

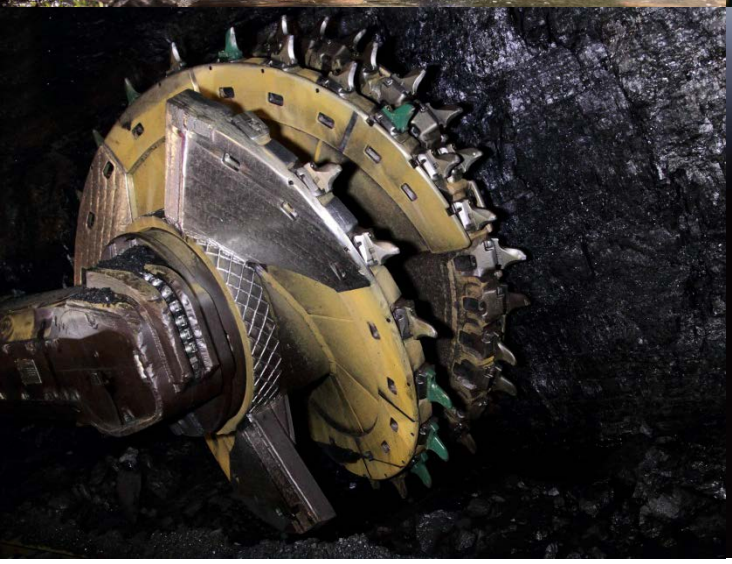


APPIN AREA 7 LONGWALL 706 END OF PANEL REPORT

ATTACHMENT D – SURFACE & GROUNDWATER REPORT

GeoTerra

Appin Colliery

Longwall 706
End Of Panel
Surface Water and Groundwater
Monitoring Report

Sth32_1 R1A
02 March 2016

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GeoTerra

South 32 Illawarra Coal Holdings Pty Ltd
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Attention: Kimberley Vaux

Kimberley,

RE: Appin Colliery End of Longwall 706 Surface Water and Groundwater Monitoring Report

Please find enclosed a copy of the above mentioned report.

Yours faithfully

GeoTerra Pty Ltd

Andrew Dawkins (AuSIMM CP-Env)
Principal Hydrogeologist

Distribution: Original GeoTerra Pty Ltd
1 electronic copy South32 Illawarra Coal Holdings Pty Ltd

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Date	Rev	Comments
19/02/2016		Initial Draft
02/03/2016	A	Incorporate Sth32 Revisions and Comments

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Executive Summary

The following table summarises the potential and observed effects on surface water and groundwater systems within the Longwall 706 subsidence area, with **Appendix B** containing the Longwall 706 Trigger Action Response Plans (TARPs) and Impact Summary.

Potential Impacts	Observed Impacts Due to Extraction of Longwall 706
Surface Water	
Bedrock cracking and loss of plateau stream flow not anticipated in plateau streams due to mitigating effects of stream sediment cover	*Stream bed cracking and loss of pool holding capacity has not been observed in the extraction area*
No adverse ecological changes to plateau streams due to subsidence	*No adverse effect on plateau stream ecology has been observed*
Possible localised ponding may occur in plateau streams	*No localised stream ponding due to subsidence has been observed*
Plateau stream bed incision may occur	*No plateau stream bed incision has been observed*
No adverse effects on plateau stream water quality anticipated	*No adverse effects on plateau stream water quality has been observed*
Nepean River water level to remain essentially unchanged	*No adverse effects on the Nepean River were observed*
Surface flow diversion from the Nepean River is very low	*No adverse effects on the Nepean River were observed*
Methane rich strata gas emissions into the river are likely, with reduced dissolved oxygen levels possible	*No adverse effects on the Nepean River were observed, although a small, new gas seep that was probably re-generated over the old Tower Colliery Longwall 16 was observed at AA7_LW706_001, along with continued low level seeps at Gas Zones 5 and 14*
Low likelihood of ferruginous spring inducement with significant impacts from pH and iron not predicted	*No adverse effects on the Nepean River were observed*

Potential Impacts	Observed Impacts Due to Extraction of Longwall 706
Groundwater	
Adverse interconnection of aquifers and aquitards is not anticipated within 20m of the surface	*No adverse interconnection between aquifers and aquitards observed within 20m of the surface*
Potential increased rate of recharge into the plateau	*No increased rate of recharge into the plateau*
Temporary lowering of regional phreatic water levels by up to 10m which may stay at that level until maximum subsidence develops	*Depressurisation of the Bulli Seam and reduction of piezometric surface in the lower Bulgo and Scarborough Sandstones due to subsidence in VWP EAW7. Minor depressurisation in the lower Bulgo and Scarborough sandstones at EAW5*
Groundwater levels should recover over a few months and no permanent post mining reduction in water levels in bores on the plateau unless a new outflow path develops	*Continued depressurisation of the Bulli Seam, lower Bulgo and Scarborough Sandstones in EAW7 and EAW5*
The yield and serviceability in registered bores may be affected by subsidence	*No private bore yields shave been affected however a gaseous seepage into a private bore (GW112441) has been sealed and rehabilitated*
Horizontal displacement may make private bores inaccessible	*No private bores reported to have been horizontally displaced due to Longwall 706 extraction*
Strata dilation and subsequent re-filling of secondary voids may temporarily lower standing water levels of private bores	*No private bore yields have been reportedly adversely affected*
Interface drainage, ferruginous, brackish seeps may be generated in streams on the plateau	*No interface drainage, ferruginous, brackish seeps have been generated in streams on the plateau*
Increased groundwater seepage inflow into the mine workings should not occur	*No notable increase in groundwater inflow to the mine has been observed*
Strata gas discharge into private bores may occur	*Strata gas discharge into a private bore (GW112441) has occurred and has adversely affected the bore (Level 3 groundwater level impact)*

1. INTRODUCTION

South32 Illawarra Coal Holdings Pty Ltd (Sth32-IC) and its predecessors, has extracted the Bulli Seam in Longwalls 701 to 706 at Appin Colliery by retreat longwall mining within the Appin Colliery lease area since October 2007.

The previous workings and the current panel (Longwall 707) are located to the north and west of the Nepean River, to the north east of Douglas Park village, south of Camden Park village and southwest of Campbelltown, as well as intervening semi-rural areas in the Southern Coalfields of NSW as shown in **Figure 1**.

This report provides a compilation of physical and geochemical groundwater and stream monitoring that has been conducted during extraction of Longwall 706, as well as observation of any subsidence related changes due to the extraction of Longwalls 701 to 706 since October 2007 within the Appin Area 7 study area (Area 7).

Surface water and groundwater features associated with, or in close proximity to, Longwall 706 include:

- the main channel and tributaries of the northerly flowing Nepean River;
- the headwaters of the southerly draining channel and tributaries of Harris Creek, which flows into the Nepean River;
- the headwaters of Foot Onslow Creek which flows into the Nepean River;
- two vibrating wire piezometer arrays in bores EAW5 and EAW7, and;
- five NOW licensed private bores (GW102548, 104602, 104661, 105339 and 108312).

Harris and Foot Onslow Creeks are 2nd order or less channels within proximity to Longwall 706.

Monitoring of the Nepean River and plateau streams has been conducted since October 2007 by assessing the;

- ephemeral or perennial nature and flow in streams over and adjacent to the panels;
- creek bed and bank erosion and channel bedload;
- stream and dam water quality, including ferruginous and gaseous seeps;
- stream bed and bank vegetation;
- nature of alluvial land along stream banks;
- presence, size and integrity of dams and their water levels, as well as;
- standing water levels and water quality in groundwater bores.

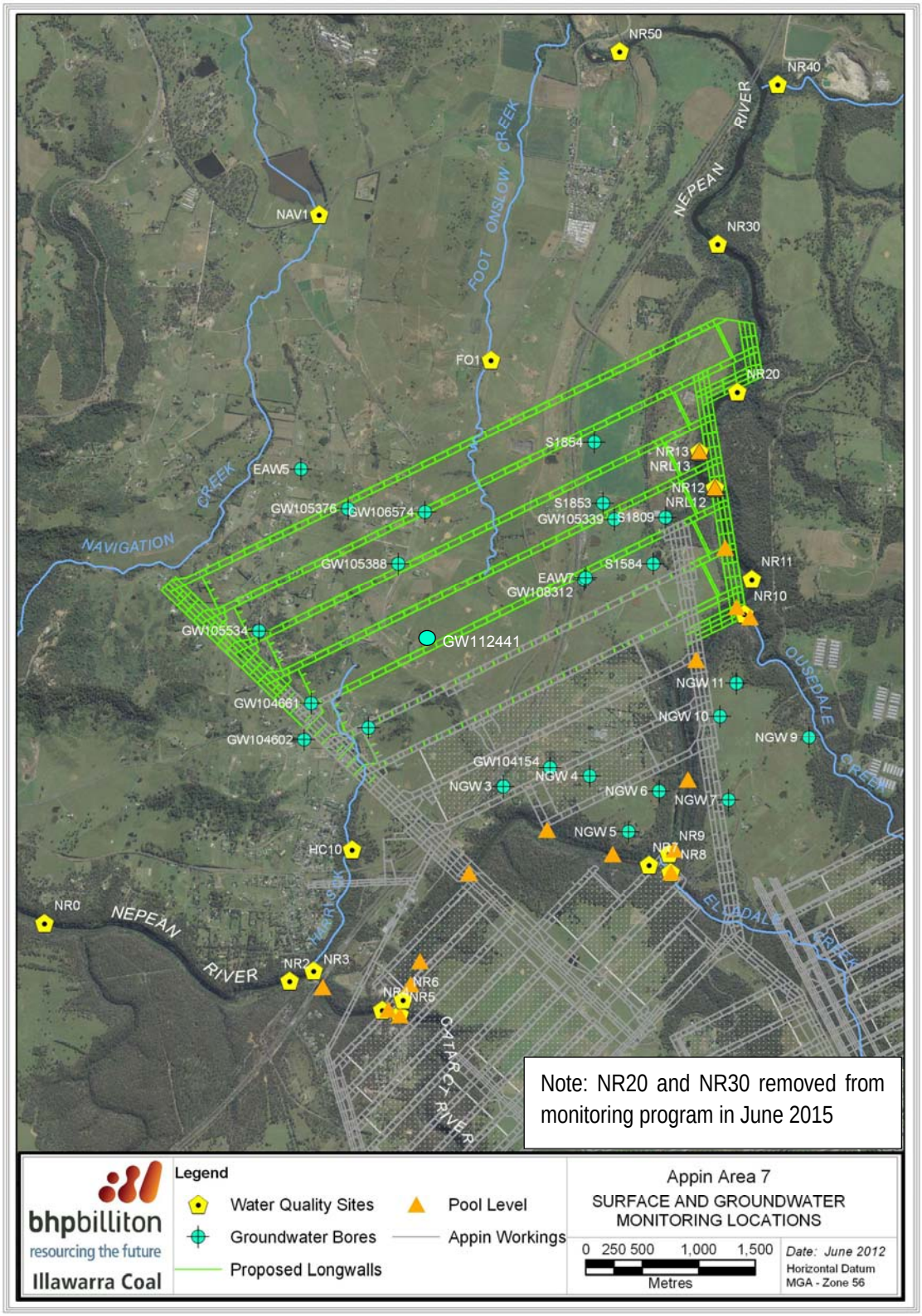


Figure 1 Area 7 Surface Water and Groundwater Monitoring Locations (Longwalls 705 and 706 EMP)

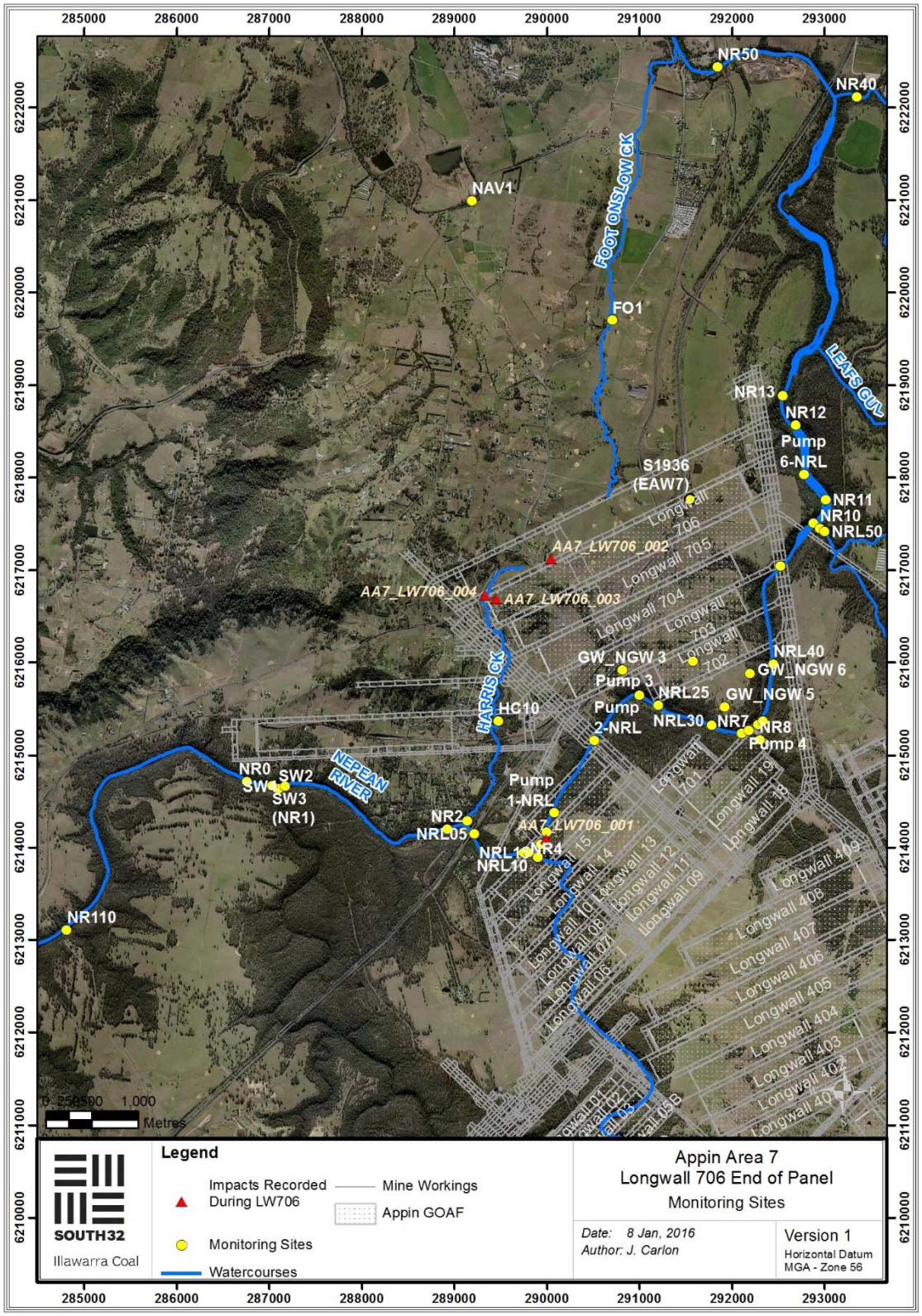


Figure 2 Area 7 Monitoring Locations

2. GENERAL DESCRIPTION

2.1 Mine Layout and Progression

Appin Colliery extracted coal by mining Longwalls 701 to 706 to the south of the current Longwall 707.

Longwall 706 commenced on 23/04/2014 and was completed on 28/11/15 as outlined in **Table 1**, with mining progressing up-dip in the Bulli Seam.

Table 1 Panel Extraction Details

Longwall	Start	Finish	Width (m)	Length (m)	Depth of Cover (m)
701	27/10/2007	09/05/2008	315	527	500 - 515
702	18/09/2008	20/04/2009	313	973	490 - 535
703	22/10/2009	03/03/2011	313	2,326	505 - 555
704	7/05/2011	29/07/2012	313	2,316	490 - 595
705	7/09/2012	27/03/2014	313	2,828	510 - 600
706	23/04/2014	28/11/2015	313	3,044	500 - 615

Extraction of Longwall 706 occurred from east to west, with the depth of cover increasing to the western end of the panel.

Seam thickness varies from 2.9 – 3.4m, with 45m wide chain pillars as shown in **Figures 1** and **2**.

2.2 Topography and Drainage

Area 7 is generally undulating on the plateau and is incised by the Nepean River gorge which can be up to 70m high, with vertical cliff faces up to 30m. The gorge is steep sided with sandstone cliffs and steep slopes.

The Nepean is part of the Hawkesbury-Nepean River system which originates in the uplands west of Wollongong and flows northward past Camden to its junction with the Warragamba River near Wallacia.

River water level in the study area is regulated by Menangle Weir, which is 4.8 km downstream and Douglas Park Weir at 1.9km upstream of the Area 7 longwalls.

The weirs, which are outside the subsidence area of Longwalls 701 to 706, have transformed the natural free flowing regime of the river and have generated a sequence of stationary, regulated water bodies.

Water levels fall by 260mm over the 14km between Douglas Park and Menangle Weir.

The catchments overlying the subject longwalls comprise up to 2nd order streams draining from the plateau to the Nepean River which usually contain earthen wall farm dams which regulate runoff to the gorge.

Harris Creek drains to the Nepean River in the south and lies to the south and west of the longwalls, whilst Foot Onslow Creek headwaters lie to the north of Longwall 706, and drains

north into the Nepean River.

2.2.1 Nepean Gorge and River Bed Geomorphology

The river has dissected the plateau, forming significant scarps and discrete cliffs on either side of the gorge.

Where the channel is close to the systematic joint direction, the cliff line is usually close to the channel. Cliffs are usually formed under competent sandstone which contain stratigraphically controlled cavernous zones with ephemeral seeps.

Sandy alluvium is dominantly located in the base of the gorge and on the alluvial flanks.

The Nepean River gorge increases from approximately 28m to 46m wide in the study area and the river is deeper where erosion is greatest at the outside of river bends.

The river generally becomes deeper with distance downstream with a depth range of less than 0.25m over sand bars to over 8m in deeper rock based pools (GeoTerra, 2005).

2.2.2 Harris Creek

The headwaters of Harris Creek overlie the western end of Longwall 706, and flows directly south-south west into the Nepean River.

Harris Creek has not been undermined by Longwalls 702 - 705.

The stream bed and banks are generally well vegetated, and do not show significant erosion or bank instability.

No NOW registered water extraction is listed within the creek.

2.2.3 Foot Onslow Creek

The headwaters of Foot Onslow Creek overlie the northern central section of Longwall 706, and flows to the north into the Nepean River.

Foot Onslow has not been undermined by Longwalls 702 - 706.

The stream bed and banks are generally well vegetated, and do not show significant erosion or bank instability.

No NOW registered water extraction is listed within the creek.

2.3 Streamflow and Water Levels

2.3.1 Nepean River Flow

The following section is an excerpt from Ecoengineers (2014).

Water flows in the Nepean River are derived from a number of sources, including;

- flows from catchment areas,
- flows from licensed discharges, including Appin Colliery and Tahmoor Colliery (the latter located adjacent to Bargo River), and
- stormwater runoff from agricultural and urban areas.

Excess flows from the Lake Nepean and Lake Avon catchment areas released over Pheasants Nest Weir contribute the majority of flows into the River.

The major tributaries upstream of Area 7 below Pheasants Nest Weir are the Bargo, Cordeaux and Cataract Rivers.

Minor amounts of water are directly drawn from the river by licensed water pumps and there are several of these close to Area 7 as shown in **Figure 2**. It is understood that the total of seven licensed extraction allocations adjacent to Area 7 is about 9 – 10 ML/day.

Runoff is also retained or retarded by small farm dams both within and outside the study area.

Flow varies greatly and is largely dependent on rainfall within the catchment. Regular monitoring is not conducted within the SMP area as it is difficult to measure flow in deep, wide channels, although river depths are measured.

The closest flow gauging station upstream of Appin Area 7 is at Maldon Weir, located approximately 14 km upriver from Longwall 705. The closest flow gauging station downstream of the SMP Area is Menangle Weir, located approximately 5 km downriver of Longwall 705.

Menangle Weir ensures that the River remains fully charged at all times, even when there is little flow in it.

The Maldon Weir has a nominal catchment of 865 km^2 when Water NSW is spilling water over Pheasants Nest Weir (about 25 km upriver of Longwall 705) on the Upper Nepean River. For the approximately 50 percentile (median) and lower flows, when Water NSW is not spilling water over Pheasants Nest Weir, the Maldon Weir catchment is comprised primarily of the Bargo River catchment (approx. 181 km2).

Relatively consistent discharges to the Nepean River below Maldon Weir come from Stone Quarry Creek (Picton), Allen's Creek (Wilton), and the Cataract River over Broughtons Pass Weir, as well as irregular flow inputs from creeks such as Harris Creek, together with approximately 1 ML/day from Allen's Creek via the Appin West Pit Top licensed discharge (GeoTerra, 2006).

The flow at Menangle Weir is considered to be far more representative of flows adjacent to Area 7 than the flow rate at Maldon Weir but it is still biased by flows from tributaries in the River between Maldon and Menangle Weirs, the largest contributor of which is by far the Cataract River catchment below Broughton's Pass Weir but also including Water NSW releases and/or 'natural' spills over the Weir.

Measured daily mean water flows at Maldon, Menangle and Broughtons Pass Weirs have been provided by Water NSW up to 1 January 2016, however there are some gaps and lesser quality data in the record.

Some cessation of flow events have been recorded by Water NSW, which reflect periods where more water is extracted from the River than is supplied from upstream, with maximum falls below the weir spill point of 36 mm at Maldon Weir and 295 mm at Menangle Weir. Subtraction of daily Maldon and Broughton's Pass Weir flows from Menangle Weir flows sometimes gave negative values either because of flow gauging errors or the effect of licensed extractions.

Water flows in the Nepean River:

- vary greatly and are highly responsive to rain events due to the significant areas of upriver catchment involved;
- reach very high levels during sustained storm events, while minimum flow is rarely likely to be less than 13 ML/day (approx. a 5 percentile flow at Menangle Weir);
- cease on a small number of occasions, usually only when the rate of pumping out of the river exceeds the rate of inflow under low flow/drought conditions; and

- are characterised by median flow rates in the Nepean River adjacent to Area 7 that are likely to be much higher than the median flow rate at Maldon Weir (33.01 ML/day), and about 15% less than the median flow rate at Menangle Weir (105.4 ML/day).

Interpolation between Maldon and Menangle Weir post millennium drought flow records suggests a median (50 percentile) flow rate adjacent to Area 7 of roughly 86 ML/day.

Water levels along the Nepean River fall slightly from a point immediately downstream of Douglas Park Weir (RL 61.10 AHD) to a point immediately upstream of Menangle Weir (RL 60.84 AHD), which represents a gradual fall of approximately 260 mm over a length of approximately 14 kilometres. This slight fall in water level most likely represents friction and head losses occurring along the river.

The bed profile changes considerably along the river's length and the river is typically between 2 and 7 metres deep.

The river is generally deeper where erosion is greatest on the outside of bends. It also becomes generally deeper as it travels downstream with a depth range from less than 0.25 metres over sand bars to greater than 8 metres in deeper rock based sections (GeoTerra, 2006).

The minimum river level between Douglas Park Weir and Menangle Weir is controlled by the spill height of Menangle Weir, which maintains the depth of water through extended dry periods, whilst rises of up to at least 9m have been recorded at Maldon Weir after significant storms.

The maximum water level in the study area is not known due to the safety limitations of measuring during flood flow, however it is clear that extreme rainfall events result in large-scale flooding of the gorge.

2.4 Nepean River Water Chemistry

The following section is an excerpt from Ecoengineers (2014).

Baseline water qualities in the Nepean River, especially under the ecologically more critical low flow conditions (<50 percentile), are clearly dominated by the following processes:

- inputs of more acidic water from Cataract River;
- low flow inputs of more saline water from Harris, Elladale and Ousedale Creeks which have negligible to minor bulk effect on overall river salinity;
- consistent inputs of low DO water from Cataract River (and Elladale Creek) which is the primary driver of DO in the Nepean River immediately downstream of the Cataract River confluence;
- a relatively low rate of re-aeration downriver of the Cataract River confluence (the flooded geomorphology of the River is such that it has a low re-aeration coefficient adjacent to Area 7; and
- consistent inputs of Fe and Mn to the river from Cataract River and Elladale Creek.

Analysis of the baseline water quality database, including water quality analyses at depth, showed that the Nepean River near the confluence and downstream of Cataract River, typically exhibits distinctive temperature/dissolved oxygen (DO) stratification, and to a lesser degree, salinity stratification between surface and deeper waters.

Oxygen stratification is most apparent in summer months or during low flow periods when turbulent mixing is limited, with deeper stretches showing low to very low DO (Ecoengineers, 2014).

Past data also show that during dry weather, when conditions are warm and sunny and flows in the Nepean River remain relatively constant (due to controlled or no release from Maldon Weir), then pH values in the river may occasionally occur naturally in the 8.2 – 9.5 pH range. This applies particularly where the Nepean River passes through an area dominated by farmland and there are pre-existing nutrient inputs (total phosphorus and nitrogen) from fertilizing and livestock waste contaminating small catchments draining into the river.

These nutrient inputs were detected in the large number of sampling campaigns conducted since July 2002. They are especially evident from sites NR11 and others further downriver, especially following significant rain.

Algal primary productivity in river pools is maximized under those circumstances. Algae absorb dissolved CO_2 and bicarbonate ions from water and produce oxygen, thereby driving pH up (when CO_2 and bicarbonate ion concentrations decrease). It is common to observe pH levels in the river rising to maximal levels as high as 9.5 during warm, sunny conditions.

Runoff into the Nepean River is dominated by a Cumberland Plain (Lowlands) landscape dominated by a mixture of Hawkesbury Sandstone and Wianamatta Shale outcrops. Even taking into account the Appin West Colliery licensed discharge to Allen's Creek, salinity of the river water (expressed in Electrical Conductivity (EC) units) is unlikely to ever exceed 1000 µS/cm and chloride and sulfate ion concentrations are unlikely to frequently exceed about 20 mg/L and 100 mg/L, respectively.

In contrast, Elladale and Simpson Creeks arise in Cumberland Plain landscape almost exclusively dominated by Wianamatta Shale. These shale-derived soils are such that salinities in the middle and lower sections of these creeks frequently exceed 3000 µS/cm, and chloride and sulfate ion concentrations are likely to frequently exceed 500 mg/L and 20 mg/L respectively.

The salinity of waters discharged from these shale catchment creeks into the Nepean River is principally based upon the cation sodium (Na+) and the anion bicarbonate (HCO3-).

The anion bicarbonate is the principal and most variable driver of salinity-based ecotoxicity in such waters. It is important to note that as the pH of the river water is lowered, the ratio of bicarbonate to carbonate anion concentrations (i.e. [HCO3-]/[CO32-]) rises, causing ecotoxicity due to salinity alone to increase (per unit of salinity). Here decreased pH is due principally to inputs of dissolved Fe and Mn and their oxidation and precipitation as hydrous oxides, and/or the addition of dissolved CO_2 from exogenous sources such as CO_2 in decomposition of natural organic matter.

The Nepean River is a lowland river where the default EC trigger value in the NWQG is 2200 µS/cm (ANZECC/ARMCANZ, 2000a & b). This conclusion is based on:

- studies which have shown that below Bargo River, the river has long been affected not only by discharges from Bargo River, the township of Picton and from Appin West Colliery, but also by agricultural land uses; and the fact that
- large areas of the River catchment are dominated by Wianamatta Shale-derived soils, the Shale being a marine sediment (Hazelton and Tille, 1990). Such marine sediments continue to provide salinity to runoff and groundwater seepages (interflow, through-flow, etc.) up to the present day.

A number of tributaries of the Upper Nepean River naturally contribute relatively saline water to the River. For example, the long term mean salinity of lower Elladale Creek at site NR8 is 3028 ± 1763 µS/cm at the one standard deviation level. This catchment is largely mantled by Wianamatta Shale-derived soils and drains to Nepean River. The creek salinity is not only highly variable but most of the time significantly exceeds the default trigger value (2200 µS/cm) even for lowland rivers for south eastern Australia in the NWQG (ANZECC/ARMCANZ, 2000a & b).

2.5 Geology

The study area is underlain by the Hawkesbury Sandstone in the Nepean River gorge.

The upper edge of the gorge contains the Ashfield Shale, whilst lithologies progressively further away from the gorge include the Minchinbury Sandstone and Bringelly Shales within the Wianamatta Group.

2.6 Soils

Soils in the study area catchment predominantly comprise the Hawkesbury Landscape (ha) in the Nepean River gorge and the Blacktown Landscape (bt) developed over sandstone basement (Hazelton, P.A,. and Tille, P.J 1990). The distribution of soil landscapes is illustrated in **Figure 3**.

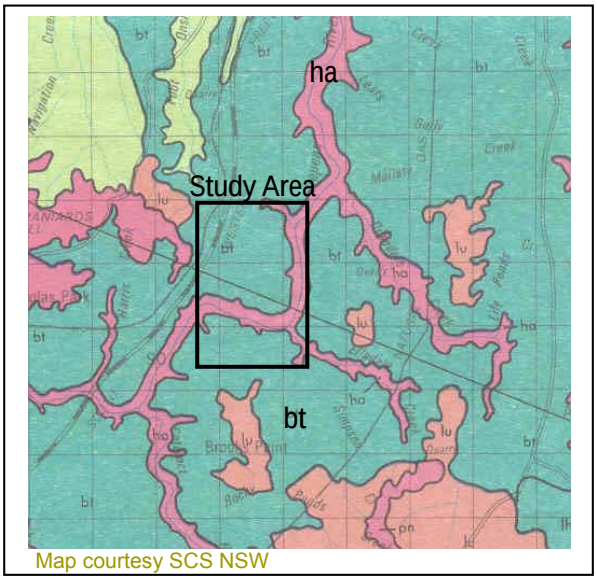


Figure 3 Area 7 Soil Landscapes

2.6.1 Hawkesbury Landscape

The Hawkesbury alluvial / colluvial landscape is developed primarily on Hawkesbury Sandstone within the Nepean River gorge. It has a local relief of 50-80m, with slopes of 5-20%.

Crests and ridges are convex with moderately inclined to precipitous slopes. Valleys are narrow (20-100m) and incised with common rock outcrops occurring as horizontal benches and broken scarps up to 10m high. Rock outcrops, surface boulders and cobbles cover up

to 50% of the ground surface.

Ironstone fragments are present in the profile, which would be a source of dissolved iron into receiving streams.

2.6.2 Blacktown Landscape

The Blacktown residual landscape consists of gently undulating rises developed over Wianamatta Shale with local relief to 30m and slopes <5%, with broad rounded crests and ridges with gently inclined slopes.

Shallow to moderately deep (<150cm) red podzolic and brown podzolic soils develop on crests, upper slopes and well drained areas, with deep (<300cm) yellow podzolic and soloths on lower slopes and drainage lines.

It is a shallow, low permeability soil with high erodibility, and is strongly acid with minimal exposed rock.

2.7 Hydrogeology

The Nepean River is a 'gaining' system, where groundwater flows from the plateau under a regional hydraulic gradient to the river, with groundwater flow being dominantly horizontal within confined flow along discrete layers that are underlain by fine grained or relatively impermeable strata.

The Hawkesbury Sandstone within the study area generally provides low yielding aquifers with low hydraulic conductivities.

2.7.1 Surface Water / Groundwater Interaction

Surface water drainage on the plateau is mainly within ephemeral first and second order gullies and streams.

The smaller gullies generally discharge into the Nepean from elevated stream beds which cascade down the cliffs after sufficient rain, whilst the majority of rainfall in the small ephemeral catchments would infiltrate into the plateau soils.

Recharge to the groundwater system would occur over an extended delay after meteoric water has soaked through the plateau's soil, Wianamatta Shale and Hawkesbury Sandstone, with the majority of water discharging from temporary seeps in the cliff face due to the significantly preferential horizontal rather than vertical flow regime in the sandstone.

The predominantly horizontal flow regime and restricted vertical recharge is essentially determined by the;

- horizontally bedded strata under both sides of the plateau with preferential flow along bedded zones with coarser grain size,
- claystone/mudstone banding at the base and tops of sedimentary facies which restrict vertical migration and enhance horizontal flow at the base of the unit,
- fracture zones enhancing horizontal flow through the strata, and
- bedding planes or unconformities located immediately above finer grained sediments or iron rich zones.

DNR data (GeoTerra, 2006) indicates that the shallowest aquifer was intersected during drilling over Longwall 703 at 116m to 119m below the plateau, whilst the shallowest aquifer was generally intersected between 40m and 78m below surface in the vicinity of

Longwall 17.

The intersected aquifer depth is generally deeper than the standing water level, as once the aquifer is drilled through, the formation water generally tends to rise up the bore due to head pressure in the overlying strata. Accordingly, standing water levels monitored in the Illawarra Coal piezometers (GeoTerra, 2006) could be interpreted to show the intersected aquifers as being located above the base of the gorge, however the majority of aquifer intersections over the proposed mining area are below the relative height of the river.

As the Nepean River is the largest regional river in the catchment, all drainage from surrounding groundwater systems and tributary streams is toward the base of the gorge, with the river then flowing under gravity along the gorge to Menangle Weir, and subsequently along the Nepean River downstream of Warragamba Dam to the Hawkesbury River.

2.7.2 Private Bores and Colliery Piezometers

Eight open standpipe piezometers (NGW3, 4, 5, 6, 7, 9, 10 and 11) were installed by Illawarra Coal over, or in the vicinity of, Longwalls 701 – 706.

Groundwater level and water quality monitoring within the Hawkesbury Sandstone to 10m below the base of the Nepean River gorge began in June 2004 from locations shown in **Figure 1**, with their details outlined in **Table 2**.

Due to the advancement of mining to the west, and the age of the installed equipment, not all sites have recent data. Illawarra Coal downloads water level data from the following piezometers;

- NGW3 (up to 3/10/2015)
- NGW4
- NGW5
- NGW6

Fully cemented, sealed vibrating wire piezometer arrays were also installed by Illawarra Coal in bores EAW5 (S1913) and EAW7 (S1936) as shown in **Figure 1**.

Five NOW registered private bores are located within the Longwall 706, 20mm subsidence area (GW102584, 104602, 104661, 105339 and GW108312) as shown in **Figure 1** and **Table 2**.

Private bores not listed in **Table 2** but shown in **Figure 1**, are used to demonstrate the distribution of private bores in the region.

These regional private bores are not discussed further in this report as they are outside the Longwall 701 to 706 SMP Area.

All NOW registered private bores in the region are located on the western plateau of the Nepean River gorge. They were drilled between 70 - 294m below surface, with water obtained primarily from sandstone aquifers, however some thin, perched horizons encountered water in the Wianamatta Shale (GW103161 at 17-18m and GW104602 at 30m).

Reported yields range up to 1.3L/sec from inflow zones ranging from 9 - 225 below surface. NOW bore data within the Longwall 701 to 705 (20mm) subsidence zone indicates regionally significant aquifers are generally intersected beneath 100m below surface from sandstone aquifers.

According to available records, private bore groundwater intersections as shallow as 9m may be present in perched aquifers with limited extent, as well as in limited, perched horizons within the Wianamatta Shale.

The actual intersected aquifer horizon is generally deeper than the measured piezometric surface of a bore because when a confined aquifer is drilled into, formation water rises up the bore due to a combination of lithostatic and hydrostatic pressures. Based on this principle, and on assessment of the NOW data, the majority of aquifer intersections over the Longwall 701 to 706 mining area lie at or below the relative height of the Nepean River, even though the bore water levels may rise under pressure to higher elevations in a bore.

The piezometer and bore monitoring data has been used to determine the pre Longwall 706 baseline status and groundwater level and water quality variations within the regional Hawkesbury Sandstone aquifer to a maximum depth of 10m below the relative level of the Nepean River bed. Groundwater levels are logged hourly using vibrating wire piezometers in the NGW and EAW series piezometers and are downloaded at the completion of longwall panels (or as required).

Table 2 Private Bore and BHPB Piezometer Summary

GW	N	E	SWL (m)	Depth (m)	Drilled	Aquifer	Lithology	YIELD (L/s)	EC (mg/L)	Purpose
Private Registered Bores in the Longwall 706 20mm subsidence area										
102584	6216445	289626	60	186	1999	54 – 60 64 - 70 108 – 112 144 – 150 177 - 179	sandstone	0.1 – 0.9	1300	Dom / Stock
104602	6216148	288909	42	231	2002	30 - 213	sandstone	0.75	2500	Stock
104661	6216470	288973	68	219	2003	113 - 212	sandstone	1.05	fresh	Dom / Stock
105339	6218356	291919	-	238	2003	139 – 140 183 - 184	sandstone	0.25	-	Dom / Stock / Irrig
108312	6217750	291534	84	175	2004	119 – 120 156 - 157	sandstone	0.16	500	Test
112441	6217284	289940	70	294	2010	113 – 113.1 136 – 136.05 140 – 140.05 225 – 225.01	sandstone	0.1	400	Dom / Stock
Private Registered Bores in the Vicinity of Longwalls 701 to 706										
34425	6215425	289085	14.6	70	1972	9 – 69.4	sandstone	0.63	good	Waste disposal
101437	6216406	291651	75	128	1997	119 - 121	sandstone	0.7	2500	Farming
104154	6216080	291240	74	165	2000	116 - 161	shale / sandstone	1.3	2200	Dom / Stock
102584	6216255	289480	60	186	1999	54 - 179	sandstone	0.9	1300	Dom / Stock
BHPB Registered Piezometers in the vicinity of Longwall 706										
NGW3	6216749.5	275027.4	1.4*	72.1	2004	-	shale / sandstone	-	-	Monit.
NGW4	6216826.2	275789.9	58	78.75	2004	-	sandstone	-	-	Monit.
NGW5	6216327.4	276124	44.3	66.45	2004	-	sandstone	-	-	Monit.
NGW6	6216680.5	276403.3	51.1	66.75	2004	-	sandstone	-	-	Monit.
NGW7	6216591.4	277026.7	50.5	69.18	2004	-	sandstone	-	-	Monit.
NGW9	6217131.4	277736.9	24.8	69.19	2004	-	sandstone	-	-	Monit.
NGW10	6217333.4	276952.2	52.9	69.5	2004	-	sandstone	-	-	Monit.
NGW11	6217624.6	277104.8	48	72.15	2004	-	sandstone	-	-	Monit.
EAW5	6218729	289027	various	612	2008	-	various	-	-	Monit.
EAW7	6217767.8	291547.3	various	556.1	2008	-	various	-	-	Monit.

Note: - no data available

3. MONITORING RESULTS AND DISCUSSION

3.1 Subsidence

The maximum monitored subsidence, tilt and strain following the completion of extraction of Longwall 706 is shown in **Table 3**.

Table 3 Maximum Subsidence at the Completion of Longwall 706

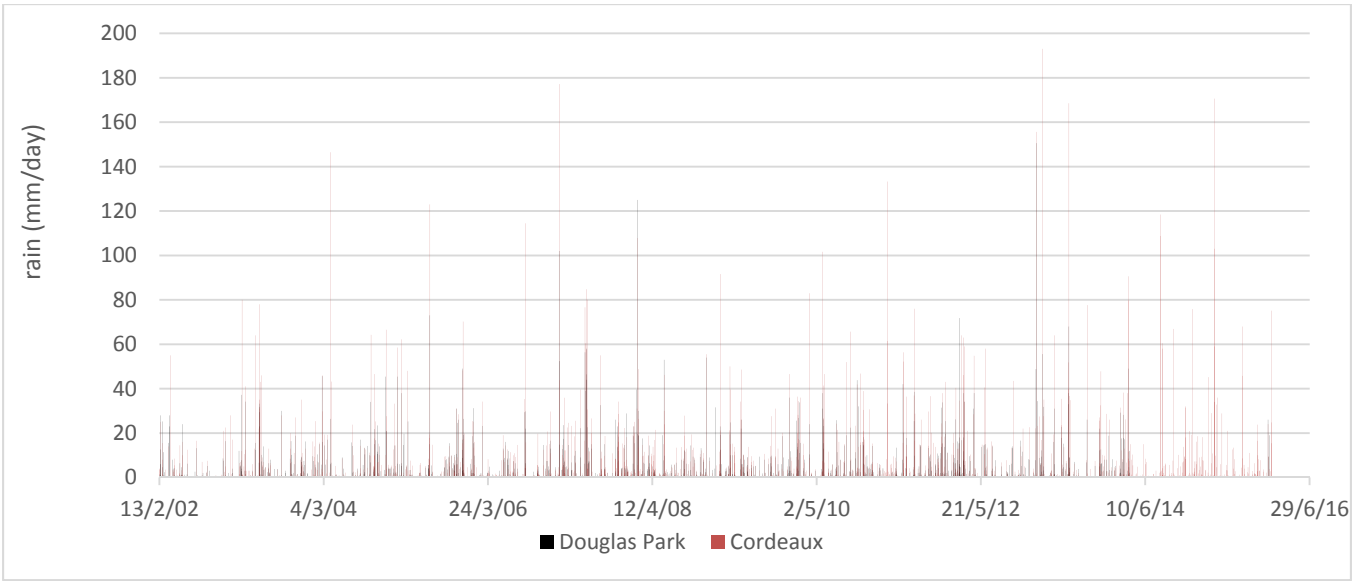
Component	Observed Total Movement	Subsidence Line Where Maximum Occurred
Vertical subsidence	1302 mm	Moreton Park Road
Tilt	7.7 mm/m	Moreton Park Road
Tensile / Compressive Strain	-1.0 / 4.8 mm/m	Moreton Park Road
Nepean Gorge Closure	151mm	NEPX-L Line

Source: MSEC (2015)

3.2 Rainfall

Daily rainfall recorded at Douglas Park (St Marys Towers BOM Station 68200) and Illawarra Coal Cordeaux Colliery since January 2002 is shown in **Figure 4**.

Mean annual potential evapotranspiration on the plateau averages around 1617 ±64mm/year, whilst annual evapotranspiration is estimated at around 660 ±111mm/year for the 2007 to 2013 period (Ecoengineers, 2014).



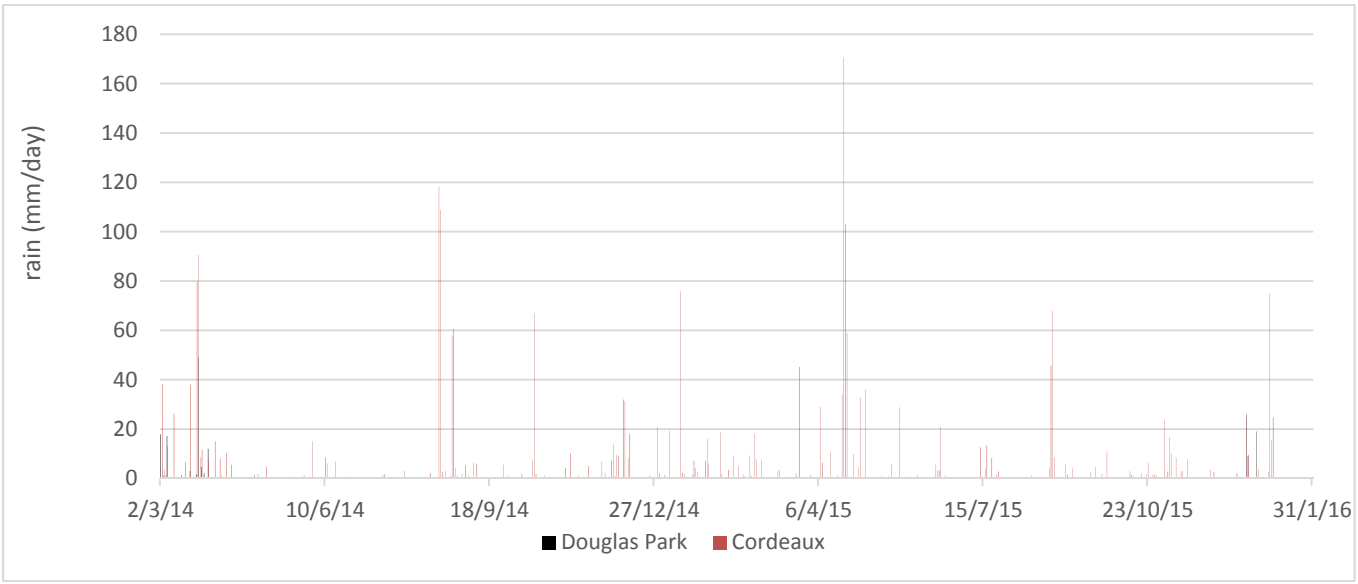


Figure 4 Rainfall

3.3 Nepean River

Stream water level as well as field chemistry and laboratory analysis of river water samples has been conducted by the Illawarra Coal Environmental Field Team (ICEFT) in the Nepean River since July 2002 at sites shown in **Figures 1** and **2**.

According to the TARP monitoring requirements, this report focusses on Sites NR2 (background), Sites NR11, 12, 13. Sites NR20 and NR30 (downstream) were approved to be removed from the monitoring program by the Department of Trade and Investment in June 2015.

3.3.1 Nepean River Height

River level with nail reference monitoring commenced in September 2001 as shown in **Figure 5** at locations shown in **Figures 1** and **2**.

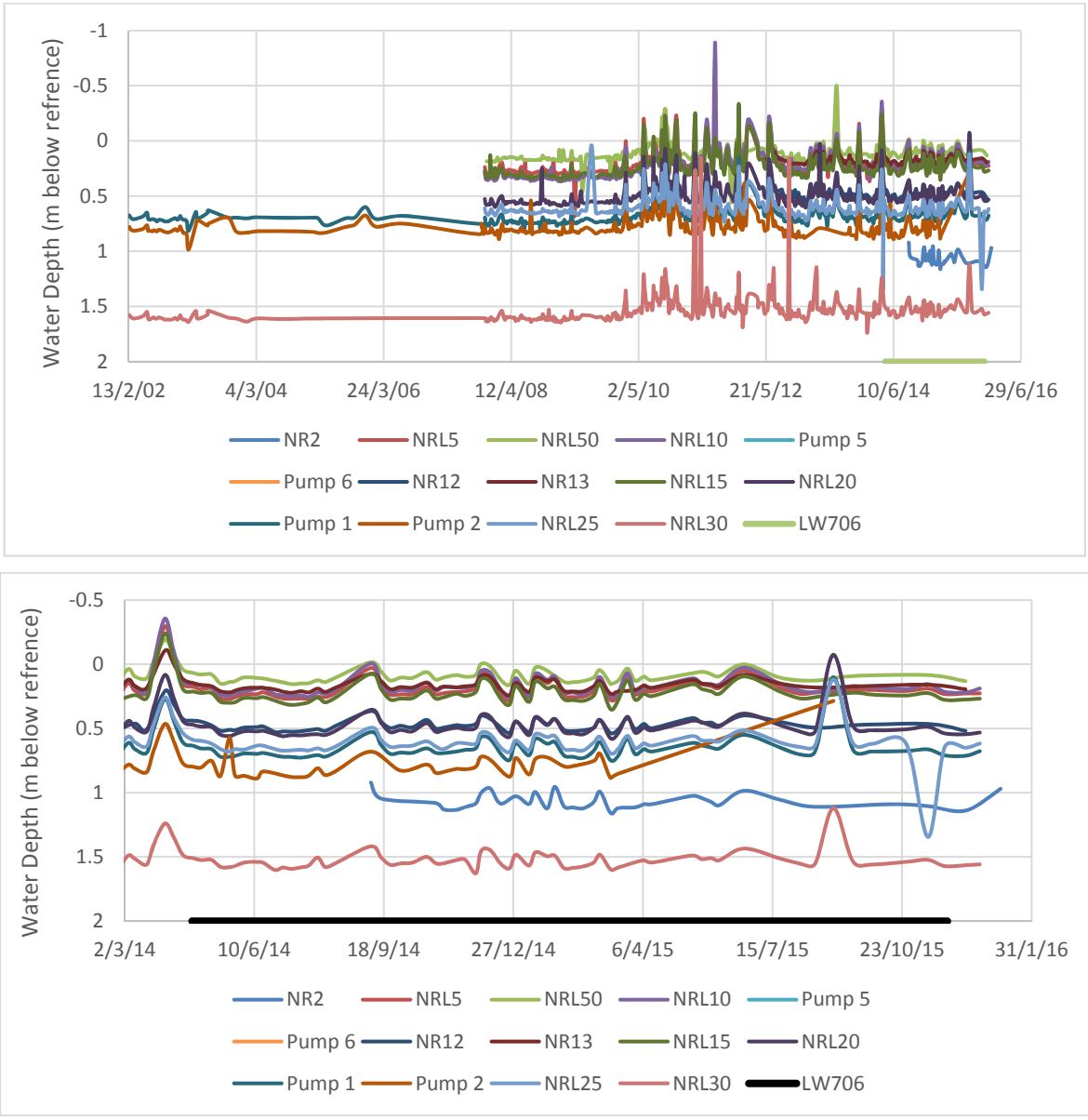


Figure 5 River Depth Monitoring at Nail Reference Locations

3.3.2 Nepean River Flow

Based on the monitoring conducted by the ICEFT and as shown in **Figures 5** and **6**, there have been no periods in the Nepean River where dry and / or flooded areas of riverbed were observed during the extraction of Longwall 706.

During Longwall 706, no TARP trigger levels were attained for water level or flow in comparison to baseline observations and flows

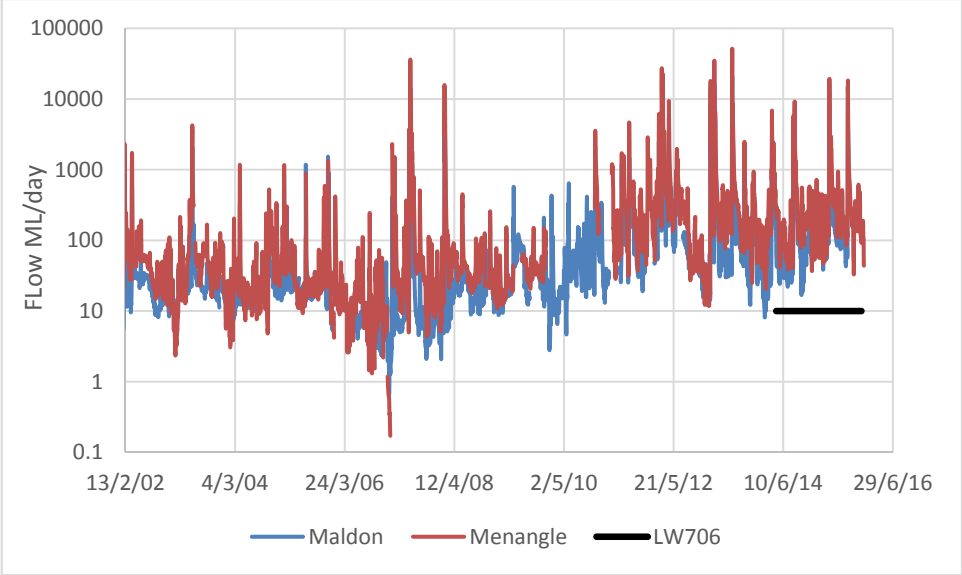
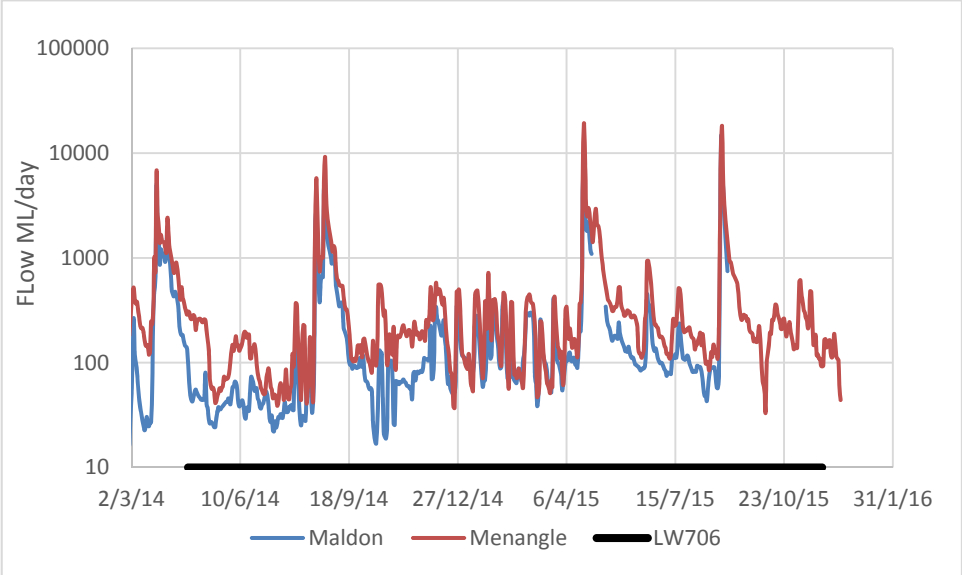


Figure 6 River Flow (2002 – 2016)



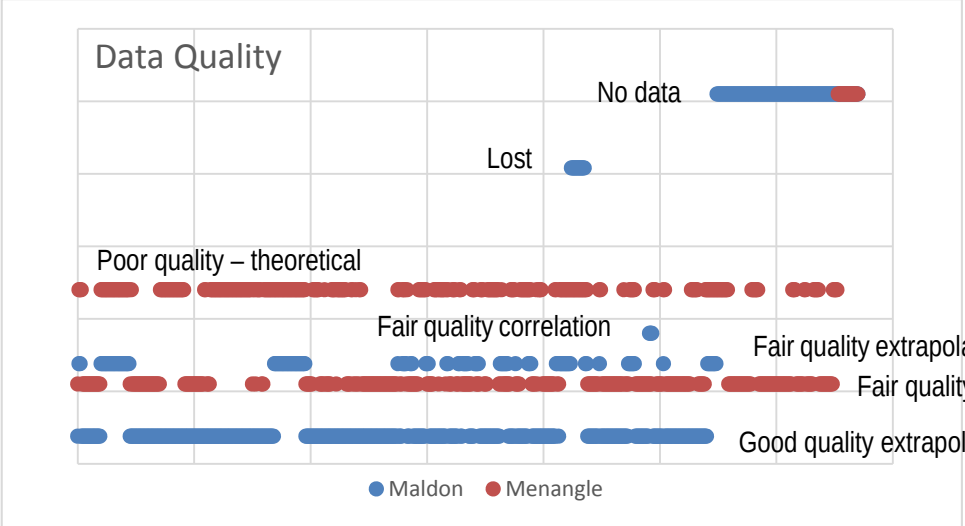


Figure 7 River Flow (During Longwall 706)

3.3.3 Nepean River Pre Longwall 706 Water Quality Observations

Prior to extraction of Longwall 706, the Nepean River was observed to have undergone subsidence associated water chemistry effects (Ecoengineers, 2014) such as;

- Iron Stain Zone One in Elladale Creek, activated during the mining of Longwall 701, was short-lived in duration and no staining was observed after October 2009.
- Iron Stain Zone Two along the bank of the Nepean River currently comprises a spring with iron staining over an approximate 2 x 2 metre area. No changes to this zone were observed over numerous monitoring visits during and since mining of Longwall 705.

3.3.4 Nepean River pH and Salinity

For the selected monitoring sites, based on historical data at the selected sites, the Nepean River has an EC and pH range as shown in **Table 4**.

For the period of extraction of Longwall 706, the trigger levels for a 1 and 2 standard deviation (compared to pre Longwall 706 mean) reduction in water quality for pH and salinity are shown in **Table 4**.

Table 4 Nepean River Water Quality Statistics (pH and Salinity)

pH	NR2	NR11	NR12	NR13
Pre 706 mean	7.96	7.70	7.53	7.41
Pre 706 SD	0.50	0.39	0.35	0.38
Pre 706 Range	5.65 – 9.47	6.58 – 8.70	6.79 – 8.36	6.24 – 8.19
1SD trigger	7.47	7.31	7.18	7.04
2SD trigger	6.97	6.92	6.83	6.66

EC	NR2	NR11	NR12	NR13
Pre 706 mean	392	310	180	179
Pre 706 SD	213	181	50	50
Pre 706 Range	109 - 1237	109 - 881	102 - 336	102 - 338
1SD trigger	605	491	230	229
2SD trigger	818	672	281	278

During the Longwall 706 extraction period, the Nepean River pH and salinity maintained a similar pre Longwall 706 variability, with no significant change to the observed ranges as a result of extraction of Longwall 706.

As shown in **Figure 8**, during the Longwall 706 extraction period, no significant change in trend or extended adverse changes occurred for pH and salinity.

During Longwall 706, no TARP trigger levels were attained for pH or salinity.

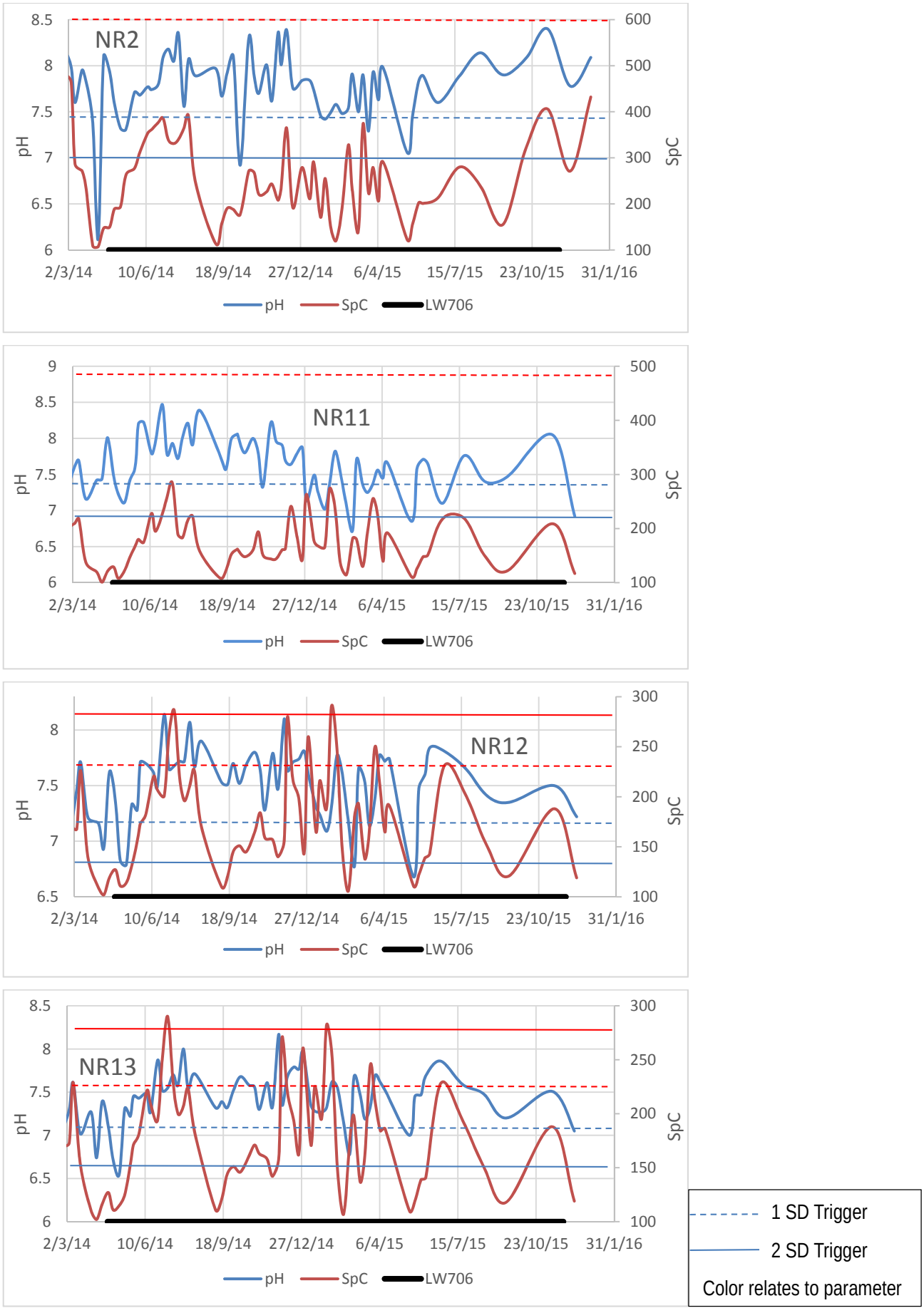


Figure 8 Nepean River pH and Salinity

3.3.5 Nepean River Dissolved Oxygen

For the selected monitoring sites, based on historical data at the selected sites, the Nepean River has a dissolved oxygen range as shown in **Table 5**.

For the period of extraction of Longwall 706, the trigger levels for a 1 and 2 standard deviation (compared to pre Longwall 706 mean) reduction in water quality for dissolved oxygen is shown in **Table 5**.

Table 5 Nepean River Water Quality Statistics (Dissolved Oxygen)

Dissolved Oxygen	NR2	NR11	NR12	NR13
pre706 mean	90	86	89	87
pre706 SD	16	16	10	14
1SD trigger	74	69	79	73
2SD trigger	58	53	68	59

During the Longwall 706 extraction period, the Nepean River dissolved oxygen maintained a similar pre Longwall 706 variability, with no significant change to the observed ranges as a result of extraction of Longwall 706.

As shown in **Figure 9**, during the Longwall 706 extraction period, no significant change in trend or extended adverse changes occurred for dissolved oxygen.

During Longwall 706, no TARP trigger levels were attained for dissolved oxygen.

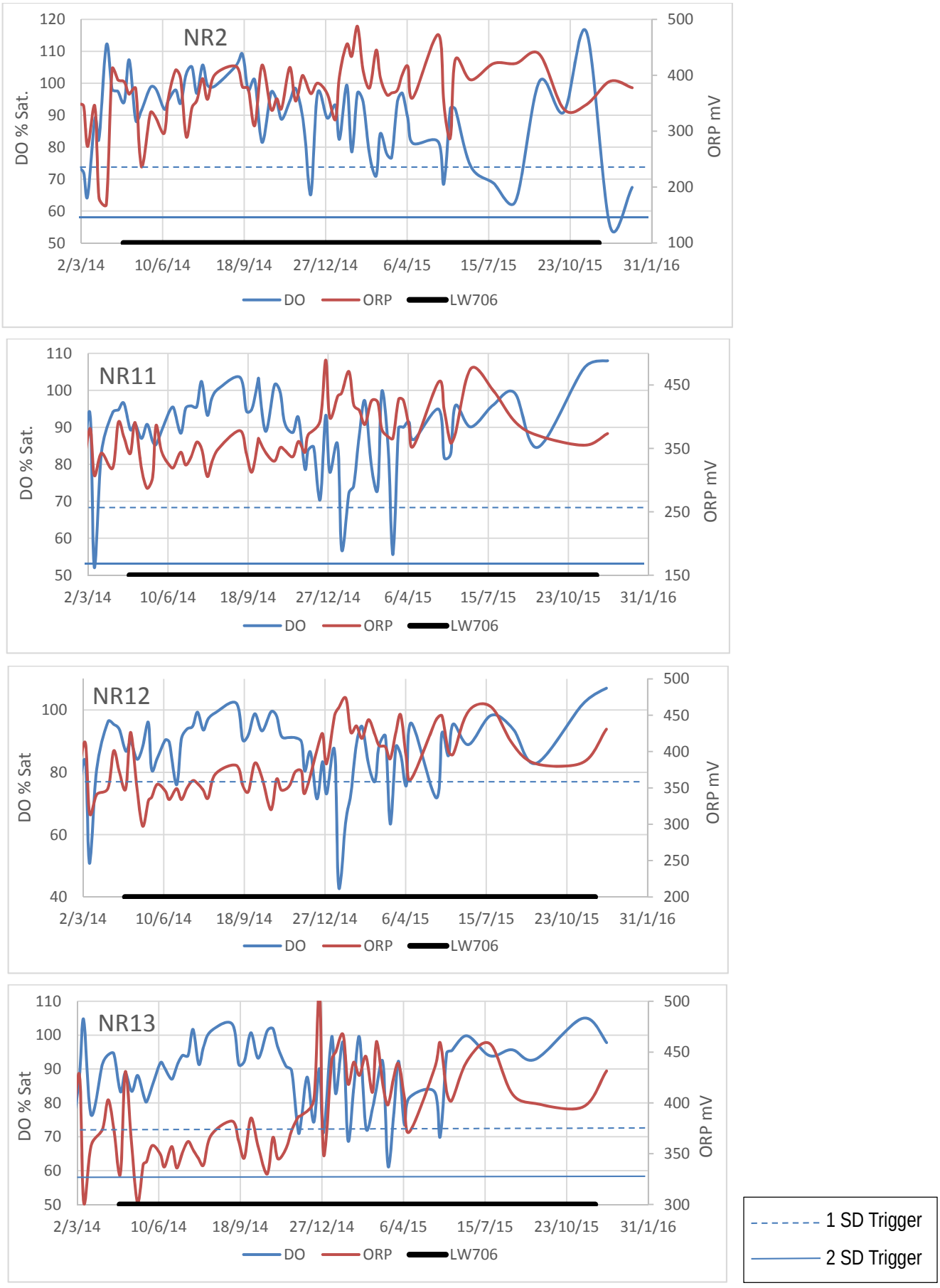


Figure 9 Nepean River Dissolved Oxygen and Oxidation Reduction Potential

3.3.6 Nepean River Iron and Manganese

For the selected monitoring sites, based on historical data at the sites, the Nepean River has a total iron and manganese range as shown in **Tables 6** and **7**.

For the period of extraction of Longwall 706, the trigger levels for a 1 and 2 standard deviation (compared to pre Longwall 706 mean) reduction in water quality for iron and manganese are shown in **Tables 6** and **7**.

Table 6 Nepean River Water Quality Statistics (Iron)

Iron (mg/L)	NR2	NR11	NR12	NR13
Pre 706 mean	0.335	0.337	0.421	0.425
Pre 706 SD	0.423	0.256	0.158	0.140
1SD trigger	0.758	0.593	0.579	0.052
2SD trigger	1.182	0.849	0.737	0.066

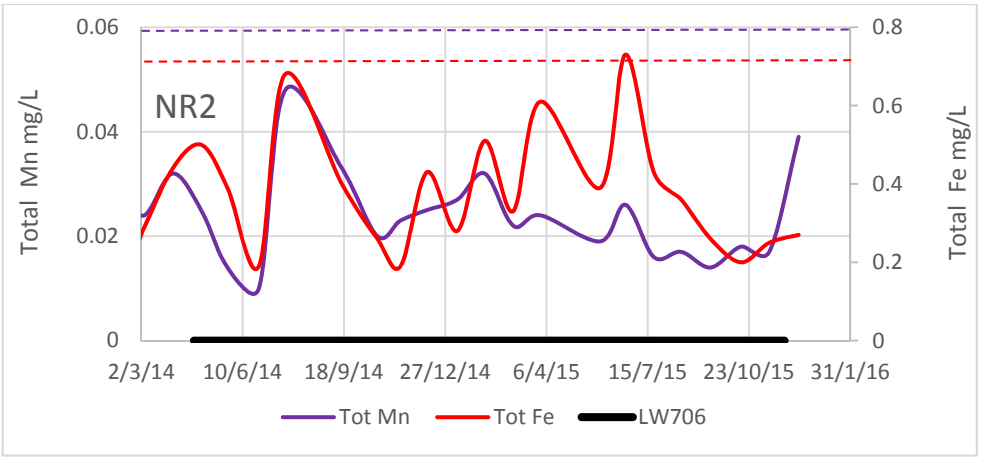
Table 7 Nepean River Water Quality Statistics (Manganese)

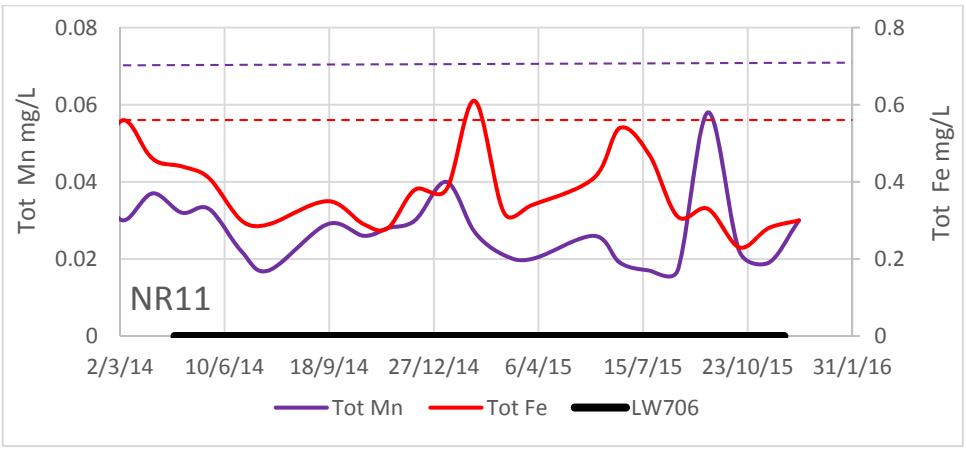
Manganese (mg/L)	NR2	NR11	NR12	NR13
Pre 706 mean	0.034	0.038	0.036	0.037
Pre 706 SD	0.026	0.036	0.014	0.014
1SD trigger	0.06	0.073	0.05	0.052
2SD trigger	0.086	0.109	0.064	0.066

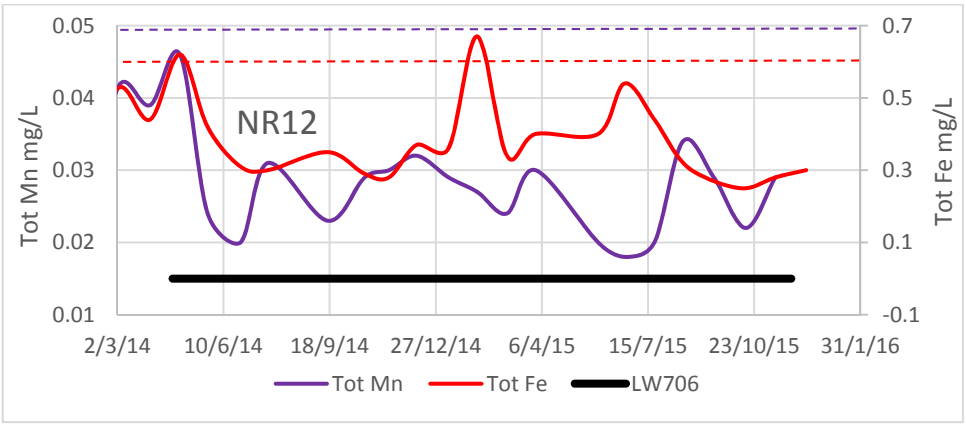
During the Longwall 706 extraction period, the Nepean River iron and manganese maintained a similar pre Longwall 706 variability, with no significant change to the observed ranges as a result of extraction of Longwall 706.

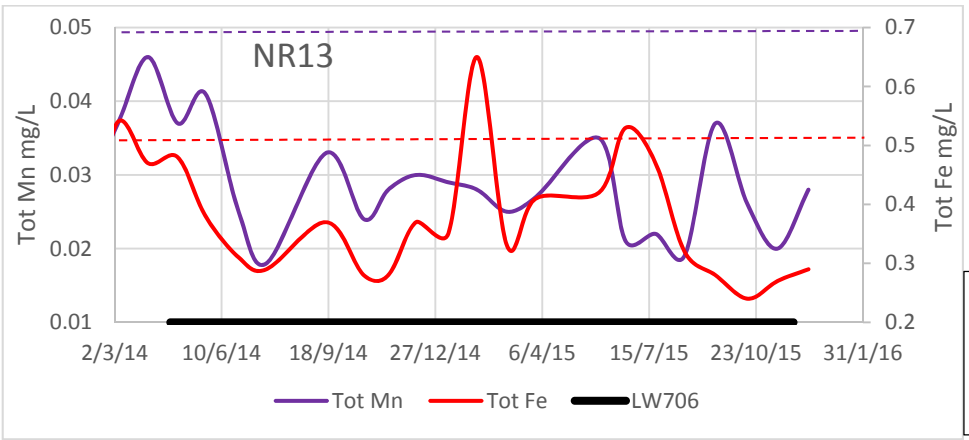
As shown in **Figure 10**, during the Longwall 706 extraction period, no significant change in trend or extended adverse changes occurred for iron and manganese.

During Longwall 706, no TARP trigger levels were attained for iron and manganese.









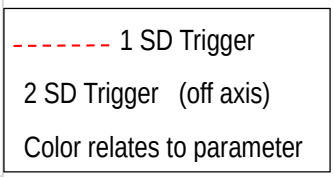


Figure 10 Nepean River Iron and Manganese

3.3.7 Gas Seeps into the Nepean River

Gas seepage was observed prior to Longwall 706 extraction period at numerous locations in the Nepean River with three new gas zones (16, 17 and 18) identified during Longwall 705 extraction.

Only Zone 18 remained active at the end of the Longwall 705 extraction period. The highest gas zone flow rate was Zone 16, at an estimated rate of 200 L/min, which is a Level 1 Impact.

During Longwall 706 extraction, an area of four gas release sites in two 2m x 1m zones were observed approximately 6m part, approximately 925m upstream of Gas Zone 15 on 13/8/2014.

The site overlaid the previously extracted Longwall 16 of the Tower Mine, which was extracted between October 1998 and August 1999.

The ICEFT interpreted it as a re-activated gas release from the mining of Longwall 16.

At the time of inspection Gas Zones 5 and 14 were low intensity single point gas release sites.

Gas Zone 16, 17 were not active on 13/8/14.

Gas Zone 5 was last observed on 13th August 2014, Gas Zone 14 on the 11th December 2015 and Gas Zone 18 on the 26th October 2015.

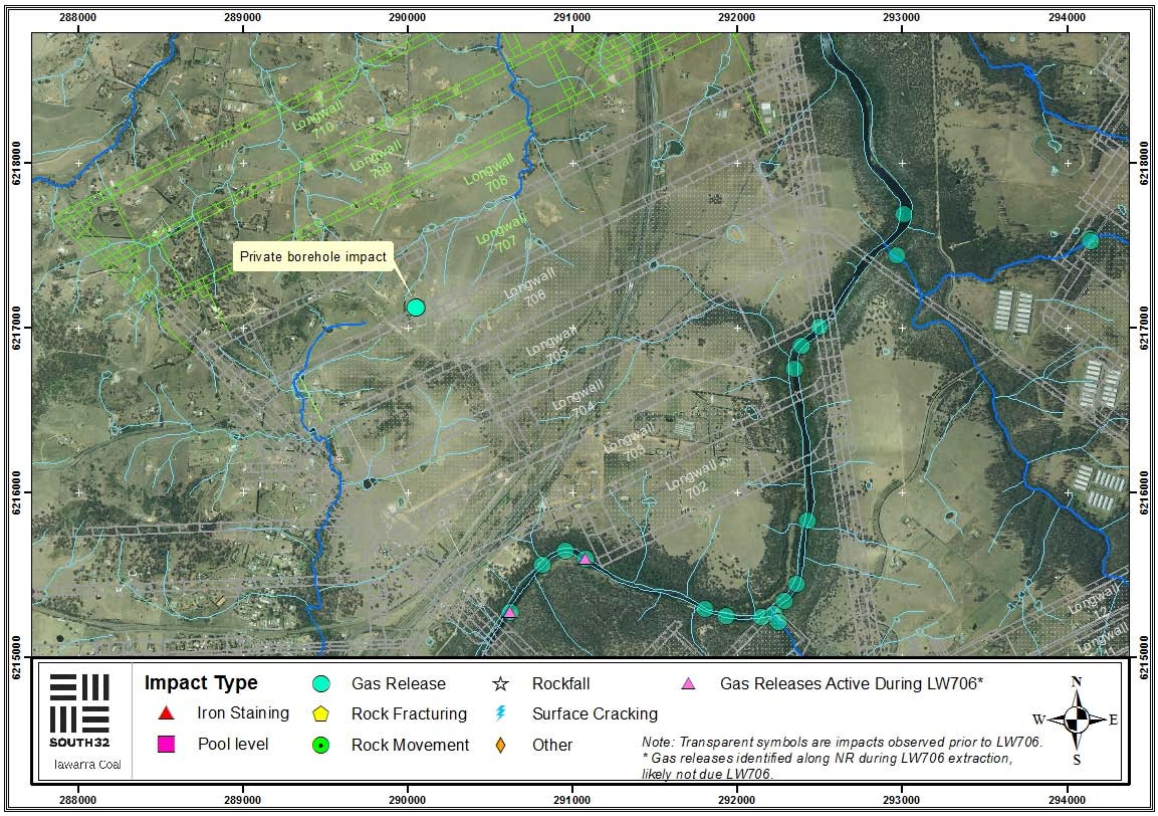


Figure 11 Nepean River and Private Bore Gas Seeps

During Longwall 706, TARP trigger levels for gas seepage in the river were Level 1.

3.4 Groundwater

Monitoring has been conducted in the study area to document any observed impacts relating to the "NGW" piezometers to the north-west of the Nepean River gorge, as well as the following private boreholes within the Longwall 702 to 706 subsidence area:

GW101437;

GW102584;

GW104154, and;

GW112441.

As outlined in **Section 2.7**, monitoring of all NGW piezometers except NGW6 was sequentially discontinued, due to either land access issues or deterioration of the equipment prior to or during extraction of Longwall 706.

Access to GW102584 for the post Longwall 706 inspection was not possible as the landowner could not be contacted.

The observed effects during extraction of Longwall 706 are outlined in the following sections.

3.4.1 Aquifer / Aquitard Interconnection

No adverse interconnection of aquifers and aquitards has been observed within 20m of the plateau surface and no increased rate of groundwater recharge into the plateau has been observed as a result of Longwall 702 - 706 extraction.

However, strata fracturing, with associated bore displacement and reduction in bore water quality was previously observed in the private bores GW104154, GW101437 and GW102584 (GeoTerra, 2015).

No reports of new adverse effects specifically for strata dewatering, adverse aquifer / aquitard interconnection or adverse bore water quality changes were observed during extraction of Longwall 706. (NB, GW112441 is discussed in Section 3.4.6)

No TARP trigger levels related to aquifer / aquitard interconnection or changes in recharge have been observed to have been reached or exceeded as a result of Longwall 706 extraction.

3.4.2 Groundwater Levels

NGW6 was not undermined by Longwall 704, 705 or 706, however a definitive response comprising an up to 2.21m fall in groundwater level occurred after Longwall 704 was completed and before Longwall 705 extraction occurred.

The Nepean River water surface averages 61.10mAHD at Douglas Park weir and 60.84mAHD at Menangle, and as a result, the NGW6 water level varied from 2.33 – 4.75m higher in elevation than the river during the Longwall 704 and Longwall 705 monitoring.

The decline in water level occurred just after Longwall 704 was completed and then erratically rose, fell, then continued to rise until the logger trace cut out on 03/09/12. Prior to re-establishment of the logger in a rising limb of the water level trace, the water level had

previously fallen by 1.02m.

The water level rise significantly flattened out around mid-October 2012, then continued to fall at a lower rate after that time until early October 2013, then rose and fell a minor amount after that time to the end of the monitoring period.

No significant water level reduction occurred during extraction of Longwall 706 in NGW3,4,5 and NGW6 as shown in **Figure 12**.

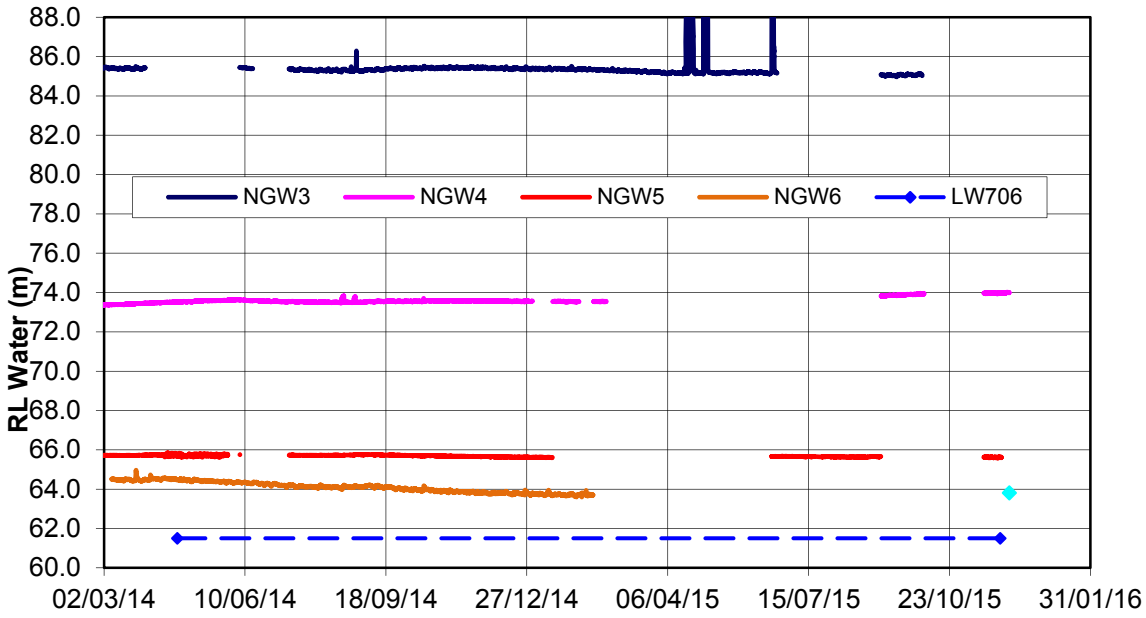


Figure 12 NGW Water Levels

3.4.3 Vibrating Wire Piezometers

Bore EAW5 [S1913] is located approximately 2.2 km north to northwest of Longwall 706.

Head declines linearly at EAW5 in the Hawkesbury Sandstone and there is a clear difference in the behaviour of groundwater pressures above and below the Bald Hill Claystone as shown in **Figure 13**.

This is evidence of the contiguous nature of the claystone across the general Appin Area 7 area and evidence of the pre-mining separation between shallow and deep aquifer heads. Within the upper Bulgo Sandstone the heads become artesian (at or above ground level), except for a slightly lower head in the Bulli Seam. The vertical profiles between the 2008-09 and June 2012 data are quite consistent, although the Bulli Seam water level rose from 2008-09 to June 2012 to an artesian level, unlike the 2008-09 data which is sub-artesian (HydroSimulations, 2013).

The EAW5 water levels were essentially unaffected by Longwall 706 extraction, outside of a gradual water level decline in the Bulli Seam, Scarborough Sandstone (505mbgl), Bulgo Sandstone (274mbgl) and a rise in the Hawkesbury Sandstone at 65mbgl.

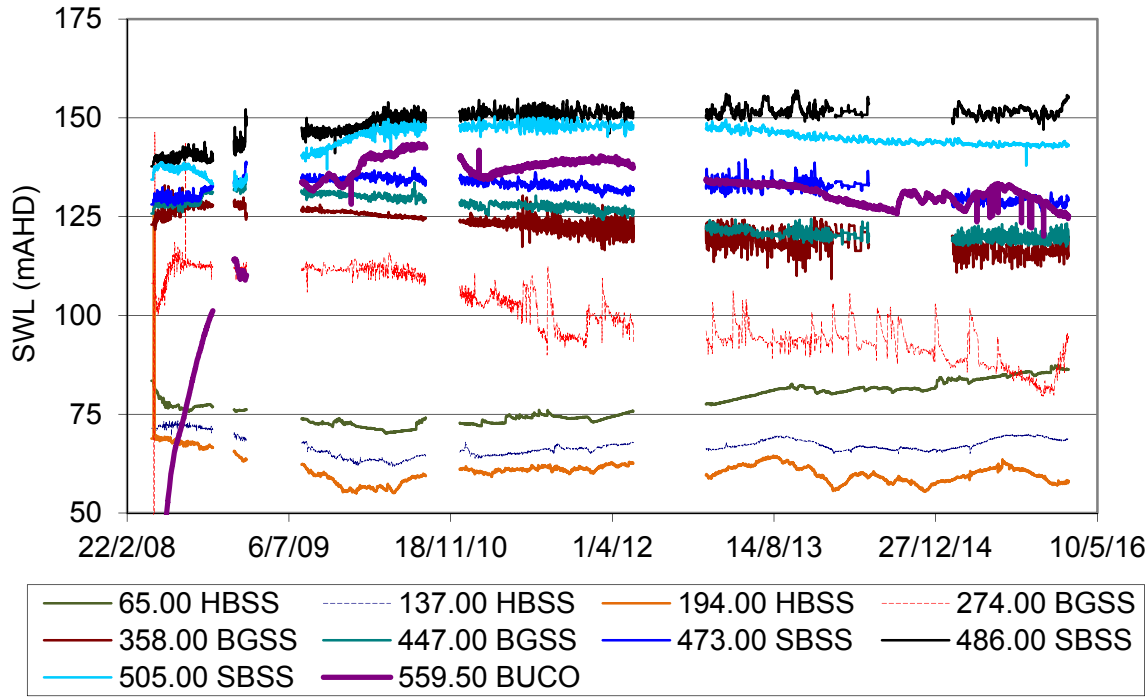


Figure 13 EAW5 Water Levels

EAW7 (S1936) is located over Longwall 706.

The deeper heads are sub-artesian at EAW7, although were generally higher than the Hawkesbury Sandstone levels at June 2012 and lower at June 2013. The head profile patterns at June 2012 and June 2013 are similar, although there is clearly more variation between 2009, 2012 and 2013 in the deeper water levels than in the Hawkesbury Sandstone. For example, within the Bulgo Sandstone, there was a decline in levels of about 6 - 17m between June 2012 and June 2013 in the middle and lower Bulgo Sandstone respectively as shown in **Figure 14**.

The decline was greater at around 30m in the Scarborough Sandstone, which is a clear mining effect due to Longwall 705. There is minimal difference in the lower Hawkesbury Sandstone water levels between 2012 and 2013 and no change was observed in the upper Hawkesbury Sandstone (HydroSimulations, 2013).

A definitive sharp fall in water levels occurred around late April 2014 in the Scarborough Sandstone at 456.2, 462.1 and 468mbgl, along with a continued enhanced reduction in water levels in the Bulgo Sandstone at 347.8 and 422.5mbgl and a distinctive pressure reduction in the Bulli Seam since the start of monitoring.

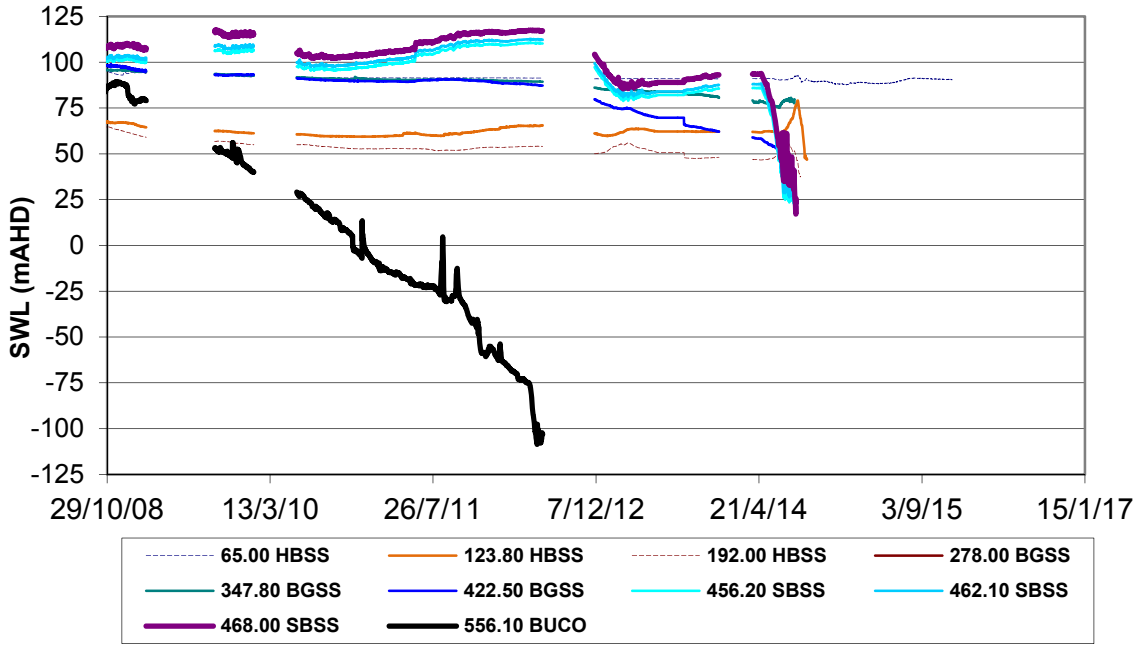


Figure 14 EAW7 Water Levels

No groundwater level reduction TARP triggers were exceeded during extraction of Longwall 706 in any private bores and no changes outside of predictions for the VWP monitoring bores occurred.

3.4.4 Well Yield and Bore Serviceability

No adverse effects on groundwater supply, well yield or bore serviceability have been monitored or reported during and following extraction of Longwalls 702 to 706.

Outside of the gas seepage effect discussed in Section 3.4.6, no well yield or bore serviceability TARP triggers were exceeded during or following the extraction of Longwall 706.

3.4.5 Groundwater Quality

The groundwater quality in NGW3 is generally fresh (344 - 434 mg/L) with circum-neutral to slightly alkaline pH (7.1 – 7.7), however as the piezometer is regularly inundated with rainwater recharge down the bore annulus, the data does not represent the actual formation water quality and is not further considered.

NGW4 may also be affected by rainwater recharge, although it does not show in the water level trace after significant storms as it also has a low salinity (434 – 458mg/L) and circum-neutral to slightly alkaline pH (7.5 – 8.0).

NGW 5, 6 and 10 generally exceed the ANZECC 2000 irrigation water quality for chloride and sodium, whilst NGW7, 9 and 11 are relatively fresh with a circum-neutral to slightly acidic pH.

Since December 2007, on-going monitoring indicates that:

- NGW5 salinity has remained essentially unchanged, and its pH has reduced from 7.9 to 6.3, whilst;
- NGW6 salinity has reduced from 5,180 to 729µS/cm, and its pH has reduced from 7.5 to 7.0.

No additional monitoring of the NGW 3, 4 and 5 piezometers groundwater quality occurred during extraction of Longwall 706.

No groundwater quality TARP triggers were exceeded during or following the extraction of Longwall 706.

3.4.6 Gas Seepage

Monitoring by ICEFT during Longwall 706 extraction on 15/07/2015 identified water cloudiness and a gaseous smell in the extracted bore water, with laboratory analysis confirming the presence of methane, along with lesser ethane, propane, butane and other hydrocarbons in GW112441 as shown in **Appendix A**.

Laboratory analysis also, however, indicated no pre and post Longwall 706 change to pH, salinity or metals.

The landowner ceased to use the bore and the area around the wellhead was fenced off. A 10,000 Litre tank was provided by Sth32-IC for livestock watering and is topped up as required by Illawarra Coal.

At this stage, a replacement bore is planned to be drilled after completion of Longwall 707 unless an alternative arrangement is agreed to by the landowner.

No bore water quality TARP triggers were exceeded during or after the extraction of Longwall 706, as there are no specified criteria for bore water gaseous emissions.

3.4.7 Potential Inflow to Mine Workings

No increased groundwater inflow to the Appin mine workings following extraction of Longwall 706, compared to the previous longwall periods, has occurred and no TARP trigger levels have been reached or exceeded, based on statutory inspection data as shown in ***Figure 15****.*

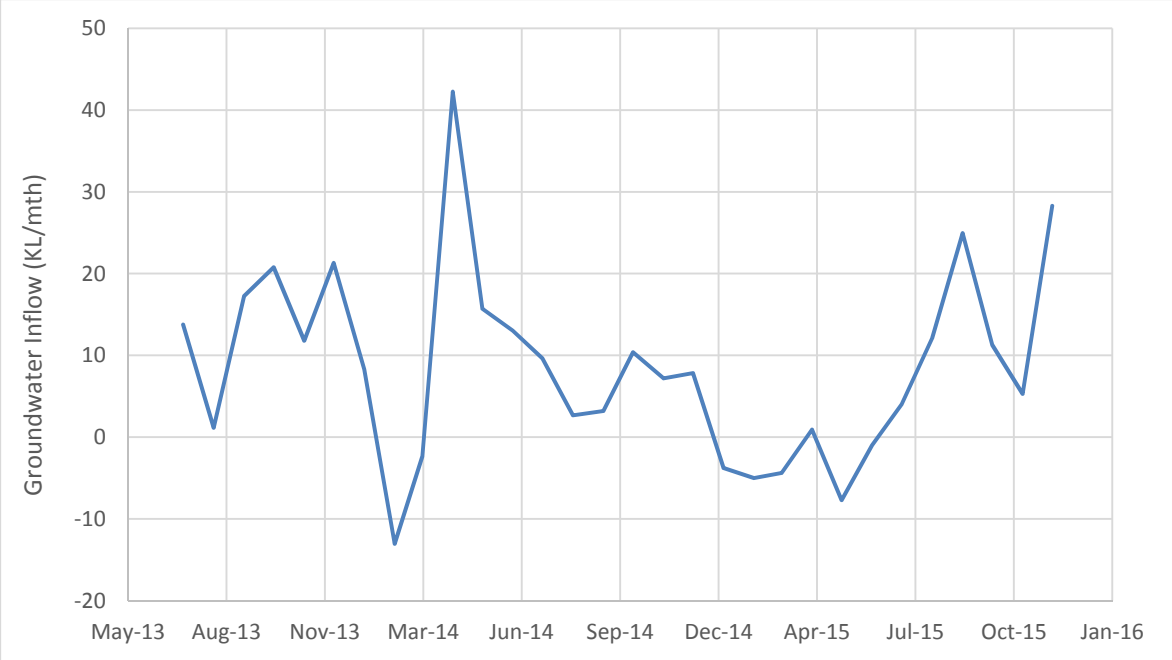


Figure 15 Appin Mine Groundwater Inflow

4. CONCLUSIONS

Based on monitoring of the Nepean River, plateau streams and groundwater conducted prior to, during and after extraction of Longwall 706, the following conclusions can be made:

- No significant stream bed cracking, or associated with a reduction in stream flow and pool desiccation has been observed in the plateau streams;
- No observable loss, diversion of water, flooding or dry reaches were observed in the Nepean River;
- A new minor gas emission was observed over the old Tower Colliery Longwall 16 workings at AA7_LW706_001, along with continued minor gas emissions at Gas Zones 5, 14 and 18 (all of which have since ceased). No associated reduction in dissolved oxygen due to microbiological consumption of oxygen was observed;
- No water quality TARP triggers were reached or exceeded for pH, salinity, dissolved oxygen, as well as total iron and manganese at sites NR11, 12, 13, 20 and 30;
- No new ferruginous springs were generated in the Nepean River;
- Significant depressurisation of the Bulli Seam, Scarborough Sandstone and lower Bulgo Sandstone has been observed in the vibrating wire piezometer bore EAW7 that overlies Longwall 706, and to a lesser degree, in EAW5;
- A hydrocarbon gas seep, dominated by methane, was generated in GW112441. The bore has been sealed and rehabilitated and is no longer in use. It will be replaced after extraction of Longwall 707 (or the water supply otherwise replaced);
- No additional adverse effects on private bore yield or water quality have been reported during or after the Longwall 706 extraction period.

5. REFERENCES

ANZECC 2000 Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Vol 1 & 2

BHPB, undated Geological and Groundwater Study – Appin Area 7

Ecoengineers Pty Ltd, 2005 Assessment of Water Quality Effects Westcliff Colliery Longwalls 31 to 33

Ecoengineers, 2011 End of Panel Assessment of Water Flow and Quality Effects Appin Colliery Longwall 703

Ecoengineers, 2012 End of Panel Assessment of Water Flow and Quality Effects Appin Colliery Longwall 704

Ecoengineers, 2014 End of Panel Assessment of Water Flow and Quality Effects Appin Colliery Longwall 705

GeoTerra, 2006 (SW) Douglas Area 7 Longwalls 702 to 704 Surface Water Assessment

GeoTerra, 2006 (GW) Douglas Area 7 Longwalls 702 to 704 Groundwater Assessment

GeoTerra, 2008 Appin Area 7 End of Longwall 701 Extraction Groundwater Monitoring Report

GeoTerra, 2009 Appin Area 7 End of Longwall 702 Extraction Groundwater Monitoring Report

GeoTerra, 2011 Appin Area 7 End of Longwall 703 Extraction Groundwater Monitoring Report

GeoTerra, 2012 Appin Area 7 End of Longwall 704 Extraction Groundwater Monitoring Report

GeoTerra, 2014 Appin Area 7 End of Longwall 705 Extraction Groundwater Monitoring Report

Heritage Computing, 2010 Bulli Seam Operations Groundwater Assessment A Hydrogeological Assessment in Support of the Bulli Seam Operations Environmental Impact Statement

HydroSimulations, 2013 Bulli Seam Operations Groundwater Data Analysis to Mid 2013 (Appin and West Cliff Areas)

SCT Operations Pty Ltd, 2011 Douglas Park Bore Investigation, Boustani and Nahkle

Mine Subsidence Engineering Consultants, 2008 The Prediction of Subsidence Parameters and the assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting From the Extraction of Proposed Longwalls 705 to 710 at Appin Colliery in Support of the SMP Application

Mine Subsidence Engineering Consultants, 2011 Appin Colliery Longwall 703 End of Panel Subsidence Monitoring Report For Appin Longwall 703

Mine Subsidence Engineering Consultants, 2012 End of Panel Subsidence Monitoring Report For Appin Longwall 704

Mine Subsidence Engineering Consultants, 2014 End of Panel Subsidence Monitoring Report For Appin Longwall 705

LIMITATIONS

This report was prepared in accordance with the scope of services set out in the contract between GeoTerra Pty Ltd (GeoTerra) and the client, or where no contract has been finalised, the proposal agreed to by the client. To the best of our knowledge the report presented herein accurately reflects the clients requirements when it was printed. However, the application of conditions of approval or impacts of unanticipated future events could modify the outcomes described in this document.

In preparing this report, GeoTerra has relied upon information and documentation provided by the client and / or third parties. GeoTerra did not attempt to independently verify the accuracy or completeness of that information. To the extent that the conclusions and recommendations in this report are based in whole or in part on such information, they are contingent on its validity. GeoTerra assume the client will make their own enquiries in regard to conclusions and recommendations made in this document. GeoTerra accept no responsibility for any consequences arising from any information or condition that was concealed, withheld, misrepresented, or otherwise not fully disclosed or available to GeoTerra.

The findings contained in this report are the result of discrete / specific methodologies used in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site in question. Under no circumstances, however, can it be considered that these findings represent the actual state of the site at all points.

Interpretations and recommendations provided in this report are opinions provided for our Client's sole use in accordance with the specified brief. As such they do not necessarily address all aspects of water, soil or rock conditions on the subject site. The responsibility of GeoTerra is solely to its client and it is not intended that this report be relied upon by any third party. This report shall not be reproduced either wholly or in part without the prior written consent of GeoTerra.

APPENDIX A

Groundwater Chemistry

	ANZECC*	10		10			20	2				5	5	2	5									
		Fe t	Fe f	Mn t	Mn f	AL t	Al f	As f	Cd f	Cs f	Cr f	Cu f	Pb f	Ni f	Zn f	Ba f	Li f	Rb f	Sr f	Br f	I f	TN	TP	DOC
GW102584	11/10/2013	0.05	0.05	0.151	0.147	0.01	0.02	0.001				0.001	0.001	0.002	0.059					2.1	0.1	0.35	0.01	9
	14/05/2014	0.92	0.57	0.252	0.239	0.11	0.01	0.001				0.001	0.001	0.002	0.011					2	0.1	0.6	0.01	4
GW112441	27/11/2012	0.39	0.38	0.039	0.039	0.01	0.01	0.012				0.001	0.001	0.003	0.006					1	0.1		0.01	1
	15/07/2015	0.5	0.38	0.047	0.044	0.04	0.01	0.004				0.001	0.001	0.001	0.005					1.2	0.1	0.9	0.02	128
NGW6	10/12/2007	1.45	0.05	1.50	1.60	8.64	0.06	0.001				0.002	0.001	0.034	0.2					1.2	0.1	0.64	0.04	6
	04/02/2009	0.95	0.05	2.16	1.88	5.33	0.02	0.001	0.002	0.001	0.001	0.002	0.001	0.051	0.281	0.064	0.019	0.022	0.274			1.1	0.01	3
	05/05/2009	3.97	3.7	2.76	2.79	1.65	0.04	0.001	0.002	0.001	0.001	0.001	0.001	0.074	0.342	0.098	0.036	0.018	0.467			0.3	0.01	6
	14/03/2011	4.34	0.36	0.692	0.806	8.94	0.19	0.001				0.005	0.002	0.022	0.257	0.16						2.8	0.07	49
	10/08/2012																							
	14/09/2012	8.05	5.96	0.484	0.467	3.73	0.19	0.001				0.001	0.002	0.007	0.041	0.255	0.008	0.011	0.318			6.5	0.09	55
	04/12/2015	3.87	0.05		0.21	3.65	0.01	0.001	0.0004	0.001	0.001	0.001	0.001	0.002	0.011	0.138	0.013	0.012	0.397			2	0.01	9

Max	8.05	5.96	2.76	2.79	8.94	0.19	0.001	0.0022	0.001	0.001	0.005	0.002	0.074	0.342	0.255	0.036	0.022	0.467	2.10	0.10	6.50	0.09	55
Min	0.05	0.05	0.15	0.15	0.01	0.01	0.001	0.0016	0.001	0.001	0.001	0.001	0.002	0.011	0.064	0.008	0.011	0.274	1.20	0.10	0.30	0.01	3
Av	2.82	1.53	1.14	1.13	3.55	0.06	0.001	0.0019	0.001	0.001	0.002	0.001	0.027	0.170	0.144	0.021	0.017	0.353	1.77	0.10	1.76	0.03	19
Median	1.45	0.36	0.69	0.81	2.69	0.02	0.001	0.0019	0.001	0.001	0.001	0.001	0.022	0.200	0.129	0.019	0.018	0.318	2.00	0.10	0.64	0.01	6
STD DEV	2.82	2.35	1.02	0.99	3.75	0.07	0.000	0.0004	0.000	0.000	0.001	0.000	0.027	0.132	0.084	0.014	0.006	0.101	0.49	0.00	2.26	0.03	23

ANZECC 2000 irrigation water trigger values for select veget (tomato cucumber) and water use t total f filtered

	ANZECC*	6 - 8.5						175-700			115-460	
		pH	EC	TDS	T Alk	SO4 f	F	Cl	Ca	Mg	Na	K
GW102584	11/10/2013	7.5	3990	2300	651	84		856	150	148	450	12
	14/05/2014	7.17	4010	1960	823	62		777	163	152	430	16
GW112441	27/11/2012	7.64	2060	1030	482	17		441	58	64	303	11
	15/07/2015	7.34	2210	1080	451	11		336	70	70	285	10
NGW6	10/12/2007	6.91	2200	1220	139	189		464	97	37	249	46
	04/02/2009	7.45	2510	1620	110	34	0.7	777	57	56	346	7
	05/05/2009	6.70	5180	2710	66	68	0.3	1560	41	140	812	8
	14/03/2011	6.48	1110	1110	186	21	0.4	329	83	26	162	4
	10/08/2012	6.35	559									
	14/09/2012	7	729	446	202	6	0.4	87	79	8	40	4
	04/12/2015	6.79	740	580	80	12	0.3	174	37	12	77	5

Max	7.50	5180	2710	823	189	0.70	1560	163.0	152	812	46
Min	6.35	559	446	66	6	0.30	87	41.00	8	40	4
Av	6.95	2536	1624	311	66	0.45	693	95.71	81	356	14
Median	6.96	2355	1620	186	62	0.40	777	83.00	56	346	8
STD DEV	0.42	1715	771	299	61	0.17	473	45.48	63	249	15

ANZECC 2000 irrigation water trigger values for select veget (tomato cucumber) and water use

APPENDIX B

Longwall 706 TARP Impact Summary

Longwall 706 TARPs and Impact Summary

Feature	Performance Measure*	Potential Impacts	*Exceeding* Prediction	TARP Trigger Level	Observed Impacts	Additional Comments / Recommendations
Water Quality						
Nepean River Impact Monitoring Sites adjacent to each Longwall: - NR11 - NR12 - NR13 - NR20* - NR30* **Notes:** Baseline upriver sites will be used for cross-checking for upriver perturbations(1) Baseline upriver site NR2 data to be updated at end of panel following completion of each longwall, subject to checks-for, and discard-of upriver perturbed data * *Monitoring sites were removed (following approval) from program 4/06/2015.*	Negligible environmental consequences including: • Negligible gas releases and iron staining; and • Negligible increase in water cloudiness	- Mining induced gas emissions. - Reduction in dissolved oxygen (DO) (in association with gas releases) at very low flows due to the microbiological consumption of methane. - Minor iron flocs in association with gas release sites.	• More than negligible gas release	***Level 1*** Impact monitoring sites: • pH reduction greater than 1 standard deviation but less than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • DO reduction greater than 1 standard deviation but less than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • Identification of strata gas plume of flow rate < 3000 L/min	No pH reduction >1 but < 2 standard deviations from the pre LW706 mean for 2 months No DO reduction >1 but < 2 standard deviations from the pre LW706 mean for 2 months No gas plumes identified >3000L/min	Continue monitoring Continue monitoring Small new gas plume at AA7_LW706_001 & continued low level gas release at Gas Zone 5, 14. Continue monitoring
				Level 2 Impact monitoring sites: • pH reduction greater than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • DO reduction greater than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months • EC, total Fe and total Mn increases greater than 2	No pH reduction >2 standard deviations from the pre LW706 mean for 2 months No DO reduction > 2 standard deviations from the pre LW706 mean for 2 months No EC, Total Fe or Mn increase >2 standard	Continue monitoring Continue monitoring Continue monitoring

Longwall 706 TARPs and Impact Summary

Feature	Performance Measure*	Potential Impacts	*Exceeding* Prediction	TARP Trigger Level	Observed Impacts	Additional Comments / Recommendations
				standard deviation from pre-mining mean resulting from the mining for two consecutive months • Identification of strata gas plume of flow rate >3000 L/min	deviations from pre LW706 means for 2 months No gas plumes identified >3000L/min	See above
				Level 3 Impact monitoring sites: • Level 2-type reduction in water quality resulting from the mining observed for six consecutive months	No Level 3 impacts identified	Continue monitoring
Water Level and Flow						
<u>Nepean River</u> Visual observations along the length of the Nepean River within the active mining area	Negligible environmental consequences including: • Negligible diversion of flows or changes in the natural drainage behaviour of pools	- Unlikely that predicted systemic subsidence would cause significant change in water level along the Nepean River. - Potential for surface water flow diversion is very low. - Fracturing may occur, but expected to be minor in nature. - Where upsidence exceeds subsidence, areas may experience a reduction in the frequency of water inundation.	More than negligible diversion of flows or changes in the natural drainage behaviour of pools.	***Level 1*** • Observation of areas of dry and/or flooded riverbed in comparison to baseline observations and flows, for less than two consecutive months.	No dry or flooded areas observed compared to pre LW706 for <2 months	Continue monitoring
				Level 2 • Observation of areas of dry and/or flooded riverbed in comparison to baseline observations and flows, for more than two consecutive months.	No dry or flooded areas observed compared to pre LW706 for >2 months	Continue monitoring
				Level 3 • Observation of areas of dry and/or flooded riverbed in comparison to baseline observations and flows, for six consecutive months.	No dry or flooded areas observed compared to pre LW706 for >6 months	Continue monitoring

* Performance Measure as defined in BSO Development Consent Approval and Longwall 705 to 706 SMP Approval (Table 1).

Longwall 706 TARPs and Impact Summary

(1) Baseline upriver sites for cross-checking for upriver perturbations impacting Area 7 monitoring sites:

- NR0 - possible perturbations from Allens Creek (>2 standard deviation)
- NR2 - upstream perturbations (>2 standard deviations) pre-Area 9 mining
- New site NR110 - possible perturbations from Area 9 (>2 standard deviations) post-Area 9 mining commencement
- Checks at Upriver sites NR4, NR5 and NR6 for possible Cataract River-based perturbations (>2 standard deviation)

Current values:

Level 1

NR11	**NR2 upstream normality checks**
• pH>6.93;<7.33	• pH>7.01
• DO>47.8%;<66.0%	• DO>55.3%
• EC>561 uS/cm;<758 uS/cm	• EC<890 uS/cm
• Total Fe>0.589;<0.866mg/L	• Total Fe<1.220 mg/L
• Total Mn>0.044;<0.074 mg/L	• Total Mn<0.090 mg/L

Level 2 and 3

NR11	**NR2 upstream normality checks**
• pH<6.93	• pH>7.01
• DO<47.8%	• DO>55.3%
• EC>758 uS/cm	• EC<890 uS/cm
• Total Fe>0.866	• Total Fe<1.220 mg/L
• Total Mn>0.074	• Total Mn<0.090 mg/L

References

Longwall 706 TARPs and Impact Summary

Feature	Performance Measure*	Potential Impacts	*Exceeding* Prediction	TARP Trigger Level	Observed Impacts	Additional Comments / Recommendations
Groundwater						
Water Level IC monitoring bores: • NGW3 • NGW4 • NGW6 • NGW5 • EAW5 • EAW7 (S1936) • Private Bores • Registered bores and any new bores within the SMP area ***Notes:*** *Impact monitoring data during longwall mining is compared to predicted groundwater levels from the BSOP (or later updates) groundwater model, during preparation of the End of Panel Report* *Privately owned water supplies are monitored as agreed with landowners*		- Temporary lowering of the piezometric surface over the subsidence area due to horizontal dilation of strata and resultant increase in secondary porosity. - Groundwater levels may reduce by up to 10m, and may stay at that reduced level until maximum subsidence develops at a specific location. - Groundwater levels should recover over a few months as the newly developed secondary porosity is recharged by rainfall sourced water. - No permanent post mining reduction in water level in bores on the plateau unless a new outflow path develops.		***Level 1*** • Up to an additional 2.5m reduction from the predicted standing water level or pressure (outside of pumping influences) over 2 consecutive months	No reduction in groundwater level or pressure greater than 2.5m over predicted effects (over 2 months)	Continue monitoring
				Level 2 • Between 2.5m and 5m additional reduction from the predicted standing water level or pressure (outside of pumping influences) over 2 consecutive months	No reduction in groundwater level or pressure greater than 2.5 - 5m over predicted effects (over 2 months)	Continue monitoring
				Level 3 • Greater than 5m of additional reduction from the predicted standing water level or pressure (outside of pumping influences) over 2 consecutive months • Privately owned water supply adversely impacted from the mining (other than impact that is negligible)	No reduction in groundwater level or pressure greater than 5m over predicted effects (over 2 months) GW112441 adversely affected by hydrocarbon gas seep	Continue monitoring Bore to be replaced after completion of LW707 , or, if an alternative arrangement is agreed with the landowner
Water Quality IC monitoring bores • NGW6 • NGW5 Private Bores • Registered bores and any new		- Potential increased iron and manganese hydroxide precipitation in discharged bore water - Potential lowering of pH in discharged bore water		***Level 1*** • Groundwater quality reduction greater than 1 standard deviation but less than 2 standard deviation from pre-mining mean resulting from the mining for two	No reduction in water quality >1 but <2 standard deviations from the pre LW706 mining mean for 2 months	Continue monitoring

Longwall 706 TARPs and Impact Summary

Feature	Performance Measure*	Potential Impacts	*Exceeding* Prediction	TARP Trigger Level	Observed Impacts	Additional Comments / Recommendations
bores within the SMP area (where water quality samples can be taken)				consecutive months		
				Level 2 • Groundwater quality reduction greater than 2 standard deviation from pre-mining mean resulting from the mining for two consecutive months	No reduction in water quality >2 standard deviations from the pre LW706 mining mean for 2 months	Continue monitoring
				Level 3 • Level 2-type reduction in water quality resulting from the mining observed for more than 6 consecutive months	No reduction in water quality >2 standard deviations from the pre LW706 mining mean for 6 months	Continue monitoring

* Performance Measure as defined in BSO Development Consent Approval and Longwall 705 to 706 SMP Approval (Table 1).

References