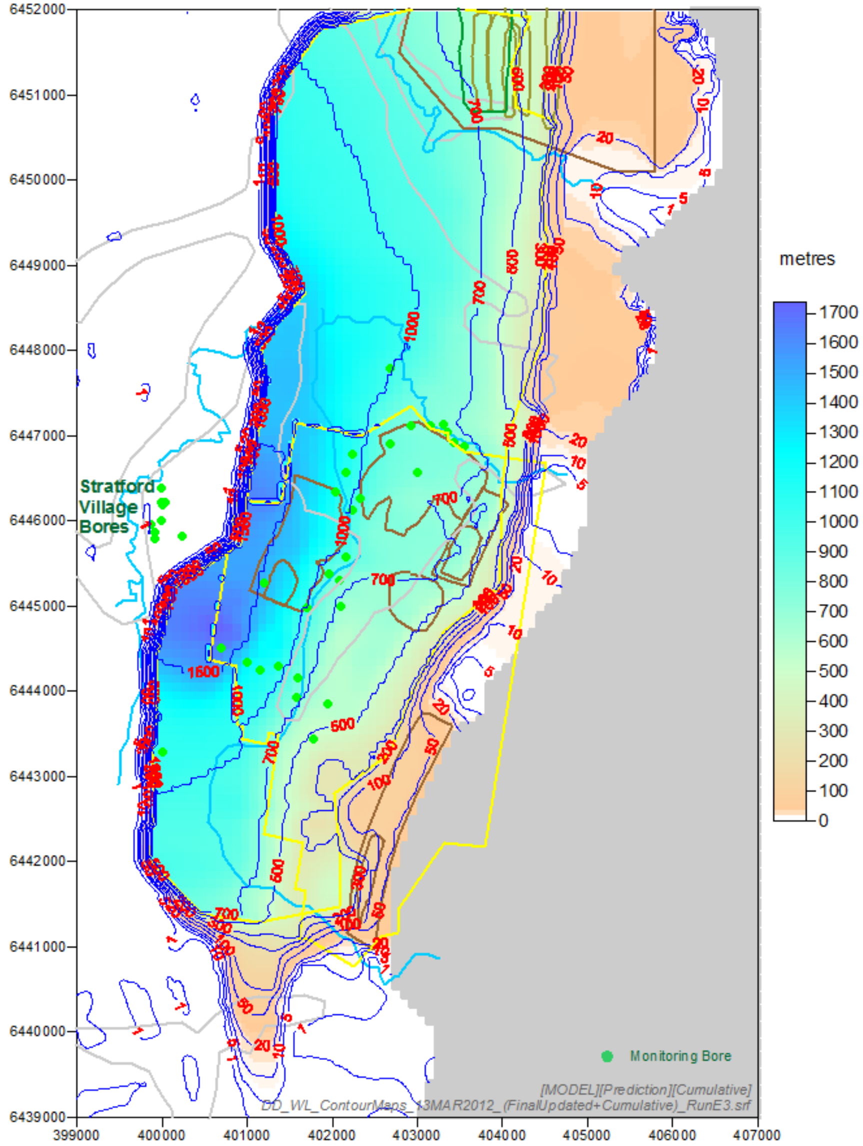
CUMULATIVE PROJECTS - LAYER 5



CUMULATIVE PROJECTS - LAYER 7



CUMULATIVE PROJECTS - LAYER 11



ATTACHMENT AE

Schoeller Diagrams

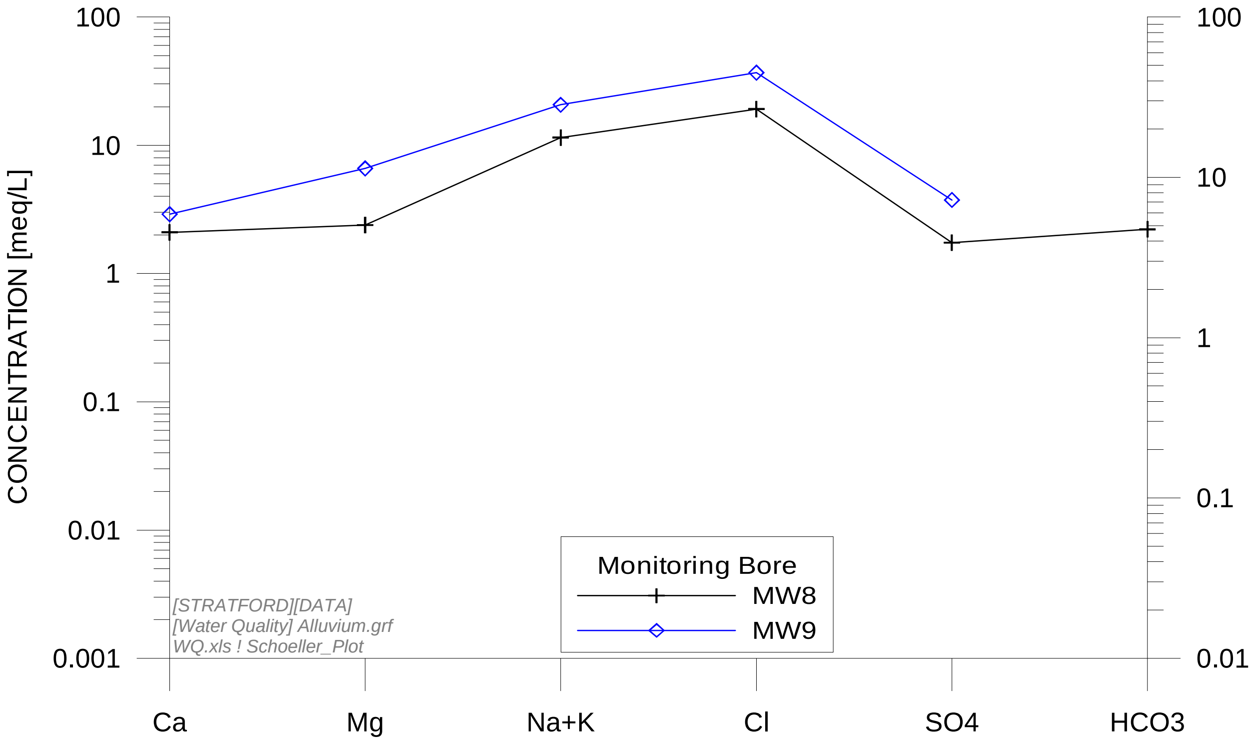


Figure AE-1. Schoeller diagram for major ions in alluvium/regolith

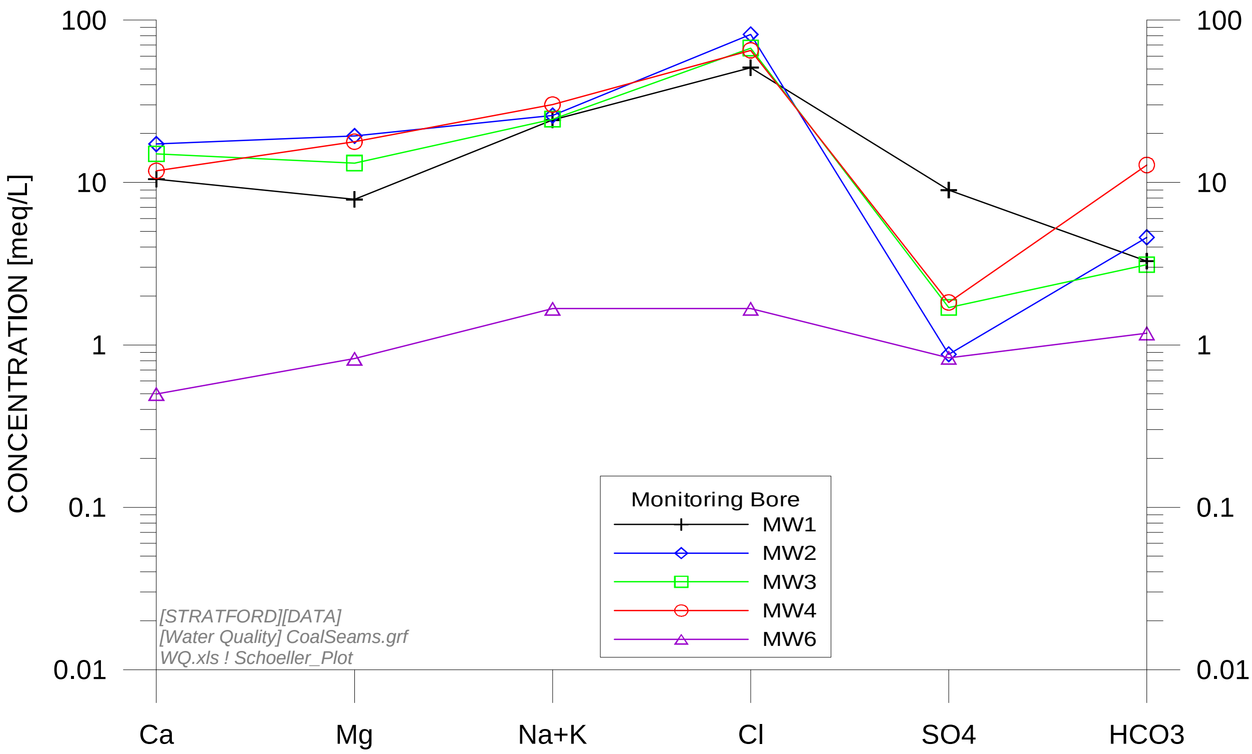


Figure AE-2. Schoeller diagram for major ions in coal seams

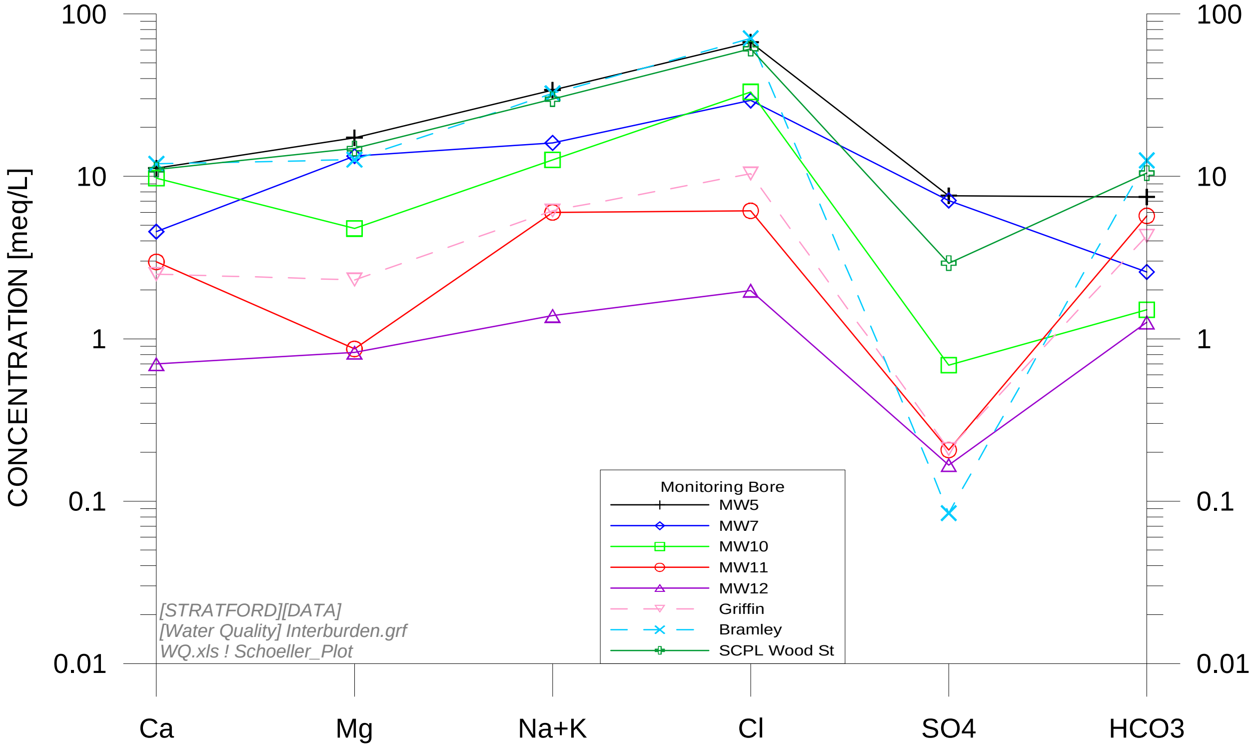


Figure AE-3. Schoeller diagram for major ions in interburden

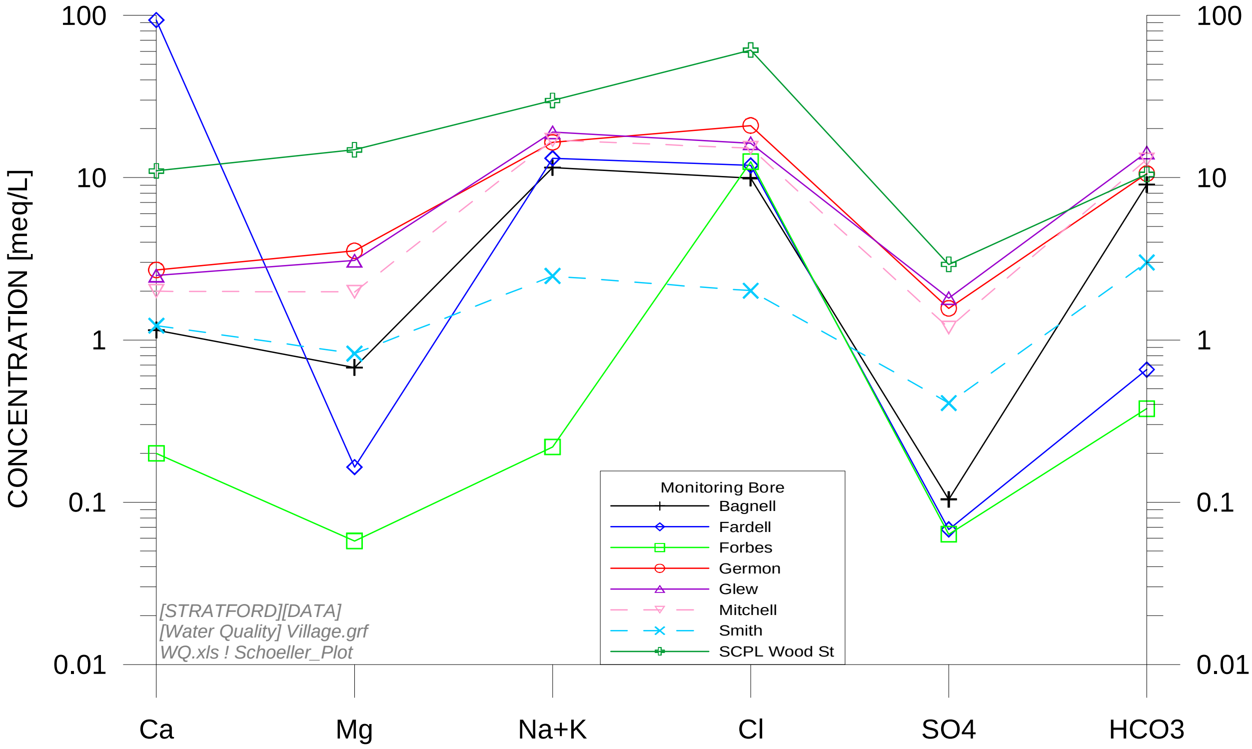
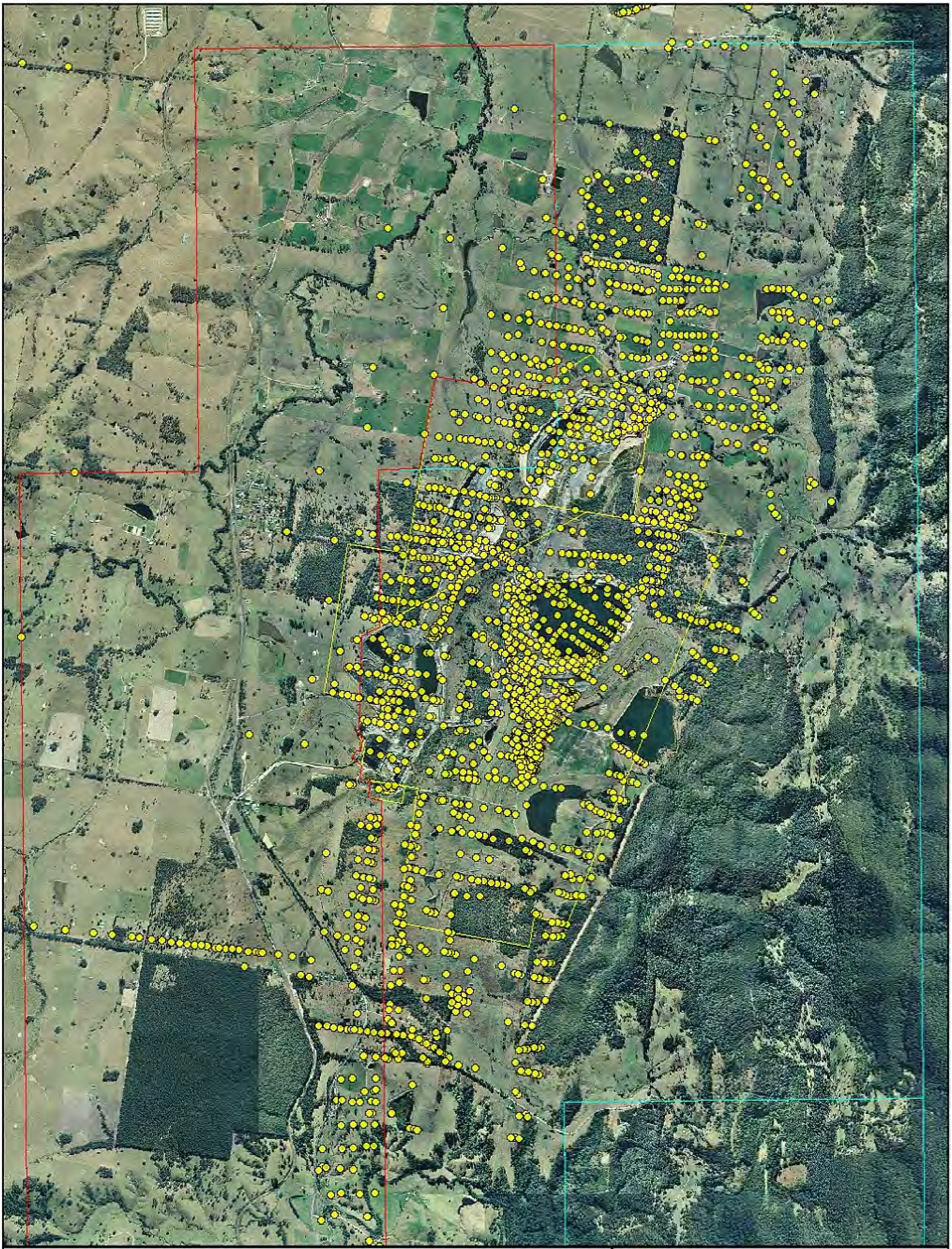


Figure AE-4. Schoeller diagram for major ions in interburden at Stratford Village

ENCLOSURE 1

Geological Logs Plan

A copy of individual drill logs shown on the enclosed figure can be provided upon request from environment@gcl.com.au



Scale: 1cm = 600m

GLOUCESTER COAL

ALL HOLES DRILLED WITHIN EXPLORATION LEASES (NORTHERN SECTION, 10M OR DEEPER)

13/06/2012