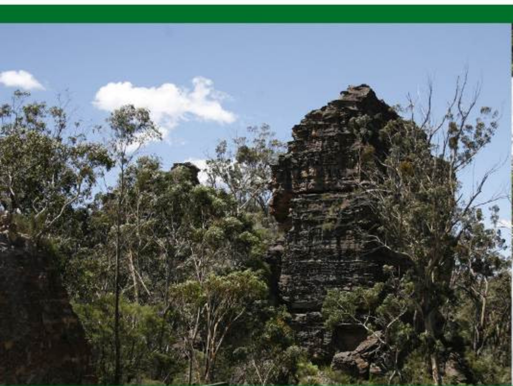
Centennial Coal

Springvale



Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan for LW 418

Springvale Mine

August 2015

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Glossary and Abbreviations

Abbreviation	Description
3-D	Three dimensional
ACARP	Australian Coal Association Research Project
AEMR	Annual Environmental Management Reports
AHD	Australian Height Datum
ANOVA **BAMM**	Analysis of Variance Biodiversity and Mapping Method
BoM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DOE	Department of the Environment
DRE	Department of Resources and Energy
EEC	Endangered Ecological Community
EP&A Act	Environmental Planning and Assessment Act (NSW)
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
EPL	Environment Protection Licence
GPS	Global Positioning System
LiDAR	Aerial Laser Scanning
LW	Longwall
MGA	Map Grid of Australia
ML	Mining Lease
MOP	Mining Operations Plan
MREMP	Mining Rehabilitation and Environmental Management Process
Mtpa	Million Tonnes per Annum
NES	National Environmental Significance
THPSS	Newnes Plateau Shrub Swamp
NPHS	Newnes Plateau Hanging Swamp
OEH	NSW Office of Environment and Heritage
POEO Act	Protection of the Environment Operations Act (NSW)
SEWPAC	Department of Sustainability, Environment, Water, Population and Communities
SMP	Subsidence Management Plan
TARP	Trigger Action Response Plan
THPSS	Temperate Highland Peat Swamps on Sandstone
TSC Act	Threatened Species Conservation Act 1995 (NSW)

1 Introduction

The Existing Springvale Mine is an underground longwall mining operation located in the Western Coalfield of New South Wales (NSW), approximately 120 kilometres (km) west-northwest of Sydney. The existing Springvale Mine is owned by Centennial Springvale Pty Limited (as to 50%) and Springvale SK Kores Pty Limited (as to 50%) as participants in the Springvale unincorporated joint venture. The Springvale Mine is operated by Springvale Coal Pty Limited (a wholly owned subsidiary of Centennial Coal Company Limited), for and on behalf of the Springvale joint venture participants.

This document is a monitoring and management plan (MMP) prepared in accordance with condition 7 of approval 2013/6881 issued to Springvale by the Department of the Environment (DOE). Approval 2013/6881 is related to a controlled action area of the Springvale Mine for the Extension Project (SSD5594) as shown in Figure 2.1. This MMP covers Longwall 418 only as shown in Figure 2.2.

These longwall panels mine directly below a section of an area known as the Newnes Plateau. The Newnes Plateau contains examples of Temperate Highland Peat Swamps on Sandstone (THPSS) which are listed as Endangered Ecological Communities (EEC) under the EPBC Act.

The terms THPSS and swamp are used interchangeably in this document and refer to the range of swamp EEC communities referred to above. Shrub swamps and hanging swamps can be identified separately due to differences in Hydrological regimes, flora assemblages and location.

The MMP details the rationale for the adoption of a reduced panel width design with widened chain pillars for Longwall 418 which is situated over the Newnes Plateau. Longwall 418 has a void width of 261m and chain pillar width of 58m. The benefit of the reduced panel width and wider chain pillars is reduced subsidence related impacts on the surface. The change in longwall design is a key mitigation measure designed to reduce subsidence related impacts on THPSS systems.

This document applies the same methodology as utilised in the Temperate Highland Peat Swamps on Sandstone Monitoring and Managements Plan for LW's 415-417 which was approved by DOE on the 21st of October 2013 and was independently peer reviewed by 2 experts.

1.1 Purpose

The purpose of the MMP is to provide a structure for monitoring THPSS systems to measure mining related impacts on THPSS systems. Measureable monitoring response triggers have been established to manage consequences from mining related impacts on THPSS systems.

1.2 Scope and structure

In accordance with the EPBC Approval Condition 7, this Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan has been prepared to manage the potential environmental consequences from mining longwall panel 418.

The MMP is structured as follows.

Section Number	Description
Section 1	Provides an introduction, the purpose of the document and responsibilities for actioning the MMP
Section 2	Provides an overview of conditions 6 and 7 of EPBC Approval 2013/6881
Section 3	Outlines the background and existing environment of the area and mining practices.
Section 4	Provides a general description of the THPSS and descriptions of individual swamps. Descriptions are provided for both the shrub swamps and hanging swamps located within the controlled area.
Section 5	Provides an assessment of the possible impacts resulting from the controlled action.
Section 6	Provides performance measures for monitoring
Section 7	Identifies the details of the monitoring programs for both shrub swamps and hanging swamps.
Section 8	Provides a summary of performance indicators and measures.
Section 9	Sets out a Trigger Action Response Plan (TARP) to provide management measures and corrective actions to deal with trigger level exceedences should any occur
Section 10	Outlines details of available remediation strategies using engineering solutions
Section 11	Outlines the requirements for MMP reviews and reporting procedures.

1.3 Responsibilities

The following Table provides a summary of the responsibilities of the relevant resources in implementing the plan.

Responsible Person	Responsibilities
Springvale Environment and Community Coordinator	Formulation and implementation of the THPSS monitoring and management plan (Condition 7q of the approval). Ongoing monitoring of the key parameters as described in this MMP.
Springvale Mine Manager	Ensuring that sufficient resources are available to implement the requirements of this MMP

2 Summary of EPBC Approval Conditions 6 and 7

Conditions 6 and 7 of EPBC Approval 2013/6881 set out the requirements of this MMP and are summarised below in Table 2.1.

Table 2.1 Summary of EPBC Approval Conditions 6 and 7 for the development of the Springvale Coal MMP

	Condition	Addressed in Section
6.	Within six months of the date of this approval, the person taking the action must submit a Temperate Highland Peat Swamps on Sandstone Monitoring and Management Plan ('Monitoring and Management Plan) for the **minister's** approval, to define clear, quantifiable and measureable criteria for monitoring the **impact** of longwall mining on temperate highland peat swamps on sandstone.	This MMP
7.	The Monitoring and Management Plan must include prevention, monitoring, mitigation and management actions for all potential **impacts** on the temperate highland peat swamps on sandstone ecological community arising from the action. The Monitoring and Management Plan must be a stand-alone document and include but not be limited to:	
(a)	monitoring must take into account the geological and hydrological context in which the swamps sit, i.e. monitoring must include methods to detect potential geological and hydrological impacts upstream of temperate highland peat swamps on sandstone	Section 5.1
(b)	monitoring must focus on surface and groundwater hydrology (including at least one piezometer per swamp), surface and groundwater quality, vegetation community structure and diversity and biological indicator species	Section 7.
(c)	monitoring must include at least one sample per season (four samples per year) at each sampling location for each parameter measured, though more frequent sampling may be required for some parameters	Section 7.1.2 Section 7.2.1
(d)	monitoring post-mining must continue for a period of at least 10 years. Monitoring frequency may be reduced once three years of post-mining swamp monitoring has been undertaken if swamp condition has not degraded as a result of mining activity	Section 7.1.2 Section 7.2.1
(e)	monitoring must include all temperate highland peat swamps on sandstone (including but not limited to both Newnes Plateau Shrub Swamps and Newnes Plateau Hanging Swamps) potentially affected by the proposed action **(impact sites)** as well as **reference sites. Reference sites** must include temperate highland peat swamps on sandstone that have never been subjected to, or are not predicted to be impacted by, **subsidence** impacts	Section 7 - Reference sites identified for each section of
(f)	details of the parameters monitored, methods, timing, frequency and location of baseline monitoring within the temperate highland peat swamps on sandstone ecological community	Section 7 – for flora, groundwater, surface water, subsidence

	Condition	Addressed in Section
(g)	definition and description of baseline conditions of individual temperate highland peat swamps on sandstone (including both **impact** and **reference sites**), including biological processes, condition, threats and the range of natural variability observed in parameters monitored	Section 3.6 – Provides an overview of land use on the Newnes Plateau that pose threats to swamps. Section 6 – describes potential impacts which are the main threats to swamp health. Appendices – Baseline conditions for flora, groundwater, surface water, subsidence
(h)	trigger levels sufficient to detect potential **impacts** of **subsidence** on the temperate highland peat swamps on sandstone ecological community, including information on how the triggers were derived using baseline monitoring and desktop study data. Triggers should be specific and measureable	Triggers levels identified in Section 6
(i)	details of the parameters monitored, methods, timing, frequency and location of **reference site** monitoring within the temperate highland peat swamps on sandstone ecological community	Section 7 – for flora, groundwater, surface water, subsidence
(j)	allowance and methods for trigger levels to be refined as more monitoring data is collected	
(k)	details of the parameters monitored, methods, timing, frequency and location of **impact site** monitoring within the temperate highland peat swamps on sandstone ecological community, sufficient to detect changes in the defined trigger levels	Section 7 – for flora, groundwater, surface water, subsidence
(l)	corrective actions to be taken should the defined trigger levels (as at condition 7h) be exceeded. These should be clear, measureable, auditable and include specific timing (e.g. within 6 months of **impact** detection). Implementation of a Response Strategy (as required at condition 13) should be included as a corrective action should **severe impacts** be detected	Section 9 and 10
(m)	details of how data collected by the proposed monitoring methods will be analysed. This must include a method to analyse data sets in an holistic manner to produce an overall indication of swamp health	Section 7 – Monitoring methodology
(n)	description of how potential **impacts** arising from the monitoring and mitigation measures themselves will be minimised or avoided	Section 7 – Monitoring methodology
(o)	maps illustrating the location of the longwall mining activity, past mining activities, expected **subsidence** limits, location of temperate highland peat swamps on sandstone within a 5 kilometre radius of the longwall mining activity and past and proposed monitoring locations for all parameters	
(p)	description of record keeping and reporting procedures	Section 11

	Condition	Addressed in Section
(q)	the plan must clearly state the person responsible, including their position or status	Section 1.3
(r)	the plan must include a timeline for review and provision for revisions to be approved by the **department** prior to their implementation	Section 11
8.	The Monitoring and Management Plan must be reviewed by two **independent reviewers** approved by the **department** prior to the submission to the department for approval	Independent reviewers approved by SEWPAC – 22 June 2012
9.	If the **minister** approves the Monitoring and Management Plan then the approved Monitoring and Management Plan must be implemented	

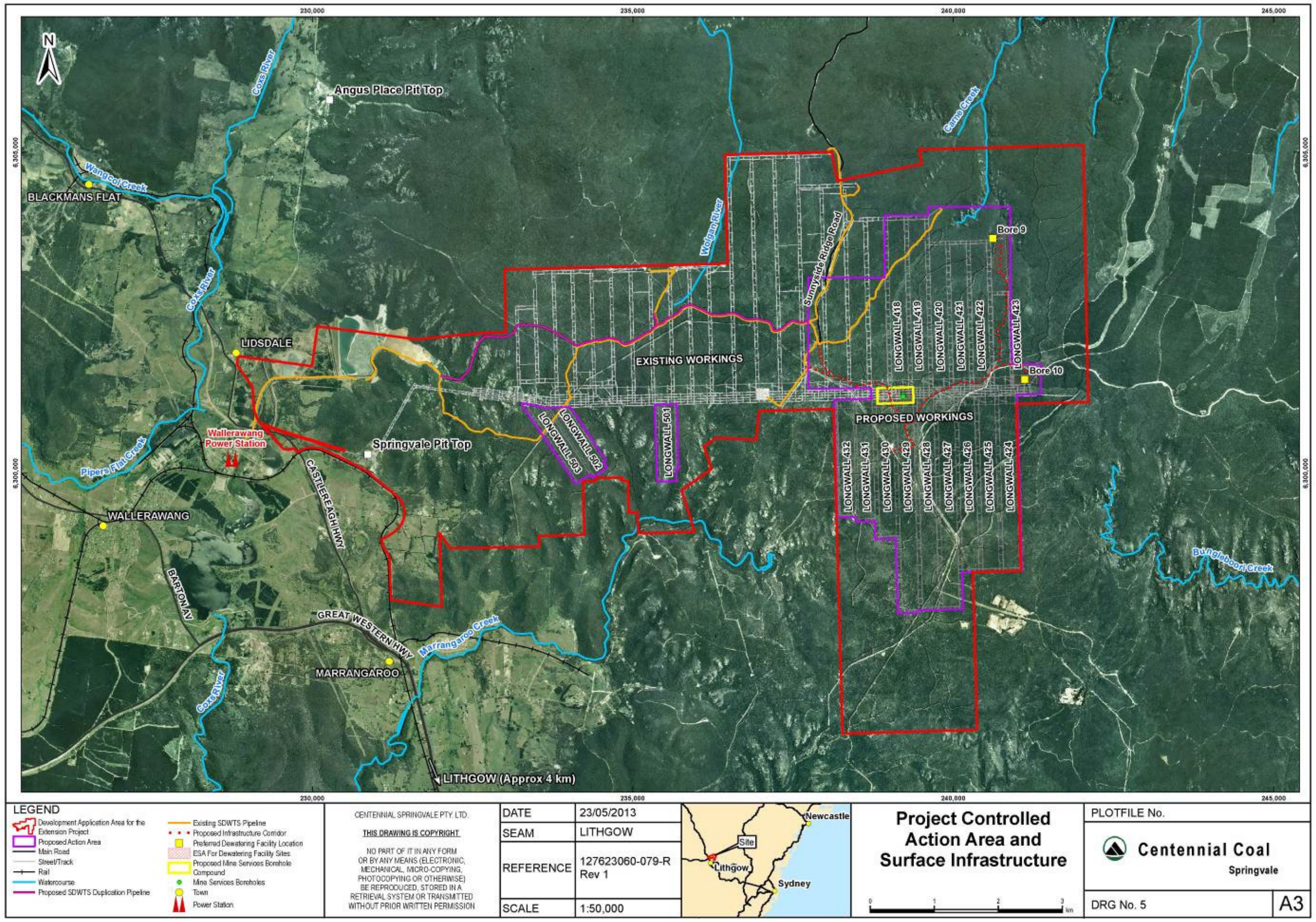


Figure 2.1 Entire Springvale Mine Extension Project Controlled Action Area

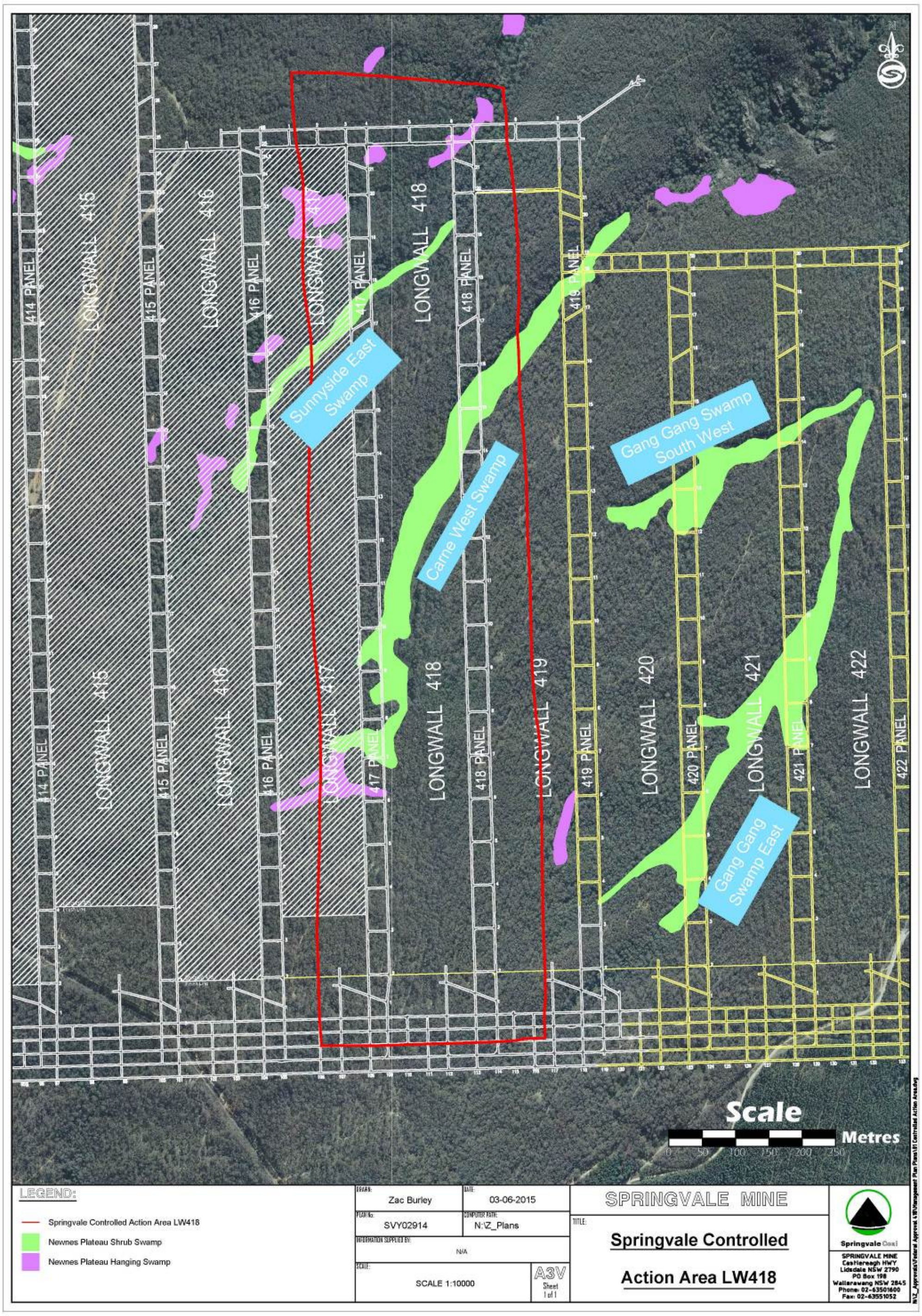


Figure 2.2 LW 418 Controlled Action Area

3 Background

3.1 Geological Setting

The area overlying Springvale Mine forms part of the Newnes Plateau. The underlying strata are mostly sandstones of the Triassic Narrabeen Group with inter-bedded shale and siltstone.

The Narrabeen Group rocks near the surface belong to the Grose Sub-group and include the Banks Wall Sandstone, the uppermost part of which is deeply weathered and generally very friable. The sandstone, which is up to 200 metres thick in this region overlies the Mt York Claystone which is a thin fine-grained stratum that limits vertical infiltration of groundwater from the overlying strata. The Mt York Claystone overlies the Burra-Moko Head Sandstone and the Caley Formation, which forms the base of the Narrabeen Group.

The Narrabeen Group overlies the Illawarra Coal Measures which are made up of claystone, siltstone, sandstone and coal seams with an average thickness of 120 metres in this area. The Lithgow Seam, which will be extracted in LW 418 is the lowermost seam in the coal measures and is typically located three to four metres above the base of the Illawarra Coal Measures. The Illawarra Coal Measures overlie the claystone/ siltstones of the Nile Group. Table 3.1 summarises the local stratigraphy.

Table 3.1 – Stratigraphy

Age	Group	Formation	Approximate Thickness	Height of base above Lithgow Seam
Triassic	Narrabeen Group	Banks Wall Sandstone	100 – 200 m	205 m
		Mt York Claystone	< 5 m	200 m
		Burra-Moko Head Sandstone Caley Formation	~100 m	105 m
Permian	Illawarra Coal Measures	Various	~100 m	0 m
		Lithgow Coal	< 3 m	

3.2 Comparison of Lithgow Geology and NSW South Coast Geology

The geology of the Lithgow and NSW South Coast areas is quite similar in that both sites have massive Narrabeen Group Sandstone units overlying Illawarra Coal Measures. The surface topography has been shaped by similar geomorphological processes as well, with strong plateau and valley systems expressed by the incumbent weathering patterns, surface lithologies and geological structure locations.

The key difference however, is the Southern Coalfield also has significant thicknesses of quartz rich sandstone associated with the Triassic Hawkesbury Sandstone, whereas the Western Coalfield does not. The Hawkesbury Sandstone is typically stronger and stiffer than the Narrabeen Group sandstones and has higher propensity to develop and sustain deeper valley gorges with significantly higher horizontal stress field magnitudes. Far-field valley closure and uplift movements due to subsidence effects are therefore the highest observed in the Australian Coalfields.

The Western Coalfield has a gentler surface topography with broader and shallower valley / plateau systems and lower valley closure response to mine subsidence.

The surface soils above the Hawkesbury sandstones also tend to be sandier and thinner than the Narrabeen Group counterparts, which increases the likelihood of surface cracking occurrences in tensile and compressive strain zones above longwall panels. The development of cracks in the Western Coalfield is similar to the Southern Coalfield only where surface sandstone rock exposures exist. In locations where deeper, clayeyer soils exist above the plateaus and peat swamps in the valleys, surface cracking is rare for tensile and compressive strains of up to 5 mm/m and 14 mm/m respectively. The width of the cracks when they occur, also tend to be significantly narrower for the strain range observed.

The above observations suggest that the soil profiles above the Western Coalfield panels, and possibly the degree of weathering of near surface Narrabeen Group strata, are more able to absorb higher strain magnitudes than the Hawkesbury Sandstone dominated terrain.

The greater depth of cover in the Southern Coalfield has already been identified as a key causal parameter for the similar magnitudes of subsidence observed between the Coalfields despite some of the Southern Coalfield longwalls being narrower (eg Metropolitan Mine) than Angus Place and Springvale Mine Panels. This is due to the greater loading and increased compression of chain pillars and roof and floor strata that occurs above the deeper panels in the Southern Coalfield.

3.3 Hydrology

The majority of rain water falling on the Newnes Plateau flows into watercourses in the form of surface runoff. However, a percentage of rainfall infiltrates below the ground surface recharging groundwater systems. This infiltration has been modelled at between 0.1 – 10% of rainfall depending on surface slope, surface disturbance and other surface characteristics. Losses associated with evapotranspiration are assumed to occur only in the upper one metre of the ground surface.

Longwall panel 418 lies within the Hawkesbury-Nepean catchment area. The site is crossed by two small drainage lines, the Sunnyside East and Carne West watercourses. These two water courses flow to the NNE into Carne Creek in the upper reaches of the Colo River. The catchment area of these two drainage lines within the proposed extraction area is around 375 hectares. The catchment is covered largely with sparse to dense woodland and both watercourses support THPSS systems.

The soils are derived from the Banks Wall Sandstone and are generally very sandy with high infiltration. This means that surface run off following rainfall in catchments undisturbed by human activity is relatively low. Both the Sunnyside East and Carne West drainage lines support perennial streams due to the groundwater feed from a lateral aquifer in a shallow groundwater system. However, these streams do cease to flow in extended dry conditions and during droughts.

3.4 Hydrogeology

Hydrogeological monitoring in the Springvale controlled action area commenced in 2005 and extensive investigations have been carried out since. Groundwater modelling work has been completed by expert consultants, ACARP research work and by the CSIRO. ACARP Project C14033, Hydrogeological Response to Longwall Mining (2007), was conducted by CSIRO to develop a conceptual hydrogeological model for the Springvale mining area using the COSFLOW modelling tool. Further monitoring and investigative work has been carried out since this time to refine and build on this original model. This conceptual model is currently being expanded to cover a 30km x 30km area which comprises a range of past and present mining operations around the Newnes Plateau area including Springvale and Angus Place mines. The modelling work has been commissioned by Centennial Coal and will be completed by the CSIRO.

The hydrogeology of the Newnes Plateau above LW 418 is influenced largely by the inter-bedded sandstones, clay stones and siltstones of the Narrabeen Group rocks. The sandstones generally have a higher permeability than the less permeable clay stones and siltstones. This leads to the formation of aquifers in the permeable sandstone layers with the clay stones and siltstones acting as aquitards. For the purposes of this document the term aquifer means stratum that has a high groundwater carrying capacity relative to the surrounding rocks.

There are three general groundwater systems that have been identified in the region. These include:

- **Perched groundwater system (AQ5)** – a discontinuous, near-surface system generally independent of the regional groundwater systems and located within 15 metres of the ground surface. The perched groundwater is derived from excess rainfall which is largely prevented from infiltrating deeper down into the regional systems by the presence of near-surface fine grained beds such as clay stone or siltstone. These systems are important for the establishment and ongoing survival of hanging swamps.
- **Shallow groundwater system (AQ4 A and AQ4 B)** – this is a regional groundwater system located in the Banks Wall Sandstone and extends to a depth of up to 100 metres (). This aquifer appears to be confined at the base by the Mt York Claystone with little or no confining layer below permanently water logged swamp systems. This aquifer is important for the development and ongoing maintenance of permanently water logged shrub swamp systems.
- **Deep groundwater system (AQ1 – AQ3)** – a deep groundwater system contained within the Illawarra Coal measures. This system is at depths greater than 200 metres and is unlikely to be important for the development or maintenance of shrub or hanging swamps.

Figure 3.1 shows a representative hydrogeological section for the Springvale Coal mining area along with a stratigraphic column showing geology.

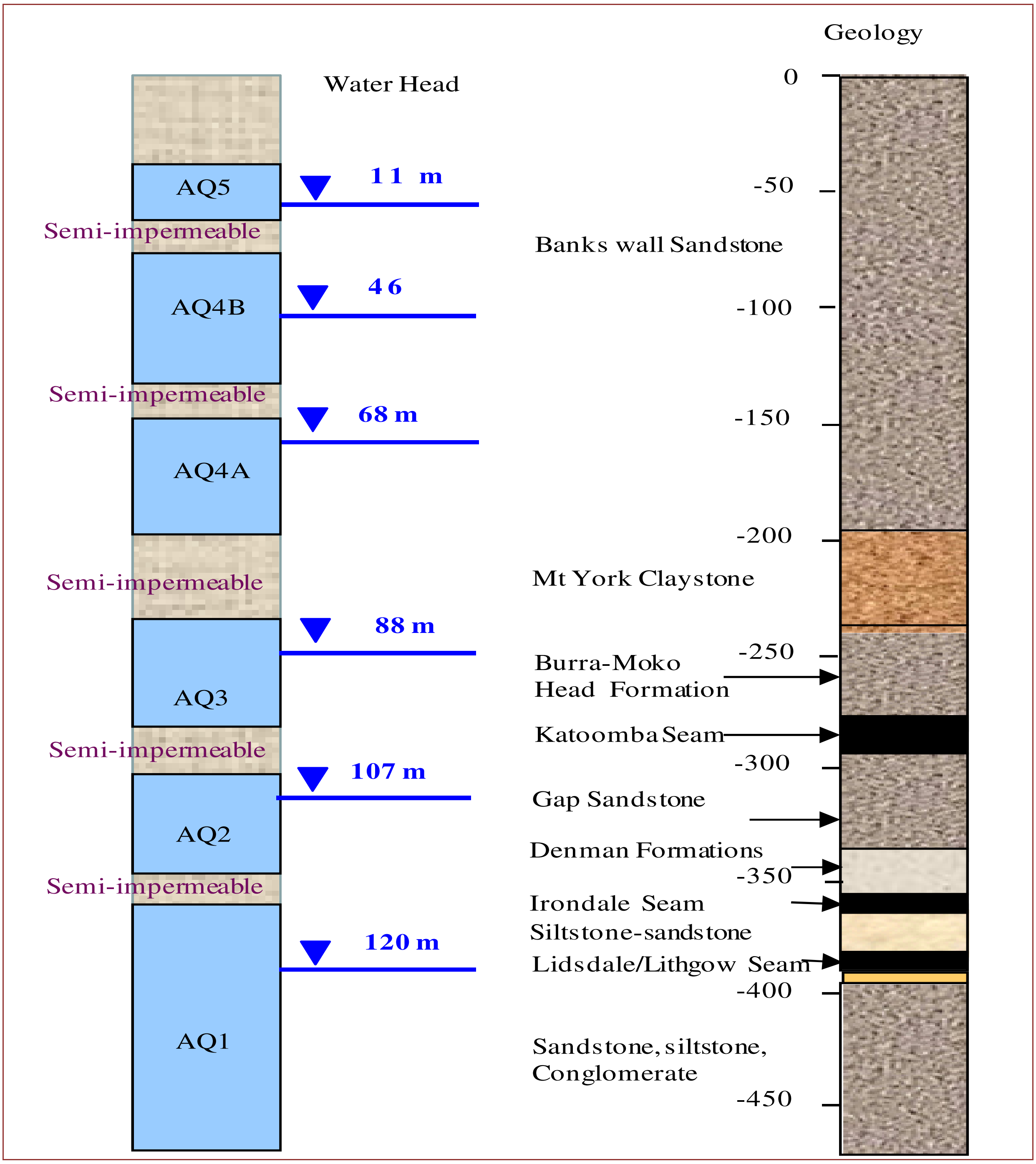


Figure 3.1. Representative Hydrogeological and Geological Section for the Springvale Coal Mining Area (ACARP C14033)

Only the perched (AQ5) and shallow groundwater (AQ4 A and AQ4 B) systems are of relevance to the Springvale THPSS MMP as these are the systems that support THPSS. The relationship between the hydrogeology and shrub and hanging swamps in the area is shown diagrammatically in Figure 3.2.

The results of the groundwater and surface water monitoring in the swamps have enabled the development of a conceptual model of the near surface hydrogeological regime in the shallow groundwater system in the Springvale lease area. This has been complemented by a series of open hole piezometers drilled along the ridgelines into the lateral aquifer that feeds the swamps. The data have been used to construct the model shown in Figure 3.3.

This figure shows the interpreted location of the local aquitard beneath swamps and ridges. Groundwater modelling suggests that the local aquitard dips in a north-easterly direction and forms a base under the peat/sand material associated with Sunnyside East Swamp and Carne West Swamp.

The groundwater held in the water-bearing strata above the aquitard discharges into the swamps located in the base of valleys, saturates the peat/sand material and flows down the in swamp drainage lines. Groundwater flows are sub perennial due to the high groundwater table beneath the ridges flanking the swamps. A clear relationship between rainfall and surface flow is observed at both Sunnyside East Swamp and Carne West. The decrease in flow and in some cases cessation of flow has been observed at both Sunnyside East Swamp and Carne West prior to mining occurring. This observation was recorded several years prior to mining occurring within the controlled action areas of the swamps

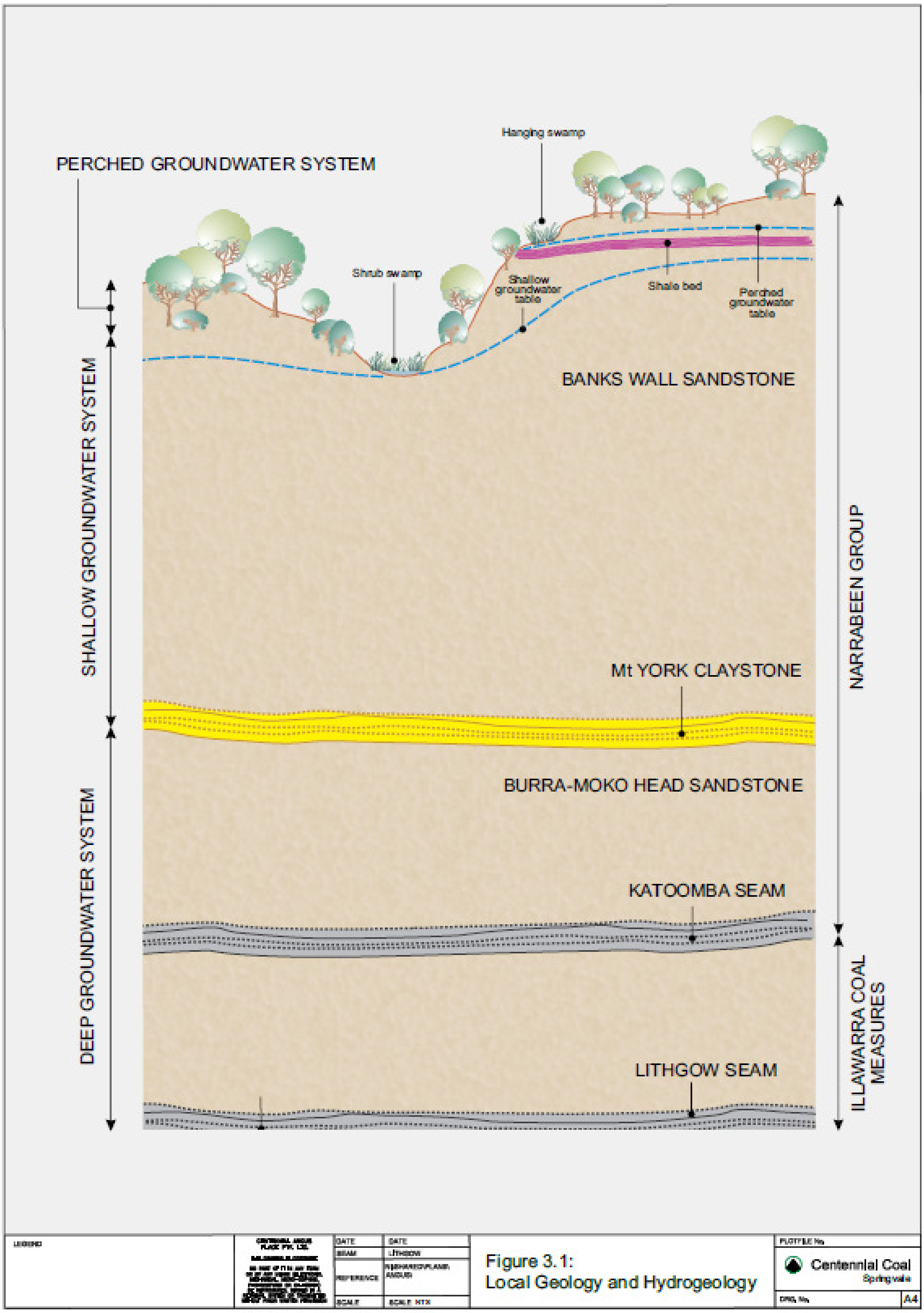


Figure 3.2 – Local Hydrogeology and Settings for Shrub and Hanging Swamps

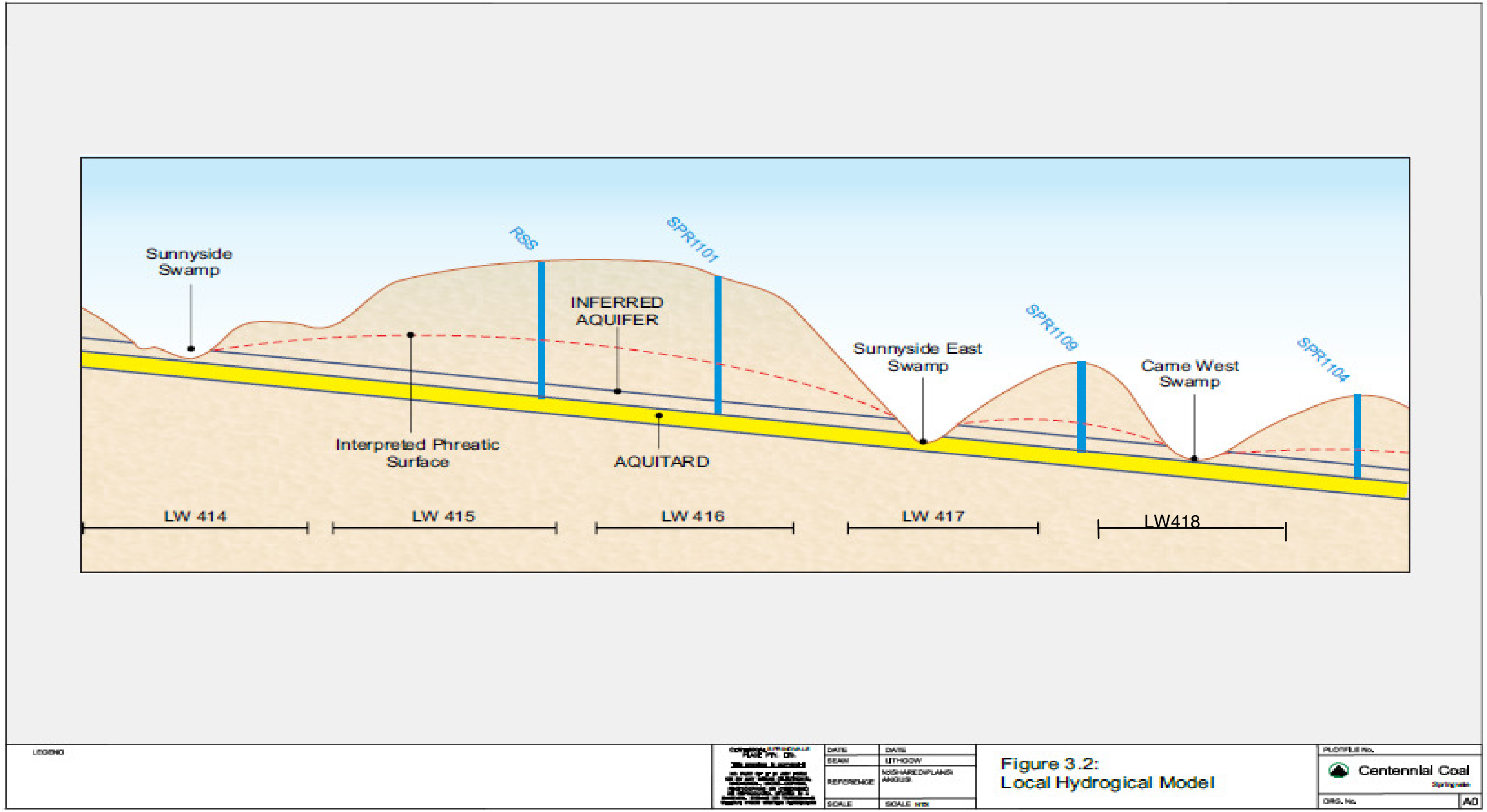


Figure 3.3 – Conceptual Hydrogeological Model for AQ 4A, AQ 4B and AQ 5

3.5 Meteorology

A weather station was established on the Newnes Plateau in 2002 in the southern area of the Springvale mining lease. The station measures rainfall and temperature. The weather station was established due to the difference in climate between the Lithgow Bureau of Meteorology station and the Newnes Plateau. However, there is a spatial relationship between weather in these two locations and this relationship is used during the analysis of monitoring data i.e. if there is a gap in the Newnes Plateau weather data then the Lithgow data are used with the relationship applied.

A summary of the rainfall data from the Newnes Plateau weather station since 2003 is presented in Table 3.2 and shown in graphical form in Figure 3.4. The graph shows that the Newnes Plateau was in rainfall deficit of more than one metre since 2003.

Apart from 2007, the period between 2003 and 2009 was relatively dry with consecutive years receiving well below the average rainfall expected for the Newnes Plateau. Half of the long term average rainfall was recorded for 2006. Above average rainfall conditions returned at the end of 2010 with total rainfall marginally above average at 1,215mm. This was followed in 2011 by reasonably average rainfall conditions. Further rainfall deficit has been observed since 2012.

Table 3.2 – Local Rainfall Conditions

Year	Plateau - Average Rainfall (mm)	Plateau - Measured Rainfall (mm)	Lithgow - Average Rainfall (mm)	Lithgow - Measured Rainfall (mm)	Rainfall Deficit/Surplus	
					Annual (mm)	Total (mm) since 2002
2003	1,026.0	855.2	869.5	612.8	-170.8	-170.8
2004		837.2		647.0	-188.8	-359.6
2005		912.6		793.8	-113.4	-473.0
2006		529.0		536.9	-497.0	-970.0
2007		1,117.3		969.6	91.3	-878.7
2008		934.6		800.7	-91.4	-970.1
2009		794.8		738.1	-231.2	-1,201.3
2010		1,215.8		968.9	189.8	-1,011.5
2011		1,030.8		884.7	4.8	-1,006.7
2012		948.6		793.3	-77.4	-1084.1
2013		794.7		741.9	-231.3	-1315.4
2014		874.8		743.4	-151.2	-1466.6

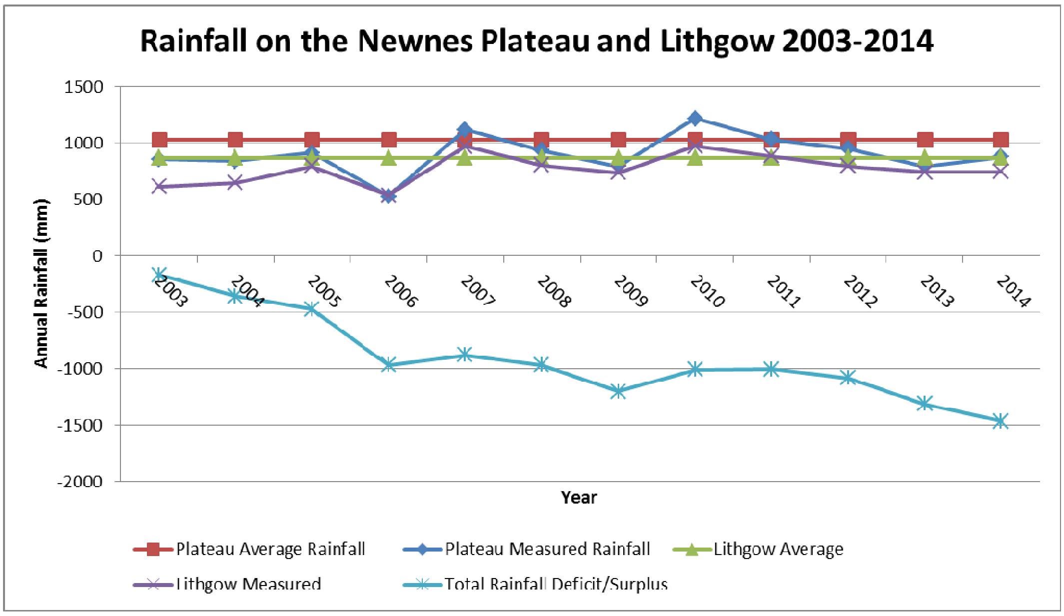


Figure 3.4 – Annual Rainfall Patterns 2003 – 2014

3.6 Mining and Subsidence Mitigation

Mining commenced at Springvale in 1992. Since this time 18 longwall panels have been mined. Details of the mining proposed in the controlled action area for LW 418 are summarised below, and the location of the longwall panel in the approved area are shown in Figure 2.1. The term approved mining used in this MMP refers to mining approved in the Springvale SMP.

Seam:	Lithgow Seam
Extraction Thickness:	3.25 metres
Depth of Cover:	360 metres
Panel Width:	260.9 metres
Chain Pillar Width:	58 metres
LW 418 Extraction:	August 2015 to March 2016

The Springvale Mine Extension Project (SSD5594) extended the life of mine for an additional 13 years with rehabilitation being undertaken after this period. Springvale Colliery provides employment for approximately 310 employees. In addition the employment flow on benefits in the region results in an additional 4.5 jobs being created for every full time person employed at Springvale.

Mine planning has been undertaken to address environmental issues as well as using commercially sound principles that enable mining to continue into the future. In 2011 Springvale Coal varied their approved Subsidence Management Plan to adopt a narrow panel longwall design with wider chain pillars that focused on achieving reduced subsidence related impacts on the environment. This design is a key mitigation initiative designed to reduce surface subsidence and therefore potential impacts on THPSS systems. The dimensions of the narrow panel longwall design were based on the threshold where the longwall design went from critical to sub-critical with respect to economic operation of the mine. Any further reduction in longwall panel width would result in marginal improvements in subsidence mitigation but would significantly affect the economics of the mining operation. A plan showing mining within a five kilometre radius of the Springvale workings is set out in an envelope at the rear of this MMP.

3.7 Land Use

It is important to identify the impacts of non-mining related land use during an assessment of mining related impacts. In circumstances when monitoring data triggers the action response plan it will be necessary to assess these non-mining related impacts before management intervention is undertaken.

The Newnes Plateau above Springvale Mine is subject to a variety of land uses. The plateau is a state forest subject to logging and is open to recreational use by public. These non-mining related land uses can result in point source and diffuse source disturbance to THPSS systems. These land uses include:

- **Forestry activity** is the most intense land use on the plateau and includes tree logging, track construction, undergrowth clearing and burning. These activities lead to significant land changes through increased run-off and sediment transport, weed invasion and an altered fire regime. These impacts are experienced throughout the plateau area including the THPSS systems.
- **Four-wheel drive and motor bike activit**y the plateau is freely accessible to the public including recreational four wheel drive enthusiasts and motor bike riders. These activities are unregulated and result in the development of tracks in and adjacent to the THPSS. Many of these tracks are unplanned and unmaintained and can result in accelerated runoff, erosion and weed invasion.
- **Feral pig activity** results in land disturbance during pig foraging activity. This results in accelerated erosion and a decrease in water quality in drainage lines.
- **Hunting** can affect native wildlife numbers and movements. New tracks are often formed which results in increased erosion and run-off.
- **General public access** can lead to an increased incidence of bushfires, introduction of weeds, introduction of feral animals and accumulation of rubbish.

3.8 Threats to Swamp Systems

There are a range of potential threats that may cause impacts to swamp systems. A list of threats is set out below. A description of specific threats that may affect individual swamps is set out in Appendix B.

Natural Threats

Bushfires

Drought

Storms

Burrowing Wildlife

Anthropogenic Threats

Changes in fire regime

Climate change

Feral animals

Forestry activities

Human recreation

Mining activities

Monitoring activities

Pine tree invasion

Rubbish

Unsealed roads

Water discharge

Water harvesting

Weeds

4 Description of Swamps

There are three characteristic THPSS systems on the Newnes Plateau. These systems are referred to as shrub swamps, hanging swamps and rush sedge snow gum hollow wooded heath. No rush sedge snow gum hollow wooded heath community was identified in the controlled action area during vegetation mapping for Western Blue Mountains mapping (DEC, 2006). Therefore a generalised description of only shrub swamps and hanging swamps is set out below. A detailed description of these swamps is set out in Appendix B.

4.1 Shrub Swamps

Shrub swamps develop on the Newnes Plateau at altitudes in excess of 1,000 metres in the bases of valleys underlain by the Narrabeen Group strata. The swamps have formed in areas which are subject to periodic to permanent waterlogging caused by a supply of water from groundwater, surface runoff and rainfall. These swamps have a characteristic floral assemblage which is largely a result of the physical location in the base of valleys and the hydrological regime. The base of these swamps characteristically have low slopes angles which means that surface water flows have a relatively low velocity and water retention is therefore high.

4.2 Hanging Swamps

Hanging swamps develop on the Newnes Plateau at altitudes in excess of 1,000 metres on the flanks of valleys underlain by the Narrabeen Group strata. The swamps have formed in areas which are subject to infrequent waterlogging caused by a supply of water from perched groundwater systems, surface runoff and rainfall. These swamps have a characteristic floral assemblage which is largely a result of the physical location on the flanks of valleys and the hydrological regime. The base of hanging swamps is generally at a higher slope angle than shrub swamps which means that hanging swamps are less able to retain water as it drains away along the higher slope angles.

Shrub swamps and hanging swamps can be identified separately due to differences in:

- **Hydrological regimes.** Shrub swamps are more likely to be permanently water logged due to a more reliable groundwater source and relatively low sloping swamp base. Hanging swamps are less likely to be waterlogged due to smaller more localised perched groundwater systems and steeper slope angles on the base of the swamps.
- **Flora assemblages.** Floral assemblages within the two swamp systems vary due to the physical setting and hydrological regimes.
- **Location.** Shrub swamps occupy the bases of valleys whereas hanging swamps develop higher up on the flanks of valleys.

THPSS systems are dynamic evolving systems similar to all other water courses. These systems experience natural perturbations such as erosion, slumping and piping and damage from wildfires and have an inherent ability to “self-repair” following these events (Goldney et al). The peat / sand substrate is flexible and mobile and can to an extent adjust to these dynamic perturbations.

The physical and hydrological setting of shrub and hanging swamps is shown on Figure 3.1. The location of the impact and reference THPSS are shown on Figure 4.1.

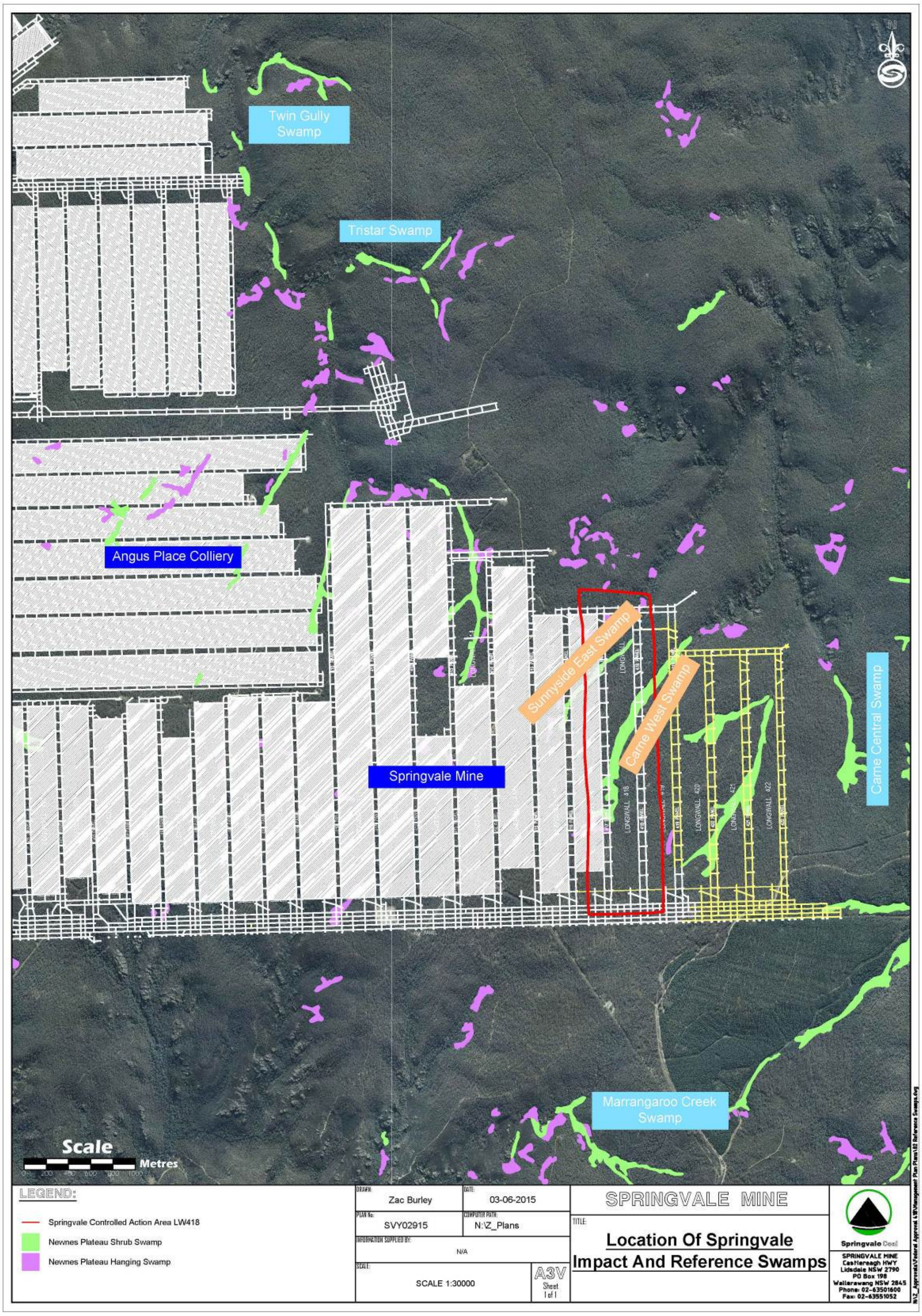


Figure 4.1. Location of Impact and Reference THPSS

5 Assessment of Potential Impacts

This section describes the potential impacts associated with the extraction of LW418 under the THPSS.

5.1 Potential for changes in Surface flows

Mining can potentially affect surface water flows through swamps, if the mining induced tilts are much greater than the natural gradients, potentially resulting in increased levels of ponding or scouring, or affecting the distribution of the captured water within swamps.

The maximum predicted tilts are 13 mm/m (i.e. 1.3 %, or 1 in 75) for both the shrub swamps and hanging swamps within the Extension Area. The mining induced tilts are small when compared with the natural gradients within the swamps. This is illustrated in Fig. 5.1 and Fig. 5.2, which show the natural grades and the predicted post mining grades along the alignments of the drainage lines through the shrub swamps.

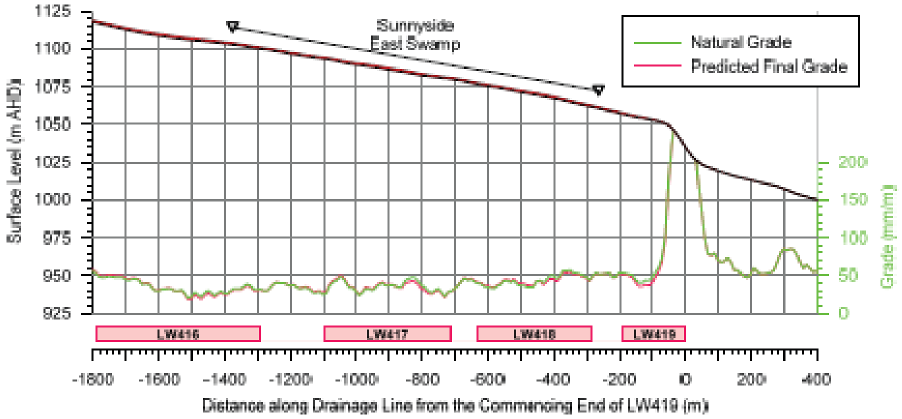


Figure 5.1 Natural and predicted post mining levels and grades for Sunny side east swamp

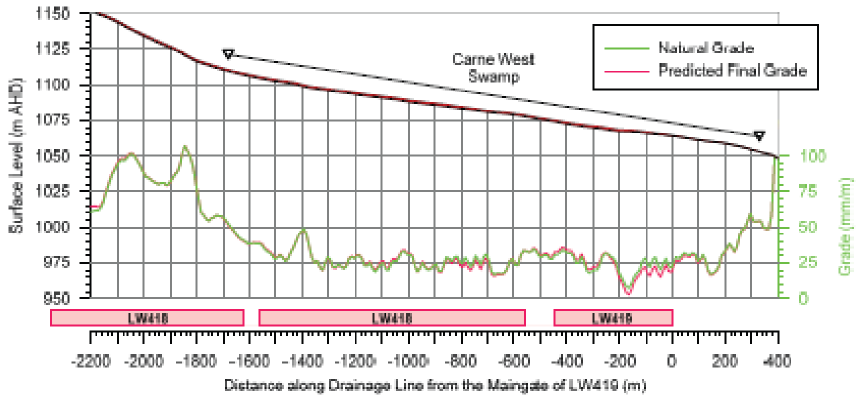


Figure 5.2 Natural and predicted post mining levels and grades for Carne West

It can be seen from the above figures, that the predicted post mining grades are similar to the natural grades within the shrub swamps. There are no predicted significant reductions or reversals of grade. The hanging swamps are located on the sides of the valleys and, therefore, that natural gradients are greater than those shown for the shrub swamps.

It is not expected, therefore, that there would be any adverse changes in ponding or scouring within the swamps resulting from the predicted mine subsidence movements. It is also not anticipated that there would be any significant changes in the distribution of the stored surface waters within the swamps as a result of the mining induced tilt or vertical subsidence.

Whilst scouring was observed in a number of swamps located above the previously extracted longwalls at Angus Place and Springvale Collieries, investigations have shown that these were generally the result of other activities such as mine water discharge, rather than mine subsidence itself

5.2 Potential for Cracking in the Swamps and Fracturing of Bedrock

Fracturing of the uppermost bedrock has been observed in the past, as a result of longwall mining, where the tensile strains have been greater than 0.5 mm/m or where the compressive strains have been greater than 2 mm/m.

The swamps which are located outside the extents of the proposed longwalls, including Sunnyside Swamp and Nine Mine Swamp, are predicted to experience tensile strains less than 0.5 mm/m and compressive strains less than 2 mm/m due to the proposed mining. It is unlikely, therefore, that the bedrock beneath these swamps would experience any significant fracturing.

Fracturing has been observed in streams located outside the extents of previously extracted longwalls in the NSW Coalfields. Minor and isolated fracturing has been observed up to 400 metres from longwalls, however, these have occurred within large river valleys in the Southern Coalfield and have not resulted in any adverse impacts. Hence, it is possible that some minor and isolated fracturing could occur in the bedrock beneath the swamps located outside the extents of the proposed longwalls, however, it is unlikely to result in any adverse impacts on these swamps.

The swamps which are located directly above the proposed longwalls are predicted to experience tensile strains greater than 0.5 mm/m and compressive strains greater than 2 mm/m. It is expected, therefore, that fracturing would occur in the top most bedrock beneath these swamps.

The surface cracking across the mining area is expected to be generally isolated and minor in nature, due to the reasonable depths of cover which typically vary between 350 metres and 400 metres, and due to the plasticity of the surface soils which allows them to more readily absorb the ground strains. Surface crack widths are expected to be similar to those observed above the previously extracted longwalls at Angus Place and Springvale Collieries, which were typically between 5 mm and 25 mm, but with isolated surface cracking in some locations greater than 50 mm.

The shrub swamps have peat layers which overlie the shallow natural surface soils and underlying bedrock along the alignments of the drainage lines. In most cases, cracking would not be visible at the surface within these swamps, except where the depths of bedrock are shallow or exposed. The shrub swamps comprise significant quantities of sediment and, therefore, fracturing of shallow bedrock beneath these swamps are likely to be filled with soil during subsequent flow events along the drainage lines.

The hanging swamps have soft soil or peat layers which overly the bedrock on the valley sides. It is expected that the potential for fracturing in these locations would be less when compared to the bases of the valleys, where higher compressive strains occur due to the valley related movements, and due to the higher depths of cover along the valley sides.

Whilst some minor surface cracking could occur in the swamps resulting from the extraction of the proposed longwalls, the previous experience of mining beneath swamps at Angus Place, Springvale and in the Southern Coalfield indicate that the likelihoods and extents of these impacts are very small.

The valley related upsidence movements could result in the dilation of the strata beneath the shrub swamps. It has been observed in the past, that the depth of fracturing and dilation of the uppermost bedrock, resulting from valley related movements, is generally less than 10 metres to 15 metres (Mills 2003, Mills 2007, and Mills and Huuskes 2004).

The dilated strata beneath the drainage lines, upstream of the swamps, could result in the diversion of some surface water flows beneath parts of the shrub swamps. It is noted, however, that the drainage lines upstream of the swamps are generally ephemeral and, therefore, surface water flows occur during and shortly after rainfall events. Any diverted surface water flows are expected to remerge short distances downstream, due to the limited depth of fracturing and dilation and due to the high natural stream gradients

An environmental monitoring program was established to assess the effects of longwall mining on the groundwater systems associated with the swamps at Angus Place and Springvale Collieries. The monitoring comprised swamp piezometers, shallow aquifer piezometers and multi-level vibrating wire piezometers at Junction, Sunnyside, Sunnyside West and West Wolgan Swamps. The monitoring results were reviewed by RPS (2012) which found that:

"In general, swamp water level fluctuations show a strong relationship to the CRD [cumulative rainfall distribution] for both A and C type swamps rather than a relationship due to longwall mining".

That is, the monitoring results provided no evidence that longwall mining had affected the groundwater systems for these swamps. Further discussions on the potential impacts on the shallow groundwater system are provided by the specialist groundwater consultant in the reports by RPS (2013b) and CSIRO (2013).

The width-to-depth ratios for the proposed LW416 to LW431 are typically between 0.65 and 0.75, which are less than those for the previously extracted longwalls at Angus Place and Springvale Collieries. Also, the predicted conventional and valley related movements for the swamps located above the proposed longwalls are similar to the ranges predicted for the swamps previously mined beneath on the Woronora Plateau. The potential impacts for the swamps within the Extension Area, therefore, are expected to be similar to or less than those which have occurred where longwalls have been previously extracted beneath swamps.

13 shrub swamps and 26 hanging swamps have been directly or partially mined beneath at Angus Place and Springvale Collieries, and over 500 swamps have been directly mined beneath on the Woronora Plateau in the Southern Coalfield. The studies undertaken indicate that the incidence of impacts on swamps due to mine subsidence ground movements is very low and, in some of these cases, the impacts that were observed were associated with natural events or mining related surface activities. It is expected, therefore, that the incidence of impacts on the swamps within the Extension Area resulting from mining induced ground movements will also be low.

Further discussions on the potential impacts due to changes in surface water flows and storage are provided by the specialised surface water consultant in the report by RPS (2013a) and the specialist ecology consultant in the report by RPS (2013c).

5.3 Impact Assessment for swamps based on increased predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilts would be 26 mm/m (i.e. 2.6 %, or 1 in 40) for the shrub swamps and hanging swamps. In this case, the mining induced tilts would still be similar to or less than the natural gradients within the swamps, which typically vary between 25 mm/m and greater than 100 mm/m. It would still be unlikely that there would be any adverse impacts on the surface water flows and storage within the swamps.

If the actual curvatures, strains or valley related movements exceeded those predicted by a factor of 2 times, the likelihood and extent of fracturing, buckling and dilation in the topmost bedrock would increase for the swamps which are located directly above the proposed longwalls. As discussed previously, significant quantities of sediment are found above the bedrock at the swamps which is highly fractured and weathered naturally.

While the predicted ground movements are important parameters when assessing the potential impacts on the swamps, experience from mining beneath swamps at Angus Place, Springvale and in the Southern Coalfield indicate that the potential for impacts is low.

Further discussions on the potential impacts on the swamps are provided by the specialist surface water consultant in the report by RPS (2013a), the specialist ground water consultant in the reports by RPS (2013b) and CSIRO (2013), and the specialist ecology consultant in the report by RPS (2013c).

6 Performance Measures, Indicators and Response Triggers

Performance measures and indicators have been designed to provide a link between monitoring data and the response triggers (triggers) that determine whether mining related impacts are occurring in the THPSS. Management actions are implemented if trigger levels are exceeded (see Section 9).

Triggers are measureable thresholds that are used to determine whether changes in the physical setting and / or ecological processes are within or above a range that would be expected to occur naturally in swamp systems. Trigger levels have been developed for subsidence, flora, groundwater and surface water. The triggers are designed to capture any early mining related impacts i.e. soon after mining has occurred below the Newnes Plateau as well as lagging triggers. The early warning triggers have been developed for subsidence and groundwater level which are designed to quickly determine whether any mining induced changes in swamp systems have occurred.

There are also a series of lagging triggers which are used to indicate whether any mining impacts are detected after mining has moved on from any point in space and time. These triggers have been set to determine effects on flora and surface water quality. Any mining related impacts on flora or surface water quality would be expected to manifest months or possibly years following mining. All triggers have been developed through statistical analysis of pre-mining monitoring data with post mining monitoring data used to determine whether trigger thresholds have been exceeded. Triggers values set out in this MMP are dynamic and will be reviewed and updated as more monitoring data are collected and added to data sets as required by condition 7(j).

Exceedence of a trigger level threshold does not necessarily mean that a severe impact has occurred on a THPSS. If a trigger level threshold has been exceeded this will initiate an investigation to determine what caused the trigger threshold to be exceeded. The investigation process is set out in Charts 2 and 3 in Section 9 of this MMP.

Performance measures, indicators and triggers are set out below and summarised in Table 8.1 in Section 8.

Performance measures and indicators for subsidence specific to Longwall 418 for shrub and hanging swamps are set out in Table 6.1.

Table 6.1 – Subsidence Performance Measures and Indicators

Location	Performance Measures	Performance Indicators
LW 418	No anomalous subsidence within shrub swamps	Subsidence
		Tilt
		Tensile strains
		Compressive strain
		Upsidence
		Closure
LW 418	No anomalous subsidence in hanging swamps	Erosion
		Cracking

Performance measures and indicators for shrub and hanging swamps for flora, groundwater and surface water are set out in Table 6.2.

Table 6.2 – Flora, Groundwater and Surface Water Performance Measures and Indicators

Feature	Performance Measures	Performance Indicators
Flora	Negligible mining-related impact on swamp vegetation communities	• diversity of species • overall change in species assemblage • condition of key species • non live ground cover
Groundwater	Negligible mining-related impact on swamp hydrogeological regime	• Groundwater levels • Groundwater quality
Surface water	Negligible mining-related impact on swamp hydrological regime	• Surface water quality

For the purposes of this plan, **negligible** as referred to in Table 6.2 is defined as:

"in the longer term being small and insignificant and causing little or no impact. Short term impacts may be greater than negligible but if they are of limited duration they may be negligible when considered over the longer term".

6.1 Trigger Overview

The following triggers have been developed using baseline monitoring data collected on the Newnes Plateau above and adjacent to Centennial Coal mines. This data have been used to develop a series of triggers that will be used to determine whether any mining related impacts have occurred during and following mining in longwall panels 418. Triggers have been developed for individual parameters that are most likely to indicate mining related impacts as shown below:

- Subsidence
- Flora
- Groundwater Level and Quality
- Surface Water Quality

Time series analysis processes have been built into the development of trigger values. For example triggers have been developed to identify short and long term mining related impacts should any occur. Monitoring will be undertaken for at least 10 years post mining. Monitoring frequency may be reduced once 3 years of post-mining swamp monitoring has been undertaken if swamp condition has not degraded as a result of mining activity. The background on how the triggers were developed for each of the individual parameters are shown below.

6.2 Subsidence Triggers

Triggers for subsidence have been developed following modelled predictions for subsidence above longwall panel 418. The modelling is based on previous monitoring data as well as subsidence theory. A summary of previous monitoring data is set out in Appendix C.

The effects of subsidence are influenced by geology, depth of cover, topography, longwall extraction height and longwall extraction width. All of these factors have been considered and included in the modelling predictions. Triggers are then developed based on the predicted subsidence effects which are referred to as anomalous subsidence. Anomalous subsidence is defined in the Springvale Coal EPBC approval 2013 / 6881 and set out in Table 6.3. A response trigger will be considered to have been reached if subsidence affects are greater than 15% of anomalous subsidence. This approach is consistent with the approved Springvale Subsidence Management Plan.

Triggers have been developed for longwall panel 418 as well as for Sunnyside East and Carne West Swamps. These triggers are set out in Table 6.3.

Condition 4 of EPBC approval 2013/6881 requires any exceedence of anomalous subsidence as set out in the definition section of approval 2013/6881within 200 metres of a THPSS will be reported to DOE. Condition 5 of approval 2013/6881 requires that this report be submitted to DOE within 10 business days.

The trigger levels presented in Table 6.3 are in the context of total conventional and non-conventional subsidence movements.

Table 6.3. Subsidence Trigger levels

Location	Survey Sites	Performance Trigger Levels#	
LW418	B Line	Subsidence	>1.45 metres
		Tilt	> 10 mm/metre
		Tensile Strain	> 5 mm/metre
		Compressive Strain	>16 mm/metre
Sunnyside East Swamp	*V-VC and W-WC Lines LiDAR*	Subsidence	>1.35 metres
		Tilt	> 9 mm/metre
		Tensile Strain	> 5 mm/metre
		Compressive Strain	>16 mm/metre
		Upsidence	>0.75m
		Closure	>1.0 m
Carne West Swamp	Y- YC2 , X-XC, B Lines LiDAR	Subsidence	>1.35 metres
		Tilt	> 9 mm/metre
		Tensile Strain	> 5 mm/metre
		Compressive Strain	>16 mm/metre
		Upsidence	>0.45m
		Closure	>0.6m

 # Triggers are considered to have been reached if subsidence is 15% greater than anomalous subsidence.

NOTE: These ranges are derived from data collected to date. As further monitoring occurs further data will become available and these ranges may be updated accordingly.

6.3 Flora Triggers

Triggers for flora have been developed using data collected from reference site monitoring carried out since 2003. The natural variability of measured parameters and how they vary in response to disturbance events such as elevated surface flow and subsidence has been investigated from 2003 in a range of swamps on the Newnes Plateau (see Vickers *et al* 2011). The triggers have been developed based on an analysis of natural variance in vegetation communities which has been determined following an analysis of reference site data. For example natural changes in species assemblages occur within vegetation communities. However, a change of greater than 30% would be outside of what has been observed in data collected from reference sites. This would be considered to be an anomalous change and therefore would result in the implementation of management actions.

Details of trigger levels for flora are set out in Table 6.4 and baseline data set out in Appendix D. Each trigger has a defined level of change and a defined timescale in which this change is to be observed which dictates that an impact on the flora may have occurred.

NOTE: These ranges are derived from data collected at reference monitoring sites to date. As further monitoring occurs, further data will become available and these ranges may be updated accordingly in consultation with SEWPAC.

Table 6.4. Flora Trigger Levels

Performance indicator	Parameter measured	Trigger level
Change in species assemblage	Change in diversity of native species	A change in the number of species of greater than 30 % for a given site within a three year period.
	Recruitment of eucalypt species	An increase in eucalypts in an impact site compared to reference sites of more than three individual plants within a one year period.
Change in condition	Condition of key species	A decline in condition score at an impact site of more than 1.5 compared to the average condition score at un-impacted sites within a one year period. Details of the condition scores are shown in Table 7.2
	Non-live ground cover	An increase of bare ground of more than 100m^2 in a site within a three year period.
	Non-native weeds	An increase in non-native weed species of more than 4 in a monitoring site (each having a cover of greater than 5%) compared to the average number in reference sites within a one year period.

The triggers set out in Table 6.4 will be applied to individual monitoring sites and not used as an average across multiple monitoring sites in a swamp(s). An example of the set out of an individual monitoring site is shown in Figure 7.9.

6.4 Groundwater Level Triggers

The methodology for developing groundwater level triggers to determine whether anomalous impacts have occurred is based on statistical analysis and the development of percentile based triggers. Statistical techniques have been applied to baseline data as shown in Appendix E. This methodology has been used due to the absence of a universally accepted methodology for development of groundwater impact triggers. This approach is similar to that used to develop groundwater response triggers for the NSW Aquifer Interference Policy.

Short-term significant changes in groundwater level are considered to occur at the 95 percentile level. However, exceedence of this level, by definition, will occur five percent of the time under natural conditions. This has led to the development of long term triggers that complement the short term triggers. Any mining-induced changes in groundwater levels will be inferred based on a set of trigger values for the groundwater depths in swamp piezometers and the groundwater elevations at ridge top aquifer piezometers installed beneath the ridges between swamps.

A single-sided trigger will be used to check if the swamps are losing water in an anomalous manner. A double-sided trigger for water elevation in deeper aquifer piezometers (at 5 and 95 percentiles) will be used to check if the water table is dropping anomalously due to deep drainage or alternatively is being built up anomalously from an overlying or adjacent water source.

The strategy checks for both short-term and long-term changes in the hydrogeological regime. The primary performance indicator is any post-mining change in groundwater depth which is assessed in the following ways:

Type of change	Description
Swamp groundwater depth (from ground surface)	
Short-term changes	Trigger level is exceeded if the groundwater depth in any piezometer > 95th percentile pre-mining groundwater depth for more than 7 consecutive days
Long-term changes	Trigger level is exceeded if the post-mining 50th percentile groundwater depth for any piezometer > 80th percentile pre-mining level
Aquifer groundwater level	
Short-term changes	Trigger level is exceeded if the groundwater level > baseline 95th percentile or < baseline 5th percentile pre-mining groundwater level for more than one month
Long-term changes	Trigger level is exceeded if the post-mining 50th percentile groundwater level for any bore is > baseline 80th percentile or < baseline 20th percentile pre-mining level

The percentile groundwater depths will be determined using the data set collected up to the end of the pre-mining period. The recorded groundwater depths and elevations during the mining of LW418 are to be seven-day moving averages to account for occasional short-term spikes due to electronic noise, false readings, or disturbance during data downloads and water quality sampling.

Long term impacts will be determined by comparing the groundwater levels in each piezometer over the active longwall panel with groundwater levels in reference piezometers and other impact piezometers that are not affected by the current mining.

The trigger levels are based on the monitoring record from 1 January 2005 up to June 2015 (or until mining was within 200m) at the swamp piezometers and aquifer piezometers. The location of groundwater monitoring sites is shown on Figure 7.10 in Section 7 as well as the plan in the envelope at the rear of this MMP.

Depth to water is used as the groundwater attribute for swamp piezometers to monitor local scale effects. Depth is immediately meaningful as it conveys information on the transient saturation of a swamp and shows whether a swamp is losing water.

Groundwater elevation is used as the groundwater attribute for aquifer piezometers, to monitor regional scale effects. Depth to water is not so meaningful here, as depths are usually substantial and depth is not critical for natural processes such as evapotranspiration at these depths. What is more important is the regional hydraulic gradient and the groundwater flow direction, and they can be discerned only from elevations. Groundwater level triggers are set out in Tables 6.5 and 6.6

Table 6.5. Groundwater Triggers for Swamp Piezometer Water Levels for Impact Monitoring Sites

Location	Short-term Change 7-day moving average greater than the Pre-mining 95th Percentile for 7 days (metres below ground level)	Long-term Change Post-mining median greater than the Pre-mining 80th Percentile (metres below ground level)
Permanently Waterlogged		
CW1	0.25	0.24
CW2	0.24	0.24
SSE3	1.71	1.48
Periodically Waterlogged		
CW3^	1.07	1.06
CW4	1.34	1.33
SSE1	2.16	2.11
SSE2	0.83	0.61

^ Triggers to be updated for longer monitoring record; currently set at swamp floor

Table 6.6. Groundwater Triggers for Aquifer Piezometer Water Levels for Impact Monitoring Sites

Location	Short-term Change (7-day moving average less than the Pre-mining 5th Percentile for 1 month)	Short-term Change (7-day moving average greater than the Pre-mining 95th Percentile for 1 month)	Long-term Change (Post-mining median less than the Pre-mining 20th Percentile)	Long-term Change (Post-mining median greater than the Pre-mining 80th Percentile)
RSS	1128.1	1131.15	1128.9	1130.2
SPR1101^	1089.9	1092.0	1090.0	1091.7
SPR1104	1069.6	1073.6	1070.4	1073.1
SPR1107	1087.1	1093.3	1088.2	1092.5
SPR1109	1068.8	1078.1	1072.1	1077.4
SPR1110	1083.7	1089.9	1084.8	1089.8

^ Triggers to be updated for surveyed ground level; current estimate 1126 mAHD

6.5 Groundwater Quality Triggers

Triggers for groundwater quality have been developed using data collected from reference sites as set out in Appendix E. This data has been assessed using the ANZECC (2000) Water Quality Guidelines for the Protection of Aquatic Life (95% species protection levels) to calculate the triggers. Groundwater quality triggers were developed using the ANZECC (2000) guidelines procedure for setting local guidelines when the water quality does not meet the default ANZECC (2000) guideline values because of local conditions. The 80th percentile value of background water quality is used as the local water quality value in the case where the background concentrations are higher than the ANZECC (2000) guidelines. The default is used if the 80th percentile is lower than the default trigger value. This approach has been used to develop the water quality triggers for groundwater.

The ANZECC (2000) guidelines provide an approach to deriving low-risk trigger values in slightly to moderately disturbed environments. The 20th and 80th percentiles of background water quality parameters should be used that may cause impacts at both high or low values. This approach has been used to derive the water quality ranges for pH. Groundwater quality triggers are set out in Table 6.7.

Table 6.7. Groundwater Quality Triggers

Element	Short-term Minor Change (1)	Short-term Major Change (2)	80th Percentile Baseline
	CW1		
pH	4.6 - 4.85	3.52	4.85
EC (uS/cm)	28-37	45	25
Fe (Filterable Mg/L)	0.25-0.54	1.21	0.25
	CW2		
pH	4.68 - 5.08	3.99	5.08
EC (uS/cm)	28-40	47.37	28
Fe (Filterable Mg/L)	0.09-0.31	0.32	0.09
	SSE3		
pH	5.24 - 5.40	4.41	5.4
EC (uS/cm)	52 - 86.50	93	52
Fe (Filterable Mg/L)	7.67 - 12.36	16.14	7.67
	Management Response		
Response to trigger exceedence	Management and corrective measures required if trigger exceedence is mining-related (see Section 9)	Response Strategy required if trigger exceedence is mining-related (see Section 10)	

NOTE: (1)**Minor Change**: For each analyte, if any measured parameter > baseline 80th percentile, but ≤ baseline 95th percentile (5th percentile for pH) trigger value for > two months
(2) **Major Change**: For each analyte, if any measured parameter > baseline 80th percentile by two standard deviations for more than two months, the changes are considered major

6.6 Flow Rate Monitoring

Accurate flow monitoring measurements generally involve the establishment of a V notch weir or similar at upstream and downstream locations on flowing THPSS systems. This approach has been attempted by Springvale in the past but proven to be unsuccessful due to the peat / sand substrate present in THPSS systems. The peat / sand substrate has low strength characteristics and piping of flows around and under the weir structure causes erosion and eventual failure of the weir.

Construction of conventional weirs in swamp systems can also cause significant short term impacts. However, Springvale consider the establishment of weirs to accurately measure stream flow as a significant issue and will continue to work towards identifying suitable sites and strategies to establish weirs. This will possibly involve construction using alternate technologies such as soft engineering techniques as set out in Section 10 of this document. This will be done in consultation with government agencies.

An alternate approach which has been introduced at Carne West THPSS is to use a combination of pool depth monitoring and in stream flow meter monitoring. The flow meter readings are calibrated using the pool depth data to establish stream flows i.e. a reduction in pool depth should have a corresponding reduction in stream flow. Springvale will use this approach and work towards determining the accuracy of this approach prior to setting stream flow triggers.

6.7 Surface Water Quality Triggers

Surface water quality triggers have been developed using the ANZECC (2000) water quality guidelines for protection of aquatic life (95% species protection levels). These have been applied to the surface water monitoring data shown in Appendix F. Minor and major variation / impacts will be assessed by using the ANZECC protocols of comparing the pre-mining 80th and 95th percentile baseline with the 50th percentile of the post-mining data and allowing for the effects of short-term spikes due to rainfall runoff events. Trigger values are set out in Table 6.8.

The guidelines require 24 measurements to set the baseline 80th and 95th percentiles, so that accurate trigger values can be set to activate appropriate corrective actions. Sufficient pre-mining data was available for individual trigger levels to be set for each piezometer prior to the area being undermined.

Minor and major changes will be determined statistically. Minor changes do not require any management or corrective actions, but provide an early warning of potential permanent changes in the water chemistry. Major changes indicate the need for management or corrective actions. The triggers are determined in the following ways:

Type of change	Description
	Minor Changes
Long-term minor changes	For each analyte, if the post-mining 50th percentile ≤ baseline 80th percentile, the changes are considered minor and would not have an unacceptable impact on aquatic life (i.e. provided the long-term increase in concentrations is such that the 50th percentile does not exceed the baseline 80th percentile, the increase is considered to be minor)
Short-term minor changes –	For each analyte, if any measured parameter > baseline 80th percentile, but ≤ baseline 95th percentile (5th percentile for pH) trigger value for ≤ two months, the changes are considered minor and would not have an unacceptable impact on aquatic life. It should be noted that about 20% of observations will exceed the 80th percentile and these are usually short-term spikes in concentrations, which are often due to rainfall runoff events. These short-term spikes generally occur for less than two consecutive months.
	Major Changes
Long-term major changes	For each analyte, if the post-mining 50th percentile > baseline 80th percentile, the changes are considered major.
Short-term major	For each analyte, if any measured parameter > baseline 80th percentile

changes	by two standard deviations for more than two months, the changes are considered major

Table 6.8. Surface Water Quality Trigger levels

Element	Short-term Minor Change (1)	Short-term Major Change (2)	80th Percentile Baseline
	Carne Swamp		
pH	4.82 - 5.28	4.15	5.28
EC (uS/cm)	26.40 - 37.05	54.74	26.40
Mn (Filterable Mg/L)	0.024 - 0.04	0.15	0.024
Fe (Filterable Mg/L)	0.39 - 0.64	0.70	0.39
	Sunnyside East Swamp		
pH	4.87 – 5.49	4.48	5.49
EC (uS/cm)	25 - 41	98	25
Mn (Filterable mg/L)	0.025 - 0.037	0.025	0.079
Fe (Filterable Mg/L)	0.30 - 0.42	0.48	0.30
	Marrangaroo Creek Upstream (Reference Site)		
pH	4.60 - 4.94	3.5	4.94
EC (uS/cm)	40 - 61.70	65	40.00
Mn (Filterable Mg/L)	0.01 - 0.02	0.09	0.01
Fe (Filterable Mg/L)	0.08 - 0.27	1.23	0.08
	Trigger Response		
Response to trigger exceedence	Management and corrective measures required if trigger exceedence is mining-related (see Section 9)	Response Strategy required if trigger exceedence is mining-related (see Section 10)	

NOTE: [(1)]**Minor Change**: For each analyte, if any measured parameter > baseline 80th percentile, but ≤ baseline 95th percentile (5th percentile for pH) trigger value for > two months
[(2)] **Major Change**: For each analyte, if any measured parameter > baseline 80th percentile by two standard deviations for more than two months, the changes are considered major

7 Monitoring Programs

Monitoring programs are designed to collect pre-mining data to further develop an understanding of the pre-mining environment as well as post mining data to determine whether any mining related impacts have occurred. Monitoring is to be carried out at sites potentially impacted by longwall mining activities and these sites are referred to as **impact sites**. The selection of these sites is determined by mining activities i.e. the impact sites are located above or at a location that will potentially be affected by mining activity.

Monitoring sites are also located away from the effects of mining activities. These sites are referred to as **reference sites**. Reference sites are monitored at the same frequency as impact sites. Reference sites are used as a comparative reference when determining whether any changes at impact sites are natural e.g. climatic or land use e.g. forestry or whether changes are the result of mining activities. The selection of reference sites is restricted by the finite number of THPSS available within and adjacent to the controlled action area. Whilst there may be a range of other THPSS on the Newnes Plateau that will not be affected by mining and which could potentially be used for future reference sites, the following considerations have been used for the selection of reference sites for this MMP.

- Reference sites need to be relatively close to impacts sites so that the reference sites have similar climatic conditions to the impact sites
- Reference sites need to be relatively close to impacts sites so that the reference sites experience similar hydrogeological conditions
- Reference sites need to be located outside the area of proposed mining related influence
- If an impact site is a permanently water logged site then a reference site needs to be permanently water logged i.e. a permanently waterlogged site differs from a periodically water logged site
- Floristic assemblages may differ between impact and reference sites but comparisons are still valid as floristic conditions or swamp health will only generally change between sites if there is an anomalous impact at either site
- All sites need to have reasonable access to allow for on ground monitoring and investigation activities to be carried out
- OH&S issues such as access and communications need to be considered

General Data Analysis

Data from both impact and reference sites will be collected and monitored at regular intervals as described in the individual sections below. The analysis of data will include comparing pre-mining and post mining data from impact sites with data from reference sites. Data from reference sites will be compared to pre-mining data at impact sites in order to establish relationships between pre-mining impact sites and reference sites. Using an analysis and comparison with reference site data will also provide an additional cross check on data from impact sites pre and post mining. A summary of the monitoring analysis and frequency is set out in Table 8.1.

Monitoring Metric	Monitoring Frequency	Data Analysis Frequency	Impact Sites	Reference Sites
Subsidence	Surveys every 200 metres of face advance when the face is between 200 metres ahead and 300 metres past the survey lines. One survey on B and M lines post mining	Immediately following subsidence surveys	✓	N/A
Flora	Quarterly – Spring, Summer, Autumn and Winter	Quarterly – Spring, Summer, Autumn and Winter	✓	✓
Groundwater Level	2 monthly	2 monthly	✓	✓
Groundwater Quality	Monthly	Monthly	✓	✓
Surface Water Quality	Monthly	Monthly	✓	✓

Details of all monitoring programs and sites are included in the following subsections including data analysis methodology.

A different approach is proposed for the monitoring of the hanging swamps relative to shrub swamps for the following reasons:

- The only mining-related effects that could impact on hanging swamps are surface cracking or excessive tilt that interfere with swamp hydrology. While cracking is theoretically possible no cracking has ever been observed in soft soil or peat-covered areas due to the relatively low strains that are normally experienced in this area. In addition, the predicted (and previously measured) tilts are well below the surface tilt required to reverse the hydraulic gradient in these swamps, which follows the dip of the local strata.
- Numerous hanging swamps have been previously undermined by more than 40 longwall panels in both Springvale and Angus Place Mines, and there has not been any report of cracking within a hanging swamp or damage to the vegetation as a result.
- Hanging swamps generally do not have a thick peat base or a consistent free groundwater surface that can be measured. As a result, the conditions are not suited to the installation of swamp piezometers.
- The base of hanging swamps is significantly steeper than in the shrub swamps so any seepage drains away relatively quickly.

It should be noted that, for the purposes of this plan, pre-mining data is defined as all data collected prior to longwall mining encroaching within 200 metres of the swamp in which the monitoring site is located. All data gathered after that time is deemed to be post-mining data. For aquifer piezometers, which are not located in the swamps, pre-mining data is defined as all data collected prior to longwall mining encroaching within 200 m of the piezometer.

7.1 Shrub Swamps

7.1.1 Subsidence

Monitoring Sites

Existing survey monitoring lines have already been installed in accordance with the approved *Springvale Subsidence Management and Reporting Plan for LW418 (August 2014)*. The lines included in the monitoring program are B, V, W, X and Y which all cross Sunnyside East and Carne West THPSS. The proposed mining layout, THPSS and installed monitoring lines are shown in Figure 7.1. The survey lines installed to date have not been established in the THPSS to minimise impacts during the establishment of the lines and during monitoring. Prior to LW418 commencing B and Y Lines will be extended to the position shown on Figure 7.1.

Additional longitudinal centre lines have been installed at several key locations to provide early-warning and three dimensional (3-D) swamp subsidence data for trigger level review and corrective action management purposes should corrective action be required.

Further detail on the extension of B and Y Lines is set out below.

1. The extension of the existing transverse Y Line to the western extremity of Gang Gang Swamp South West.
2. The extension of the existing transverse B Line to the western extremity of Gang Gang Swamp.

It is also proposed to monitor shrub swamps using Aerial Laser Scanning (LiDAR) techniques to measure subsidence effects. The laser scanning will be carried out at the end of each longwall panel, and will cover the entire controlled action area. LiDAR data will be gathered as part of a research program into low impact monitoring methodologies and the data will be reviewed and assessed for applicability in ongoing monitoring programs.

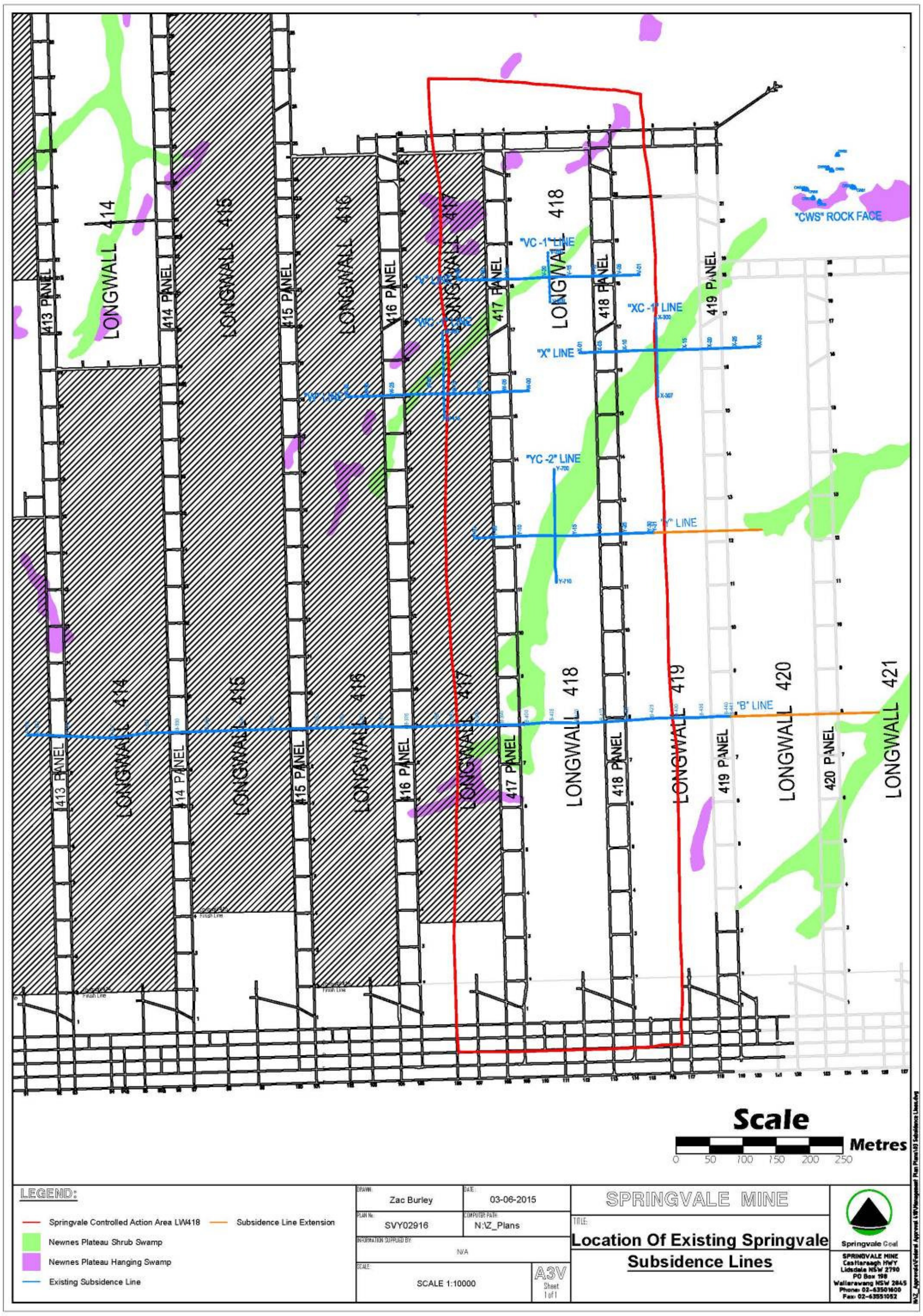


Figure 7.1 – Installed subsidence lines LW418

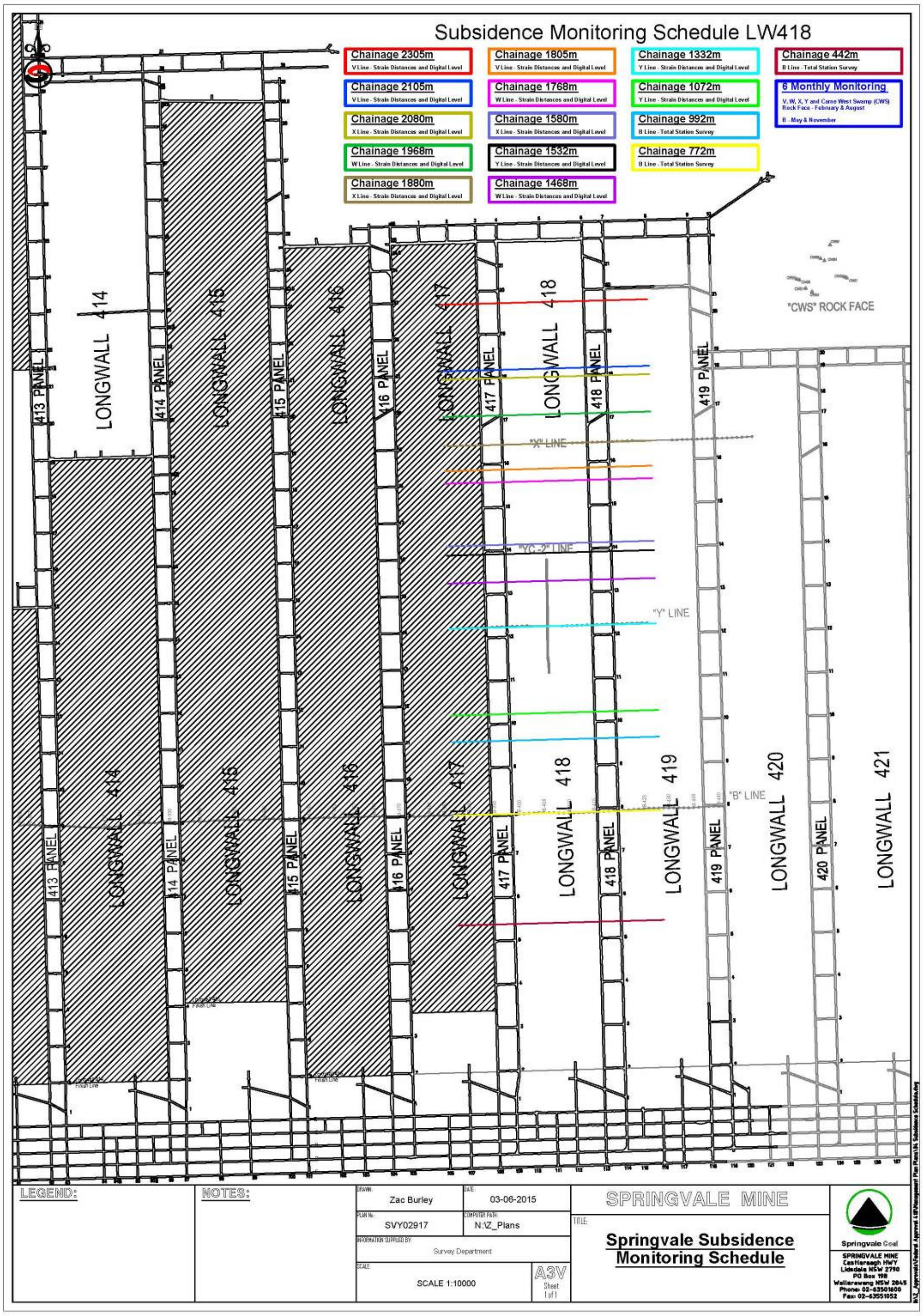


Figure 7.2 – Subsidence Monitoring Program LW418

Monitoring Methodology

The following campaigns are proposed to gather early warning data to allow informed assessments to be made in regards to potential trigger level exceedences prior to extracting each longwall, and to provide 3-D monitoring data for swamps that are directly undermined:

B Line Subsidence Monitoring

Subsidence Line B was established to monitor subsidence, tilt, stain and angle of draw across Longwalls No.1 to 418. This line will be extended east to the edge of Gang Gang Swamp South West. The installation and monitoring details for Line B are shown in **Table 7.1.**

Table 7.1: Subsidence Line B Details

Mark Type	Star Pickets driven to refusal at 15m intervals
Length Of Extension	440m
Survey Starting Point	Station B350
Survey Monitoring Method	Total Station (3-D Coordinates)
Target Accuracy	+/- 10mm level +/- 10mm distance
Monitoring Frequency	LW chainages 992, 772 & 442, with additional 6 monthly surveys.

V Line Subsidence Monitoring

Subsidence Line V to be installed to monitor subsidence, strain, tilt associated with the extraction of Longwall 418. The installation and monitoring details for Line V are shown in **Table 7.2.**

Table 7.2: Subsidence Line V Details:

Mark Type	Star Pickets driven to refusal at 15m intervals
Length of Line	V Line - 540m VC Line – 150m
Survey Monitoring Method	Digital Level & Standard Steel Tape
Target Accuracy	+/- 3mm level +/- 2mm distance
Monitoring Frequency	LW chainages 2305, 2105 & 1805 with additional 6 monthly surveys.

W Line Subsidence Monitoring

Subsidence Line W to be installed to monitor subsidence, strain, tilt associated with the extraction of Longwall 418. The installation and monitoring details for Line W are shown in **Table 7.3.**

Table 7.3: Subsidence Line W Details:

Mark Type	Star Pickets driven to refusal at 15m intervals
Length of Line	540m
Survey Monitoring Method	Digital Level & Standard Steel Tape
Target Accuracy	+/- 3mm level +/- 2mm distance
Monitoring Frequency	LW chainages 1968, 1768 & 1468 with additional 6 monthly surveys.

X Line Subsidence Monitoring

Subsidence Line X to be installed to monitor subsidence, strain, tilt associated with the extraction of Longwall 418. The installation and monitoring details for Line X are shown in **Table 7.4.**

Table 7.4: Subsidence Line X Details:

Mark Type	Star Pickets driven to refusal at 15m intervals
Length of Line	540m
Survey Monitoring Method	Digital Level & Standard Steel Tape
Target Accuracy	+/- 3mm level +/- 2mm distance
Monitoring Frequency	LW chainages 2080, 1880 & 1580 with additional 6 monthly surveys.

Y Line Subsidence Monitoring

Subsidence Line Y to be installed to monitor subsidence, strain, tilt associated with the extraction of Longwall 418. This line will be extended east to the edge of Gang Gang Swamp South West. The installation and monitoring details for Line Y are shown in **Table 7.5.**

Table 7.5: Subsidence Line Y Details:

Mark Type	Star Pickets driven to refusal at 15m intervals
Length of Extension	325m
Length of Line	Y Line - 865m (Extended Length), YC2 Line – 340m
Survey Monitoring Method	Digital Level & Standard Steel Tape
Target Accuracy	+/- 3mm level +/- 2mm distance
Monitoring Frequency	LW chainages 1532, 1332 & 1072 with additional 6 monthly surveys.

Each campaign will require subsidence development and potential variation between panel surface and geological conditions to be assessed. It is therefore proposed to complete subsidence monitoring surveys along the relevant transverse and longitudinal line sections shown in 2 during active subsidence.

Visual inspections of shrub swamps will be conducted on a monthly basis during active subsidence development at the site.

The active subsidence zones for each survey campaign are defined as the zone when the longwall face is within 200 metres ahead and 300 metres past the survey lines. Subsidence Monitoring Surveys will be completed at the beginning of the active subsidence zone, as the longwall extraction takes it past the subsidence line and at the end of the active subsidence zone.

Survey Monitoring Techniques

The following measurements will be undertaken during surveys of B Line:

- Peg Level (AHD)
- Peg location in the horizontal plane (Easting, Northing) in MGA
- Calculated Horizontal strain between pegs from surveyed Easting and Northings
- Valley closure and uplift

The following measurements will be undertaken during surveys of V, W, X and Y Lines:

- Peg Level (AHD)
- Horizontal strain between pegs
- Valley closure and uplift

The two survey line extensions will have pegs installed at 15 metre spacing and driven soundly into the soil profile or pinned soundly into exposed bedrock as required.

Monitoring campaigns for the swamps aim to achieve the following accuracies in regards to peg locations and strain measurements:

- total station levels : ±10 mm
- total station horizontal displacements: ±10 mm
- standard steel tape measurements: ± 3 mm
- digital level measurements ± 3 mm

Due to the difficult topography and accessibility of the Newnes Plateau benchmark survey stations are set for each survey via the use of GNSS Surveys. The accuracy of these benchmarks is ±25mm in reduced level and ±15mm for Easting and Northing.

Aerial LiDAR surveys will measure ground level at the end of each longwall panel. Each LiDAR survey is compared against the previous survey data to give the incremental subsidence since the previous survey. This allows cumulative subsidence effects to be measured to within ±150 mm with minimal disturbance to the THPSS. LiDAR subsidence measurement accuracy is not as high as conventional on ground methods. It is low impact, covers a broader area and will indicate any areas of anomalous subsidence not covered by the conventional point survey techniques. LiDAR data will be gathered as part of a research program into low impact monitoring methodologies and the data will be reviewed and assessed for applicability in ongoing monitoring programs.

Baseline Monitoring Data

The predicted conventional subsidence parameters for the longwalls were determined using the Incremental Profile Method, which was developed by MSEC, formally known as Waddington Kay and Associates. The method is an empirical model based on a large database of observed monitoring data from previous mining within the Southern, Newcastle, Hunter and Western Coalfields of New South Wales.

The database consists of detailed subsidence monitoring data gathered from the Southern, Newcastle, Hunter and Western Coalfields of New South Wales and from the Bowen Basin in Queensland, including: Angus Place, Appin, Awaba, Baal Bone, Bellambi, Beltana, Blakefield South, Bulga, Bulli, Burwood, Carborough Downs, Chain Valley, Clarence, Coalcliff, Cook, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Donaldson, Eastern Main, Ellalong, Elouera, Fernbrook, Glennies Creek, Grasstree, Gretley, Invincible, John Darling, Kemira, Kestrel, Lambton, Liddell, Mandalong, Metropolitan, Moranbah North, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, NRE Wongawilli, Oaky Creek, Ravensworth, South Bulga, South Bulli, Springvale, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, West Cliff, West Wallsend, and Wyee.

The review of the detailed ground monitoring data from the NSW Coalfields showed that whilst the final subsidence profiles measured over a series of longwalls were irregular, the observed incremental subsidence profiles due to the extraction of individual longwalls were consistent in both magnitude and shape and varied according to local geology, depth of cover, panel width, seam thickness, the extent of adjacent previous mining, the pillar width and stability of the chain pillar and a time-related subsidence component.

Based on the extensive empirical data, MSEC has developed standard subsidence prediction curves for each of the Coalfields in New South Wales and Queensland. The predictions curves can then be further refined, for the local geology and local conditions, based on the available monitoring data from the area.

The prediction of subsidence is a three stage process where, first, the magnitude of each increment is calculated, then, the shape of each incremental profile is determined and, finally, the total subsidence profile is derived by adding the incremental profiles from each longwall in the series. In this way, subsidence predictions can be made anywhere above or outside the extracted longwalls, based on the local surface and seam information.

For longwalls in the Western Coalfield, the maximum predicted incremental subsidence is initially determined, using the IPM subsidence prediction curves for a single isolated panel, based on the longwall void width (W) and the depth of cover (H). The incremental subsidence is then increased, using the IPM subsidence prediction curves for multiple panels, based on the longwall series, panel width-to-depth ratio (W/H) and pillar width-to-depth ratio (Wpi/H). In this way, the influence of the panel width (W), depth of cover (H), as well as panel width-to-depth ratio (W/H) and pillar width-to-depth ratio (Wpi/H) are each taken into account.

The shapes of the incremental subsidence profiles are then determined using the large empirical database of observed incremental subsidence profiles from the Western Coalfield, including Angus Place and Springvale. The profile shapes are derived from the normalised subsidence profiles for monitoring lines where the mining geometry and overburden geology are similar to that for the proposed longwalls.

Finally, the total subsidence profiles resulting from the series of longwalls are derived by adding the predicted incremental profiles from each of the longwalls. Comparisons of the predicted total subsidence profiles, obtained using the Incremental Profile Method, with observed profiles indicates that the method provides reasonable, if slightly conservative, predictions where the mining geometry and overburden geology are within the range of the empirical database. The method can also be further tailored to local conditions where observed monitoring data is available close to the mining area.

Data Analysis Methodology

Empirical models will be used to estimate worst case subsidence effects based on differences between observed and predicted smooth subsidence profiles. It is not practical or reasonable to compare continuous, smooth profile predictions of subsidence, tilt and strain to measured subsidence effect profiles that may include effects of discontinuous strata behaviour such as valley up-sidence and cracking.

Smooth profile predictions of subsidence, tilt and strain will be used to provide systematic predictions relative to the proposed mining layout, but do not include discontinuous strata behaviour effects. The predictions provided to-date have therefore included a field calibration factor for estimating worst case values for a given mining geometry.

LiDAR data will be gathered as part of a research program into low impact monitoring methodologies and the data will be reviewed and assessed for applicability in ongoing monitoring programs. The measured subsidence in the swamps determined in the LiDAR surveys will be compared to the maximum panel predictions for each longwall panel. The LiDAR will also be used to determine the change in gradient along the swamps so that any anomalous changes can be identified and checked in the field.

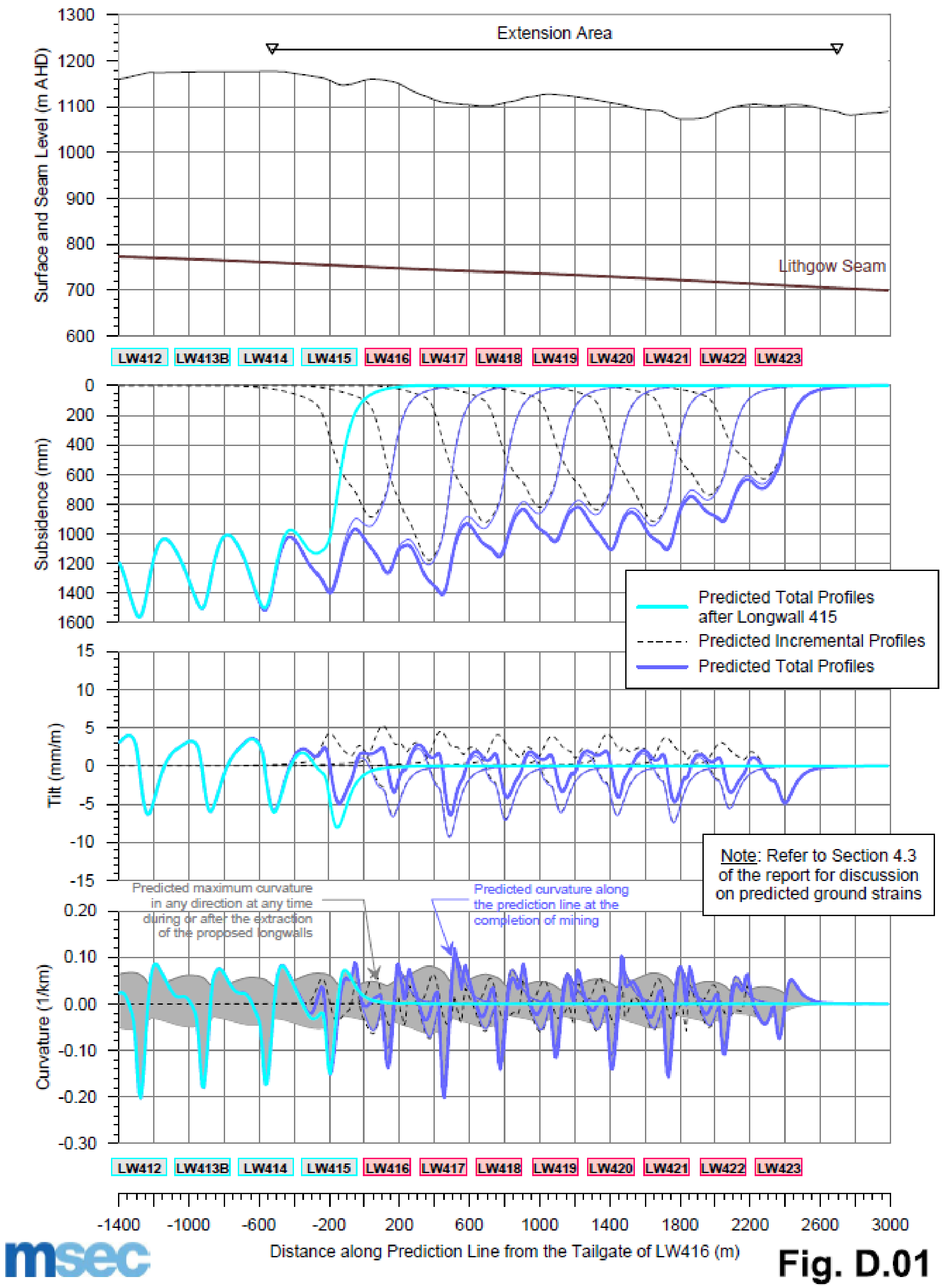


Figure 7.3: Predicted Profiles of Conventional Subsidence Tilt and Curvature for Resulting from extraction of LWSs 401-423

7.1.2 Flora

Monitoring Sites

Centennial Coal has conducted flora monitoring of THPSS across the Newnes Plateau since 2003. Forty six sites are now monitored which includes undermined swamps and swamps that have not been undermined. The data from these sites will be used as reference data where needed in combination with the specific sites that will be monitored as part of this MMP.

It is not possible to design an on ground flora monitoring program that provides 100% coverage of any swamp system without causing significant impacts to vegetation and other swamp processes. Monitoring programs therefore need to provide a balance between the detection of any impacts and damage to swamps during monitoring activities. The following points were considered when designing the flora monitoring program.

- Monitoring will be carried out seasonally. This is a relatively intense program and means that specialist flora monitors will be assessing swamps on a regular basis
- The current monitoring sites have been selected as most of the sites have been monitored previously and therefore have historical data sets which provide a history of what has occurred in the past
- Too many monitoring sites will cause unnecessary impacts on swamp systems i.e. there will be a minimum of 4 visits to the monitoring sites per year. This will increase if trigger related investigations are also required
- Baseline monitoring using the Rapid Assessment Methodology developed by Goldney et al will be carried out on both impact and reference swamps prior to mining. This methodology provides an overall qualitative measure of swamp health and will be used to complement the quadrat monitoring
- The Rapid Assessment Methodology will then be used to re-assess swamps if a mining related subsidence or groundwater trigger is exceeded
- More flora monitoring sites will be added to the monitoring program if required
- Centennial Coal are involved with investigating low level low impact remote sensing using aerial photography vegetation mapping which will be used to complement the quadrat and Rapid Assessment Methodology should the remote sensing prove successful. This is part of an active coal industry ACARP research program.

All monitoring sites on the Newnes Plateau are shown in Figure 7.4. The specific flora monitoring sites to be monitored as part of this MMP are shown on Figure 7.5 and described in Table 7.1.

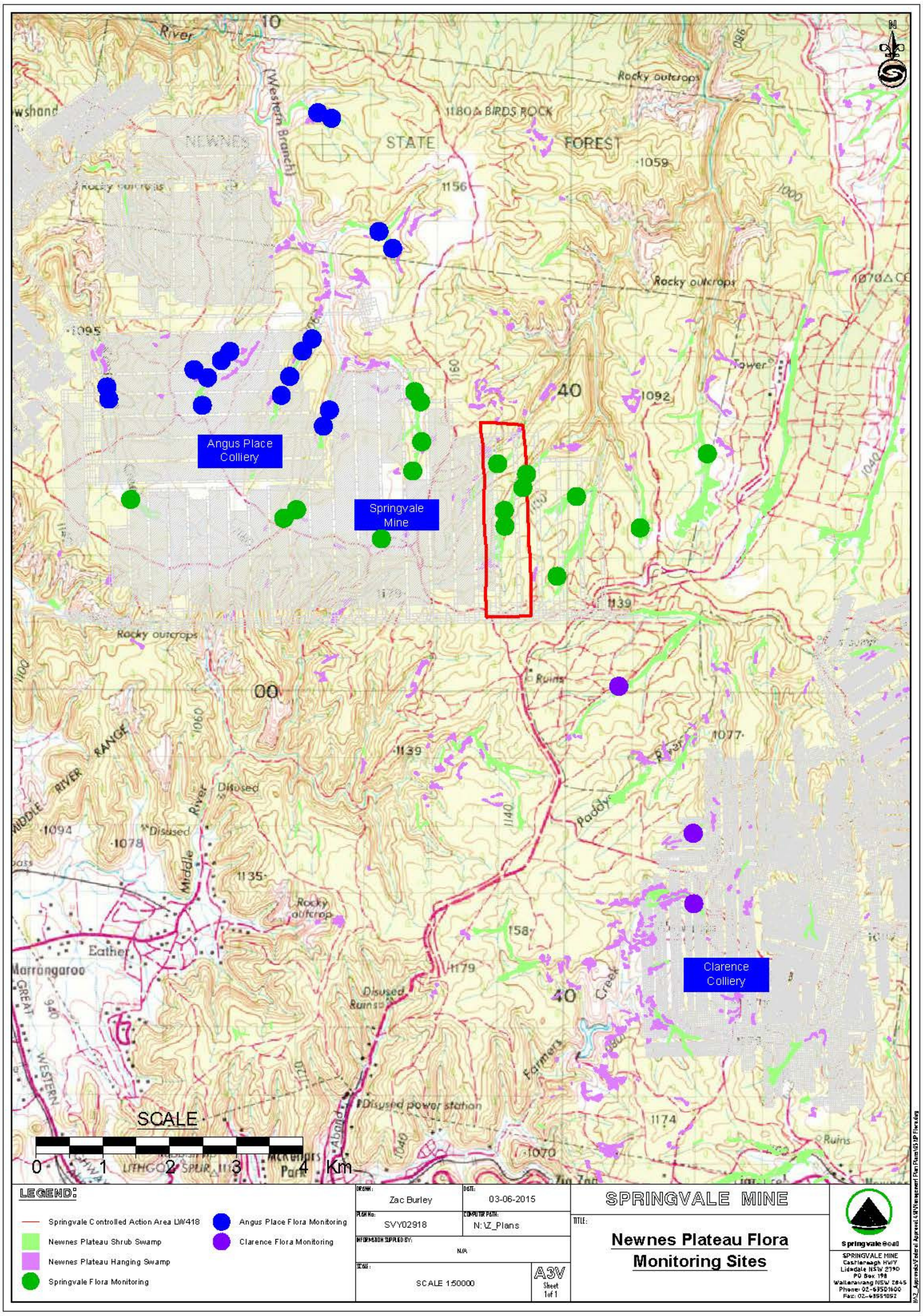


Figure 7.4 – All Newnes Plateau Flora Monitoring Sites

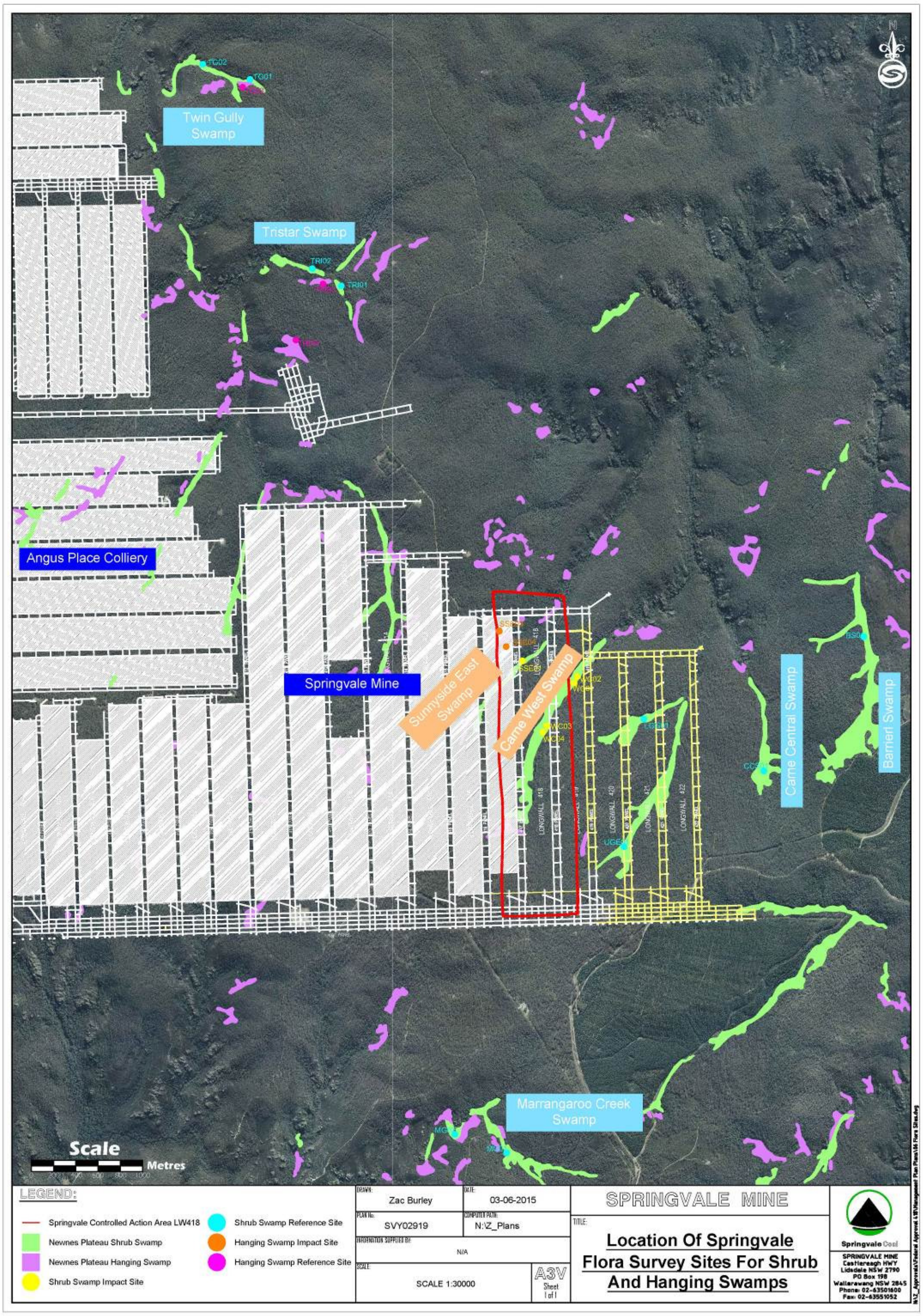


Figure 7.5– Springvale Flora Monitoring Sites

Table 7.1 – Details of the flora monitoring and reference sites

Monitoring site name	Swamp	Easting (GDA94)	Northing (GDA94)	Description
Impact Sites				
WC01	Carne West Swamp	239461	6303219	Permanently wet, groundwater fed swamp. Dominated by *Gymnoschoenus sphaerocephalus*, *Lepidosperma limicola*, *Leptospermum grandifolium*, *Gleichenia dicarpa*, *Xyris gracilis ssp. gracilis* and Baeckea linifolia.
WC02	Carne West Swamp	239461	6303321	Permanently wet, groundwater fed swamp. Dominated by *Gymnoschoenus sphaerocephalus*, *Lepidosperma limicola*, *Leptospermum grandifolium*, *Gleichenia dicarpa*, *Xyris gracilis ssp. gracilis* and Baeckea linifolia.
WC03	Carne West Swamp	239195	6302908	Permanently wet, groundwater fed swamp. Dominated by *Gymnoschoenus sphaerocephalus*, *Lepidosperma limicola*, *Leptospermum grandifolium*, *Gleichenia dicarpa*, *Xyris gracilis ssp. gracilis* and Baeckea linifolia.
WC04	Carne West Swamp	239157	6302773	Permanently wet, groundwater fed swamp. Dominated by *Gymnoschoenus sphaerocephalus*, *Lepidosperma limicola*, *Leptospermum grandifolium*, *Gleichenia dicarpa*, *Xyris gracilis ssp. gracilis* and Baeckea linifolia.
SSE01	Sunnyside East	239022	6303531	Southern half is generally dry and channelized. Northern half likely permanently wet. Dominant species include *Gleichenia dicarpa, Leptospermum grandifolium*, *Baumea rubiginosa* and *Gahnia sieberiana*
Reference Sites				
TG01	Twin Gully	236565	6308755	Permanently wet, groundwater fed swamp. Dominant species include *Baeckea linifolia*, *Grevillea acanthifolia*, *Gleichenia dicarpa* and *Sphagnum cristatum.*
TG02	Twin Gully	236439	6308765	Permanently wet, groundwater fed swamp. Dominant species include *Baeckea linifolia*, *Grevillea acanthifolia*, *Gleichenia dicarpa* and

Monitoring site name	Swamp	Easting (GDA94)	Northing (GDA94)	Description
				Sphagnum cristatum.
TRI01	Tristar	236565	6308755	Permanently wet, groundwater fed swamp. Dominated by *Baeckea linifolia, Gleichenia dicarpa, Grevillea acanthifolia, Lepidosperma limicola, Leptospermum grandifolium*
TRI02	Tristar	236439	6308765	Permanently wet, groundwater fed swamp. Dominated by *Baeckea linifolia, Gleichenia dicarpa, Grevillea acanthifolia, Lepidosperma limicola, Leptospermum grandifolium*
LGG01	Lower Gang Gang Swamp	240148	6303040	Permanently wet, groundwater fed swamp, with channelised flows. Dominated by *Leptospermum grandifolium, Lepidosperma limicola, Boronia deanei and Gleichenia dicarpa.*
UGE01	Upper Gang Gang East Swamp	239928	6301878	Ephemeral, likely rainfall fed. Dominated by *Gleichenia dicarpa, Leptospermum grandifolium, Lepidosperma limicola, Gymnoschoenus sphaerocephalus and Xyris gracilis ssp. gracilis.*
BS01	Barrier Swamp	242111	6303738	Permanently wet, groundwater fed swamp. Dominated by *Gleichenia dicarpa, Leptospermum grandifolium, Lepidosperma limicola, Gymnoschoenus sphaerocephalus and Xyris gracilis ssp. gracilis.*
CCS01	Carne Central Swamp	241196	6302578	Ephemeral, likely rainfall fed. Dominated by *Lepidosperma limicola*, *Empodisma minus*, *Callistemon pityoides*, *Grevillea acanthifolia.*

Monitoring Methodology

Parameters monitored

To detect whether an impact has occurred in a THPSS a methodology is required that determines the following:

1. When a given swamp has changed so that it no longer has a species assemblage within the range of natural variability that exists among Newnes Plateau THPSS
2. When the condition of the extant vegetation has declined. This may occur despite the species assemblage not significantly changing.

Research over the last three and half years by the Centre for Mined Land Rehabilitation at the University of Queensland has led to the development of five monitoring parameters for use in detecting the above impacts in Newnes Plateau Shrub Swamp communities. These parameters will be used in this MMP and include:

1. Reduction in the number of native swamp species present
2. Reduction in the condition of key species (qualitative scores 1-5)
3. Expansion of non-live ground cover (including bare ground and dead plant material)
4. Recruitment of non-swamp species (presently eucalypts)
5. Establishment of non-native weeds.

Monitoring Method

Data on each of the six parameters will be collected within permanently established 400m^2 quadrats (generally 20 x 20 metres). At least one quadrat will be located at each of the impact and reference sites. Figure 7.6 illustrates the layout of a typical monitoring quadrat

Four transects will be assessed within each quadrat. The starting points of these transects will be positioned randomly along a predetermined edge of the fixed monitoring quadrat. This means that while transect orientation will be fixed at each monitoring time, the start location along the plot axis will be randomised to minimise impact of monitoring activities.

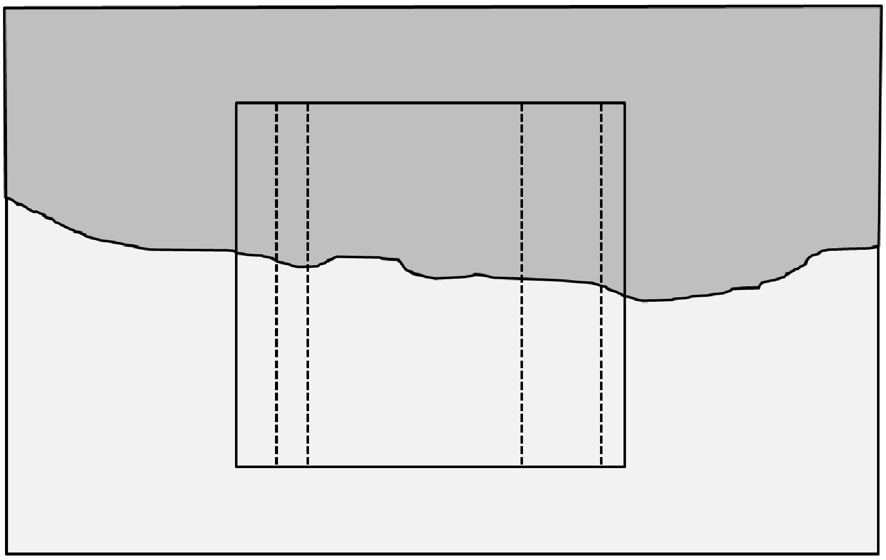
Quantitative sampling will be conducted using the point intercept method, scoring all vegetation between ground and sky that intercept a vertical line from the point on the ground. The data collected at each point will include species identification condition score of species present and presence/absence of non-live ground cover.

Additionally, along each transect 50cm x 50cm quadrats will be scored at 1 metre intervals for the presence/absence of eucalypt species and weed species. This will provide a total of approximately 80 quantitative measurements of weed and eucalypt presence/absence per monitoring plot. This methodology is described in detail in Erskine and Fletcher (2011). The condition score ratings are set out in Table 7.2.

Table 7.2 – Condition score definitions

1	**Severe damage/dieback**
2	Many dead stems
3	Some dead branches present
4	Minor damage
5	Healthy

Figure 7.6 – Diagram of 20mx20m plot showing orientation to vegetation assemblage boundaries and direction of point intercept transects (Erskine and Fletcher, 2011)



Solid line- Boundary of 20mx20m permanent plot
Broken lines- transect lines at time n.
Grey shades- different vegetation assemblages within plot.

Monitoring timing and frequency of survey events

Monitoring of flora will be undertaken for a period of at least 3 years and up to 10 years post-mining. The five monitored parameters will be measured seasonally during this period. The monitoring frequency could then potentially be reduced to less frequent monitoring where swamp monitoring has found no degradation of the swamp flora condition after a three year period.

Baseline Monitoring Data

A summary of baseline flora monitoring activities is set out in Appendix D.

Data Analysis Methodology

Data collected since 2003 has been analysed using a range of statistical techniques (see Denny 2011 and Erskine and Fletcher 2011). However, in this plan the strong trend lines found in the range of measured values and the time taken for these values to respond to disturbance and return to pre-disturbance values are used as trigger values for detecting potential impact. This means that simple easily understood numerical values that are clear and precise are used for each of the five trigger levels used in this plan.

Table 7.3 – Summary of flora monitoring data analysis techniques

Performance indicator	Parameter measured	Data Analysis and Trigger Methodology
Change in species assemblage	Change in diversity of native species	A change in the number of species of greater than 30 % for a given site within a three year period.
	Recruitment of eucalypt species	An increase in eucalypts in an impact site compared to reference sites of more than three individual plants within a one year period.
Change in condition	Condition of key species	A decline in condition score at an impact site of more than 1.5 compared to the average condition score at unimpacted sites within a one year period.
	Non-live ground cover	An increase of bare ground of more than $100m^2$ in a site ($400m^2$) within a three year period.
	Non-native weeds	An increase in non-native weed species of more than 4 in a site (each having a cover of greater than 5%) compared to the average number in reference sites within a one year period.

7.1.3 Groundwater

The THPSS baseline groundwater monitoring program commenced in May 2005 and has been gradually expanded to incorporate groundwater level and groundwater quality monitoring. Baseline groundwater monitoring has been carried out at the same frequency as the groundwater monitoring program outlined below. The conceptual groundwater model presented in section 3 identifies a shallow sub perennial laterally extensive groundwater system that feeds the sub-permanently and permanently water logged THPSS (generally referred to as shrub swamps). This groundwater monitoring program has therefore been set up to monitor this shallow groundwater system and to determine whether there are any mining related impacts.

Groundwater is monitored using a series of piezometers as shown in Figure 7.7. Piezometers have been installed in swamp systems and are referred to as Swamp piezometers. These piezometers are hand augured to refusal and are shallow with a depth of up to 3 metres. These piezometers are used for direct measurement of swamp groundwater fluctuations.

Piezometers have also been installed outside of swamp systems and are referred to as aquifer piezometers. These piezometers often extend down through ridge lines and are deeper than the swamp piezometers extending to a depth of up to 30 metres. The aquifer piezometers are used to measure groundwater fluctuations outside of swamp systems.

Details of the groundwater monitoring program are presented below.

Monitoring Sites – Swamp Piezometers

The swamp piezometers are generally located on the edges of the swamps to minimise damage to swamp vegetation. The groundwater level measured at the swamp margin is representative of the groundwater level across the swamp. This is because all of the piezometers penetrate the sand layer which underlies the peat substrate and the pore pressure in this layer does not vary significantly across the swamp due to the inherent high permeability. Variations in groundwater level are more likely to occur longitudinally rather than laterally as the gradient changes or the degree of waterlogging increases along the THPSS. The monitoring strategy is designed to monitor these variations by installing a series of piezometers longitudinally along the swamps.

Groundwater chemistry is monitored only in piezometers located in permanently waterlogged swamp conditions as sampling in periodically waterlogged conditions is often not possible due to the lack of groundwater in the piezometer.

Groundwater levels and water chemistry are monitored in piezometers in the two main impact swamps within the Springvale controlled action area. The locations and dates of installation of the piezometers are listed below:

Sunnyside East Swamp: three monitoring piezometers:	SSE1, SSE2 and SSE3: installed March 2010 to provide full length (longitudinally down the drainage line) monitoring coverage in this swamp which was only recently identified as a THPSS.
Carne West Swamp: four monitoring piezometers:	CW1 and CW2: installed May 2005, originally to provide background data on hydrogeological conditions in the swamp as well as comparative background data for other swamps. These two piezometers will give an indication if any severe impacts occur in Carne West Swamp upstream of the monitoring sites
	CW3 and CW4: installed in October 2011 at the southern end of the swamp to provide monitoring coverage in the vicinity of LW 417 and 418

The location of the impact swamp piezometers is shown on Figure 7.7. Groundwater monitoring in each swamp and details of mining, are summarised in Table 7.4.

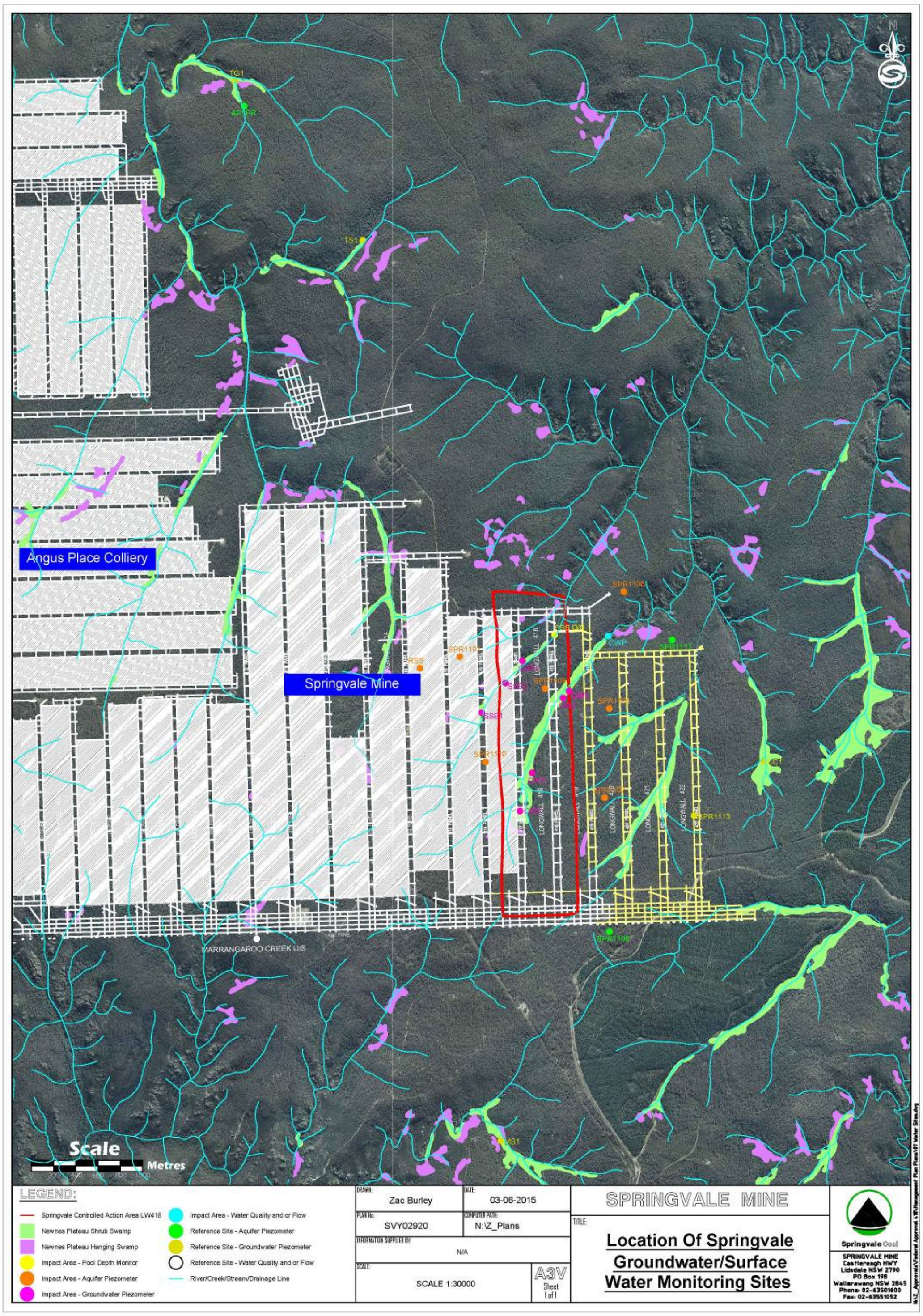


Figure 7.7 – Location of groundwater and surface water monitoring sites

Table 7.4 – Impact Swamps – Groundwater Monitoring

Site name	Easting (GDA94)	Northing (GDA94)	Location	Mining date (estimated)	Parameters monitored	
					Depth	Water Quality
			Sunnyside East Swamp			
SSE1	238668	6303143	Over LW416/417	January 2015	✓	
SSE2	238831	6303352	Over LW 417	Undermined December 2014	✓	
SSE3	239064	6303558	Over LW 418	September 2015	✓	✓
			Carne West Swamp			
CW1	239352	6303196	Over LW 419	May 2016	✓	✓
CW2	239382	6303247	Over LW 419	June 2016	✓	✓
CW3	238977	6302179	Over LW 417/418	January 2016	✓	
CW4	239070	6302377	Over LW 418	December 2015	✓	

Four swamps have been selected for installation of reference piezometers. The data collected from the reference piezometers will be used to filter out climatic fluctuations in groundwater changes when looking for mining related impacts. The locations and dates of installation of the reference piezometers are shown below and shown on Figure 7.10.

Carne Central Swamp: one monitoring piezometer	CC1: installed October 2011 to provide an indication of conditions in a swamp supported by the same aquifer as the impact swamps, but in an area that will not be undermined.
Marangaroo Swamp: one monitoring piezometer	MS1: installed October 2011 to provide an indication of conditions in a swamp supported by a different aquifer to the impact swamps, in an area that will not be undermined for some considerable time.
Tristar Swamp: one monitoring piezometer (two others not used in this plan)	TS1: installed October 2011 to provide an indication of conditions in a remote swamp (over Angus Place) supported by a different aquifer to the impact swamps, in an area that will not be undermined for some considerable time
Twin Gully Swamp: one monitoring borehole:	TG1: installed October 2011 to provide an indication of conditions in a remote swamp (over Angus Place) supported by a different aquifer to the impact swamps, in an area that will not be undermined.

Groundwater monitoring in each swamp and details of mining are summarised in Table 7.5.

Table 7.5 – Reference Swamps – Groundwater Monitoring

Site name	Easting (GDA94)	Northing (GDA94)	Mining Area	Mining date (estimated)	Parameters monitored	
					GW depth	water chem
			Carne Central Swamp			
CC1	241193	6302693	East of LW 418	No approved mining to date	✓	✓
			Marangaroo Swamp			
MS1	238860	6299169	East of LW 418	Quarter 4 2022	✓	✓
			Tristar Swamp			
TS1	237559	6307289	Over Angus Place – NE Area	No approved mining to date	✓	
			Twin Gully Swamp			
TG1	236438	6308766	Over Angus Place – NE Area	No approved mining to date	✓	

Installation and monitoring of swamp piezometers can result in impacts on swamp systems. However, impacts have been minimised by the measures set out below.

- The number of piezometers has been limited to the minimum that will allow detection of any mining impacts on the swamp.
- All swamp piezometers are located near the edge of the swamps so that the length of the access path to each site is minimised and hence the disturbance to the vegetation during installation and monitoring is minimised.
- Swamp piezometers have been installed using a hand auger so that only a very small area (< 1 m^2) is disturbed during installation.
- The site of the swamp piezometer is inspected prior to installation so that any rare or endangered species can be identified avoided.
- Data logging techniques are used to collect data wherever possible so that the frequency of site access to collect data is minimised.
- Vehicles used for monitoring activities will be restricted to traveling on currently formed roads where possible.
- The number of personnel assigned to monitoring duties will be minimised to reduce the number of visits to each monitoring site.
- All rubbish generated during monitoring activities will be collected prior to the completion of monitoring and disposed of in maintained bins on the Newnes Plateau or off site.
- No monitoring vehicles will be driven into swamp systems.

Monitoring Sites – Aquifer Piezometers

The aquifer piezometers are located outside of swamp systems in the laterally extensive shallow aquifer to monitor groundwater fluctuations around the periphery of THPSS. The data collected from these piezometers provides a comparison with any fluctuations measured in the Swamp piezometers to detect any mining related impacts.

Groundwater chemistry is not monitored in aquifer piezometers because these piezometers are located at a greater depth from the surface (i.e. on ridge lines) than Swamp Piezometers and the oxidation of analytes such as Fe and Mn is unlikely due to a lack of freely available oxygen at this depth from surface

Details of the Aquifer piezometers installed in impacts sites are set out below and shown on Figure 7.7.

RSS:	Installed December 2006. Located on the ridge between Sunnyside and Sunnyside East Swamps (over LW 415)
SPR1101:	Installed November 2011 on the ridge between Sunnyside and Sunnyside East Swamps over LW 416
RCW/SPR1104:	Originally installed December 2006. Located on the ridge to the east of the Carne West Swamp over LW420 (RCW was destroyed by forestry operations in 2010 but was replaced in November 2011 by SPR1104). This piezometer is located outside the controlled action area, but will give an indication of any down dip impacts on the aquifer from mining up-dip
SPR1107:	Installed in November 2011 on the ridge to the east of the Carne West

	Swamp over LW 420. This piezometer is located outside the controlled action area, but will give an indication of any down dip impacts on the aquifer from mining up-dip
SPR1109:	Installed in December 2011 on the ridge between Sunnyside East and Carne West Swamps over LW 418, just outside the controlled action area

Groundwater monitoring in each aquifer piezometer, and details of mining, are summarised in Table 7.6.

Table 7.6 – Impact Sites – Aquifer Groundwater Monitoring

Site name	Easting (GDA94)	Northing (GDA94)	Location	Mining date (estimated)	Parameters monitored	
					Depth	Quality
RSS	238072	6303500	Over LW 415	Undermined July 2012	✓	
SPR1101	238484	6303627	Over LW 416	Undermined November 2013	✓	
RCW/ SPR1104	239746	6303184	Over LW 420	To be undermined December 2016	✓	
SPR1107	239739	6302330	Over LW 420	To be undermined February 2017	✓	
SPR1109	239186	6303314	Over LW 418	To be undermined October 2015	✓	
SPR1110	238699	6302635	Over LW 416 / 417	Undermined February 2015	✓	

Four swamps have been selected for installation of reference piezometers. The data collected from the reference piezometers will be used to filter out climatic fluctuations in groundwater changes when looking for mining related impacts. The locations and dates of installation of the reference piezometers are shown below and shown on Figure 7.7

SPR1108:	installed November 2011. Located on the ridge south of LW 420 and at the northern end of LW 427, upstream of the controlled action area
SPR1111:	installed December 2011. Located on the ridge north of LW 422 and east of Carne West Swamp, downstream of the controlled action area
SPR1113:	installed December 2011. Located on the ridge between Gang Gang Swamp and Carne Central Swamp over LW423, east of the controlled action area
AP5PR:	installed in July 2008 to provide an indication of conditions in a remote aquifer (over Angus Place)

Groundwater monitoring in each swamp, and details of mining, are summarised in Table 7.7

Table 7.7 – Reference Sites – Aquifer Groundwater Monitoring

Site name	Easting (GDA94)	Northing (GDA94)	Location	Mining date (estimated)	Parameters monitored	
					GW depth	water chem
SPR1108	239840	6301075	South of LW 420 Over LW427	To be undermined 2021	✓	
SPR1111	240404	6303692	Nth of LW 422	Will not be undermined	✓	
SPR1113	240625	6302160	Over LW 423	To be undermined 2018 if approved	✓	
AP5PR	236523	6308535	NE of Angus Place Mine	Will not be undermined in the foreseeable future	✓	

Installation and monitoring of aquifer piezometers can result in impacts on areas around the piezometers. However, impacts have been minimised by the measures set out below.

- Where possible, exploration bores are utilised as aquifer piezometers to minimise the number of disturbed sites above the workings.
- Where possible aquifer piezometers are located as close as possible to existing tracks so that no new tracks need to be constructed and further disturbance is minimised.
- The site of each aquifer piezometer is inspected prior to installation so that any rare or endangered species can be identified and the site of the piezometer moved to a location where there are no endangered species if required.
- Data logging techniques are used to collect data wherever possible so that the frequency of site access to collect data is minimised.
- Vehicles used for monitoring activities will be restricted to traveling on currently formed roads where possible.
- The number of personnel assigned to monitoring duties will be minimised to reduce the number of visits to each monitoring site.
- All rubbish generated during monitoring activities will be collected prior to the completion of monitoring and disposed of in maintained bins on the Newnes Plateau or off site.
- No monitoring vehicles will be driven into swamp systems.

Monitoring Methodology – Swamp Piezometers

The Swamp piezometers are installed in 100 mm diameter boreholes drilled with a hand auger to refusal. The depth of these boreholes is up to three metres. The area temporarily disturbed during the installation of these bores is of the order of one square metre. A length of 50 mm class 12 UPVC casing is installed into the hole. The bottom 1.5 to two metres of the casing is slotted and enclosed in filter sock to permit groundwater movement into the casing but to exclude other material that may cause blockages. The annulus around the casing is filled with sand and the collar enclosed in concrete or bentonite to prevent water ingress from surface runoff.

Groundwater levels are measured at three hourly intervals by automatic water level logging instruments installed in the boreholes. The groundwater level data are downloaded at two-monthly intervals. This involves visiting each piezometer to remove the instrument from the borehole and download the data with a lap top computer.

Chemical analysis is carried out for analytes that will indicate mining-induced changes in the swamp systems. The main possible impact on groundwater quality from mining is the potential for oxidation of fresh rock surfaces in subsidence-induced cracks that may form in the rock under the base of a swamp. The main parameters that are monitored as indicators of any mining-related impacts and the justification for their use, are:

- **pH:** Water pH in the permanently waterlogged swamps is low (~3.5 to 6) due to the presence of humic acids in the peat. Any mining-induced effects may alter the pH on a local basis. This is the most important parameter as any long-term change in the pH could affect the vegetation in the swamp
- **EC**: Conductivity of the groundwater in the swamps is normally very low (< 50 µs/cm) and any abnormal chemical or physical processes could result in an increase in the TDS and a consequent increase in conductivity
- **Fe**: Iron-based minerals are common in the sandstones. These minerals can oxidise as a result of cracking in the sandstone and subsequent exposure to oxygen from dissolved oxygen in swamp water

The groundwater sampling and testing program is designed to detect any such changes. Samples and subsequent analysis will be taken on a monthly basis at three sites for detailed analyses. Sampling is carried out using recognized sampling protocols and sent to a NATA certified laboratory for analysis. The selected piezometers monitored for groundwater analyses include:

- Piezometer SSE3
- Piezometer CW1
- Piezometer CW2

The samples are tested for a full range of parameters including the following:

- EC
- pH
- Calcium
- Magnesium
- Sodium
- Potassium
- Chlorine
- Sulphate
- Alkalinity
- Iron
- Copper
- Zinc
- Aluminum
- Total Hardness
- Nitrate
- Chromium

All of the above analytes will be monitored. However, pH, EC and Fe will be used as the main indicators of water quality change. The remaining analytes will be used as investigative parameters should any water quality triggers be exceeded.

Monitoring Methodology – Aquifer Piezometers

Aquifer piezometers are installed in open boreholes drilled from ridge tops and are designed to intersect the aquifer that feeds the swamps. Some piezometers have been installed in exploration bores that have been grouted up to the aquifer base. A length of 50 mm class 12 UPVC casing is inserted into the bore. The bottom six to nine metres of the casing is slotted and enclosed in filter sock to permit groundwater movement into the casing and to exclude other material that may cause blockages. The annulus around the casing is filled with sand and the collar enclosed in concrete or bentonite to prevent water ingress from surface runoff.

Automatic water level logging instruments are installed and groundwater levels are measured at three hourly intervals by automatic water level logging instruments. The groundwater level data are downloaded at two-monthly intervals using a laptop computer.

Data Analysis Methodology

Groundwater Level

The data from the swamp piezometers and the aquifer piezometers will be analysed every two months to determine if mining has had any impact on groundwater levels. The raw data from the water level measuring instruments is calibrated using ground surface levels in order to calculate water depth. The three hourly readings are then averaged to obtain an average daily water depth. The data is also analysed to determine natural variations in groundwater fluctuations. This requires a base line data set that has been collected for at least two years pre-mining and allows for a robust time series groundwater analysis.

A post-mining cumulative distribution function (CDF) will be calculated and examined for comparison of shape and magnitude with the pre-mining CDF after sufficient post-mining groundwater level data has been gathered for the impact site. Similar CDF plots will be prepared for the reference sites. If a trigger has been breached, a normalization procedure will be applied to the reference site data to check if climatic conditions have caused any significant difference in the pre and post-mining groundwater levels. This will be done by calculating the ratio (r) of the pre-mining (M1) and post-mining (M2) median groundwater levels in the reference piezometer:

$$r = M1 / M2$$

and then applying the ratio to the post-mining groundwater level median (L_t) to get a corrected groundwater depth data series (L'_t):

$$L'_t = r \times L_t$$

This is then compared with the actual pre-mining data series (L_t) for the impact site. Alternative causes will be investigated if the trigger is still breached including rainfall mass balance which could have an impact on the relative response of the groundwater levels at different times.

It is important when comparing data between piezometers in different swamps or different aquifers that hydrogeologically similar swamps are compared. This should not be problematical as the data gathered to date has allowed the swamps to be categorised into permanently waterlogged and periodically waterlogged swamps.

Groundwater Quality

The groundwater chemistry monitoring program will provide data that can be evaluated for any significant changes that may result from mining activities. Any mining induced changes can be determined using the trigger values set out in Table 6.7. The trigger values have been developed using the ANZECC (2000) water quality guidelines for the protection of aquatic life (95% species protection levels). These trigger values will be compared to groundwater monitoring data from swamp piezometers. Minor and major water quality variations will be assessed by using the ANZECC protocols of comparing the 80th and 95th percentile baseline water quality with the 50th percentile post mining water quality and allowing for the effects of short term spikes due to rainfall runoff events.

Samples will be analysed for key groundwater chemistry parameters that may indicate effects of cracks in the local rocks due to mining activities. These key parameters were selected on the basis of water quality conditions that may be affected when mining starts. The key parameters for setting trigger values for assessment of cracks in rocks on groundwater quality are conductivity, pH, and iron. Changes will be tracked in all these parameters using Control Charts, as set out in Standard Methods (e.g. APHA, 1998 or later versions), Section 1020B and the ANZECC guidelines for Monitoring and Reporting.

7.1.4 Surface Water

Monitoring Sites

The most significant surface water flows in the Springvale controlled action area in the drainage lines that feed into the sub-permanently and permanently waterlogged swamps.

Details of the surface water monitoring sites are given in Table 7.8.

Table 7.8 – Details of Surface Water Monitoring Sites

Site Name	Easting (GDA94)	Northing (GDA94)	Location	Mining date (estimated)	Parameters monitored		
					water depth	flow rate	water quality
Surface Water Quality - Impact Sites							
Carne West	239808	6303782	Nth end of Carne West Swamp	Swamp will be undermined in April 2015 and November 2016		✓	✓
CWP	239816	6303814	Nth end of Carne West Swamp	Will not be undermined	✓		
SS3 D/S	239363	6303908	Nth end of Sunnyside East Swamp	Swamp to be undermined December 2013, December 2014, March/November 2015, August 2016			✓
Surface Water Quality - Reference Site							
Marangaroo Creek Upstream	236633	6301063	Marangaroo Creek upstream	Will not be undermined		✓	✓

Monitoring Methodology

Flow Rate Monitoring

Flow rate monitoring using flow meters has been adopted due to the difficulty in establishing stream flow weirs. Fortnightly flow readings are taken at the downstream end of the Carne West Swamp and Marrangaroo Upstream site using a Pygmy flow meter. The flow velocity in the watercourse is measured and read directly from the flow meter as the number of revolutions of the propeller for a fixed period of time. This is converted to a velocity using a conversion formula. The flow volume in ML/day is calculated by multiplying the flow velocity by the estimated cross sectional area of the flow.

Pool Water Level

Water pool level monitoring will be used in combination with flow rate monitoring in order to monitor stream flow. Pool water level monitoring has been recently introduced to assist with calculating flows in combination with flow meter monitoring. A twelve month data set of flow metering and pool level data will be collected and assessed for accuracy prior to developing triggers. The water level in the pool at the downstream end of Carne West Swamp is measured at three hourly intervals by an automatic water level logging instrument installed in the base of the pool. The water level data are downloaded at two-monthly intervals. This involves visiting the pool site to remove the instrument from the pool and download the data to a hand held computer.

Water Quality

Surface water quality is measured in both Sunnyside East and Carne West Swamps. The Carne West water monitoring site is the same as the flow monitoring site which was established in 2005, and the Sunnyside East site was established in 2010. Sampling of the surface water is carried out fortnightly. The main parameters that are monitored to detect these impacts, and the justification for their use, are:

- **pH:** Typically, pH in the permanently waterlogged swamps is low (~5 to 6), and any oxidation of minerals in the rock may alter the pH on a local basis. This is the most important parameter as any long-term change in the pH could affect the vegetation in the swamp.
- **EC:** Conductivity of the surface water in the swamps is normally very low (< 50 µs/cm) and chemical processes could result in an increase in the TDS and a consequent increase in conductivity.
- **Fe:** Iron-based minerals are common in the sandstones and tend to oxidise on exposure to surface conditions.
- **Mn:** Like iron, Mn is common in the sandstones and will oxidise when exposed to surface conditions.
- **TSS:** Although erosion is not expected to occur the monitoring of total suspended solids will give an indication of the onset of any erosion upstream in the swamp. Monitoring of TSS commenced in June 2012.

In addition, the same parameters will be measured in Marrangaroo Creek Upstream which will be used as a reference site for surface water quality. This site has been selected as water quality in Marrangaroo Creek Upstream exhibits similar characteristics with Sunnyside East and Carne West.

Data Analysis Methodology

The surface water chemistry monitoring program will provide data that can be evaluated for any significant changes that may result from mining activities. Any mining induced changes can be determined using the trigger values set out in Table 6.8. The trigger values have been developed using the ANZECC (2000) water quality guidelines for the protection of aquatic life (95% species protection levels). These trigger values will be compared to surface water monitoring data from monitoring sites. Minor and major water quality variations will be assessed by using the ANZECC protocols of comparing the 80^{th} and 95^{th} percentile baseline water quality with the 50^{th} percentile post mining water quality and allowing for the effects of short term spikes due to rainfall runoff events.

Samples will be analysed for key water chemistry parameters that may indicate water quality changes due to mining activities. These key parameters were selected on the basis of water quality conditions that may be affected when mining starts. The key parameters for setting trigger values for assessment of cracks in rocks on water quality are conductivity, pH, manganese and iron. Changes will be tracked in all these parameters using Control Charts, as set out in Standard Methods (e.g. APHA, 1998 or later versions), Section 1020B and the ANZECC guidelines for Monitoring and Reporting.

7.1.5 Fauna

Centennial Coal has carried out fauna monitoring on the Newnes Plateau for 8 years. Fauna monitoring will continue to be carried out into the future as part of general research efforts on the plateau. There are statistical methods that can be used to determine changes in faunal distributions and numbers in given areas. However, it is difficult to relate any changes directly to any impacts that may occur due to mining activities. This is particularly difficult given the inherent mobility of fauna species, the difficulty that is often experienced in finding individual species at any one location in time and the diversity of land use on the plateau.

No triggers will therefore be proposed in this MMP due to the difficulties in developing direct relationships between mining and faunal behaviour.

More meaningful triggers that can be more accurately related directly to any mining related impacts have been set out in this MMP. These triggers include:

- Subsidence
- Groundwater
- Surface water
- Flora

The assessment of ground and surface water in combination with flora allows a robust assessment of ecological processes and in combination with subsidence will allow a comprehensive analysis of whether any mining related impacts have occurred and the magnitude of any possible impacts.

Centennial Coal will continue to work towards developing meaningful mining related faunal triggers. The data that has been collected in the past and into the future will provide a comprehensive baseline data set.

7.1.6 Rapid Assessment Methodology for determining THPSS health

THPSS systems are unique and complex ecosystems with respect to flora assemblages and hydro / hydro-geological characteristics. These systems are sensitive to surface disturbances and can be difficult to access and traverse. One of the objectives of this MMP is to provide a monitoring program that allows any changes to be detected in a timely manner whilst reducing the impact of monitoring activities on the THPSS systems. Goldney et al (2010) developed a low impact Rapid Assessment Methodology (RAM) that can be used to gauge overall THPSS health with little or no monitoring related disturbance. RAM is made up of a 14 point condition assessment protocol which includes:

1. Location details
2. Topography and land surface
3. Land use and longwall mining
4. Fringing vegetation
5. Location of swamp within the catchment
6. Geology and soils
7. Geomorphology
8. Hydrology
9. Water quality
10. Swamp vegetation
11. Impacts and extent
12. Fauna observed
13. Ecosystem condition, thresholds, condition trend
14. Impact of longwall mining

RAM will be used to establish a baseline condition of impact and reference THPSS systems prior to mining and again if any mining related triggers are deemed to have occurred. A full description of the RAM taken directly from Goldney et al is set out in Appendix G.

7.2 Hanging Swamps

Hanging swamps to be monitored as part of this MMP are set out in Appendix B. The proposed monitoring for hanging swamps will include the following:

- Site inspections will be carried out at hanging swamps located within a 26.5 degree angle of draw before and after the passage of each longwall panel to check for any visible surface subsidence damage such as cracking, slumping or erosion. This will include pre and post mining photographic monitoring
- Aerial photographic monitoring will be carried out on all of the swamps on a regular basis. This will allow the condition of the total area of all of the hanging swamps (as well as the shrub swamps) to be assessed.
- Rapid Assessment Method flora monitoring will be carried out pre-mining where access to hanging swamps is available. Further Rapid Assessment Method monitoring will be carried out post mining if any cracking or erosion occurs.
- No groundwater or surface water monitoring will be carried out due to the lack of ground and surface water in these systems.
- LiDAR data will be gathered as part of a research program into low impact monitoring methodologies and the data will be reviewed and assessed for applicability in ongoing monitoring programs. LiDAR techniques will be used to monitor subsidence, and will allow cumulative subsidence effects to be measured to within ±150 mm. This method will provide 100% coverage of the hanging swamps with minimal disturbance

7.2.1 Subsidence

Monitoring Sites

Pre-mining inspections of hanging swamps will be used to identify any significant features such as rock bars, cliff lines and general swamp health.

Monitoring Methodology

Visual inspections of hanging swamps will be conducted on a fortnightly basis (as per shrub swamps) during active subsidence development at the site. Any anomalous changes or impacts to the sites such as cracking, erosion and /or ponding will be recorded and photographed.

LiDAR will allow cumulative subsidence effects to be measured to within +/- 150 mm with minimal disturbance to the swamps. LiDAR data will be gathered as part of a research program into low impact monitoring methodologies and the data will be reviewed and assessed for applicability in ongoing monitoring programs.

Baseline Monitoring Data

LiDAR surveys will be conducted before the commencement of subsidence and after the completion of each longwall panel. A photographic record of each swamp will be prepared for comparison with post-mining conditions. LiDAR data will be gathered as part of a research program into low impact monitoring methodologies and the data will be reviewed and assessed for applicability in ongoing monitoring programs.

8 Summary of Performance Indicators

Section 7 outlined the details of the monitoring program for LW 418, including data analysis methodology and establishment of performance indicators and trigger levels. This data is summarised for all of the monitoring programs in Table 8.1 below.

Table 8.1 – Summary of monitoring against performance indicators and measures

Performance Measure	Monitoring			Data Analysis to assess against performance	Performance Indicator	Performance Indicator Investigation Triggers	Management Measures
	Sites	Parameters	Frequency				
SUBSIDENCE							
No anomalous subsidence in shrub swamps	LW 418 B Cross line	• Subsidence • Tilt • Tensile strain • Compressive strain •	Surveys every 200 metres of face advance when the face is between 200 metres ahead and 300 metres past the survey lines. One survey on B and M survey lines post mining	Comparison of measured subsidence against predicted subsidence	Exceedence of anomalous subsidence levels	Anomalous subsidence trigger level will be exceeded if: • Subsidence >1.45 m • Tilt > 10 mm/m • Tensile Strain > 5 mm/m • Compressive Strain >16 mm/m	If anomalous subsidence trigger is exceeded > 15% once. Within 2 months: • Inspect site for visible surface effects and assess need for additional survey or wait for next scheduled survey. If Anomalous Subsidence Trigger Exceeded > 15% twice at same location on consecutive surveys. Within 2 months: • Review prediction model and input assumptions. • Notify stakeholders and carry out field inspections for visible subsidence effects (cracking, ponding, slumping, and erosion) to determine if an impact has occurred. • Develop Response Strategy if persistent impacts have been identified.
No anomalous subsidence in shrub swamps	**Sunnyside East Swamp** • V-VC and • W-WC Lines	• Subsidence • Tilt • Tensile strain • Compressive strain • Upsidence • Closure	• Surveys every 200 metre of face advance when the face is between 200 metre ahead and 200m past the survey lines	Comparison of measured subsidence against predicted subsidence	Exceedences of anomalous subsidence levels	Anomalous subsidence trigger level will be exceeded if: • Subsidence >1.35 metre • Tilt > 9 mm/m • Tensile Strain > 5 mm/m • Compressive Strain >1 mm/m • Upsidence >0.75m • Closure >1.0m	
	• **Carne West Swamp** • Y-YC2, X-XC and B Lines					Anomalous subsidence trigger level will be exceeded if: • Subsidence >1.35metre • Tilt > 9 mm/m • Tensile Strain > 5 mm/m • Compressive Strain >16 mm/m • Upsidence 0.45m • Closure 0.6m	

Performance Measure	Monitoring			Data Analysis to assess against performance	Performance Indicator	Performance Indicator Investigation Triggers	Management Measures
	Sites	Parameters	Frequency				
GROUNDWATER LEVEL							
Negligible mining-related impact on regional shallow aquifer hydrogeological regime	**AQUIFER PIEZOMETER IMPACT SITES:** *Piezometers:* RSS, SPR1101, SPR1104, SPR1107, SPR1109, SPR1110, SPR1110 **AQUIFER PIEZOMETER REFERENCE SITES:** *Piezometers:* SPR1108, SPR1112, SPR1113, AP5PR	Groundwater level	Daily – data downloaded two-monthly	• Groundwater level data will be reduced and analysed • Statistical analysis using 7-day floating average – including median, 5^{th}, 20^{th}, 80^{th} and 95th percentile pre-mining groundwater depths for comparison with post-mining data and the post-mining median depth • Reference sites used to analyse climate related changes	**Primary** • Any significant change in groundwater level relative to pre-mining groundwater level behaviour **Secondary** • Any significant change in groundwater level not related to recent meteorological conditions • Any significant change in groundwater level relative to groundwater level behaviour at reference sites during the same period	Performance indicators will be considered to have been exceeded if statistically significant changes are indicated by the data such as: • For short-term change – if the groundwater level < 5^{th} percentile or > 95^{th} percentile pre-mining groundwater level for more than one month • For long-term change – if the post-mining 50^{th} percentile groundwater level for any piezometer < 20^{th} percentile or > 80^{th} percentile pre-mining level An assessment will be made against the performance measure	If the primary performance indicator has been exceeded suitable management measures and/or corrective actions will be implemented including. Within 2 months: • Check for trigger level exceedences of secondary performance indicators • Check for anthropogenic or other natural causes of the anomalous data • Carry out field inspection to determine the extent and causes • Consider additional or more frequent monitoring • Engage a hydro geologist to provide an opinion on the trigger level exceedences, if required • The results will be reported to appropriate state and federal government agencies. See Section 9 for details
Identify any lowering of groundwater levels or increased interactions between surface and groundwater in shrub swamps	**SWAMP PIEZOMETER IMPACT SITES:** **Carne West Swamp** *Piezometers:* CW1*, CW2*, CW3, CW4 **Sunnyside East Swamp*** *Piezometers:* SSE1, SSE2, SSE3*	Groundwater level	Daily – data downloaded two-monthly	• Groundwater level data will be reduced and analysed. • Statistical analysis using 7-day floating average – including median, 80^{th} and 95th percentile pre-mining groundwater depths for comparison with post-mining data • Reference sites used to	**Primary** • Any significant change in groundwater level relative to pre-mining groundwater level behaviour. **Secondary** • Any significant change in groundwater level not related to recent meteorological conditions.	Performance indicators will be considered to have been exceeded if statistically significant changes are indicated by the data such as: • For short-term change – if the groundwater depth > 95^{th} percentile pre-mining groundwater depth for more than 7 consecutive days • For long-term change – if the	If the primary performance indicator has been exceeded suitable management measures and/or corrective actions will be implemented including. Within 2 months: Compare with data and statistical analyses from reference sites for any differences

Performance Measure	Monitoring			Data Analysis to assess against performance	Performance Indicator	Performance Indicator Investigation Triggers	Management Measures
	Sites	Parameters	Frequency				
	SWAMP PIEZOMETER REFERENCE SITES: **Carne Central Swamp** *Piezometer:* CC1* **Marangaroo Swamp** *Piezometer:* MS1* **Tristar Swamp** *Piezometer:* TS1 **Twin Gully Swamp** *Piezometer:* TG1			check for climate related fluctuations	• Any significant change in groundwater level relative to groundwater level behaviour at reference sites during the same period.	post-mining 50^{th} percentile groundwater depth for any piezometer > 80^{th} percentile pre-mining level An assessment will be made against the performance measure.	Check for trigger level exceedences of secondary performance indicators Carry out field inspection to determine the extent and causes See Section 9 for details. Carry out an investigation to determine the cause of the water quality change Consider additional or more frequent monitoring
GROUNDWATER QUALITY							
Change in groundwater water quality	**SWAMP PIEZOMETER IMPACT SITES:** **Carne West Swamp** *Piezometers:* CW1*, CW2*, CW3, CW4 **Sunnyside East Swamp*** *Piezometers:* SSE1, SSE2, SSE3* **SWAMP PIEZOMETER REFERENCE SITES:** **Carne Central Swamp** *Piezometer:* CC1*	• Groundwater quality in piezometers marked * – full chemical analyses • *EC, pH and Iron*	Monthly analysis – Groundwater samples taken and analysed monthly	• Samples will be analysed by a NATA registered laboratory. • Relevant data will be reduced and plotted on a spread sheet. • Initially, only the indicative parameters EC, pH, Fe will be assessed for any change. • Statistical analysis – the pre-mining mean, standard deviation, 80^{th} and 95^{th} percentile level, and post-mining 50^{th} percentile level will be determined for each indicative parameter in impact and reference sites • Random check for accuracy	**Primary** • Any significant change in analyte concentrations relative to pre-mining groundwater quality **Secondary** • Any significant change in analyte concentrations relative to pre mining. • Any significant change in analyte concentrations relative to groundwater quality behaviour at reference sites.	Performance indicators will be considered to have been exceeded if statistically significant changes are indicated by the data such as: • For short-term change – if any measured parameter > baseline 80^{th} percentile by two standard deviations for more than two months. • For long-term change – if the post-mining 50^{th} percentile level for any analyte exceeds the 80^{th} percentile pre-mining level An assessment will be made against the performance measure.	If the primary performance indicator has been exceeded suitable management measures and/or corrective actions will be implemented including. Within 2 months: • Compare with data and statistical analyses from reference sites for any differences • Check for trigger level exceedence of secondary performance indicators • Carry out field inspection to determine the extent and causes • Carry out an investigation to determine the cause of the

Performance Measure	Monitoring			Data Analysis to assess against performance	Performance Indicator	Performance Indicator Investigation Triggers	Management Measures
	Sites	Parameters	Frequency				
	Marangaroo Swamp *Piezometer:* MS1* **Tristar Swamp** *Piezometer:* TS1 **Twin Gully Swamp** *Piezometer:* TG1			using the ion balance method			water quality change • Consider additional or more frequent monitoring See Section 9 for details.
SURFACE WATER QUALITY							
Change in surface water quality	**IMPACT SITES:** *Surface Water Quality:* Carne West, Sunnyside East **REFERENCE SITE:** *Surface Water Quality:* Marangaroo Upstream	• Surface water quality – limited chemical analyses • EC, pH, Iron, Manganese, TSS	Monthly	• Samples will be analysed by a NATA registered laboratory. • Relevant data will be reduced and plotted on a spread sheet. • The indicative parameters EC, pH, Fe, Mn and TSS will be assessed for any change. • Statistical analysis – the pre-mining mean, standard deviation, 80th percentile level and post-mining 50th percentile level will be determined for each indicative parameter • Random check for accuracy using the ion balance method	**Primary** • Any significant change in analyte concentrations relative to pre-mining. **Secondary** • Any significant change in analyte concentrations not related to recent meteorological conditions. • Any significant change in analyte concentrations relative to water quality behaviour at reference sites.	Performance indicators will be considered to have been exceeded if statistically significant changes are indicated by the data such as: **Surface Water Quality** • For short-term change - if any measured parameter > baseline 80th percentile by two standard deviations for more than two months. • For long-term change – if the post-mining 50th percentile level for any analyte exceeds the 80th percentile pre-mining level	Management measures and/or corrective actions will be implemented if the primary performance indicator has been exceeded. Within 2 months:: • Check for trigger level exceedance of secondary performance indicators • Check for anthropogenic or other natural causes of the anomalous data • Carry out field inspection to determine the extent and causes • Consider additional or more frequent monitoring See Section 9 for details.

Performance Measure	Monitoring			Data Analysis to assess against performance	Performance Indicator	Performance Indicator Investigation Triggers	Management Measures
	Sites	Parameters	Frequency				
FLORA							
Identify mining impacts on THPSS flora	**SHRUB SWAMP** **IMPACT SITES:** **Carne West Swamp*** ***Quadrats:*** WC01 WC02 WC03 WC04 **Sunnyside East Swamp*** SSE01 **SHRUB SWAMP** **REFERENCE SITES:** **Twin Gully Swamp** TG01 TG02 **Tri-star Swamp** TRI01 TRI02 **Carne Central Swamp** CCS01 **Lower Gang Gang Swamp** LGG01 **Upper Gang Gang East Swamp** UGE01 **Barrier Swamp** BS01	• Change in diversity of native species • Recruitment of eucalypt species • Condition of key species • Non-live ground cover • Non-native weeds	Quarterly – Spring, Summer, Autumn and Winter.	• Data indicates a decrease in native species diversity (of swamp species) • Data indicates an increase in eucalypts • Data indicates a decline in condition • Data indicates an increasing non-live ground cover	• Any significant change in species diversity • Any significant change (increase) in eucalypt species numbers • Any significant change (decrease) in condition/health of the swamp flora • Significant increase in non-live ground cover • Significant increase in weed species	Indicators will be considered to have been exceeded if: • Data indicates an increasing trend in non-native weeds • A change in the number of species of greater than 30% for a given site within a three year period. • An increase in eucalypts in an impact site compared to reference sites of more than three individual plants within a one year period. • A decline in condition score at an impact site of more than 1.5 compared to the average condition score at unimpacted sites within a one year period. • An increase of bare ground of more than $100m^2$ in a site ($400m^2$) within a one year period. • An increase in non-native weed species of more than 4 in a site (each having a cover greater than 5%) compared to the average number in reference sites within a one year period	If the data indicates the performance indicator has been exceeded or is likely to be exceeded suitable management measures and an assessment will be made against the performance measure. Within 2 months: • Carry out field inspection to determine the extent and cause • Study and determine hydrological conditions to determine if natural colonisation is likely • Carry out more frequent monitoring • Removal of weeds using bush regeneration techniques • Restoration of any swamp flora via natural colonisation following soft engineering solutions (coir logs, peat restoration etc.) • Restoration of swamp flora via seed collection and seedling establishment if natural colonisation is unlikely • Monitor the change (restoration) of the affected vegetation until the affected area is within the normal range for all monitored parameters (species diversity; number of eucalypts; condition; non-live ground cover; non-native weeds) and then for a following period of two years

9 Management Measures and Corrective Actions

If the trigger levels outlined in Section 6 are exceeded, a series of checks will be made to discern non-mining-related impacts from mining-related impacts. Once this process is followed then management measures and/or corrective actions can be implemented if required. If non-mining-related impacts are indicated as the cause of the trigger level exceedence, a notification to the relevant authorities will be undertaken. If mining-related impacts are suspected then a series of corrective actions within a defined process will be actioned. The response to these exceedences will take the form of a Trigger Action Response Plan (TARP).

Since the occurrence of a trigger level exceedence for anomalous subsidence is reported and handled differently to an exceedence from other monitoring programs, a separate TARP is used for subsidence monitoring. This TARP is used to determine if the anomalous subsidence has resulted in any visible surface impacts on the swamps. This process is outlined in Table 9.1 below.

The TARP for the remainder of the monitoring programs outlines a process where checks are made to determine if the trigger level is due to non-mining-related impacts. An outline of the means by which the TARP will be implemented is presented in Charts 1 to 3. Details of this process and the appropriate management measures are given in Table 9.2.

Table 9.1 – Subsidence monitoring management measures

Trigger type	Response to trigger	Possible cause of trigger	Management measures
Determine whether anomalous subsidence is due to a data error			
Data error	• Check data • Check methodology • Check survey marks • Check calculations	• Misreading • Data handing error • Survey marker damage • Calculation error	• Amend any erroneous data • Review data handling processes and improve if possible • Repair survey marker if necessary • No need to report to DOE if data error
Anomalous subsidence results within 200 metres of THPSS ecological community			
Anomalous subsidence trigger exceeded > 15% once	• Determine extent and magnitude of anomalous subsidence • Determine likely reasons for anomalous subsidence • Determine the potential impacts of the anomalous subsidence on the THPSS	• Undetected data error • Previously unidentified structural discontinuity in the overburden • Other unexpected geological or topographical conditions • Inadequate prediction model	• Inspect site for visual impact • Assess the need for additional survey or wait for next scheduled survey • Report on trigger level exceedence to DOE within 10 working days
Anomalous subsidence trigger exceeded > 15% twice at same location on consecutive surveys.		• Previously unidentified structural discontinuity in the overburden • Other unexpected geological or topographical conditions • Inadequate prediction model	• Inspect site for visual impact • Assess the need for additional survey • Review prediction model and input assumptions. • Notify stakeholders of exceedence • Check for Performance Indicator Exceedance • Report on trigger level exceedence to DOE within 10 working days

Table 9.2 – Non subsidence monitoring programs and management measures

Trigger type	Response to trigger	Possible cause of trigger	Management measures
Determine whether anomalous conditions are due to a data error			
Data error	• Check data • Check methodology • Check any instrumentation	• Misreading • Human error • Instrument malfunction • Instrumental error • Data handing error • Calculation error • Plotting error	• Amend any erroneous data • Review data handling processes and improve if possible • Repair/recalibrate instruments if necessary • No need to report to DOE if data error
Report all trigger level exceedences below to SEWPAC within 5 working days **Determine whether the trigger is non-mining-related**			
Various non-mining-related	• Check for similar anomalous conditions in the data at reference sites	Anomalous conditions seen at reference sites as well as impact sites indicates non-mining impact	• Determine the likely cause of trigger level exceedence and the anomalous conditions if possible • Review the relevant trigger levels and modify if necessary
	• Check for local non-mining anthropogenic activity • Check for impacts from any natural occurrences	Anthropogenic or natural impacts such as: • Forestry activity • Human recreational activities • Feral animal activities • Bushfire • Vandalism	• Report activities/impacts to relevant authorities • If impact is mining related, monitor to determine if natural regeneration / stabilisation is likely to be successful. • For persistent impacts develop a response strategy
Various non-mining-related	• Check recent meteorological data • Check for any weather-related impacts	Abnormal weather conditions such as: • Above average rainfall period • Storm event • Lightning • Dry or drought conditions	• Confirm the likely cause of trigger level exceedence if possible • Review the relevant trigger levels and modify if necessary • Repair/restoration of any damage if related to mining activities
	• Check location of current extraction for proximity to monitoring site	Statistical exceedence is a possible cause if active mining is not nearby. For all triggers based on statistical analyses, there is the possibility of non-mining-related trigger exceedences under normal conditions	• Review trigger levels and modify if necessary • Re-check at the next data review • Additional or more frequent monitoring may be warranted
If a trigger is determined to be mining-related, use appropriate corrective actions – see below			

Where the assessment of data against the performance indicators suggests that the trigger level exceedence is possibly mining-related, a series of time-dependant corrective actions are required to ensure that any impacts are minimised, and any severe impacts are identified. The following steps in Table 9.3 below outline the actions that must be taken if a potential mining-related impact is reported.

Table 9.3 – Administrative and Corrective Actions

Timeframe	Administrative and Corrective actions
Day 1	Trigger level exceedence indicating anomalous conditions possibly caused by mining-related impacts is detected by the Responsible Person
Within 5 business days from Day 1	**Administrative Action** For all mining-related trigger level exceedences from monitoring programs, except subsidence monitoring: • Report the exceedence to DOE • Provide monitoring results showing the anomalous conditions • Explain the likely or possible cause of the exceedence and the anomalous conditions
Within 10 business days from Day 1	**Administrative Action** If anomalous subsidence data is the trigger: • Report anomalous subsidence to DOE • Provide details of the level and extent of anomalous subsidence • Provide explanation of the likely reasons for the anomalous subsidence • Outline potential impacts on the THPSS resulting from the anomalous subsidence
Within 4 weeks from Day 1	**Corrective Actions** • Review all data for any additional trigger exceedences • Review data from other monitoring programs for any anomalies • Carry out a field inspection to examine conditions, and check for any adverse impacts on the swamp vegetation • Investigate the need for more frequent or additional targeted monitoring to better define the mining-related impacts • Make recommendations for any other future actions or investigations
Within 8 weeks from Day 1	**Corrective Actions** • Report the proposed corrective actions to DOE • Develop and implement any recommended additional monitoring, investigation and inspection programs
Six months from implementation of the additional monitoring, investigation and inspection programs	**Corrective Actions** • Carry out any investigations • Review data from all monitoring programs • Make an assessment whether the anomalous conditions have become worse or not
If any assessment of the monitoring data indicates that the anomalous	**Administrative Action** • Notify DOE of the return to normal conditions • Return to normal THPSS monitoring regime

Timeframe	Administrative and Corrective actions
conditions are no longer in evidence	
If any assessment of the monitoring data indicates that there is no change in the anomalous conditions	**Corrective Actions** • Notify DOE of the ongoing conditions • Monitor conditions for an additional six month period. • Undertake any necessary additional investigations • Investigate the feasibility and cost of potential engineering solutions • Liaise with relevant government departments on approvals for future engineering solutions • Make an assessment on whether the anomalous conditions have become worse at end of the six month period
If any assessment of the monitoring data indicates that the anomalous conditions have become worse	**Corrective Actions** • Notify DOE of the worsening conditions in the swamp • Notify the relevant state government authorities (OEH, DTIRIS) of the worsening conditions • Monitor conditions for an additional six month period. • Undertake any necessary additional investigations • Obtain opinions from appropriate experts on possible solutions • Investigate the feasibility and cost of potential engineering solutions • Liaise with relevant government departments on approvals for future engineering solutions • Make an assessment on whether the anomalous conditions have become worse or not at end of the six month period and whether the impacts represent a “severe impact”
SEWPAC Minister, or in-house assessment of the anomalous conditions, determines that conditions represent a “Severe Impact”	• Develop and implement a Response Strategy as required by the approval condition 11

Chart 1 - Trigger Action Response Plan – Overview

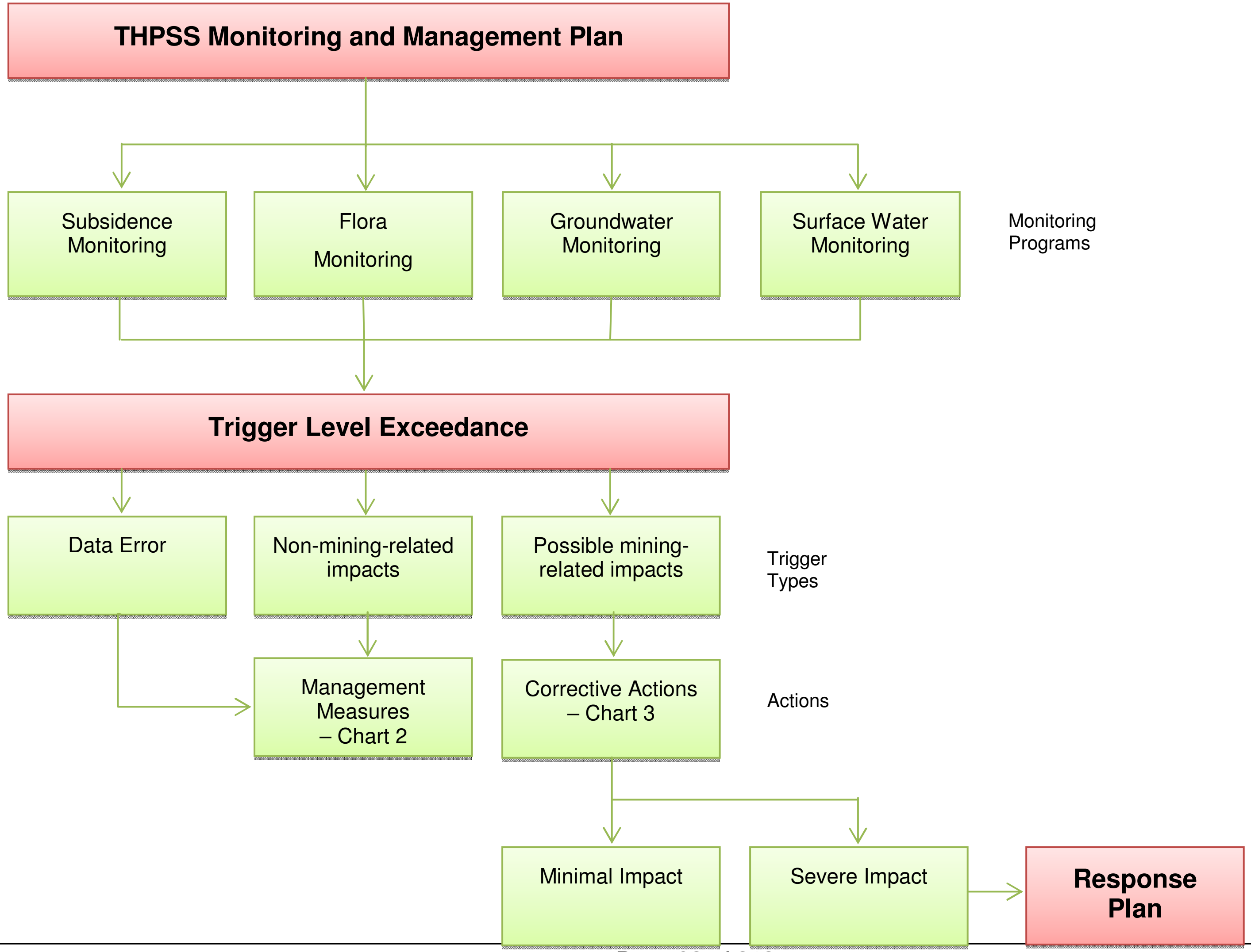


Chart 2 - Trigger Action Response Plan – Management Measures

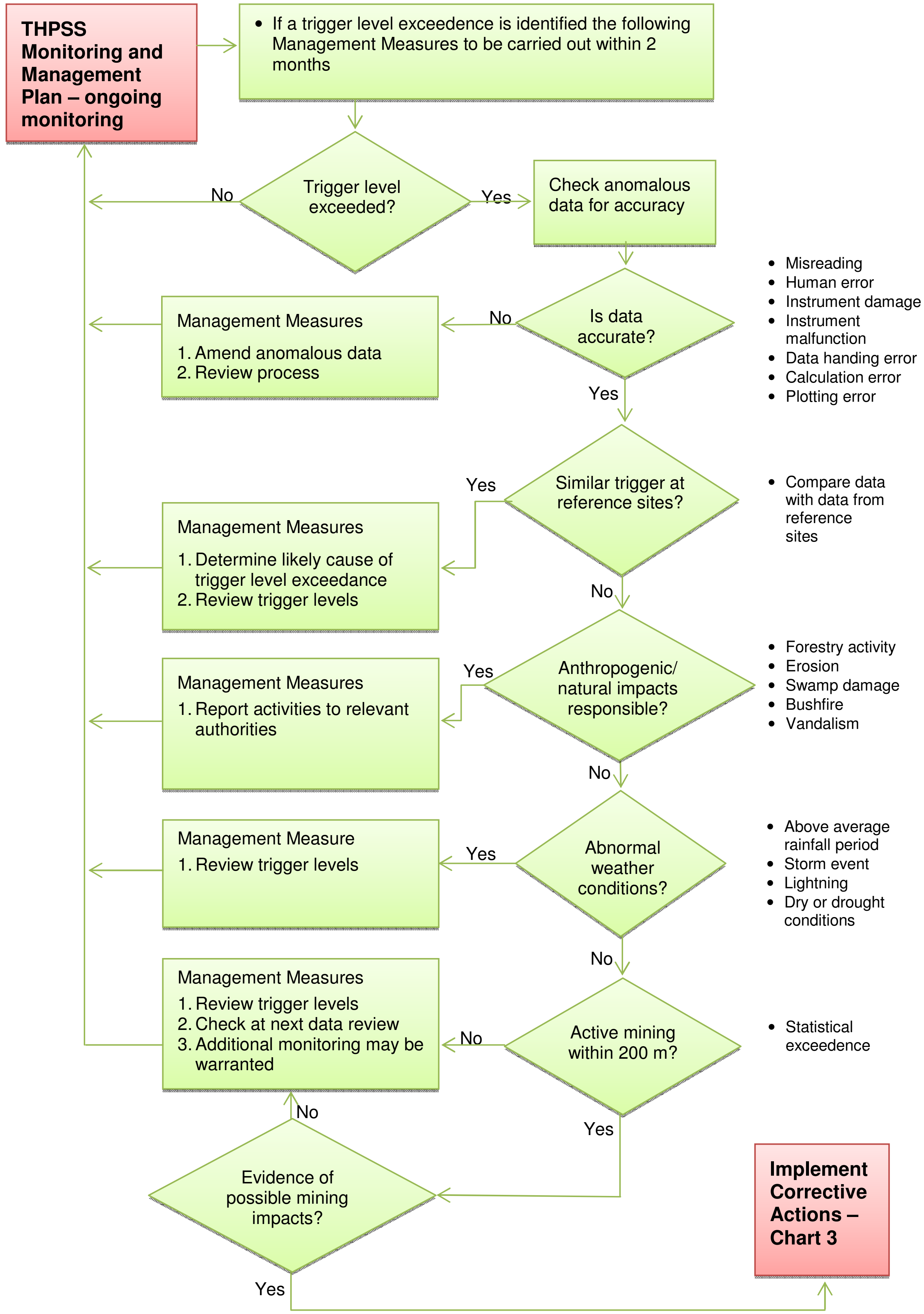
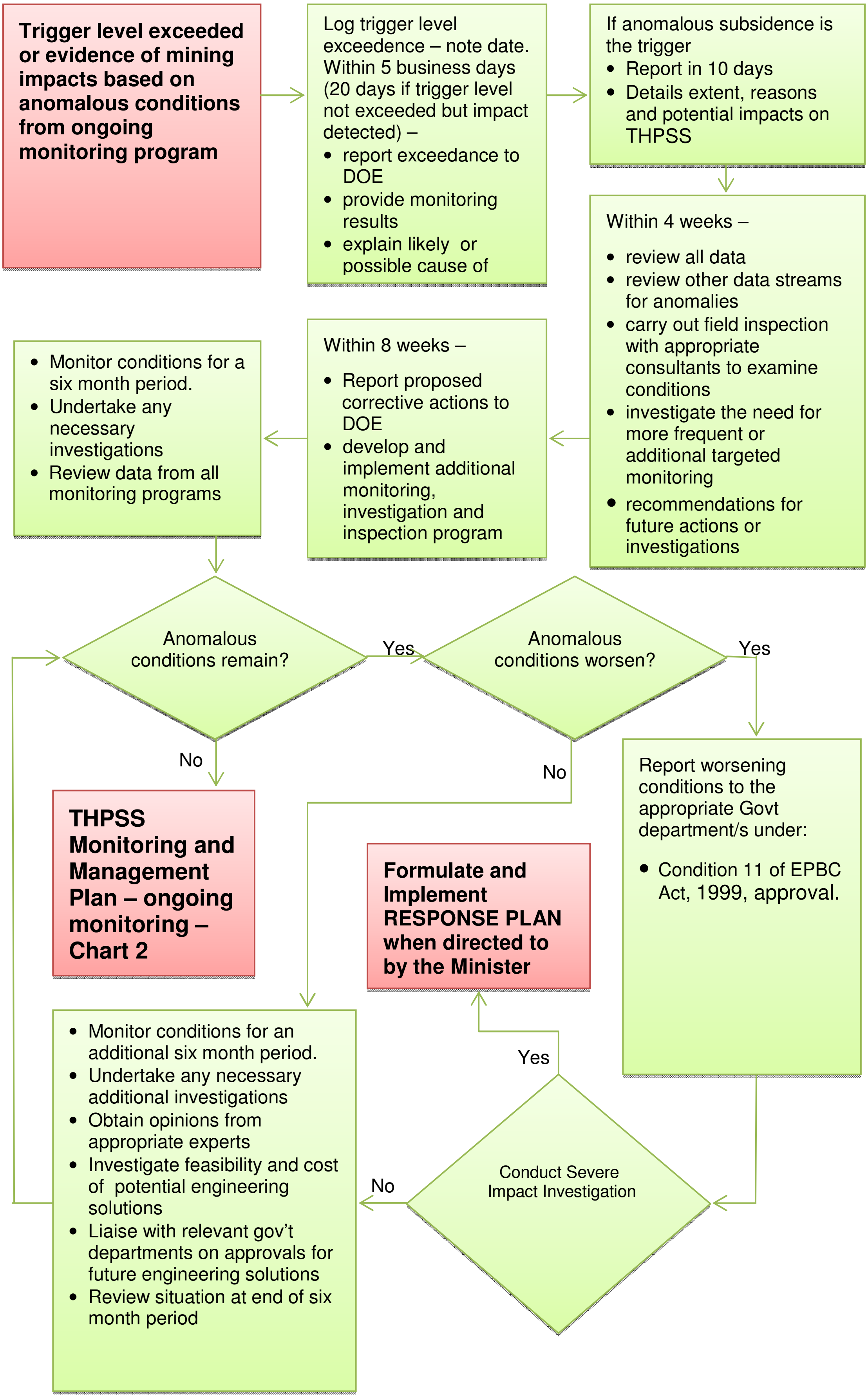


Chart 3 - Trigger Action Response Plan - Corrective Actions



10 Remediation Actions for Response Strategies

The conditions of approval for the controlled action require that a Response Strategy be prepared if the Minister determines that any anomalous conditions constitute a "severe impact". This section provides a summary of remediation strategies that have been used on the Newnes Plateau and elsewhere to remediate swamps that have been affected by anthropogenic activities.

Remediation measures can be classified into two main categories. These are:

- **Soft Engineering Solutions** such as coir logs, jute matting, geotextile, rock armouring, timber log dissipaters and a range of other options that are generally designed to repair cracks and erosion and prevent recurrence by regulating the flow of surface and subsurface water. These solutions are generally biodegradable and therefore integrate into the swamp systems
- **Hard Engineering Solutions** such as the use of concrete and various grouting techniques. These solutions are used where subsidence cracking is persistent and results in water losses from swamps and streams

The swamp remediation strategies set out in this section are therefore based on successful strategies used on the NSW central coast, the NSW southern coalfields and the Newnes Plateau in the Blue Mountains.

A hierarchy of control will be used when implementing remediation works. Soft engineering solutions will be used initially to remediate any impacts that may occur. These soft engineering works will be monitored and maintained to ensure design performance. Hard engineering solutions will be used if monitoring demonstrates that the soft engineering solutions require additional works.

10.1 Soft Engineering Solutions

10.1.1 Erosion Control

Ground movement due to subsidence may result in a change in flow patterns in swamps. This can lead to the development of sub surface tunnelling through peat layers which can then collapse forming an erodible channel. Head ward erosion can result in an unstable channel which requires stabilisation. In this situation, coir log dams will be constructed across the flow path to spread flows across a wider area and reduce flow rates to prevent the propagation of head ward erosion. This will accelerate the natural healing properties that THPSS systems experience when natural erosional processes occur. Square coir logs have been specifically designed for this application in swamp remediation and have been successfully used on the Newnes Plateau.

The coir log dams are designed so that water backing up behind the structures fills to just over the crest which results in a spreading of water and slowing of flow. A series of coir log dams may be required along a flow line depending on the height of the head ward erosion, the slope of the swamp and the predicted peak flows for the swamp system. A series of successfully installed coir logs along a previously eroding swamp drainage line are shown in Figure 10.1 below.

Figure 10.1 – Coir logs used to decrease water velocity and repair an eroded section of swamp

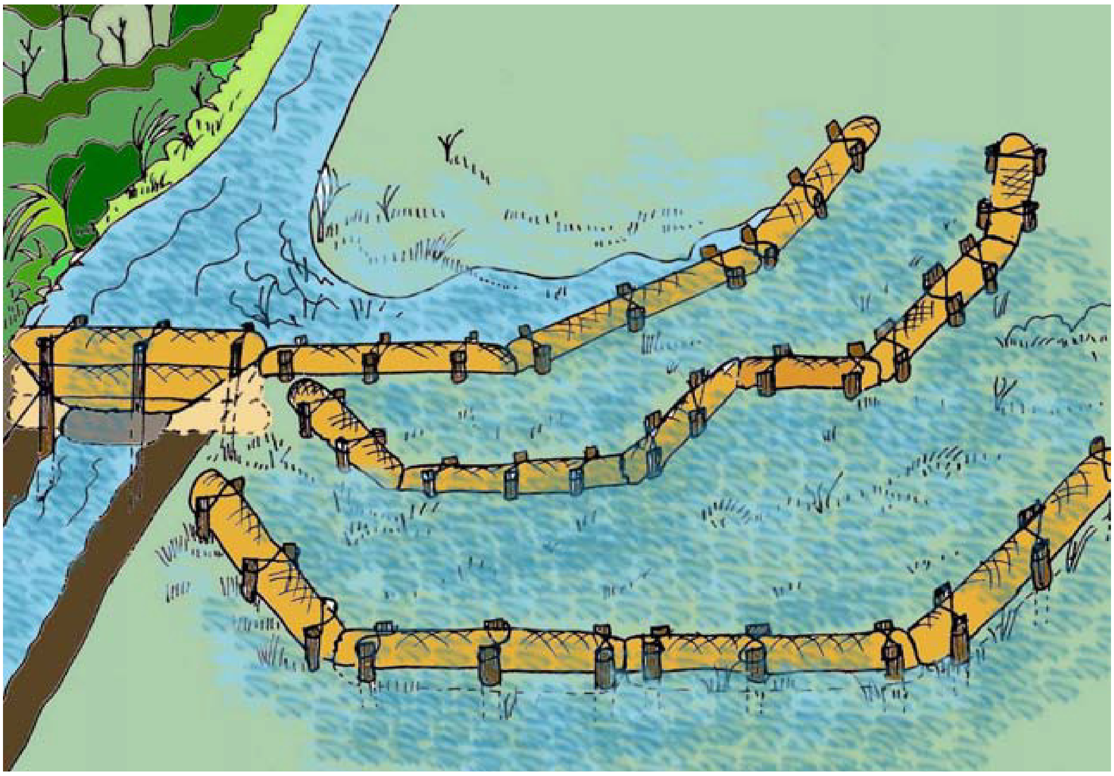
The result is a non-erosive flow of water through the swamp rather than a high energy erosive flow through or around the swamp. The swamp then becomes a net retainer and user of water due to enhanced low flow infiltration rather than a net loser of water. Multiple layers of coir logs may be required to construct the dams across the flow path. This again depends on the depth of the eroding channel. It is important that the first layer of coir logs are placed in a trench that has been excavated down to the underlying substrate / sandstone base of the swamp. This prevents any tunnelling, collapse and subsequent erosion. Jute matting wrapped around the coir logs can also be used to increase water retention if required.

These structures would be monitored and maintained as required. More logs may need to be added to the structure over time as the system silts up and stabilises.

10.1.2 Spreading and distribution of water

Spreading of water in swamps is important for keeping the peat layer moist and distributing water for use by vegetation. Coir logs can be used to improve the spreading of water across swamp systems. This involves placing coir logs in shallow trenches along the contour of the swamp system so that water flowing through the swamps builds up behind the logs, spreading sideways as well as slowly filtering through the semi permeable logs. These logs can generally be installed along the higher margins of the swamps as shown in Figure 10.2.

Figure 10.2 – A generalised example of how coir logs can be used to slow and distribute water flows and provide a solution against erosion and swamp desiccation



Coir logs biodegrade and eventually become part of the swamp system as the swamp silts up and returns to a natural flow regime. The logs are also flexible enough to respond to any shifting or moving as the swamp system evolves and stabilises. Hard structures such as concrete barriers do not have the same flexibility and are less likely to produce the same result. There is no post rehabilitation removal of coir logs so therefore no post rehabilitation disturbance of swamp systems.

Coir logs would be the main soft engineering stabilising structures used in swamp remediation. However, the logs may also be used in combination with other soft engineering solutions such as rock armouring, timber logs, jute matting and geotextile.

10.2 Hard Engineering Solutions

Hard engineering solutions may be required where cracking of the base of a THPSS may cause drainage of water away from the THPSS, which may have the potential to affect to the health of the system. Aquifer modelling and the groundwater and swamp health case studies presented in this document show that this is extremely unlikely. However, proven technologies related to other mining operations developed to remediate cracking of rock structures are now discussed. The integrity of the water retaining structure is restored through the implementation of these remediation strategies. The strategies have been researched and modified so as to suit the specific THPSS systems above the Springvale mining operation.

10.2.1 Injection Grouting

Grouting of rock formations has been occurring since the 1800's *(Heidarzadeh et al (2007)*), the technology has evolved since this time. It can be used in a range of different applications. Grouting is utilised to either stabilise rock formations or to manage the flow of groundwater and has been implemented successfully for decades in underground coal mines in Australia and overseas.

This technology has been recently adapted to seal mine subsidence related surface and sub-surface cracking in rock bars in the southern coalfields of NSW.

"Injection grouting" is the process of injecting grout using pre-drilled holes into a cracked rock bar or swamp substrate. Grouting involves injecting a permanent low permeability material into cracked areas to provide a seal to control vertical or horizontal water flows. There are various types of grouts that can be used but generally they will be either cement based or polyurethane resins (PUR). The use of injection grouting for remediating subsidence cracking has been pioneered in the southern coalfields of NSW and has been used to successfully repair cracking in surface and near surface rock substrates.

Grout is pumped into the targeted area at low pressure once the grouting holes have been drilled. High viscosity grouts are used for vertical fracturing as the setting time for vertical holes needs to be shorter to optimise the use of the grout which flows faster in vertical cracks under the influence of gravity. Lower viscosity grouts would be used where horizontal cross linking of cracks is present.

A specific example of where PUR grouting has been shown to successfully repair a rock substrate can be seen at Helensburgh Coal Pty Ltd (HCPL) in the NSW Southern Coalfields. Experience at HCPL has shown that grouting using PUR can be used to successfully fill cracks ranging from small sub millimetre sized cracks to open fractures greater than 100mm. A trial was conducted at HCPL on the WRS4 rock bar in the *Waratah Rivulet* and was followed by a remediation report (*Waratah Rivulet Remediation Trial Activities – Completion Report (2007*)). The main findings of the remediation report were:

- PUR is non-toxic
- PUR injection can be conducted in an environmentally acceptable fashion
- PUR injection is suitable for sealing cracking in rocks from less than 1mm to greater than 100mm
- Pre and post permeability testing showed that permeability was reduced by several orders of magnitude following PUR injection
- The PUR injection process was transferrable to other areas where cracking of rock had occurred

The HCPL PUR grouting programs are used to seal cracking in outcropping rock bars. However, it is considered that this technology is transferrable and can be used to seal cracks in swamp bases as a swamp *base* is analogous to a rock bar, albeit one covered with peat and sand. A comprehensive case study of the HCPL PUR grouting program is set out in Appendix 6.

Previous experience of subsidence cracking at Springvale and Angus Place and predictive modelling shows that significant subsidence cracking above the two collieries is unlikely. With the event of cracking unlikely, it is hence unlikely that grouting will need to be used to repair rock bars or swamp substrates. However, this technology has been identified as a proven remediation strategy should anomalous cracking be identified.

10.3 Remediation Monitoring and Maintenance

A monitoring and post-implementation remedial maintenance program would be developed and implemented following any remediation works carried out on swamp ecosystems. The monitoring program would consist of monthly inspections to inspect the integrity of all structures and diversion works, and ensure remediation works were performed to design standards. Maintenance works would be implemented where it was determined that remediation works require further attention.

11 Review and reporting

11.1 Review and Updating of the MMP

This MMP will be reviewed and updated as required annually in line with the annual reporting date to DOE. This will be aligned with the AEMR and the Annual Review required by NSW state government agencies and will include:

- A review of trigger levels to determine whether changes are required
- Details of any additional monitoring sites
- A review of any remediation works
- A review of any work planning for ensuing 12 months
- A review of mine planning scheduled for ensuing 12 months
- The reviewed MMP to be submitted to DOE for assessment and approval

11.2 Reporting procedure and requirements

In accordance with the conditions of the approval, an annual report will be prepared detailing the results of actions carried out under the MMP. The conditions of approval require the report to include:

- A holistic assessment of overall swamp health
- A review of trigger levels
- A listing of trigger levels exceeded
- Actions taken in response to trigger level exceedences
- A review of the need for a response strategy for any exceedences

A template for the annual report is provided below.

11.2.1 Reporting template

The annual report to DOE will take the following form:

Chapter		Description
1.	Introduction	Stated requirements of the conditions of approval
2.	Monitoring Sites	Note all active monitoring sites under the MMP
3.	Mining activity	Details of the mining carried out in the controlled action area during the previous 12 months
4.	Meteorological conditions	Summary of the meteorological conditions during the previous 12 months
5.	Monitoring results	Brief summary of the results of monitoring from all monitoring programs (subsidence, flora,

Chapter		Description
		groundwater, surface water), including a review of trigger levels for all performance indicators
6.	Trigger level exceedences	A listing of all trigger level exceedences noted during the previous 12 months, including any investigations, management or corrective actions taken
7.	Response strategies	A review of the need for any response strategies following trigger level exceedences, note any potential future response strategy requirements
8.	Summary	An holistic assessment of overall swamp health within the controlled action area, taking into consideration the results of all monitoring programs as a whole, and including a statement of the overall impact of the mining on the swamp health

11.2.2 Record keeping and data storage

All raw data and results of data analyses and reports prepared for DOE will be stored securely in a dedicated management system. This system will provide secure record keeping and retrieval of records as per condition 7(p) of the EPBC approval.

11.3 Approval Reporting Requirements

The EPBC 2013/6881Approval Conditions outline the reporting and auditing requirements for the controlled action. These have been summarised in Table 11.1 below.

Table 11.1 – Summary of reporting requirements in accordance with the Conditions of Approval EPBC 2013/6881

#	Description	Timeframe
General Reporting Requirements		
6	Within six months of the date of this approval, Centennial must submit THPSS MMP for approval	Once off until requiring review
10	A report detailing the results of actions carried out under the MMP must be prepared and provided to SEWPAC annually on the anniversary date of the approval of the MMP. The Minister may request that the report be reviewed by an independent reviewer approved by the Department.	Annually by 19 March each year
29	A report must be publicised on the Centennial website addressing compliance with each of the conditions of the approval, including implementation of any management plans, reports, strategy etc	Within 3 months of anniversary date of the commencement of the action.
34	Unless otherwise agreed to in writing by the minister, Centennial mush publish all management plans, reports strategies etc referred to in the conditions of approval on their website.	Within 1 month of being approved by DOE
Reporting requirements in the event that a severe impact is triggered		
11	This condition outlines the reporting requirements when an impact is a defined trigger level being exceeded.	Addressed in Table 9.3 – Administrative and Corrective Actions
13	If a severe impact notification letter from the Minister is received, a Response Strategy must be prepared. The response strategy must be a stand-alone document and must be reviewed by two independent reviewers	Within 3 months of the date of the Ministers letter. See Section 10
17	A report detailing results of actions carried out under the Response Strategy must be prepared	Time to be agreed in writing with DOE
26	Centennial must publish all documents required under these conditions on their website except where agreed in writing with the department on the grounds of potentially sensitive commercial information.	

11.3.1 Auditing

In accordance with Condition 30 of the Conditions, the minister may direct Centennial to undertake an independent audit of compliance with the Conditions of Approval. The Minister must approve the auditor and the audit criteria prior to commencement of the audit. The audit report will be submitted to the Minister for review and must address the criteria to the satisfaction of the Minister.

11.4 Future Approvals

Since future mining at Springvale may be in an area overlain by THPSS, this MMP will be updated to accommodate monitoring of future extraction under future mining approvals.

12 Research

This section outlines the research projects that Centennial Coal are evaluating to further progress the understanding of the THPSS environment as well as developing low impact remote sensing vegetation monitoring techniques.

12.1 University of Queensland Handbook Implementation

The University of Queensland was commissioned in early 2012 to develop an appropriate monitoring methodology for THPSS with "the power to detect change". The post-doctoral fellows Drs Gretchen Brownstein, Caitlin Johns, Ray Blick, Andrew Fletcher, Peter Erskine, have prepared the following handbook:

Centre for Mined Land Rehabilitation, The University of Queensland, *Flora Monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps,* May 2014, University of Queensland Report.

This handbook will be cited as "UQ Flora Monitoring (UQFM) Handbook" or UQFM. As required by Peer Reviewer feedback, it outlines the datasets, analyses, and reporting required to conduct a statistically rigorous and sensitive flora monitoring program to detect change in Newnes Plateau Shrub Swamps and Hanging Swamps (hereafter referred to collectively as swamps or communities), at an individual swamp community scale, due to underground mining.

Benefits of the program includes

1) sufficient replication at the swamp scale such that analysis of key indicators of community composition and health can be assessed in a statistically rigorous manner

2) clearly defined and ecologically meaningful trigger values and

3) a clear framework outlining required management actions.

The sampling methodology consists of two components: a seasonal aerial survey and an annual intensive ground survey; designed to assess the full extent of each community under investigation. The aerial seasonal monitoring measures vegetation and swamp condition by capturing changes in live canopy cover and the extent of non-vegetated areas. In addition the seasonal aerial mapping will detect rapid changes in the environment from direct and indirect impacts (e.g.4x4 recreational vehicle activity).

The ground control points for the aerial survey will also provide seasonal information on cover of exotic species. The time-series air photos will provide a clear record of change throughout the duration of the monitoring program. The annual intensive ground survey will measure parameters associated with vegetation composition and condition by recording individual species abundance and the extents of non-vegetated areas. The annual survey records trends in species presence and abundance at an ecologically relevant time scale. It is recommended that the ground surveys are carried out when species are most easily identified (i.e. summer).

This new approach increases the quantity and quality of floristic information recorded while minimising impact from trampling

12.2 Satellite DinSAR for Monitoring Mine Subsidence

The objective of this research is to conduct monitoring through a satellite differential radar interferometry (DInSAR) survey to give an overview of ground deformation at the mines in the vicinity of the Newnes Plateau. It is proposed to gain good quality research information on monitoring mine subsidence via the use of DlnSAR. Initial analysis will focus on near-field deformation (mainly vertical), with the possibility of a future project which would focus on far-field deformation (mainly horizontal).

DInSAR has been demonstrated to deliver high levels of accuracy in measuring mine subsidence. Earlier studies by UNSW at Appin and Westcliff Mines show DInSAR and conventional line levelling give very similar results. A DInSAR survey will give an overview of ground deformation at the mines and can be conducted on a single-epoch or multi-epoch basis.

13 References

ACARP (2003): Review of Industry Subsidence Data in Relation to the Impact of Significant Variations in Overburden Lithology and Initial Assessment of Sub-Surface Fracturing on Groundwater. ACARP Project No. C10023. Ditton, S.G. and Frith, R.C. Strata Engineering Report No. 00-181-ACR/1 (September).

ACARP (2007): Hydrogeological Response to Longwall Mining. ACARP Project No. C14033. Hua Guo; Adhikary, D.P and Gaveva, D.

ANZECC (2000): Australian Water Quality Guidelines for Fresh and Marine Waters. Australian and New Zealand Environmental Conservation Council, ACT.

APHA (1998): Standard Methods for the Examination of Water and Wastewater. Quality Control: Control Charts. Section 1020B.

Aurecon (2009): Newnes Plateau Shrub Swamp Management Plan, *Investigation into Irregular Surface Movement within East Wolgan Swamp*, September 2009

Aurecon (2011a): Hydrogeological Assessment Longwalls 415, 416 and 417 Proposed Action Referral, Springvale Mine.

Aurecon (2011b). Angus Place and Springvale Groundwater and Surface Water Monitoring: Response to SEWPAC Requesting For Information. 2011.

Catling, P.C., and Burt, R.J. (1995): Studies of the ground-dwelling mammals of eucalypt forests in south-eastern New South Wales: the effect of habitat variables on distribution and abundance. *Wildlife Research* **22**, 271–288.

Catling, P.C., Burt, R.J., and Forrester, R.I. (1998): Models of the distribution and abundance of ground-dwelling mammals in the eucalypt forests of south-eastern New South Wales. *Wildlife Research* **25**, 449–466.

Catling, P.C., Burt, R J., and Forrester, R.I. (2000): Models of the distribution and abundance of ground-dwelling mammals in the eucalypt forests of north-eastern New South Wales in relation to habitat variables. *Wildlife Research* **27**, 639–654.

CSIRO (2004): Interpretation of Hydrogeological Data At Springvale Mine, CSIRO (Adhikary, Guo,Shen and Knight). November 2004.

DEC (2004): Threatened Biodiversity Survey and Assessment: Guidelines for Developments and Activities. Working Draft. November 2004.

DEC (2006): *The Vegetation of the Western Blue Mountains including the Capertee, Cox's, Jenolan and Gurnang Areas*, DEC and CMA.

DECCW (2009) Environment Protection Licence No. 3607. Springvale Coal Pty Ltd.

Denny, M. (2010): Then and now – fauna monitoring within Sydney Basin in *The Natural History of Sydney.* D.Lunney, P. Hutchings and D. Hochuli (editors) Royal Zoological Society of NSW.

Denny, M. (2011): Response to request by SEWPAC for additional information concerning longwall mining at Angus Place Mine and Springvale Mine, NSW. August 2011.

DEWHA (2010a): *Survey Guidelines for Threatened Birds*

DEWHA (2010b): *Survey Guidelines for Threatened Mammals*

DEWHA (2010c): *Survey Guidelines for Threatened Reptiles*

DEWHA (2010d): *Survey Guidelines for Threatened Amphibians*

DgS (2011): Subsidence Prediction and Impact Assessment for the Proposed Longwalls 415 to 417 at Springvale Mine, Wallerawang. DgS Report No. SPV-003/1. 28 February 2011.

DgS, 2012. Response to Submissions Regarding the SEWPAC Referral on Impacts to Temperate Highland Peat Swamps on Sandstone Due to the Proposed Angus Place LWs 900W / 910 and Springvale LWs 415 - 417 DgS Report No. ANP-002/3 (06/01/12)

Erskine, P. and Fletcher, A. (2011): Flora monitoring of swamp communities potentially impacted by Angus Place Longwalls 910 and 900W and Springvale Longwalls 415-417. September 2011.

Goldney, D, Mactaggart, B and Merrick, N. Determining whether or not a significant impact has occurred on Temperate Highland Peat Swamps on Sandstone within the Angus Place Mine lease on the Newnes Plateau (2010)

Lindenmayer, D.B., Incoll, R.D., Cunningham, R.B., Pope, M.L., Donnelly, C.F., MacGregor, C.I., Tribolet, C. and Triggs, B.E. (1999): Comparison of hairtube types for the detection of mammals. *Wildlife Research 26:* 745-753.

Maltby, E. (2009): The wetlands handbook. John Wiley and Sons

McHugh (2011): Hanging Swamps within the Angus Place/Springvale Lease Area, Preliminary report , Beth McHugh, September 2011

NSW NPWS (2001) Blue Mountains Water Skink (*Eulamprus leuraensis*) Recovery Plan, NSW National Parks and Wildlife Service, Sydney.

RPS (2011): Preliminary Documentation – Longwall Mining at Angus Place Mine and Springvale Mine. Report No: 109493, October 2011.

Save Our Swamps Project. Soft engineering solutions for swamp remediation – a "how to guide" (2010).

Schaller, J, Brackhag, C, Mkandawire, M and Dudel, E G (2011): Metal/metalloid accumulation/remobilization during aquatic litter decomposition in freshwater: A review. *Science of the Total Environment 409*: 4891-4898.

SEWPAC (2012). Temperate Highland Peat Swamps on Sandstone in Community and Species Profile and Threats Database, Department of Sustainability, Environment, Water, Population and Communities, Canberra. Available from: http://www.environment.gov.au/sprat. Accessed 2012-06-27T11:49:04EST

Springvale Coal Project Environmental Impact Statement (1992).

Springvale Coal Pty Ltd (2009) SMP Application for Longwalls 411-414 – Written Report, Springvale Pty Limited.

Springvale Coal Pty Ltd (2006) Newnes Plateau Shrub Swamp Management Plan.

Springvale Coal Pty Ltd (2009) Subsidence Environmental Monitoring Program SV-MS-036. Revised August 2009.

Springvale Coal Pty Ltd (2010). Springvale Mine Longwalls 411-418 Subsidence Management Plan Variation Application. Variation of Installation Face Position for Longwall 414.

Springvale Coal Pty Ltd (2011). Subsidence Management and Reporting Plan for LW415 to 417. September 2011.

Vickers, H et al (2011). Summer 2011 Swamp Vegetation Monitoring at Centennial Coal Operations, Newnes Plateau. A report for Centennial Coal – CMLR University of Qld.

APPENDIX A

Summary of relevant Commonwealth and State legislation

Legislation	Brief Summary
Commonwealth Legislation	
Environment Protection and Biodiversity Conservation (EPBC) Act 1999	The EPBC Act is the Commonwealth Government's central piece of environmental legislation and provides a legal framework to protect and manage nationally and internationally important matters of national environmental significance (MNES). As the THPSS is listed as an EEC under the EPBC Act, approval by Commonwealth Minister for DOE is required if the action may have a significant impact on any matter of NES.
State Legislation	
Environmental Planning and Assessment (EP&A) Act 1979	The EP&A Act sets out the major concepts and principles for addressing development applications. Development consent to commence mining activities at Springvale Mine was originally granted under the EP&A Act on 27 July 1992. The consent approved the production of up to 3.4 million tonnes per annum (Mtpa) of run of mine coal. Since this time, some modifications have been made to the development consent under the EP&A Act. SSD5594 is the the Springvale Life of Mine project which includes the ongoing operation of the mine and construction of various infrastructure of the Newnes Plateau. It also includes the extraction of Longwalls 416 to 432 and 501 to 503. Further detail regarding inclusions within the project are documented in SSD5594.
Threatened Species Conservation (TSC) Act 1995	This TSC Act identifies and protects native plants and animals in danger of becoming extinct and sets out matters that must be taken into account when deciding whether there is likely to be a significant effect on threatened species, populations or ecological communities, or their habitats. Schedule 1 of the act lists endangered species, populations and ecological communities, including the Newnes Plateau Shrub Swamp in the Sydney Basin Bioregion.
Mining Act 1992	The Mining Act makes provision for a variety of mining authorities, including mining leases and exploration licences which are required for the prospecting and mining of minerals and coal. The Mining Act also makes provision for the protection of the environment in relation to mining activities, including rehabilitation of areas affected by mining activities. Part 11 of the Act deals with the protection of the environment and provides that conditions may be imposed upon a mining authority or mineral claim requiring that land affected by mining activities be rehabilitated. Standard conditions generally imposed upon a mining lease include requirements to submit an Mining Operation Plan (MOP) prior to the commencement of mining operations as well as Annual Environmental Management Reports (AEMR). These documents form the Mining Rehabilitation and Environmental Management Process

Legislation	Brief Summary
	(MREMP). Subsidence Management Plans (SMPs) are prepared by lease holders to predict potential impacts of underground operations and identify how important natural and built features are to be managed. Management may involve the avoidance of damage to particularly significant features, the mitigation of damage, or rehabilitation of subsidence related impacts.
Protection of the Environment Operations Act (POEO) 1997	Schedule 1 of the POEO Act sets out the activities that constitute "scheduled premises" and which require an Environment Protection Licence (EPL) issued under the POEO Act. Mining for coal is listed in Clause 28 of Schedule 1 and therefore requires an EPL. The EPLs are issued and regulated by the NSW Office of Environment and Heritage (OEH). Springvale Mine operates under EPL 3607.
Water Act 1912	The Water Act 1912 authorises the taking of water, the use of water and water supply works. Various water licences have been issued to Springvale Coal in respect of monitoring and water extraction for the purposes of dewatering underground workings
Forestry Act 1916	The Forestry Act aims to provide for the dedication, reservation, control, and use of State forests, timber reserves, and Crown lands for forestry and other purposes. The Newnes Plateau is located above the majority of the underground workings and therefore an Occupation Permit is required from Forests NSW. Springvale Mine has an occupation permit which provides approval to occupy the land.

APPENDIX B

Description of Temperate Highland Peat Swamps on Sandstone (THPSS)

Swamp name: Sunnyside East

Status: Potential impact

Mapped swamp type (DEC 2006): Shrub Swamp (MU 50)

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (238604, 6302993)
2. RAP 2 (239187, 6303655)

Vegetation: The vegetation of this swamp, its position in the landscape and the presence of peat was consistent with mapping of this swamp as MU 50. The ground layer and shrub layer was simplified in the upper part of the swamp (RAP 1) with the ground layer being dominated by *Gleichenia dicarpa* (**Plate 1**). The shrub layer was dominated by *Leptospermum grandifolium* and *Baeckea linifolia* and some trees grew on the margins (and arguably within the swamp). Lower down in the catchment the swamp currently has greater diversity and structural complexity in the ground and shrub layers with additional species such as *Leptospermum obovatum* and *Grevillea acanthifolia* present and being indicative of a generally moist swamp environment.

Range of natural variability: Fire has caused some variability in successional state across this swamp. At RAP 1 (**Plate 1**) the shrub layer has been impacted by fire with shrubs surviving or unburnt in some areas but with shrubs burnt (and possibly killed) in other areas. This variability may decline over time as the upper swamp regenerates (the peat layer appeared to be substantially undamaged by the fire). The adjacent forest type to the swamp appeared to change from that recorded adjacent to RAP1 (with a dominance of *Eucalyptus oreades*) to a dry sclerophyllous woodland adjacent to RAP 2. These different adjacent vegetations would have some influence on the species composition at the different locations in the swamp.

Biological processes: The upper swamp (in the south) is generally dry and channelized, whilst the northern part (lower swamp) is likely to be permanently wet. The hydrological model for Sunnyside East (Aurecon 2011) indicates that the swamp is fed by shallow groundwater whilst a relatively high water table in the surrounding hills would maintain a generally continuous flow. However, it has been predicted that this flow may decline in drought. This hydrological model is reflected in the wetter conditions downstream in the swamp. Notably, however, plant species that predominate in continuously wet systems (e.g. *Gymnoschoenus sphaerocephalus*; *Xyris juncea*) are not a dominant components of the swamp as they are in wetter swamps to the east. Despite this, the wetter conditions downs stream would support higher rates of decay, may reduce fire impacts and provide an ecologically more stable system than upstream.

Threats: There is potential for alteration to fire regimes, mining activities and some actions / changes that could result from forestry (including localised erosion and flow alterations) to impact upon Sunnyside Swamp.

Condition: Sunnyside East was assessed using the methodology of CES (2010) as having a condition score of 3 at RAP 1 and 4 at RAP 2.

Plate 1. Sunnyside East Shrub Swamp RAP 1

Plate 2. Sunnyside East Shrub Swamp RAP 2

Swamp name: Carne West

Mapped swamp type (DEC 2006): Shrub Swamp (MU 50)

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (239016, 6302504)
2. RAP 2 (238903, 6302175)

Vegetation: The vegetation of this swamp, its position in the landscape and the presence of peat was consistent with the mapping of this swamp as MU 50 at RAP 1, but not so at RAP 2. The vegetation at RAP 1 was a species diverse and very high quality and structurally complex Shrub Swamp. Dominant species include *Leptospermum obovatum*, *Leptospermum grandifolium* and *Grevillea acanthifolium* in the shrub layer with *Gleichenia dicarpa*, *Gahnia sieberiana* and *Empodisma minus* being ground layer dominants. At RAP 2 the vegetation was very different floristically. The shrub layer was floristically simple (it included *Leptospermum myrtifolium*, *Leptospermum grandifolium* and *Baeckea linifolia* whilst the shrub layer included *Epacris microphylla*, *Poa sieberiana* and *Lepyrodia scariosa* as dominants). Trees of *Eucalyptus pauciflora* also occurred on the edge of this swamp at RAP 2.

Range of natural variability: The dominance of *Leptospermum myrtifolium* and the presence of *Eucalyptus pauciflora* and *Poa sieberiana* is consistent with MU 52 in DEC (2006) and the mapped vegetation for this polygon is considered to be a gradation across these vegetation types. Hence this mapped wetland grades from MU 52 (upslope) to MU 50 down slope. The upper part of this polygon connects to a mapped hanging swamp (MU 51 - see hanging swamp descriptions below).

Biological processes: Carne West Swamp is generally lower than Sunnyside West Swamp (see above) but connected to the same groundwater aquifer (Aurecon 2011). Thus flow monitoring points located in the lower parts of this swamp have measured flow when flow had ceased in Sunnyside West Swamp during drought conditions. This is consistent with the predominance of hydrophilic plant species and shrubs species that prefer very moist conditions at RAP 1. Upslope (at RAP 2) the plant species present are consistent with a swamp system which experiences more prolonged dry periods. Shrubs such as *Leptospermum myrtilloides* are generally found in upslope depressions / swamps and favoured by a longer dry period within the wetting – drying cycle. The upslope part of Carne West Swamp is also less species diverse and would also be more fire prone than the moist down slope locations.

Threats: The drier upslope parts of this swamp may be somewhat dependant on shallow groundwater or surface flows. Forestry has known impacts on water yields (Cornish & Vertessy 2001; Eamus & Froend 2006; Eamus, Froend, Loomes, Hose & Murray 2006; MacKay 2006; Webb 2010) and the upper catchment of Carne West Swamp has and continues to be part of an active logging program. This could potentially alter the hydrology of the upper swamp. A range of other threats exist for Carne West Swamp including erosion associated with recreational activities (unsealed trails / tracks), altered fire regimes and mining related impacts (including potential subsidence related impacts and surface impacts).

Condition: Carne West Swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at RAP 1 and 3 at RAP 2 (reflecting the presence of bare patches in the swamp, some potential for continued erosion and possible forestry impacts).

Plate 3. Carne West Shrub Swamp RAP 1

Plate 4. Carne West Shrub Swamp RAP 2

Swamp name: Carne West Hanging Swamp

Mapped swamp type: Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (238765, 6301990)
2. RAP 2 (238869, 6302067).

Vegetation: The vegetation of this swamp is consistent with that expected for a hanging swamp (MU 51). The dominant species include *Leptospermum grandifolium, Epacris paludosa* and *Baeckea linifolia* in the shrub layer and a dominant layer of *Gleichenia dicarpa* in the ground layer.

Range of natural variability: The vegetation within this swamp is largely uniform in structure and floristics. It, however, is floristically distinct from some other hanging swamps (hanging swamps are largely variable in species composition from swamp to swamp). This swamp is not dominated by species such *Xyris juncea* which is dominant in wetter hanging swamps. However, the dominance of *Gleichenia dicarpa* (which prefers relatively stable moist conditions) indicates that this swamp is not a very dry example of a hanging swamp.

Biological processes: This swamp is towards the upper part of the Carne West catchment (but in a relatively low landscape position). It does not support the larger flowering species (such as *Banksia spinulosa*) which are important nectar resources for nectivorous birds, but the *Leptospermum* species present are likely to provide good resources for some insect pollinators. This swamp is likely to experience fires more frequently than those in moist and lower positions in the landscape, however the species present are likely to be relatively fire tolerant.

Threats: This swamp is dissected and fringed by a trail (used by trail bikes) with active erosion and some deep gullying. Soil deposition has occurred directly into the swamp as a result of this trail. The swamp is potentially threatened by forestry or mining activities if management is not adequate to minimise hydrological alteration. It is likely to be relatively resilient to altered fire regimes, unless these changes are extreme.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 3-4 at RAP 1 and 3 at RAP 2 (reflecting that the swamp is of low diversity, possibly somewhat dry and subject to ongoing erosion).

Plate 5. Carne West Hanging Swamp RAP 1

Plate 6. Carne West Hanging Swamp RAP 2

Swamp name: Sunnyside East Hanging Swamp 1

Mapped swamp type: Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (238344, 6303089)
2. RAP 2 (238329, 6303030)

Vegetation: The floristics of this site are only partly consistent with those specified in DEC (2006) for MU 51 (Newnes Plateau Hanging Swamp). *Baeckea linifolia* is a co-dominant in the shrub layer and is a positive diagnostic species for MU 51, but other dominant species (e.g. *Leptospermum polygalifolium*; *Acacia longifolia*; *Pteridium esculentum*) are not recorded by DEC (2006) as strongly associated with MU 51. Because MU 51 is currently defined on only two quadrats and also because the floristics present at this site do not clearly correspond to any current map unit within DEC (2006) this site is tentatively retained as potentially fitting within a broad definition of MU 51. Tree cover is largely reduced to absent from the site.

Range of natural variability: This site varies from shrub dominated (*Leptospermum polygalifolium*) to a braken dominated (*Pteridium esculentum*) community. *Lomandra longifolia*, *Gleichenia dicarpa* and *Patersonia fragilis* occur across the site in the ground layer (with *Gleichenia dicarpa* occurring as patches and *Patersonia fragilis* as individual plants).

Biological processes: This site contains no peat and is situated on an upper slope. The presence of *Patersonia fragilis* and *Baeckea linifolia* is however indicative of a moist site within the general surrounding forest. Given its locale it is considered that the site is likely to be maintained by very shallow groundwater and / or surface flows. The site is unlikely be of particular ecological importance for fauna and could potentially undergo a successional change through time.

Threats: The major threats to this site are considered to be via direct impacts (clearing / trails) or changes that affect shallow groundwater or surface flows.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 3 at RAP 1 and 3-4 at RAP 2 (reflecting that some of swamp vegetation was dry and with dead foliage).

Plate 7. Sunnyside East Hanging Swamp 1 RAP 1

Plate 8. Sunnyside East Hanging Swamp 1 RAP 2

Swamp name: Sunnyside East Hanging Swamp 2

Mapped swamp type (DEC 2006): Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (238495, 6302984)
2. RAP 2 (238495, 6302930)

Vegetation: The vegetation within this mapped polygon is both structurally and floristically consistent with that expected for a hanging swamp (MU 51). The shrub layer was dominated by *Epacris paludosa*, *Baeckea linifolia* and *Leptospermum grandifolium* and the ground layer by *Gleichenia dicarpa*, *Empodisma minus*, *Xyris juncea*, *Gahnia sieberiana* and *Pteridium esculentum.*

Range of natural variability: RAP 1 in the north of the polygon appeared to be a wet part of the hanging swamp because the ground layer was dominated by species such as *Xyris juncea* and *Empodisma minus* whilst the ground layer at RAP 2 was dominated by *Pteridium esculentum* (which is generally favoured by drier conditions and / or fire). However, the shrub layer was largely consistent across the extent of the swamp (and it had a low overall coverage).

Biological processes: This swamp is lower in the catchment than Sunnyside East Hanging Swamp 1 and perhaps naturally more moist. Some peat appeared to be present. The swamp does not have a very dominant shrub layer and large bird pollinated shrub species are in low number. There is good habitat present for some frog species.

Threats: Altered hydrology from any infrastructure built up slope or other near surface disturbances pose a potential risk to this swamp. The swamp would also be at risk from any altered fire frequency (for example, if an asset protection zone was implemented for infrastructure). Subsidence from mining is more likely to impact Shrub Swamps than hanging Swamps, however, monitoring of the swamp in relation to any mining is still a prudent measure. Track construction and associated erosion / deposition could also pose a risk for this swamp.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 4 (in very good condition) at both RAP 1 and RAP 2.

Plate 9. Sunnyside East Hanging Swamp 2 RAP 1

Plate 10. Sunnyside East Hanging Swamp 2 RAP 2

Swamp name: Sunnyside East Hanging Swamp 3

Mapped swamp type (DEC 2006): Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP1 (238572, 6303142)
2. RAP2 (238564, 6303118).

Vegetation: The vegetation on this site consists of a sparse tree layer of some forest eucalypts characteristic of the general forest of the area (*Eucalyptus radiata*; *Eucalyptus oreades*) with *Eucalyptus mannifera* also present (which is a species that is associated with swamps and hollows). The shrub layer was sparse (2-10% cover recorded) and dominated by *Baeckea linifolia* (a species characteristic of swamps). The ground layer was dominated by *Gleichenia dicarpa* (characteristic of swamps), but also *Pteridium esculentum* (which can occur in a range of communities and is favoured by fire). Hence the site is considered to only partly conform to MU 51 (Newnes Plateau Hanging Swamp).

Range of natural variability: This site has been recently burnt and it is likely that this would partly mask variations in the shrub layer which may become visible as the site regenerates (it may take several years for the shrub layer to at least partly return). The ground layer is likely to remain largely dominated by *Gleichenia dicarpa* and *Pteridium esculentum* over time, however the relative dominance of these two species over time will be likely driven by the interplay of soil moisture and fire regime.

Biological processes: As stated above the interplay of fire regime and soil moisture is likely to be critical in determining changes and successional processes for this site over time. Colonisation by eucalypts, for example, is likely to occur if the site significantly dries over time and the site would then transition towards a part of the surrounding forest. The site has limited swamp faunal values at present, but may support some swamp frog species.

Threats: Alteration of surface flows or perched groundwater movements could significantly impact upon this site. This could result from infrastructure works, forestry or track construction (either planned or created by recreational use). High fire frequencies could also threaten this site.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 3 (in fair condition) at both RAP 1 and RAP 2. This lowered score was the result of a possible reduced diversity due to fire and the presence of a track which dissected the site.

Plate 11. Sunnyside East Hanging Swamp 3 RAP 1

Plate 12. Sunnyside East Hanging Swamp 3 RAP 2

Swamp name: Sunnyside East Hanging Swamp 4

Mapped Swamp type (DEC 2006): Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (238671, 6303354),
2. RAP 2 (238700, 6303392).

Vegetation: This hanging swamp has an open tree layer of *Eucalyptus radiata* and *E. dalrympleana* to 20 metres in height and 10% cover. The shrub layer was patchy with 5% cover containing *Baeckea linifolia* and *Leptospermum grandifolium* which are both associated with swamps. The ground layer was dominated by *Gahnia sieberiana* and *Gleichenia dicarpa* also both characteristic of swamps. Hence the site is considered to conform to MU 51 (Newnes Plateau Hanging Swamp).

Range of natural variability: This swamp was generally uniform in structure and floristics with a low cover of the shrubs (*Baeckea linifolia* and *Leptospermum grandifolium*) and high cover of the ground layer (*Gahnia sieberiana* and *Gleichenia dicarpa*) across the swamp. However the margins of the swamp did include some Acacia shrubs.

Biological processes: The presence of a developed peat layer and dominance of a shrub and ground layer by swamp species associated with generally wet conditions indicates that this swamp is likely to remain moist under normal conditions. The site provides good habitat for swamp fauna including reptiles and amphibians as the ground layer is thick and offers protection for these species. The shrub layer, however, is limited in extent and of little value for nectar feeding species.

Threats: Alteration of surface flows or perched groundwater flows could significantly impact upon this site and result in its shift towards a drier vegetation type. This could result from infrastructure works, forestry or track construction (either planned or created by recreational use). High fire frequencies could also threaten this site.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 4 (in good condition) at both RAP 1 and RAP 2.

Plate 13. Sunnyside East Hanging Swamp 4 RAP 1

Plate 14. Sunnyside East Hanging Swamp 4 RAP 2

Swamp name: Sunnyside East Hanging Swamp 5

Mapped Swamp type (DEC 2006): Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (239036, 6304194),
2. RAP 2 (239090, 6304170).

Vegetation: This swamp has a tree layer to 15 metres with 15% projected foliage cover. Common tree species were *Eucalyptus oreades* and *E. radiata* which are characteristic of the general forest of the area with *E. mannifera* also present (which is a species that is associated with swamps and hollows). The shrub layer was patchy to 3 metres in height with 20% cover containing *Banksia spinulosa*, *Leptospermum grandifolium, Baeckea linifolia* and *Grevillea acanthifolia* (which are all swamp species). The ground layer was dominated by the swamp species *Gleichenia dicarpa* and *Gahnia sieberiana* with *Pteridium esculentum* and *Lomandra longifolia* also present. Hence the site is considered to conform to MU 51 (Newnes Plateau Hanging Swamp).

Range of natural variability: The swamp was found to extend outside of the mapped polygon to a significant extent (hence RAP 2 is some way from the mapped swamp polygon). In some areas shrub species (e.g. *Acacia obtusifolia*) which are more characteristic of forest communities occur within the swamp. Other shrub species (e.g. *Banksia spinulosa*) have a scattered occurrence within the swamp. These variations in the shrub layer provide a degree of variability to the swamp.

Biological processes: A very small amount of sphagnum was observed, however it appeared to be in good condition. The swamp is considered to be a variant that would exist under moderately moist conditions. There is a natural channel within the swamp and steep sides to the swamp so that water would flow in a defined direction down the swamp. The swamp provides a structurally complex habitat and would provide good habitat for diverse faunal assemblage. Given the position of this swamp in an incised gully, some natural erosion can be expected, but the dense vegetation structure would generally ameliorate this process.

Threats: Alteration of surface flows or perched groundwater movements could significantly impact upon this site. This could result from infrastructure works, forestry or track construction (either planned or created by recreational use) immediately upslope of the swamp.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 4 (in good condition) at both RAP 1 and RAP 2.

Plate 15. Sunnyside East Hanging Swamp 5 RAP 1

Plate 16. Sunnyside East Hanging Swamp 5 RAP 2

Swamp name: Sunnyside East Hanging Swamp 6

Mapped Swamp type (DEC 2006): Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed at two locations.

1. RAP 1 (238977, 6303923)
2. RAP 2 (238966, 6303876)

Vegetation: The site has a tree layer to 20m with a cover of 10 to 15%. Common tree species are *Eucalyptus oreades, E. radiata* and *E. seiberiana* which are species associated with the surrounding drier forest and *E. mannifera* which is a species associated with swamps and hollows. The shrub layer was 2 to 3 metres in height with a 20% cover, common species were *Baeckea linifolia, Leptospermum grandifolium* (both swamp species) and *Persoonia myrtilloides* (a forest species). Common species in the ground layer were *Gleichenia dicarpa, Gahnia seiberiana* (swamp species) with *Pteridium esculentum* and *Amperea xiphoclada* also (species found in a variety of habitats). This site is considered to conform to MU 51 (Newnes Plateau Hanging Swamp).

Range of natural variability: This swamp is considered to be an example of a moderately wet hanging swamp. Some evidence of recent fire (estimated to be approximately 5 years previously at RAP 2 was found). The ground layer thus changed in dominants across the swamp. The observed ground layer variability may decrease with time since time.

Biological processes: Although moderately moist, peat was not a dominant component of the ground substrate across the swamp. No sphagnum was recorded at either RAP for this swamp. The swamp is, likely to be strongly dependent upon shallow groundwater that or surface flows. There is suitable habitat for frog and reptile species but limited habitat for nectivorous bird species.

Threats: Alteration of surface flows or perched groundwater movements could significantly impact upon this site. This could result from infrastructure works, forestry or track construction (either planned or created by recreational use).

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 4 (in good condition) at both RAP 1 and RAP 2.

Plate 17. Sunnyside East Hanging Swamp 6 RAP 1

Plate 18. Sunnyside East Hanging Swamp 6 RAP 2

Swamp name: Sunnyside East Hanging Swamp 7

Mapped Swamp type (DEC 2006): Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed at two locations.

1. RAP 1 (238888, 6303827)
2. RAP 2 (238860, 6303823)

Vegetation: The tree layer is 20 metres tall with a 10 to 15% projected foliage cover. The dominant tree species are *Eucalyptus radiata* (a forest species) and *E. mannifera* (a species associated with swamps and hollows). Shrubs were up to 2 metres tall but with 5% cover, common species present were *Baeckea linifolia, Gahnia seiberiana* and *Cyathea australis* (all associated with swamps or moist vegetation) as well as *Lomatia silaifolia, Persoonia myrtilloides* and *Acacia obtusifolia* (forest species). The ground layer contained species such as *Gleichenia dicarpa, Gahnia sieberi* (swamp species) and *Viola silicestris, Pteridium esculentum* (forest species). The site is considered to conform to MU 51 (Newnes Plateau Hanging Swamp).

Range of natural variability: There was evidence of a recent fire at both RAP sites within this swamp. Hence this swamp is structurally and floristically simple at present (uniformly across the site). Over time the structure and floristic diversity can be expected to change and it may begin to become less uniform. The shrub layer may also become much more dominant.

Biological processes: This swamp is currently in an early post-fire successional stage. Over time it is expected to regenerate. Hence the faunal habitat values will change and species that prefer denser more structurally complex habitat will recolonise the swamp. Some small scale erosion has occurred since the fire, but this should be stabilised as the vegetation cover increases in the ground and shrub layers.

Threats: Like other hanging swamps in the area disturbances to shallow groundwater or natural surface flow patterns could impact upon this swamp. Direct impacts (e.g. tracks construction) are also potential risks.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 3 (in moderate condition) at both RAP 1 and RAP 2. This score was influenced by the small level of erosion observed within the swamp. It is likely that this erosion will stabilise as the swamp regenerates from the fire.

Plate 19. Sunnyside East Hanging Swamp 7 RAP 1

Plate 20. Sunnyside East Hanging Swamp 7 RAP 2

Swamp name: Sunnyside East Hanging Swamp 8

Mapped Swamp type (DEC 2006): Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed at two locations.

1. RAP 1 (238881, 6303660)
2. RAP 2 (238891, 6303682)

Vegetation: No tree layer occurred in this swamp. Shrubs are up to 1 metre tall with up to 20% projected foliage cover. Common shrub species were *Banksia spinulosa, Leptospermum grandifolium* and *Baeckea linifolia* which are species associated with swamps or moist areas. The ground layer included *Lepidosperma limicola*, *Xyris juncea* and *Gleichenia dicarpa* as dominants, which are all species associated with wet swamps and moist habitats. *Lepidosperma limicola* and *Xyris juncea,* in particular, only persist in hanging swamps which are very wet (with almost permanently wet upper soil layers). No exotic or weed species were observed. The site is considered to be a moist variant of MU 51 (Newnes Plateau Hanging Swamp).

Range of natural variability: There was clear evidence of a recent fire at both RAP sites within this swamp. The fire appears to have occurred approximately 12 months prior to the assessment. The structural diversity was simple to moderate, while the species diversity was moderate mainly due to the early stages of recovery from the fire. Despite the fire having extended across all of the swamp, the upper part of the swamp was dominated by *Xyris juncea* whilst the lower part of the swamp was dominated by *Gleichenia dicarpa* and *Lepidosperma limicola*.

Biological processes: Post-fire regeneration of the swamp is a dominant process at present and it is expected that succession will drive significant changes in the structure, floristics and habitat values of this swamp over the next 5 years.

Threats: Alteration of surface flows or perched groundwater movements could significantly impact upon this site. This could result from infrastructure works, forestry or track construction (either planned or created by recreational use). Some ground layer dominants are highly dependent on a relatively stable flow to the swamp.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 3-4 and 4 at RAP 1 and RAP 2 respectively.

Plate 21. Sunnyside East Hanging Swamp 8 RAP 1

Plate 22. Sunnyside East Hanging Swamp 8 RAP 2

Swamp name: Sunnyside East Hanging Swamp 9

Mapped Swamp type (DEC 2006): Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed at two locations.

1. RAP1 (238704, 6304362)
2. RAP2 (238678, 6304415)

Vegetation: *Banksia spinulosa*, *Leptospermum grandifolium* and *Baeckea linifolia* are shrub layer dominants, whilst the ground layer is dominated by *Gleichenia dicarpa*, *Xyris juncea* and *Empodisma minus*. These species are all species associated with wetter variants of MU 51.

Range of natural variability: The species at both RAP locations were similar in both the ground and shrub layer indicting that this swamp is relatively uniform floristically.

Biological processes: This swamp is part of a complex of hanging swamps in the area (including Sunnyside East Hanging Swamp 10) that together cover a substantial area. The dominance of moisture dependant ground and shrub species indicate this this swamp is a moist variant and likely to relatively stable in moisture status over time.

Threats: This swamp is large relative to a number of the other hanging swamps in the Sunnyside East catchment. This suggests that it will be more resilient to small localised disturbances to flows of surface or shallow (perched) groundwater. However, such disturbances may still have some impact upon the swamp. Alteration to the hydrology of the area (to surface flows and shallow perched water movements) are still the major potential threat to this swamp.

Condition: Dead Shrubs are evident in this swamp the result of a past fire event. However, although some change can expected over time (as the current shrub layer grows in height and matures) the swamp was still assessed as in very good condition currently (condition score of 4 at both RAP locations).

Plate 23. Sunnyside East Hanging Swamp 9 RAP 1

Plate 24. Sunnyside East Hanging Swamp 9 RAP2

Swamp name: Sunnyside East Hanging Swamp 10

Mapped swamp type (DEC 2006): Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (238720, 6304498)
2. RAP 2 (238725, 6304583)

Vegetation: A few eucalypt species found in the adjacent forest (*Eucalyptus oreades*; *Eucalyptus sieberi*) grow in the upper part of this swamp (with a low cover of only about 1%). *Eucalytpus mannifera* also grows within the swamp. The shrub layer is also sparse (ranging from 5-10% cover at RAP 1 and RAP 2 respectively). The ground layer, however, is very dominant in cover (up to 50% cover recorded at RAP 2) and species such as *Gleichenia dicarpa* and *Empodisma minus* (which are restricted to wet habitats) occur, however *Gahnia subaequiglumis* also occurs throughout the swamp (which can occur in dry conditions).

Range of natural variability: This hanging swamp, like Sunnyside East Hanging Swamp, is a relative large hanging swamp and it generally contains species indicative of a swamp that is remains wet for long periods of time. Floristically the presence of *Olearia quercifolia* at RAP 2 is of interest (this is a species that prefers wet swamp habitats and often is found in Shrub Swamps). The upper part of the swamp has been recently burnt and has a much reduced shrub layer.

Biological processes: It is expected that this swamp will show relatively large floristic and structural changes over time in that the shrub layer is expected to regenerate in the upper part of the swamp. The swamp is likely to be important habitat for swamp fauna because of its size, connectivity to other swamps and floristic diversity.

Threats: No tracks, erosion or infrastructure were noted to be in close proximity to this swamp. It was floristically diverse and expected to recover well from the recent fire.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 3-4 and 4 at RAP 1 and RAP 2 respectively.

Plate 25. Sunnyside East Hanging Swamp 10 RAP 1

Plate 26. Sunnyside East Hanging Swamp 10 RAP 2

Swamp name: Sunnyside East Hanging Swamp 11

Mapped Swamp type (DEC 2006): Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (238931, 6304450)
2. RAP 2 (238971, 6304469)

Vegetation: This swamp has an open appearance with an absence of a tree layer and a sparse shrub cover (*Baeckea linifolia*; *Leptospermum grandifolium*; *Epacris paludosa*). The ground layer was dominated by *Xyris juncea*, *Lepyrodia scariosa* and *Gleichenia dicarpa*.

Range of natural variability: The upper part of the swamp was dominated by a ground layer that is characteristic of wet hanging swamp variants (*Xyris juncea*; *Gleichenia dicarpa*; *Gonocarpus micranthus*) whilst the lower part of the swamp included species such as *Epacris obtusifolia*, *Damperia stricta* and *Gahnia subaequiglumis* that can prefer drier sites).

Biological processes: This swamp is regenerating from a recent fire and successional changes in the floristics and structure of the swamp are likely to occur over coming years.

Threats: Erosion from an adjacent trail was noted near this swamp and the swamp has experienced a recent intense fire. However, the major threat to this swamp is again considered to be potential changes to near surface groundwater or surface flows resulting from forestry, recreational uses or infrastructure that might occur upslope of this swamp.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at both RAP 1 and RAP 2.

Plate 29. Sunnyside East Hanging Swamp 11 RAP 1

Plate 30. Sunnyside East Hanging Swamp 11 RAP 2

Swamp name: Sunnyside East Hanging Swamp 12

Mapped swamp type: Hanging Swamp (MU 51).

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (238914, 6304629)
2. RAP 2 (238983, 6304634)

Vegetation: No tree layer occurs in this swamp but it has a diverse and complex shrub and ground layer. Shrubs include those which are typical of wetter swamps (*Leptospermum grandifolium*; *Epacris paludosa*; *Beackea linifolia*) whilst the ground layer includes species such as *Gahnia sieberiana*, *Lepidosperma limicola*, *Drosera binata*, *Lindsaea linearis* and *Gonocarpus micranthus*.

Range of natural variability: This large swamp is species rich and likely to show considerable small scale variation in species in the ground layer in response to localised variations in moisture and in response to other variables across the swamp.

Biological processes: This swamp occurs in a lower catchment position, is species rich and has a range of species common to both hanging swamps and shrub swamps. The size and connectivity of this swamp with other swamps along the drainage line along with the high species diversity it contains indicate that this is a functionally important swamp. It forms part of an important larger swamp complex which includes Sunnyside East Hanging Swamps 9, 10 and 11.

Threats: Hydrological alteration to surface and groundwater flows are again the major threat to this swamp. Its floristic diversity is likely to be a result of a complex hydrological pattern that is in part linked to the functioning of the other swamps which occur around it.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at both RAP 1 and RAP 2.

Plate 27. Sunnyside East Hanging Swamp 12 RAP 1

Plate 28. Sunnyside East Hanging Swamp 12 RAP 2

Swamp name: Sunnyside Hanging Swamp

Mapped swamp type: Hanging swamp (MU 51)

Status: Undermined

RAP location(s): This swamp was assessed from two locations.

1. RAP1 (238089, 6303959)
2. RAP2 (238050, 6303891)

Vegetation: This swamp contains a number of tree species characteristic of the surrounding forest (*Eucalyptus sclerophylla*, *Eucalyptus oreades*, *Eucalyptus sieberi*) as well as *Eucalyptus mannifera*. The shrub layer includes *Leptospermum obovatum*, *Baeckea linifolia*, *Grevillea acanthifolia* as well as *Leptospermum polygalifolium*. The ground layer is dominated in some areas by *Gleichenia dicarpa*, *Lepidospermum limicola* and *Empodisma minus* however *Lepyrodia scariosa* and *Boronia pinnata* dominate in other areas.

Range of natural variability: This swamp varies from a moist hanging swamp variant (at RAP 1) to a drier variant (at RAP 2) and is floristically inconsistent with being a hanging swamp in these drier areas.

Biological processes: The swamp at RAP 1 is in an incised gully and this provides a moist channelized flow pattern that maintains the wet hanging swamp variant in this area. However, the absence of species such as *Xyris juncea* suggests that swamp is perhaps too shady or not consistently wet. The drier areas of the mapped swamp (at RAP 2) are floristically simplified, although there is a developed shrub cover.

Threats: This swamp has a large natural variability maintained by differing landscape features. It sits below a relatively large disturbed area and this area could be viewed as having potential for infrastructure development. Disturbances upslope could however effects flow patterns to the swamp.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at both RAP 1 and RAP 2 (although floristically RAP 2 may not conform well to being a hanging swamp).

Plate 31. Sunnyside Hanging Swamp RAP 1

Plate 32. Sunnyside Hanging Swamp RAP 2

Swamp name: Carne Central Hanging Swamp

Mapped swamp type: Hanging Swamp (MU 51)

Status: Potential Reference site (RECOMMENDED REFERENCE SITE)

RAP location(s): This swamp was assessed at one location due to access difficulties. A general meander was also undertaken near the swamp.

1. (241012,6303537)

Vegetation: This swamp was dominated by shrub species such as *Banksia spinulosa*, *Banksia ericifolia* and *Epacris paludosa* with a ground layer of *Gleichenia dicarpa*. A few small trees (*Eucalyptus oreades*) also occurred within the swamp.

Range of natural variability: This swamp is on a steep ravine edge with a shallow soil layer on sandstone. Hence the swamp is dominated by the low growing *Gleichenia dicarpa* which is favoured by the moist conditions generated from an adjacent waterfall.

Biological processes: This swamp occurs on a steep rocky area and continuous moisture from upstream flows, shallow groundwater and vapour from the adjacent waterfall are important in maintaining the viability of this swamp. A recent landslide indicates that the area is likely to have a degree of natural instability.

Threats: Changes to stream flow or shallow groundwater may impact upon this swamp. Stability of the underlying rock is important and dips or movements in the rock strata could trigger further soil instability.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at RAP 1.

Plate 33. Carne Central Hanging Swamp RAP 1

Swamp name: Gang Gang Hanging Swamp

Mapped swamp type: Hanging swamp (MU 51)

Status: Potential Reference site (RECOMMENDED REFERNCE SITE)

RAP location(s): This swamp was assessed from two locations.

1. RAP1 (239555, 6301801)
2. RAP2 (239548, 6301852)

Vegetation: The vegetation of this swamp is indicative of a swamp which is a dry variant of MU 51. Ground layer species include *Gleichenia dicarpa*, *Lepyrodia scariosa*, *Pteridium esculentum*, *Gahnia sieberiana* and *Damperia stricta*. The shrub layer does contain *Leptospermum grandifolium, Baeckea linifolia* and *Epacris paludosa* (characteristic of hanging swamps). Some trees occur within the swamp (*Eucalyptus oreades*; *Eucalyptus blaxlandii*).

Range of natural variability: This is a relatively small swamp, however, it does vary somewhat with *Gahnia sieberiana* being much more dominant at RAP 2 than RAP 1.

Biological processes: This swamp is likely fed by localised flows of shallow ground and surface water. It is of only moderate importance for fauna (it is small, likely to dry at times and with only some nectar resources).

Threats: Loss or change to the localised flows of shallow groundwater or surface flows.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at RAP 1 and RAP 2. However, forestry operations have recently occurred just above the swamp and some impacts may occur as a result over time.

Plate 34. Gang Gang Hanging Swamp RAP1

Plate 35. Gang Gang Hanging Swamp RAP 2

Swamp name: Tristar Hanging Swamp 1

Mapped swamp type: Hanging swamp (MU 51)

Status: Potential Reference site (RECOMMENED REFERENCE SITE)

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (238138, 6307336)
2. RAP 2 (238065, 6307296)

Vegetation: This swamp is in on an upper slope and it is contains some species that can occur in dry habitats (*Lomandra longifolia*; *Dillwynia phylicoides*; *Acacia terminalis*) but does have a range of swamp species (*Leptospermum grandifolium*; *Baeckea linifolia*; *Gleichenia dicarpa*). Thus it is unlikely that the whole mapped polygon well represents a hanging swamp or it may fall into a very broad definition of these swamps (but this is also true for some potential impact hanging swamps).

Range of natural variability: The mapped polygon has a broad range of species characteristic of a number of vegetation types.

Biological processes: This mapped swamp area has some moist areas that are probably dependent upon shallow groundwater.

Threats: Changes to the shallow water system (ground or surface water) could impact upon this mapped swamp However, it is well removed from most potential disturbances at present (with the potential for some forestry to take place adjacent to it).

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at RAP 1 and RAP 2 (however at least some of the polygon is unlikely to be MU 51).

Plate 36. Tristar Hanging Swamp 1 RAP 1

Plate 37. Tristar Hanging Swamp 1 RAP 2

Swamp name: Tristar Hanging Swamp 2

Mapped swamp type: Hanging swamp (MU51)

Status: Potential Reference site (RECOMMENDED REFERENCE SITE)

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (237607, 6307216)
2. RAP 2 (237607, 6307197)

Vegetation: This swamp was a typical wet variant of a hanging swamp below a certain point in the mapped polygon where groundwater is forced to the surface. Species below this point include *Xyris juncea*, *Lepidosperma limicola* and *Drosera spatulata* in the ground layer as well as characteristic shrub species of these swamps (*Leptospermum grandifolium*; *Baeckea linifolia*; *Banksia spinulosa*).

Range of natural variability: RAP 2 was undertaken downslope in an incised area which was characterised by a more dominant shrub layer and the dominance of *Gleichenia dicarpa*. Apart from this variation the upper part of the swamp is very uniform.

Biological processes: The major driver of this swamps presence and the variations within it relate to the groundwater discharge that occurs and the protected incised gully at the bottom of the swamp. Hence, it can be expected that these differing water inputs to the swamp may undergo variations through time that drive alterations to the swamp.

Condition: This hanging swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at RAP 1 and RAP 2.

Plate 38. Tristar Hanging Swamp 2 RAP 1

Plate 39. Tristar Hanging Swamp 2 RAP 2

Swamp name: Gang Gang Swamp

Mapped swamp type (DEC 2006): Shrub swamp (MU 50).

Status: Potential Reference site (RECOMMENDED REFERNCE SITE)

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (239874, 6301785)
2. RAP 2 (239969, 6301995)

Vegetation: Gang Gang shrub swamp is a large shrub swamp in a lower landscape position that supports a structurally and floristically diverse swamp assemblage. Shrubs such as *Grevillea acanthifolia*, *Epacris paludosa* and *Olearia quercifolia* are widespread whilst the ground layer includes species only dominant under moist favourable conditions (e.g. *Gymnoschoenus sphaerocephalus*; *Baumea rubignosa*). The swamp florsitics are complex and vary from place to place in response to small scale hydrological variations within the swamp).

Range of natural variability: There is a large natural spatial variability in this swamps floristics driven by localised hydrological differences.

Biological processes: There is an extensive thick peat bed and high levels of decay in the swamp. The swamp is important habitat for a range of fauna (including reptiles, amphibians and birds) and it provides important ecological services in managing water flow patterns and water quality.

Condition: This swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at RAP 1 and RAP 2.

Plate 40. Gang Gang Shrub Swamp RAP 1

Plate 41. Gang Gang Shrub Swamp RAP 2

Swamp name: Tristar Shrub Swamp

Mapped swamp type (DEC 2006): Shrub Swamp (MU 50)

Status: Not undermined (RECOMMENDED REFERENCE SITE)

RAP location(s): This swamp was assessed at two locations. One (RAP 1) was a standard Rapid Assessment Point. The second point was a full floristic quadrat.

1. (237377, 6307135)
2. (237263, 6307047)

Vegetation: Tristar Shrub Swamp is dominated by a shrub layer which is characteristic of a typical shrub swamp (*Leptopsermum obovatum*; *Leptopsermum grandifolium*; *Grevillea acanthifolia*; *Epacris paludosa*). Likewise the ground layer is dominated by species typical of a shrub swamp in good condition (*Lepidosperma limicola*; *Empodisma minus*; *Gleichenia dicarpa*). Some trees are present within the swamp (*Eucalyptus viminalis*), but these have a low overall cover (5% at RAP 1).

Range of natural variability: The ground and shrub layer shows considerable variation among locations where conditions favour species that prefer moist conditions (e.g. *Juncus flavidus*; *Paspalum distichum*; *Baloskion australe*) or dry conditions e.g. (*Galium austral*e; *Carex inversa*; *Pultenaea ferruginea*; *Boronia pinnata*).

Biological processes: The noted variation from species that prefer wet to dry conditions often occurs over small distances due the hummocky nature of the peat. This peat structural variation is therefore important in maintaining a high diversity within the swamp and potentially any decline in this peat structure would reduce the swamps diversity.

Threats: The swamp is isolated from most disturbances and whilst this remains the swamp is likely to be under low threat. Forestry activities and trail construction (including recreational trails) are two processes that pose risk at present.

Condition: This swamp was assessed as having a condition score of 4 at RAP 1 and at the site of the full floristic quadrat.

Plate 42. Tristar Shrub Swamp RAP 1

Plate 43. Tristar Shrub Swamp full floristic quadrat

Swamp name: Twin Gully

Mapped swamp type: Shrub Swamp (MU 50)

Status: Not undermined (RECOMMENDED REFERNCE SITE)

RAP location(s): This swamp was assessed from two locations. RAP 1 is currently not within the mapped polygon of DEC (2006), however it conforms to the floristics and landscape position of a shrub swamp and is connected to the mapped Twin Gully Shrub Swamp.

1. RAP1 (236190, 6309128)
2. RAP2 (235926, 6308892)

Vegetation: The swamp has a low tree cover of *Eucalyptus dalrympleana* and *Eucalytpus radiata* upslope at RAP 1 whilst there are some emergent trees of *Eucalyptus mannifera* in the more open downslope swamp. The shrub layer (*Leptospermum grandifolium*; *Leptospermum obovatum*; *Baeckea linifolia*; *Grevillea acanthifolia*; *Epacris paludosa*) and the ground layer (*Gleichenia dicarpa*; *Empodisma minus*; *Hypoleana fastigata*; *Blechnum cartilagineum*) are characteristic of shrub swamps.

Range of natural variability: The swamp ranges from a narrow swamp with some tree species and a ground layer with a large percentage cover of *Blechnum cartilagineum* upslope to an open shrub dominated moist variant of a shrub swamp.

Biological processes: The swamp is relatively narrow and in an incised gully and likely subject to more concentrated flows compared to the broader swamps to the south-east. This likely affects the hydrological conditions present although modelling would be required to confirm this. Otherwise the swamp is likely to be similar to other shrubs swamps on the plateau.

Threats: This swamp is largely remote from most disturbances and as for Tristar Swamp forestry and recreation activities pose some low level risk.

Condition: This swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at RAP 1 and RAP 2.

Plate 44. Twin Gully Shrub Swamp RAP 1

Plate 45. Twin Gully Shrub Swamp RAP 2

Swamp name: Angus Place Hanging Swamp 1

Mapped swamp type: Hanging swamp (MU 51). However the swamp conforms floristically to MU 52 (Newnes Plateau Rush – Sedge Snow Gum Hollow Wooded Heath) and its position in a low depression is also consistent with this community.

Status: Potential impact

RAP location (s): This swamp was assessed from two locations.

1. RAP1 (234053, 6305481)
2. RAP2 (233996, 6305489)

Vegetation: This swamp is dominated by a shrub layer of *Leptospermum myrtifolium* with *Leptopsermum grandifolium* and also *Baeckea linifolia* common. *Eucalyptus mannifera* and *Eucalyptus radiata* occur on the margins of the shrub or where it narrows. The ground layer is dominated by *Lepyrodia scariosa* with a range of species such as *Gonocarpus micranthus* and *Bauma rubignosa* providing some diversity to this layer.

Range of natural variability: The dominant shrub layer is generally consistent across the mapped polygon providing a generally consistent floristic pattern the swamp. There are however patches where shrubs are absent and bare ground and forbs dominate.

Biological processes: The presence of *Leptospermum myrtifolium* interspersed with bare ground appears to be a common pattern in MU 52 (Newnes Plateau Rush – Sedge Snow Gum Hollow Wooded Heath based on current observations – the unit being based originally on only one floristic quadrat). This community appears to be generally dry (compared to MU 50 and 51) but probably is subject to periodic inundation. Species that require extended wet periods are generally of restricted occurrence in this community.

Threats: A permanent alteration of hydrology in the catchment will shift the species composition of this community. Adjacent disturbances (that cause erosion and lead to soil deposition) may also lead to filling of some of the depression. A suitable buffer to logging and trail construction should limit these potential impacts.

Condition: This swamp was assessed using the methodology of CES (2010) as having a condition score of 3-4 at RAP 1 and RAP 2.

Plate 46. Angus Place Hanging Swamp 1 RAP 1

Plate 47. Angus Place Hanging Swamp 1 RAP 2

Swamp name: Angus Place Hanging Swamp 2

Mapped swamp type: Hanging Swamp (MU 51). However the swamp more correctly conforms floristically to MU 52 (Newnes Plateau Rush – Sedge Snow Gum Hollow Wooded Heath) and its position in a low depression is also consistent with this community.

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP1 (233882, 6305335)
2. RAP2 (233845, 6305341)

Vegetation: This mapped polygon is dominated by a shrub layer of *Leptospermum myrtifolium*, *Leptospermum grandifolium* and *Baeckea linifolia* interspersed with areas where shrubs are absent and a ground layer dominated by *Lepyrodia scariosa* and forbs such *Gonocarpus micranthus* and *Viola silicestris* dominate. No tree layer occurs.

Range of natural variability: There is a low variability due to the small size of the area and the fact that the whole area is uniform in landform (a west facing slope). The area has been partly disturbed by forestry works (track construction) and this may mask some natural variability that may become apparent through time.

Biological processes: This area is partly disturbed but is likely to represent a small moist area within the surrounding forest matrix. The species present on site, however, indicate that this area is more likely a variant of MU 52 (Newnes Plateau Rush – Sedge Snow Gum Hollow Wooded Heath) than MU 51 (although no *Eucalyptus pauciflora* or *Eucalyptus mannifera* or any tree species were observed in the site which is now partly disturbed by forestry works).

Threats: This area is expected to recover from forestry works over coming years even though some soil disturbance has taken place. Forestry works should be undertaken with an appropriate buffer to this area. Altered hydrology is again considered the major threat to this site (which could occur as a result of forestry, recreational track construction, etc.).

Condition: This swamp was assessed using the methodology of CES (2010) as having a condition score of 3 at RAP 1 and RAP 2.

Plate 48. Angus Place Hanging Swamp 2 RAP 1

Plate 49. Angus Place Hanging Swamp 2 RAP 2

Swamp name: Angus Place Hanging Swamp 3

Mapped swamp type: Hanging Swamp (MU 51).

Status: Potential impact

RAP location (s): This swamp was assessed from two locations.

1. RAP1 (235336, 6305266)
2. RAP2 (235274, 6305166)

Vegetation: This mapped hanging swamp consists of an elongated polygon running across slope on an upper west facing slope. The vegetation within the polygon is patchy and effectively consists of patches of *Gleichenia dicarpa* with *Lepyrodia scariosa* and some forbs.

Range of natural variability: The mapped polygon is an open largely treeless area but floristically it varies being effectively a grassland with patches of *Gleichenia dicarpa* and other moisture dependant species occurring within this grassland. Hence there is considerable floristic variation within the polygon.

Biological processes: The moist patches within the polygon are likely to be maintained by shallow groundwater reaching the surface. This is the principle driver of the occurrence of this vegetation.

Threats: Alteration to the shallow groundwater flow is the dominant threat and this could be driven by major works (infrastructure or other significant disturbances in the catchment above this area).

Condition: This swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at RAP 1 and RAP 2. This assumes that the observed floristic pattern within the mapped polygon is natural.

Plate 50. Angus Place Hanging Swamp 3 RAP 1

Plate 51. Angus Place Hanging Swamp 3 RAP 2

Swamp name: Angus Place Hanging Swamp 4

Mapped swamp type: Hanging swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed at only one location because it is very small (approximately 5 x 7 m) and with no significant variation present and fully visible from one point.

1. RAP 1 (235205, 6305252).

Vegetation: This mapped polygon consists of a *Gleichenia dicarpa* dominated moist area within an open grassy woodland. It is floristically simple with *Lepyrodia scariosa* and some forbs interspersed among the *Gleichenia dicarpa* clumps.

Range of natural variability: This small area has effectively little variation.

Biological processes: This moist patch is (like those within Angus Place Hanging Swamp 3) maintained by shallow groundwater reaching the surface. This is the principle driver of the occurrence of this vegetation.

Threats: Alteration to the shallow groundwater flow is the dominant threat and this could be driven by major works (infrastructure or other significant disturbances in the catchment above this area).

Condition: This swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at RAP 1.

Plate 52. Angus Place Hanging Swamp 4

Swamp name: Narrow Swamp (North)

Mapped swamp type: Shrub Swamp (MU 50)

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (236132, 6305289)
2. RAP 2 (235938, 6304896)

Vegetation: The swamp has undergone disturbance at some locations (e.g. RAP 1) and the vegetation in these areas consists of some native shrubs typical of a shrub swamp (e.g. *Leptopsermum obovatum*; *Grevillea acanthifolia*), some native sedges (*Juncus* and *Baumea* species) but also a variety of weeds typical of disturbed ground (e.g. *Cirsium vulgare*). At other locations a healthy shrub swamp with a typical shrub and ground layer species exists (e.g. RAP 2).

Range of natural variability: Narrow Swamp (naturally) is a shrub swamp which ranges from the drier to the mid range moisture status of shrub swamp vegetation. Those species that typify the very wet shrub swamp areas of the eastern plateau are in low numbers in Narrow Swamp. It has an average natural range of variability.

Biological processes: The name (Narrow Swamp) is apt for this swamp as it is not a broad swamp compared to many of the other shrub swamps on the plateau. Hence flows are likely to be relatively concentrated after high rainfall events and erosion risks perhaps somewhat high. However, the swamp does have naturally a thick fibrous peat layer and this presumably provides a buffering effect to the moisture status of the swamp. The swamp would also be fed from the more constant flow from deeper ground water. Being narrow, there is an increased risk that fire events (or other edge effects) will permeate well into this swamp.

Threats: Narrow Swamp has been subject to water discharges and a decline of the vegetation in particular locations is evident. Works are proposed to regenerate these areas, but state approval for these works has not yet been granted. There is a risk that decline may continue in the absence of this approval and this poses a significant risk to the swamp.

Condition: This swamp was assessed using the methodology of CES (2010) as having a condition score of 2 at RAP 1 and 4 at RPA 2.

Plate 53. Narrow Swamp (North) RAP 1

Plate 54. Narrow Swamp (North) RAP 2

Swamp name: Angus Place Hanging Swamp 5

Mapped swamp type: Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (236110, 6305329)
2. RAP 2 (236095, 6305373)

Vegetation: This hanging swamp sits on an upper slope and consequently is lacks species associated with wetter hanging swamps. The dominants include *Epacris paludosa*, *Baeckea linifolia*, *Leptospermum grandifolium* (as shrubs) and *Gleichenia dicarpa*, *Empodisma minus* and *Blechnum cartilegium* in the ground layer. A number of species often associated with the surrounding forest also occur within the mapped swamp.

Range of natural variability: This swamp is relatively uniform in its floristics.

Biological processes: The topographic position and steep uniform slope impart a simplistic hydrology to this swamp (presumably a simple uniform flow from shallow ground water). The swamp also sits in a exposed position in relation to wildfire and it is likely to be burnt with a high intensity when wildfires do occur (and it is small and likely to be fully burnt).

Threats: Logging has recently taken place immediately above this swamp and this poses some risk in relation to run-off and altered flows to the swamp. Otherwise it is relatively isolated from disturbance.

Condition: This swamp was assessed using the methodology of CES (2010) as having a condition score of 3 at both RAP 1 and RPA 2 (because much of the vegetation appeared to be suffering dieback).

Plate 55. Angus Place Hanging Swamp 5 RAP 1

Plate 56. Angus Place Hanging Swamp 5 RAP 2

Swamp name: Angus Place Hanging Swamp 6

Mapped swamp type: Hanging Swamp (MU 51)

Status: Potential impact

RAP location(s): This swamp was assessed from two locations.

1. RAP 1 (235997, 6305142)
2. RAP 2 (235981, 6305096)

Vegetation: *Eucalyptus oreades* grows around this swamp and some trees also grow within the swamp. The shrub layer is dominated by *Leptospermum obovatum*, *Leptospermum grandifolium* and *Baeckea linifolia* whilst the ground layer is heavily dominated by *Gleichenia dicarpa* and *Blechnum cartilagineum*.

Range of natural variability: The swamp is relatively uniform in vegetation. However at RAP 2 *Epacris paludosa* and *Derwentia blakleyii* also were noted. There is a small gully in part of the swamp that would favour species that prefer more moist conditions, otherwise the swamp is relatively uniform in vegetation.

Biological processes: This hanging swamp is in a low landscape position, however it is also has a relatively high cover of trees. Therefore a range of species that prefer moist open positions in hanging swamps (e.g. a number of sedge species and *Xyris* species) do not occur in this swamp.

Threats: This swamp is generally isolated from potential disturbances and being close to the adjacent shrub swamp it is unlikely to be subject to planned disturbances (e.g. formal trail construction; infrastructure) but could be disturbed by informal trails etc. It is generally at a low risk.

Condition: This swamp was assessed using the methodology of CES (2010) as having a condition score of 4 at both RAP 1 and RPA 2.

Plate 57. Angus Place Hanging Swamp 6 RAP 1

Plate 58. Angus Place Hanging Swamp 6 RAP 2

APPENDIX C

Subsidence Monitoring Data Summary

This appendix provides a summary of and conclusions drawn from subsidence monitoring at Springvale and Angus Place Collieries as well as from other studies conducted throughout the NSW coalfields. A summary of this work is set out in Table 1. This summary provides conclusions on the use of 26.5 degree angle of draw as a boundary that can be used to define subsidence based impacts.

The design of mining layouts that have been approved by the Department of Resources and Energy (DRE) to-date have applied what are known as "practical angles of draw" (referred to as Design AoD).

These are conservative angles of draw that recognise the potential variability in actual draw angles, but will probably result in negligible surface impacts outside their limits. It should be understood that surface features are generally only impacted by differential subsidence movements such as tilt, curvature (i.e. bending) and horizontal strain once they exceed a certain tolerable value.

Practical angles of draw therefore provide limits to the differential movements such as tilt, curvature and strain to tolerable magnitudes, rather than attempt to limit subsidence to 20 mm.

In the NSW Coalfield's, the practical or design angle of draw applied to sensitive features is typically 26.5° and has been applied successfully to cliff lines, waterways and sensitive archaeological sites. In some instances an additional buffer zone has been added to the design angle of draw to allow for uncertainties in final mining limits and geological and/or topographical factors.

The effectiveness of the design angle of draw of 26.5° at SPVC can be demonstrated by reviewing the angles of draw to the key impact parameters of tilt, curvature and strain that have been measured to-date at SPVC and Centennial Angus Place Mine (CAPC).

Reference to **NERDDP, 1993, ACARP, 2002** and local mine site data indicate the following subsidence profile limits are appropriate for minimising impact to cliff lines and sensitive environmental features:

- Subsidence: 50 - 100 mm
- Tilt: 1.5 - 2 mm/m
- Curvature: 0.06 - 0.1 km^{-1} (radius of curvature > 10 km)
- Tensile Strain: 1.5 - 2 mm/m

- Compressive Strain: 2 - 2.5 mm/m

The limits above also take into account the survey accuracy limits for the available data.

The measured angles of draw to the above parameters at SPVC and CAPC are summarised in the following table.

Table 1. Subsidence Monitoring Summary

Impact Parameter Limit	Measured Angle of Draw (^{o}) mean value (range)		
	Angus Place (CAPC)	Springvale (SPVC)	Combined
Cross line Data			
20 mm Subsidence	51 (46 - 55)	44 (39 - 61)	47 (39 - 61)
50 mm Subsidence	33 (23 - 40)	31 (15 - 59)	32 (15 - 59)
1.5 mm/m Tilt	15 (2 - 24)	16 (5 - 25)	14 (2 - 25)
0.1 km^{-1} Curvature*	6 (0 - 13)	10 (0 - 27)	8 (0 - 27)
1.5 mm/m Tensile Strain*	4 (0 - 19)	9 (0 - 28)	7 (0 - 28)
Centre line Data			
20 mm subsidence	19 (19 - 19)	15 (10 - 18)	16 (10 - 19)
50 mm subsidence	10 (5 - 19)	4 (0 - 8)	7 (0 - 19)
1.5 mm/m Tilt	11 (5 - 23)	22 (21 - 22)	16 (5 - 23)
0.1 km-1 Curvature*	0 (0 - 0)	18 (0 - 22)	11 (0 - 22)
1.5 mm/m Tensile Strain*	0 (0 - 0)	17 (16 - 19)	9 (0 - 19)

*** - curvature and strain angle of draw impact limits are based on survey method accuracy and observed impacts to-date.**

It is apparent from the results in the Table 1 and experience at Springvale and Angus Place that a design angle of draw of 26.5^o from the sides and ends of longwall panels to sensitive surface features is very unlikely to impact a given feature.

APPENDIX D

Baseline Flora Monitoring Summary

Baseline Monitoring Data

Extensive field flora surveys carried out since 2003 have established the range of values which occur for most of the flora monitoring parameters in THPSS. Baseline surveys have also established the current status of each monitoring site with respect to these parameters (**Table 13.1**). Flora monitoring sites are shown of Figures 7.7 and 7.8 in the main body of this MMP. The baseline flora monitoring methodology used to survey baseline sites is the same as the methodology set out in Section 7.1.2 in the main body of this MMP. The seasonal frequency of monitoring is the same for both baseline data collection and for data collection described in this MMP.

Work will continue in these monitoring sites over coming years to further validate and strengthen this baseline data. More monitoring sites may be added if it is considered that this is likely to strengthen the monitoring program.

Variability in species assemblage

Multivariate statistical analyses carried out by the Centre for Mined Land Rehabilitation, based on past monitoring data, have shown that the species assemblages found in individual plots in unimpacted THPSS are each comprised of distinct assemblages of plant species. Despite these differences, each swamp community still conforms to one of two map units defined in the Vegetation of the Western Blue Mountains (DEC 2006):

- map unit 50 (Newnes Plateau Shrub Swamp) or
- map unit 51 (Newnes Plateau Hanging Swamp).

These two units in turn comprise most of the EEC THPSS on the Newnes Plateau with map unit 52 also comprising a small amount of this endangered community. Variations in plant species assemblages among swamps are part of the natural variation that occurs within the endangered community. In comparison, the differences in species composition recorded between unimpacted plots have remained consistent across the temporal scales analysed (seasons and years).

Table 13.1 – Range of natural variability for monitored flora parameters in shrub swamps (1)

	Species Assemblage (number of species)	Non-native weeds (number of species)	Condition	Non-live ground cover (% cover increase over 3 years)	Non-swamp species assessed by abundance of Eucalypts	Non-native weeds abundance
Range in unimpacted swamps	16 to 36	0-4 species	4-5	0-1	0-2 individuals	0-2
WC01	16 (max 20 min 12)	0	4-5	This data will be collected as part of the MMP flora monitoring program	Refer to Vickers *et al.* (2011) Section 5.3 Figures 41-52 for a detailed time series for the number of eucalypts in monitoring quadrats which shows numbers pre and post mining for a number of quadrats that has been used to predict expected ranges in unimpacted and impacted swamps	Refer to Vickers *et al.* (2011) Section 5.2 Figures 24-39 for a detailed time series for the number of non-native weeds in monitoring quadrats which shows numbers pre and post mining for a number of quadrats that has been used to predict expected ranges in unimpacted and impacted swamps
WC02	19 (max 24 min 13)	0	4-5			
WC03	15 (max 19 min 11)	0	4-5			
WC04	16 (max 20 min 13)	0	4-5			
SSE01	29 (max 29 min 28)	1	4-5			
TG01	23 (Max 26 min 20)	0	4-5			
TG02	26 (max 30 min 24)	0	4-5			
TRI01	36 (max 37 min 35)	0	4-5			
TRI02	18 (max 19 min 17)	0	4-5			
CCS01	29 (max 31 min 27)	1	4-5			
LGS01	29 (max 32 min 27)	0	4-5			
UGE01	26 (max 28 min 24)	1	4-5			
BS01	18 (max 20 min 16)	0	4-5			

NOTE: (1) Expected range for control and impact informed by data from mine water discharge sites at Narrow and East Wolgan Swamps

Flora monitoring sites are shown in Section 7 of this MMP on Figures 7.7 and 7.8 as well as on the plan in the envelope at the rear of this MMP.

APPENDIX E

Baseline Groundwater Monitoring Summary

Baseline Monitoring Data – Swamp Piezometers

The baseline monitoring data for the swamp groundwater levels are presented in Figure 13.1 and Figure 13.2. The location of groundwater monitoring sites is shown on Figure 7.10 in Section 7 as well as the plan in the envelope at the rear of this MMP.

The data for the permanently waterlogged sites, in both impact and reference swamps, are shown in **Figure 13.1**.The data for periodically waterlogged sites are given in **Figure 13.2**. The impact and reference sites are grouped together for similar swamp types to show the similarity in their hydrogeological behaviour.

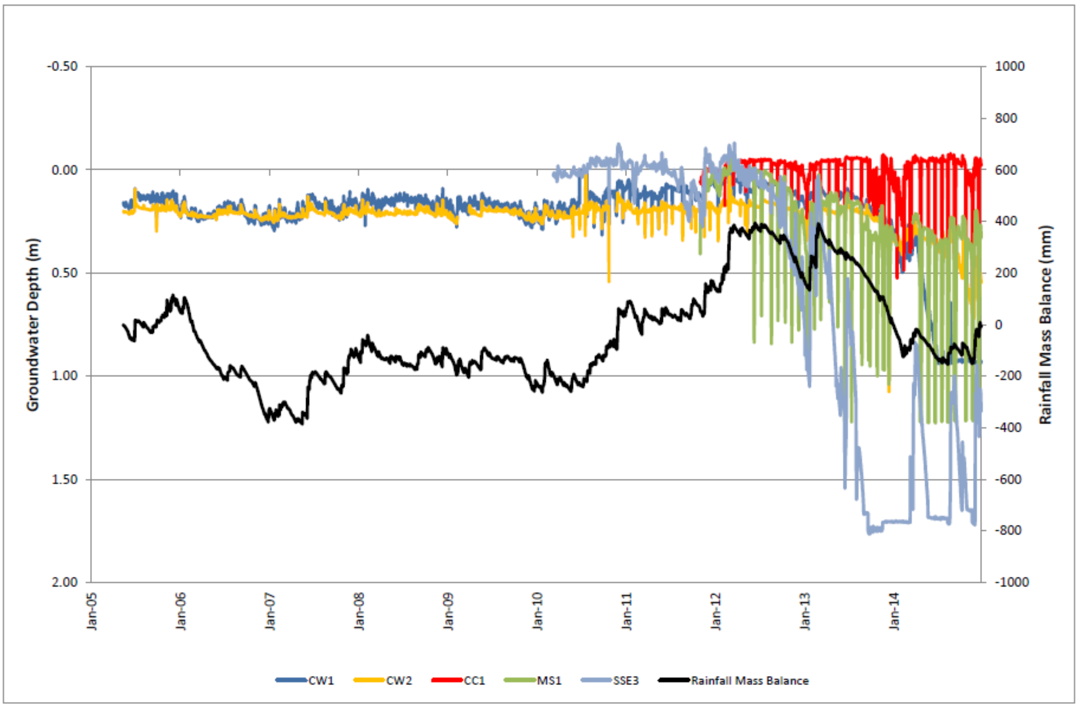


Figure 13.1 – Baseline data – groundwater levels - permanently waterlogged sites

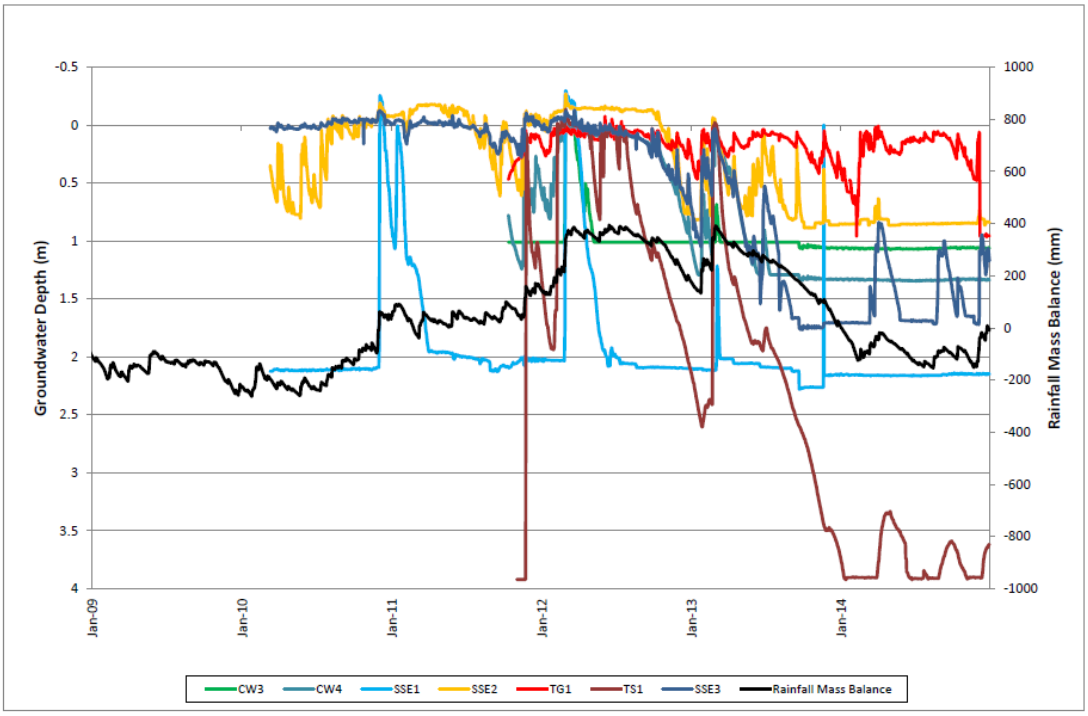


Figure 13.2 – Baseline data – groundwater levels - periodically waterlogged sites

Carne West Swamp – Impact Site

Groundwater Depth

The groundwater depths measured since 2005 in the two monitoring bores (CW1 and CW2) at the northern end of the Carne West Swamp are shown in Figure **13.**3 and Figure 13.4 along with daily rainfall data. The data shows a very consistent pattern, with groundwater levels rising slightly following rainfall events, followed by a slower decay in level prior to the subsequent rainfall event. The range in levels is less than 0.3 metres over the entire monitoring period, which included severe drought conditions during 2006 as well as well above average rainfall at the beginning of 2012. This indicates that this part of the swamp is fed consistently by groundwater from a lateral aquifer, and confirms its classification as a permanently waterlogged swamp.

The two monitoring bores located at the southern end of the Carne West Swamp near LW 417 show a different groundwater level response, which indicates quite different hydrogeological conditions in this part of the swamp (Figure 13.5 and Figure **13.**). CW3, at the upper end of the swamp, was initially dry when it was installed in November 2011. However, following heavy rainfall in early 2012, the groundwater level rose to near the ground surface, where it stayed for less than one month, before declining again to the base on the bore in April 2012. This response to rainfall is typical of a periodically waterlogged swamp. Piezometer CW4, located a little further towards the north, shows less response to rainfall than CW3, but still displays some of the characteristics of a periodically waterlogged swamp. While this piezometer has never been dry, the groundwater level at this site has ranged between a depth of 1.2 metres from the ground surface to near ground level. Rapid rises in groundwater level following rainfall events are followed by a decline in level in the weeks following the event. This behaviour indicates that the swamp at this site is largely reliant on rainfall, and less so on groundwater, and is classified as periodically waterlogged.

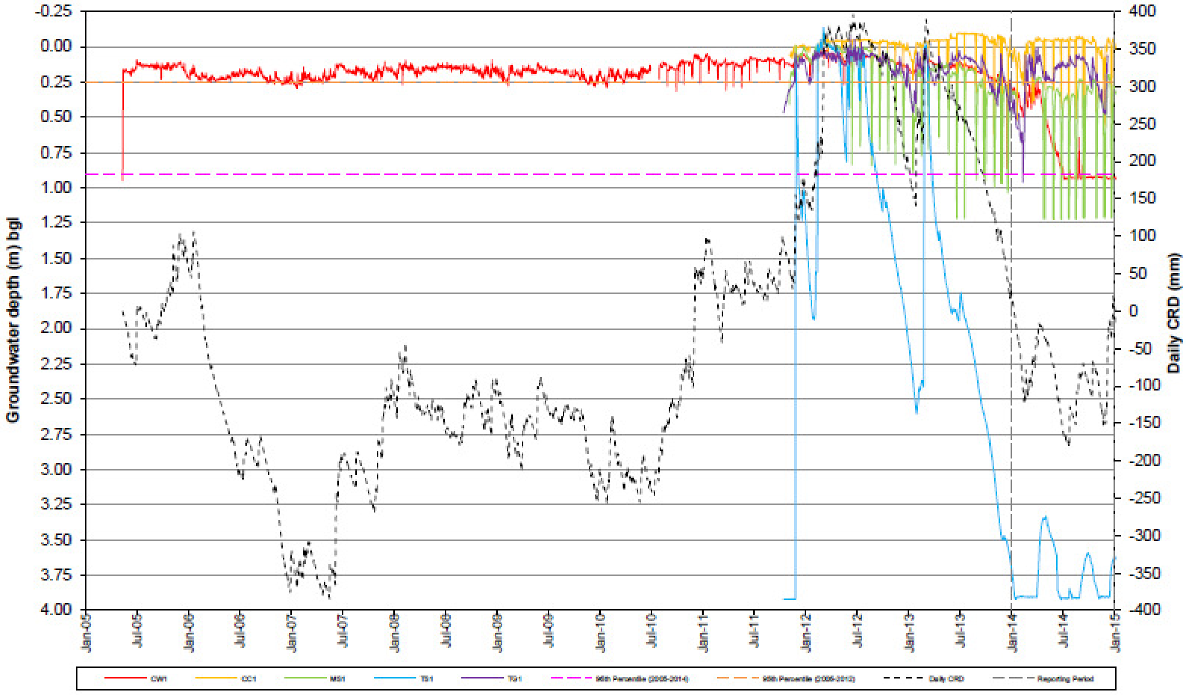


Figure 13.3 - CW1 hydrograph compared with 95 percentile water depth, reference sites and rainfall trend [Permanently Waterlogged Swamp]

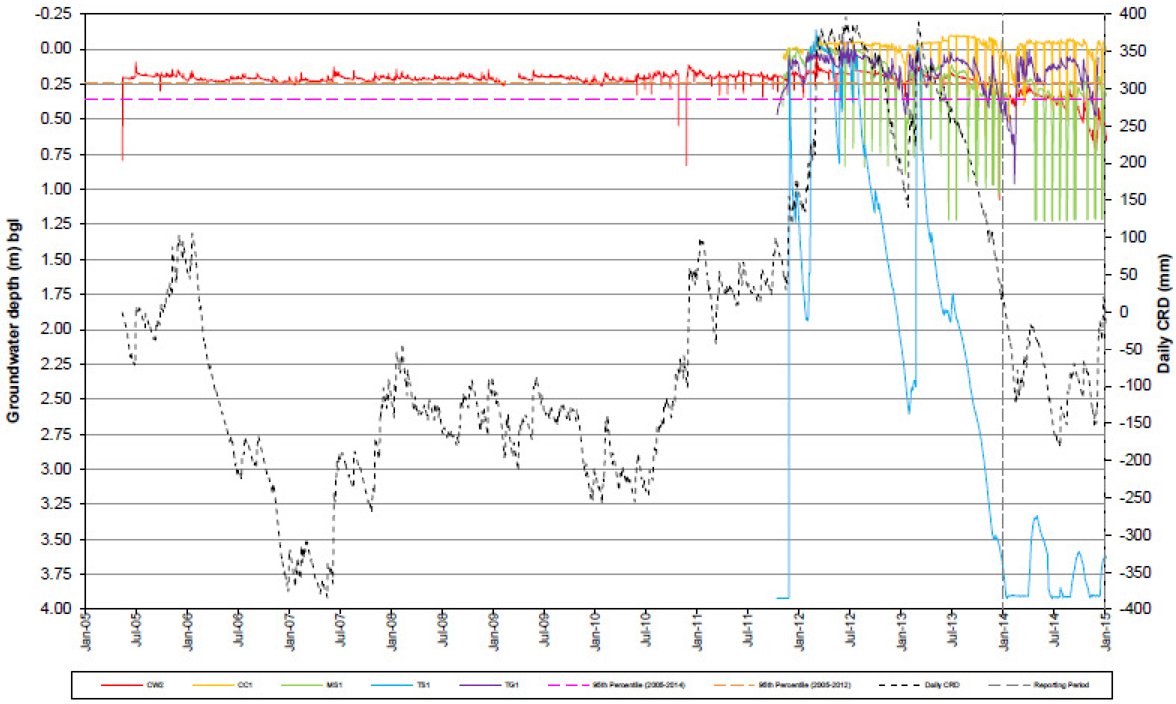


Figure 13.4 – CW2 hydrograph compared with 95 percentile water depth, reference sites and rainfall trend [Permanently Waterlogged Swamp]

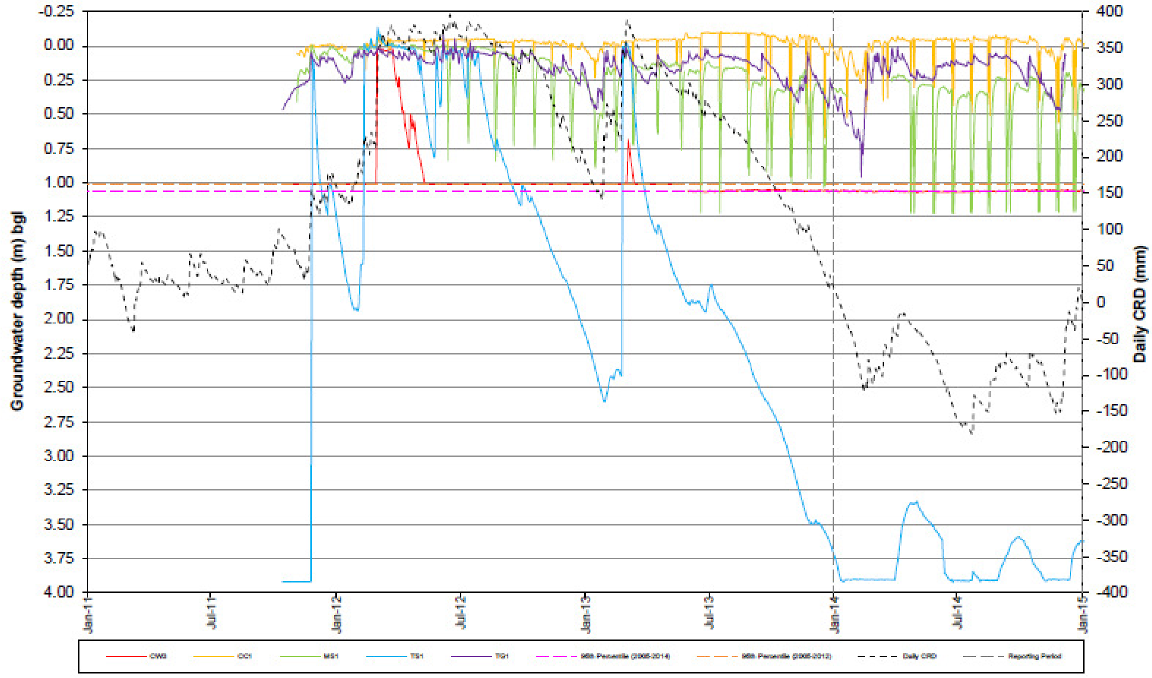


Figure 13.5 - CW3 hydrograph compared with 95 percentile water depth, reference sites and rainfall trend [Periodically Waterlogged Swamp]

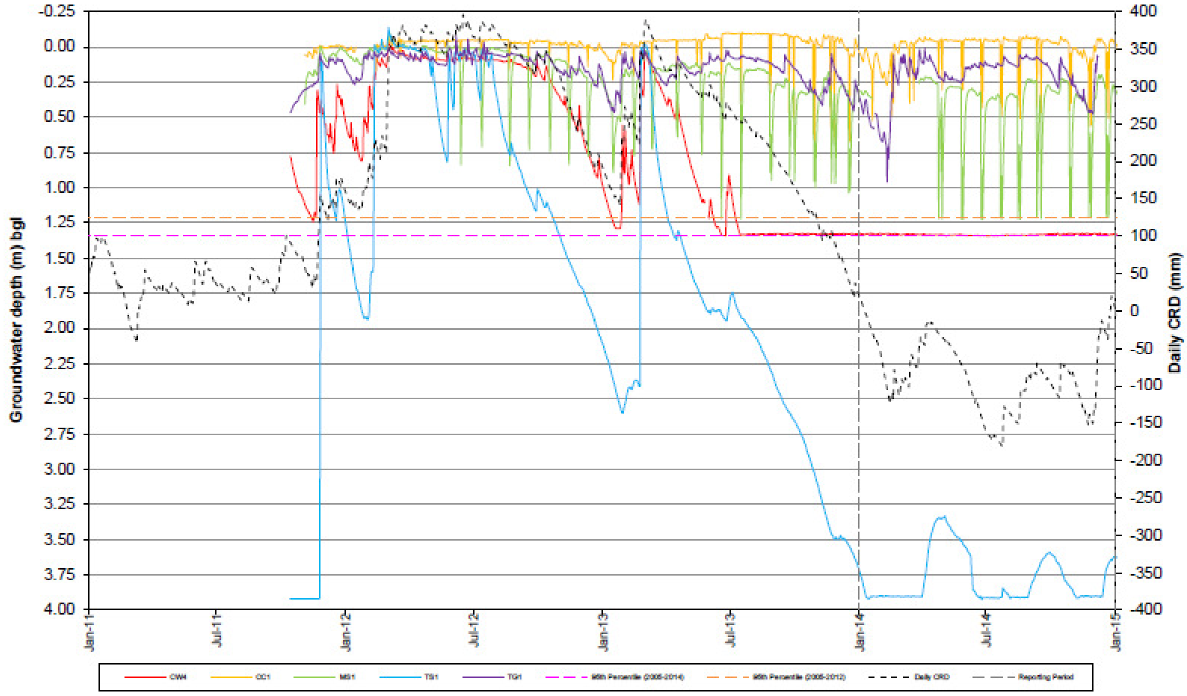


Figure 13.6 - CW4 hydrograph compared with 95 percentile water depth, reference sites and rainfall trend [Periodically Waterlogged Swamp]

Groundwater Quality

Table 13.2 below shows the existing pre-mining groundwater quality data for CW1, starting from 31 May 2011 to June 2015+, and provides a comparison with trigger values set out within the ANZECC Guidelines. The table also shows the pre-mining 80th and 95th percentiles as well as the average of all the data.

Table 13.2 – Springvale Mine Groundwater Quality Baseline Data CW1

Element	Pre-Mining 80th Percentile(3)	Pre-Mining 95th Percentile(3)	Pre-mining average	ANZECC Guideline
CW1 General Water Quality (mg/L)				
pH	4.87	4.69	5.18	6.5 – 8.0
EC (µs/cm)	25	38	24	350
Oil & Grease	<5	<5	<5	-
Total Alkalinity as $CaCO_3$	3.00	8.95	3.18	-
Ca	<1	<1	<1	
Mg	<1	<1	<1	
Total Hardness as $CaCO_3$	<1	<1	<1	
Chlorine (total)	0.12	0.22	0.08	0.003
Chloride	5	6	4.45	350 (1)
K	<1	<1	<1	-
Na	3	4	2.63	-
SO_4	1	2	2.20	1000
Dissolved Oxygen	8.80	10.32	7.45	>6
Nitrate as N	0.04	0.07	0.04	0.015
Total Nitrogen as N	1.40	1.90	0.98	0.25
CW1 Trace Metals (mg/L)				
Al (filterable)	0.22	0.46	0.15	-
Cr (filterable)	0.001	0.001	0.001	0.001
Cu (filterable)	0.52	0.67	0.32	0.0014
Fe (filterable)	0.29	0.56	0.25	0.3 (2)
Zn (filterable)	0.15	0.20	0.11	0.008

NOTE: (1) irrigation water moderately tolerant crops; irrigation.
(2) drinking water
(3) for pH, these figures are 20th and 5th percentiles

The table shows the following characteristics of the groundwater in the Carne West Swamp:

- Salinity is low, as shown by the low conductivity, chloride and sulphate

- Alkalinity is low due to acidic conditions in the wetland, as shown by the low pH
- Nutrients (nitrate and total nitrogen) are high, indicating accumulation of organic matter from catchment runoff and decomposition within the wetland
- Trace metals are high, particular iron and aluminium which are abundant in the groundwater in the area. Copper is also found at elevated levels, with Zinc found at lower, but still enriched, levels.

Changes over time for pH, EC and Iron levels have been compared to the minor and major trigger values in **Figure 13.7, Figure 13.8** and **Figure 13.9** and discussed in more detail below

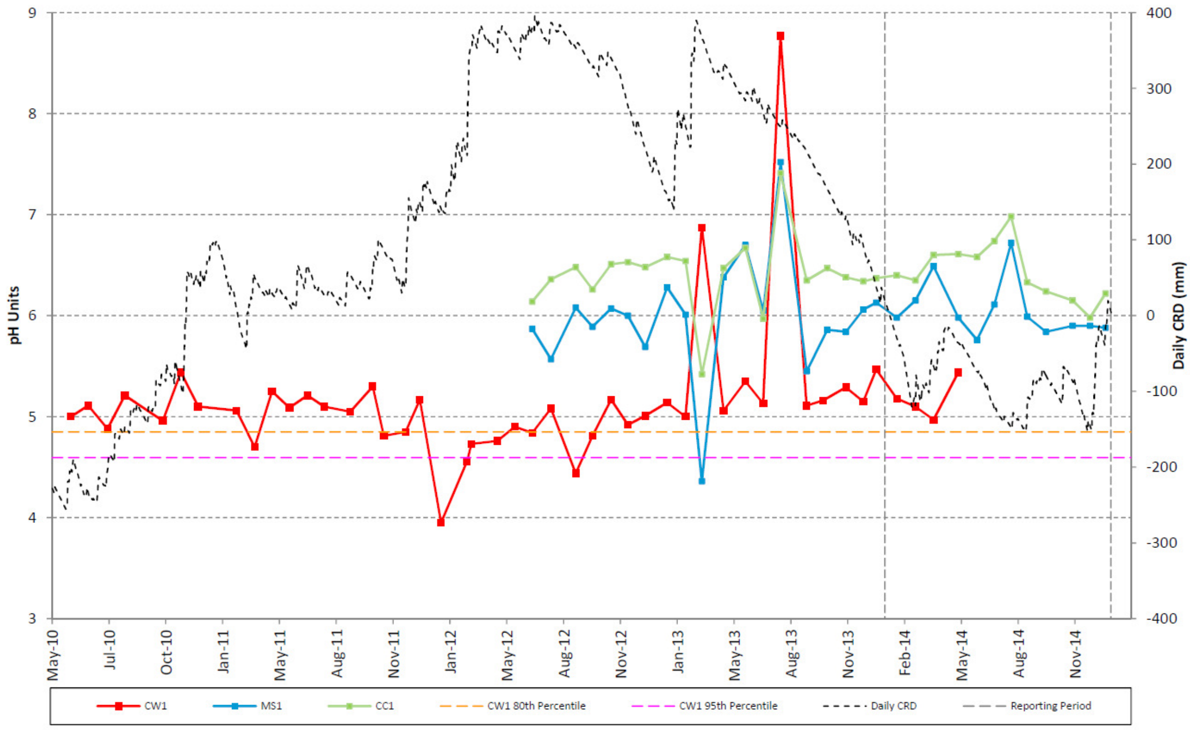


Figure 13.7 – CW1 Groundwater pH

The groundwater at CW1 is acidic with an average pH of 5.18 and is typical of Temperate Highland Peat Swamps on Sandstone in the area (DSEWPC 2012).

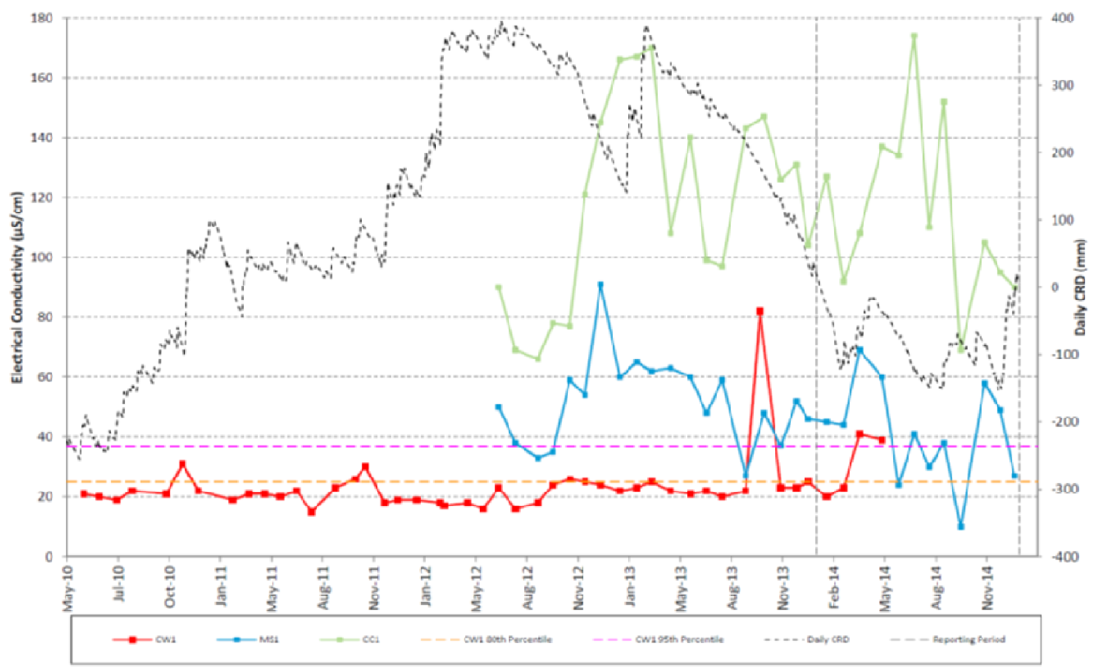


Figure 13.8 – CW1 Groundwater Electrical Conductivity

Existing pre-mining electrical conductivity levels are low, averaging 24 µS/cm. This is well below the 350 µS/cm levels prescribed by the ANZECC Guidelines (2000) for upland rivers in NSW.

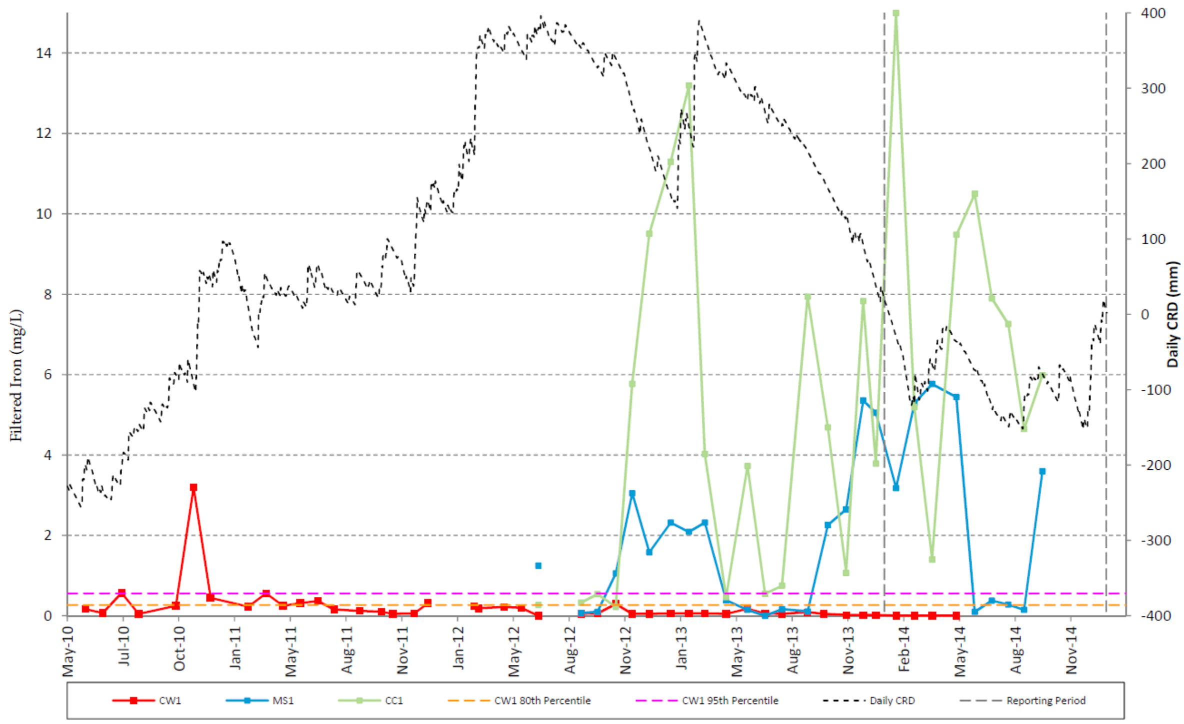


Figure 13.9 – CW1 Groundwater Iron Concentrations

The average iron concentration at CW1 is 0.25 mg/L which is slightly below the 0.3 mg/L set for drinking water in the ANZECC Guidelines (2000).

Table 13.3 shows the existing pre-mining groundwater quality data for CW2 starting from 22 February 2011 to June 2015 and provides a comparison with trigger values set out within the ANZECC Guidelines.

Table 13.3 – Springvale Mine Groundwater Quality Baseline Data CW2

Element	Pre-Mining 80th Percentile(3)	Pre-Mining 95th Percentile(3)	Pre-mining average	ANZECC Guideline
CW2 General Water Quality (mg/L)				
pH	5.18	4.69	5.37	6.5 – 8.0
EC (µs/cm)	31	41	25	350
Oil & Grease	<5	<5	<5	-
Total Alkalinity as $CaCO_3$	4.00	5.75	3.12	-
Ca	<1	<1	<1	-
Mg (filterable)	<1	<1	<1	1.9
Total Hardness as $CaCO_3$	<1	<1	<1	-
Chlorine (total)	0.07	0.12	0.06	0.003
Chloride	4.00	5.70	4.21	350 (1)
K	1.00	1.00	1.12	-
Na	3.00	3.70	2.53	-
SO_4	1.00	10.00	1.94	1000
Dissolved Oxygen	9.05	10.37	7.44	>6
Nitrate as N	0.03	0.08	0.21	0.015
Total Nitrogen	0.80	1.40	0.82	0.25
CW2 Trace Metals (mg/L)				
Al (filterable)	0.07	0.10	0.06	-
Cr (filterable)	0.001	0.001	0.024	0.001
Cu (filterable)	0.71	0.94	0.54	0.0014
Fe (filterable)	0.09	0.31	0.10	0.3 (2)
Zn (filterable)	0.20	0.29	0.13	0.008

NOTE: (1) irrigation water moderately tolerant crops; irrigation.
(2) drinking water
(3) for pH, these figures are 20th and 5th percentiles

The table shows the following characteristics of the groundwater in the Carne West Swamp:

- Salinity is low, as shown by the low conductivity, chloride and sulphate.
- Alkalinity is low due to acidic conditions in the wetland, as shown by the low pH.

- Nutrients (nitrate and total nitrogen) are high, indicating accumulation of organic matter from catchment runoff and decomposition within the wetland.
- Dissolved oxygen is just above the minimum recommended for ambient waters, probably due to consumption by the decomposing organic matter. Organic matter decomposition is also consistent with the low pH.
- Trace metals are low for iron and aluminium which are normally abundant in the groundwater in the area. High levels of zinc and copper are present in the groundwater.

Changes over time for pH, EC and Iron levels have been compared to the minor and major trigger values in **Figure 13.10, Figure 13.11** and **Figure 13.12** and discussed in more detail below

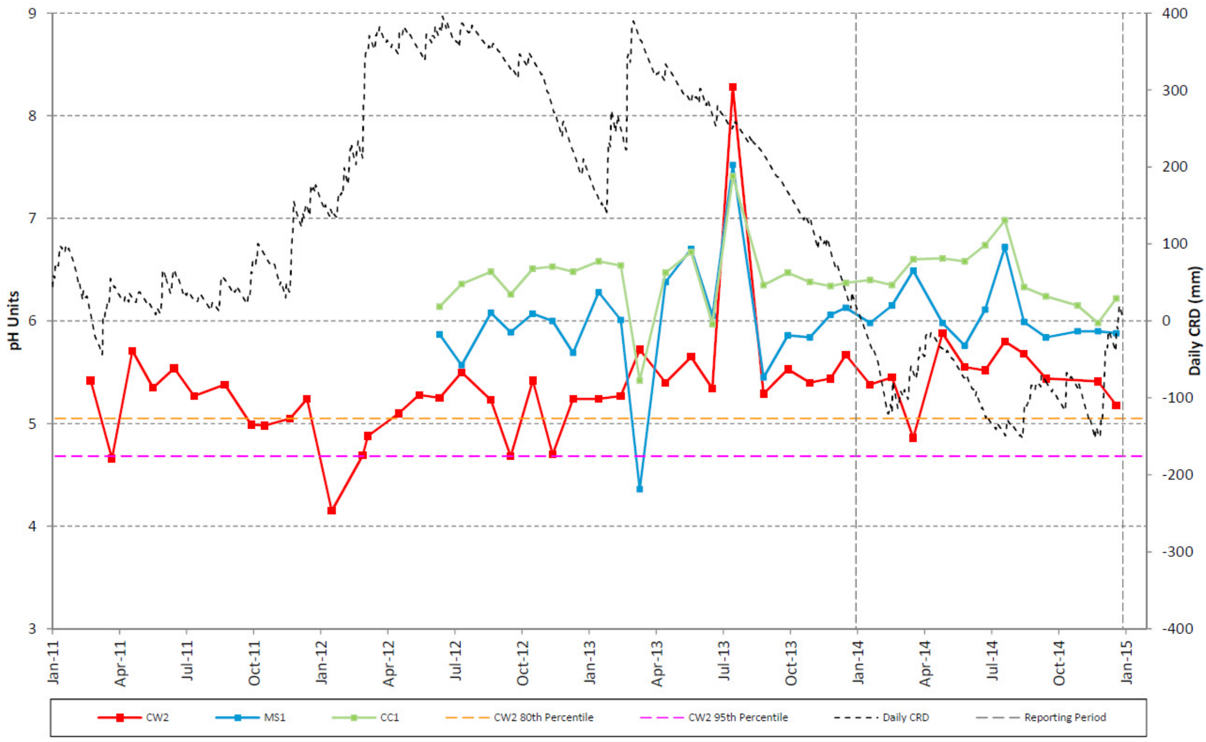


Figure 13.10 – CW2 Groundwater pH

The groundwater at CW2 is acidic with an average pH of 5.37. This can be attributed to the natural characteristics of Temperate Highland Peat Swamps on Sandstone.

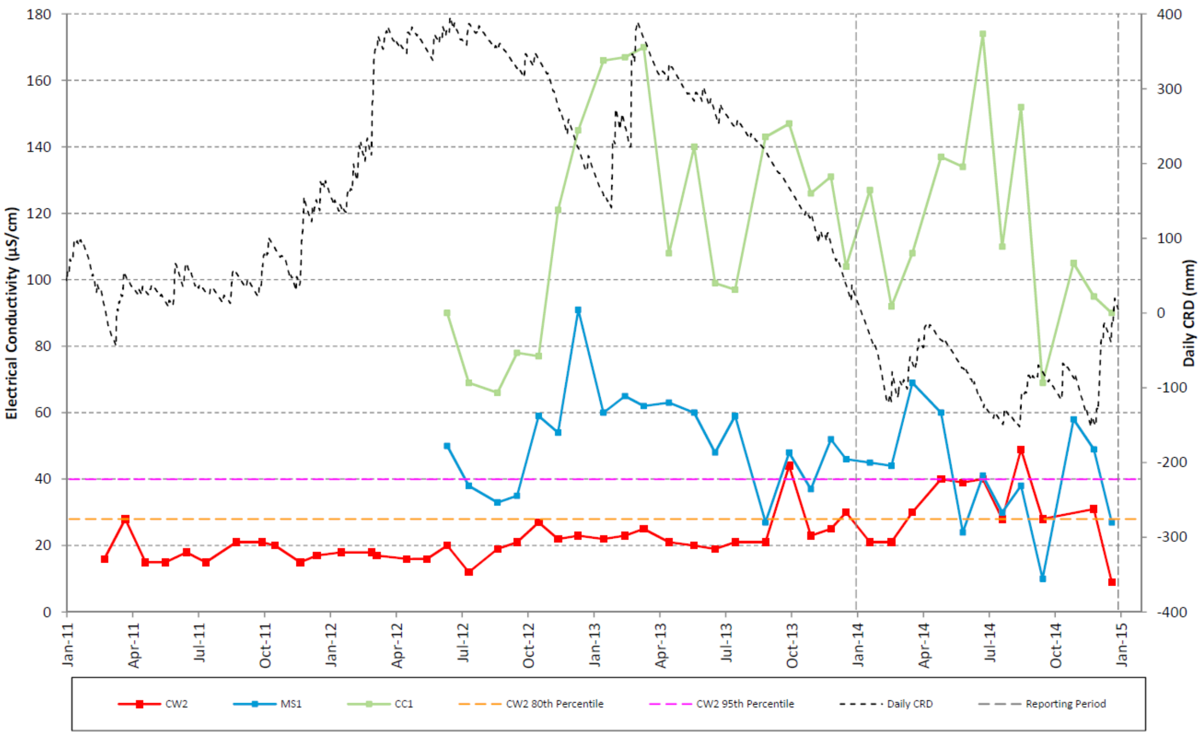


Figure 13.11 – CW2 Groundwater Electrical Conductivity

Similar to CW1, this site exhibits low conductivity well below the 350 µS/cm levels prescribed by the ANZECC Guidelines (2000).

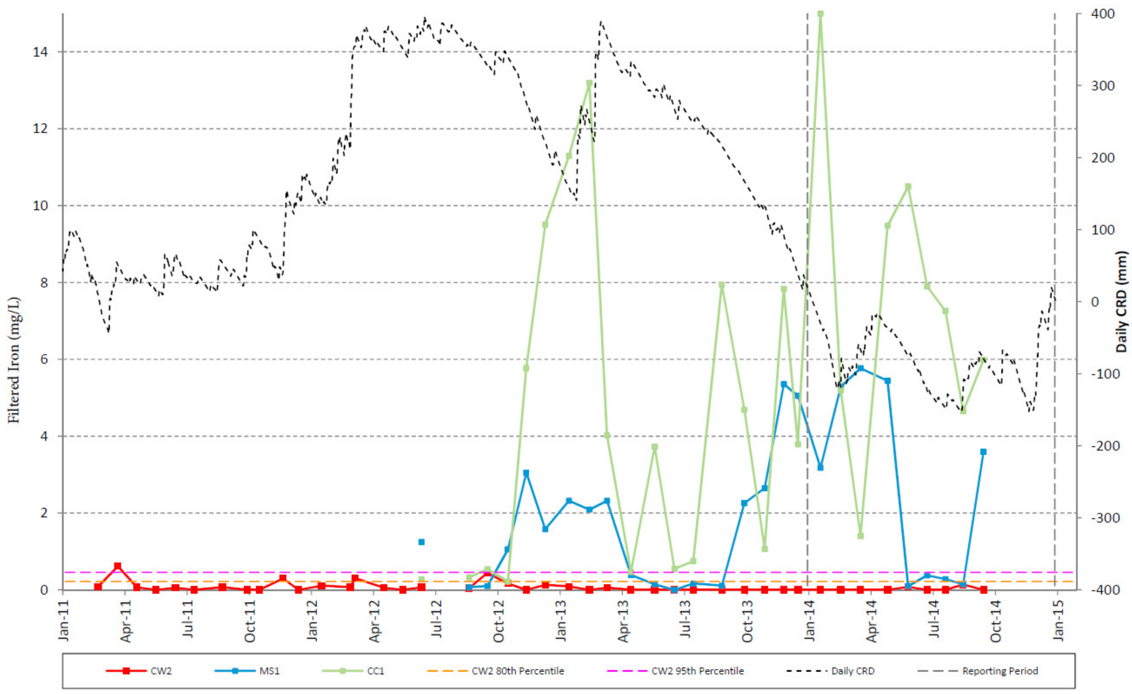


Figure 13.12 – CW2 Groundwater Iron Concentrations

Iron levels in the groundwater at CW2 average 0.10 mg/L which is below the ANZECC (2000) guideline of 0.3 mg/L used for drinking water.

Sunnyside East Swamp – Impact Site

Groundwater Level

Groundwater level data from the three monitoring bores in the Sunnyside East Swamp (SSE1, SSE2 and SSE3) are plotted on Figure 13.13,
Figure **13.**14 and
Figure **13.**15. These piezometers were installed in March 2010 so that there is now sufficient data to give an indication of the hydrogeological classification of the swamp. The data from SSE1 near the head of the swamp indicates that the swamp at this site is periodically waterlogged, since the groundwater table is below a depth of two metres, and is not responsive to most rainfall events. In the two years since it was installed, the groundwater level has only risen twice to the ground surface in response to major rainfall events, but has declined shortly afterwards. This behaviour is typical of periodically waterlogged swamps.

The piezometer in the centre of the swamp (SSE2) shows groundwater level behaviour which is less reliant on rainfall. The groundwater level in this bore has ranged between 0.8 metres below the ground surface and 0.2 metres above. The pattern of groundwater level movements suggest that this site is both rainfall and groundwater dependant, with significant contributions from both sources. For the purposes of this plan, it has been grouped with the periodically waterlogged swamps, as there is a large range in hydrogeological conditions in this swamp type. SSE3, the piezometer in the lower part of the swamp shows a groundwater level that ranges between 0.3 metres below the ground surface and 0.2 metres above the ground level. The response to rainfall in this piezometer is limited, which gives a good indication that the lower part of the Sunnyside East Swamp near this site is permanently waterlogged.

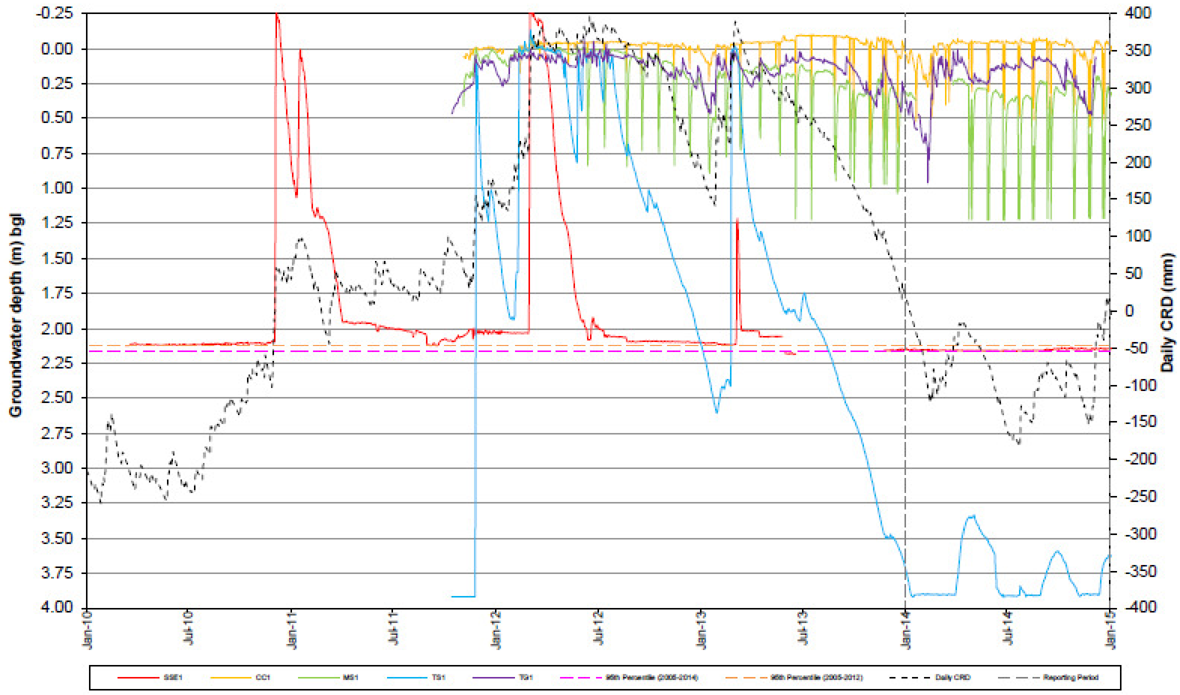


Figure 13.13 - SSE1 hydrograph compared with 95 percentile water depth, daily rainfall and rainfall trend [Periodically Waterlogged Swamp]

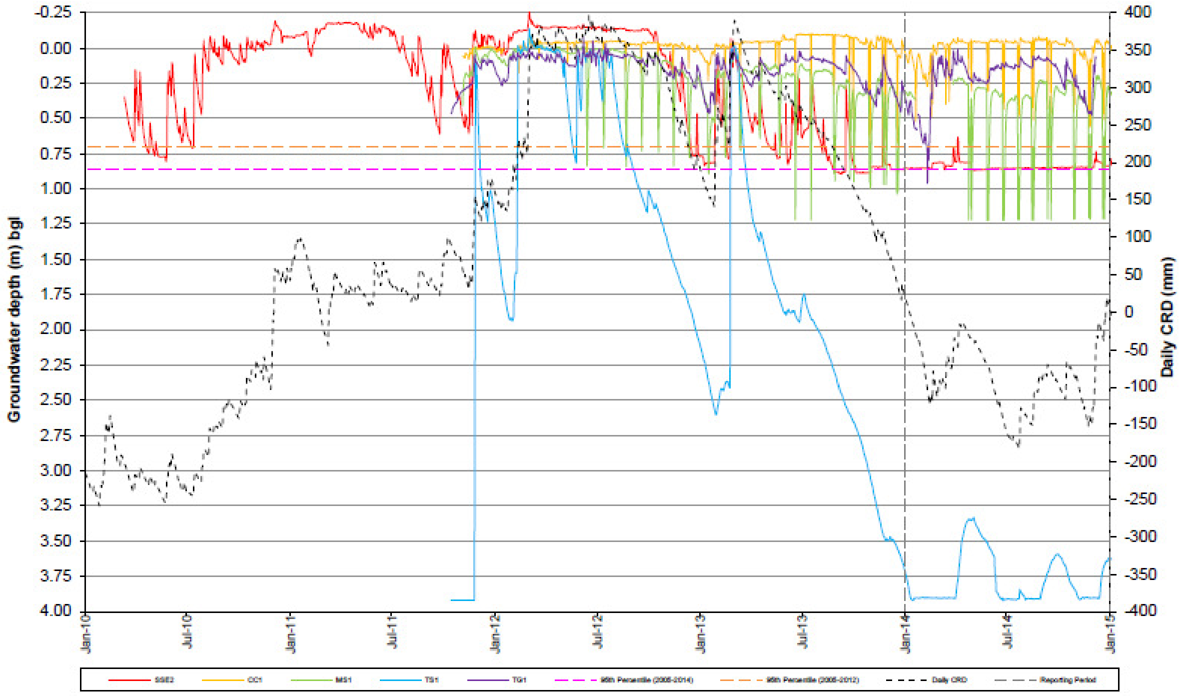


Figure 13.14 - SSE2 hydrograph compared with 95 percentile water depth, daily rainfall and rainfall trend [Periodically Waterlogged Swamp]

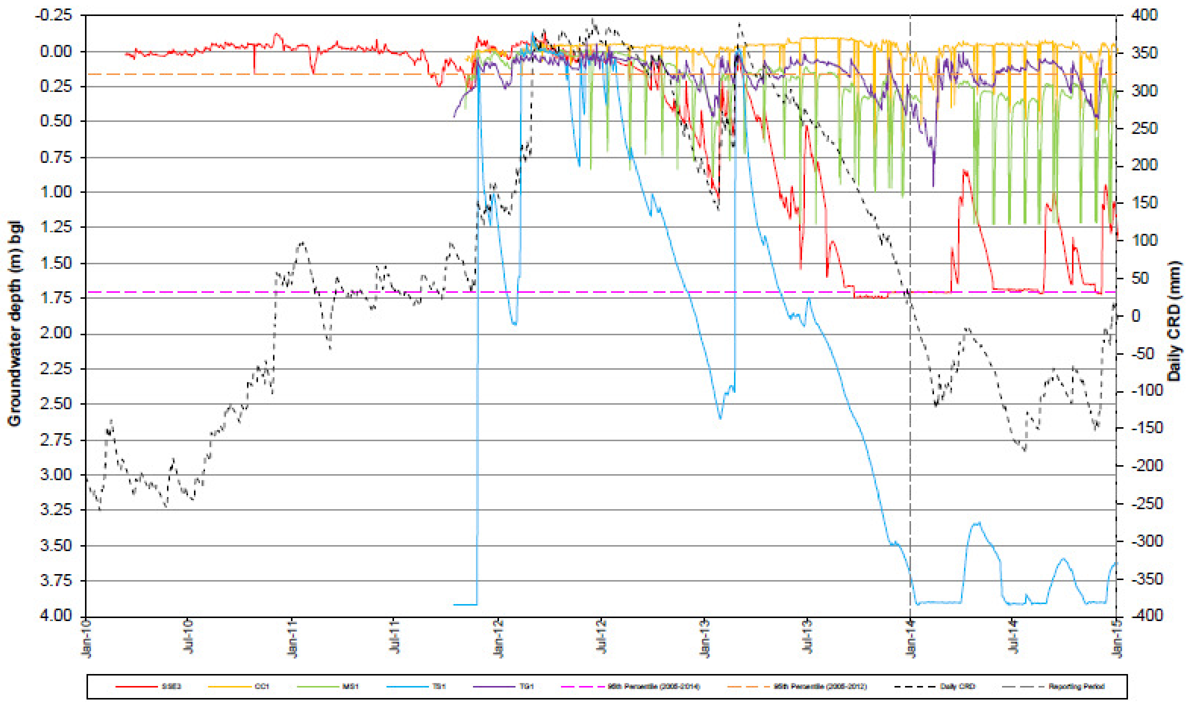


Figure 13.15 – SSE3 hydrograph compared with 95 percentile water depth, daily rainfall and rainfall trend [Permanently Waterlogged Swamp]

Groundwater Quality

Table 13.4 shows the existing pre-mining groundwater quality at SSE3 starting from 22 February 2011 to present, and provides a comparison with the trigger values set out within the ANZECC Guideline.

Table 13.4 – Springvale Mine Groundwater Quality Baseline Data SSE3

Element	Pre-Mining 80th Percentile(3)	Pre-Mining 95th Percentile(3)	Pre-mining average	ANZECC Guideline
SSE3 General Water Quality (mg/L)				
pH	5.40	5.24	5.76	6.5 – 8.0
EC (µs/cm)	51	87	45	350
Oil & Grease	<5	<5	<5	-
Total Alkalinity as $CaCO_3$	4.00	4.50	3.00	-
Ca	<1	<1	<1	
Mg	<1	<1	<1	
Total Hardness as $CaCO_3$	<1	<1	<1	
Chlorine (total)	0.06	0.14	0.04	0.003
Chloride	6.80	7.00	5.55	350 (1)
K	<1	<1	<1	-
Na	4.80	6.00	4.32	-
SO_4	1.80	7.75	1.82	1000
DO	8.27	9.22	6.07	>6
Nitrate as N	0.04	1.07	0.18	0.015
Total Nitrogen	2.26	3.67	5.25	0.25
SSE3 Trace Metals (mg/L)				
Al (filterable)	0.22	0.65	0.22	-
Cr (filterable)	0.001	0.001	0.001	0.001
Cu (filterable)	0.02	0.05	0.02	0.0014
Fe (filterable)	7.67	12.44	4.45	0.3
Zn (filterable)	0.06	0.10	0.05	0.008

NOTE: (1) irrigation water moderately tolerant crops; irrigation.
(2) drinking water
(3) for pH, these figures are 20th and 5th percentiles

The table shows the following characteristics of the groundwater in the Sunnyside Swamp:

- Salinity is low, as shown by the low conductivity, chloride and sulphate.
- Alkalinity is low due to acidic conditions in the wetland, as shown by the low pH.
- Nutrients (nitrate and total nitrogen) are high, indicating accumulation of organic matter from catchment runoff and decomposition within the wetland.

- Dissolved oxygen was just below the minimum recommended for ambient waters, probably due to consumption by the decomposing organic matter. Organic matter decomposition is also consistent with the low pH.
- Trace metals are high, particularly in iron and aluminium which are abundant in the groundwater in the area. Lower, but still enriched, levels of zinc and copper were also present in the groundwater.

Changes over time for pH, EC and Iron levels have been compared to the minor and major trigger values in **Figure 13.16**, **Figure 13.17** and **Figure 13.18** and are discussed in more detail below.

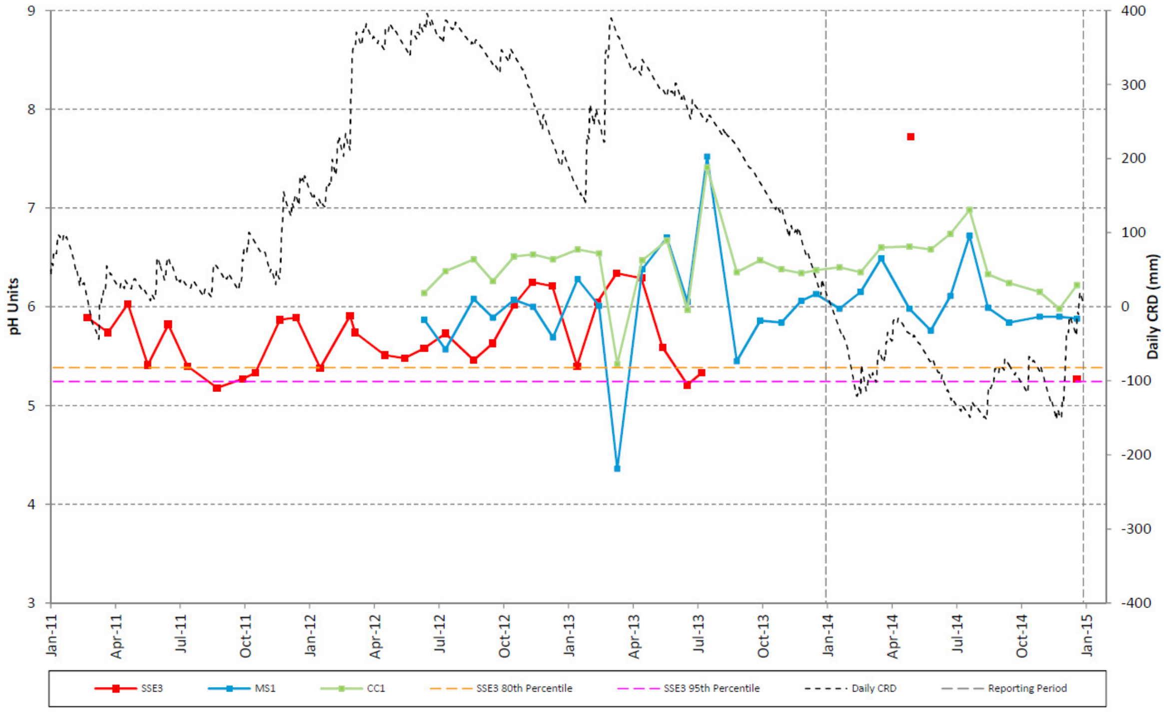


Figure 13.16 – SSE3 Groundwater pH

The acidic pH of Sunnyside East waters is characteristic of organic wetland soils which tend to be acidic, particularly in oligotrophic peat (Maltby 2009).

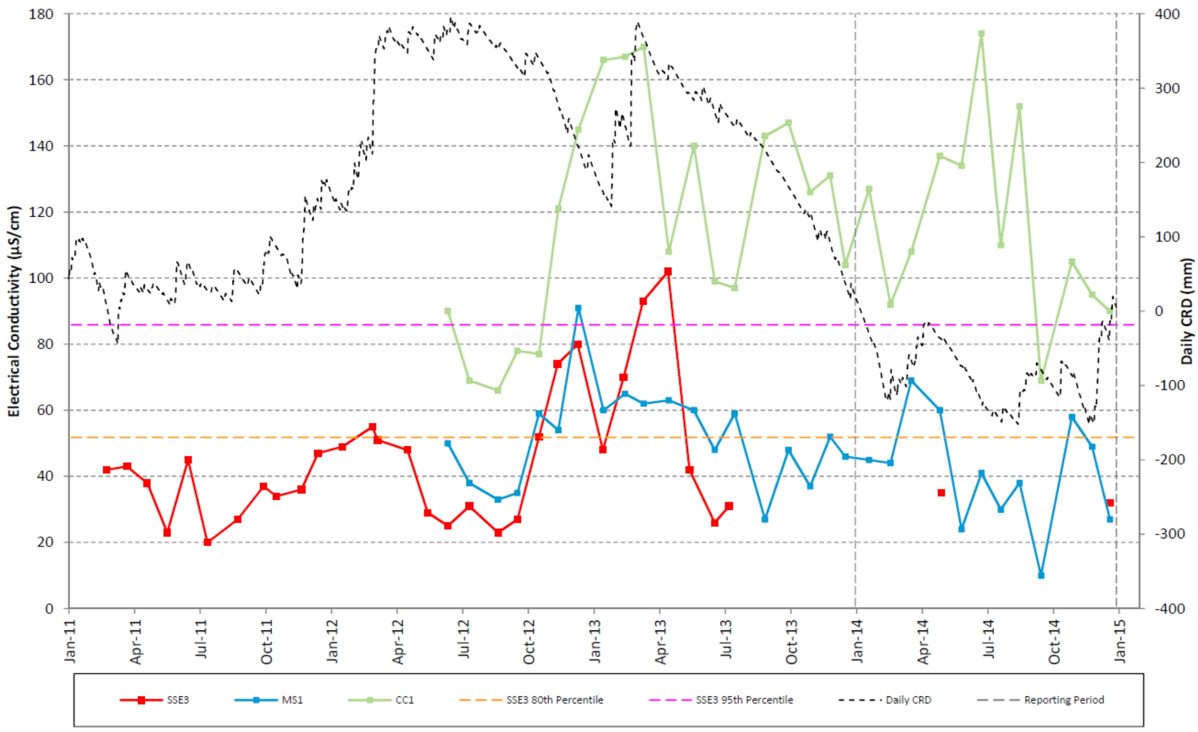


Figure 13.17 – SSE3 Groundwater Electrical Conductivity

SSE3 displays low electrical conductivity levels averaging 45 µS/cm and well below the 350 µS/cm ANZECC Guidelines (2000) for upland rivers in NSW.

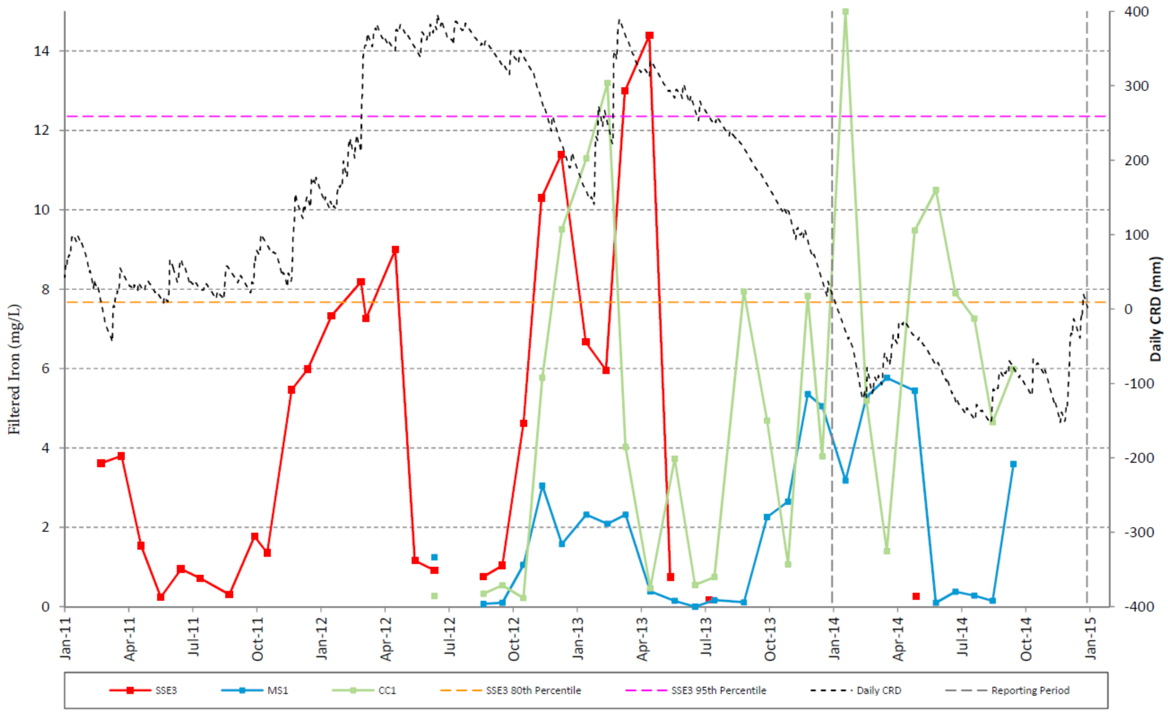


Figure 13.18 – SSE3 Groundwater Iron Concentrations

SSE3 groundwater iron concentrations are significantly higher than samples collected from Carne West Swamp with an average concentration of 3.84 mg/L and a maximum of 9 mg/L taken from the most recent sampling occurrence.

There is no indication of any mining-related impacts on the swamp, which is not unexpected as the current mining activity is located several hundred metres to the west of the swamp.

It is noted that a fire (hazard reduction burn carried out by Forests NSW) passed through the area around 21 April 2010. Fortunately, none of the piezometers were lost in this swamp. To date there appear to be no impacts from the fire on groundwater behaviour measured by the three piezometers, although the rising iron content could be due to the onset of erosion.

Carne Central Swamp – Reference Site

Groundwater Level

The piezometer in this swamp (CC1) was only installed in November 2011 so that limited groundwater level baseline data is currently available. Since that time, the groundwater table measured in the piezometer has been within 0.1 metres of the ground surface (
Figure **13.**19). The groundwater level behavior is indicative of a permanently waterlogged swamp, and shows a subdued response to major rainfall events.

Groundwater Quality

Sampling of groundwater from piezometer CC1 for water chemistry analyses commenced in June 2012 and and there are insufficient data at this time to determine appropriate levels and trends for these sites. It is noted that a sufficient number of samples will be collected prior to the commencement of undermining of the first impact site above Longwalls 415 – 417.

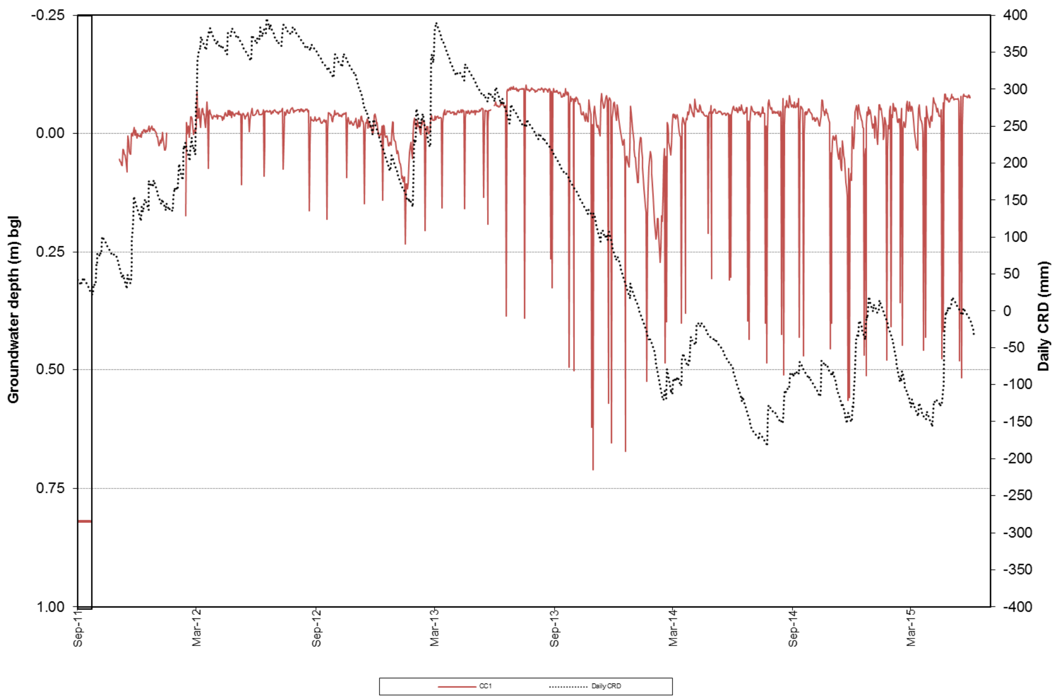


Figure 13.19 - CC1 hydrograph compared with 95 percentile water depth, daily rainfall and rainfall trend [Permanently Waterlogged Swamp]

Marangaroo Swamp – Reference Site

Groundwater Level

The piezometer in this swamp (MS1) was only installed in November 2011 so that limited groundwater level baseline data is currently available. Initial monitoring in the Marangaroo Swamp indicates that the swamp is a permanently waterlogged swamp, with a water table generally within 0.5 metres of the ground surface. The response to rainfall events appears to be greater than for the monitoring site in the Carne Central Swamp, but the groundwater level behavior indicates that this is a permanently waterlogged site (
Figure **13.**20).

Groundwater Quality

Sampling of groundwater from piezometer MS1 for water chemistry analyses commenced in June 2012 and and there are insufficient data at this time to determine appropriate levels and trends for these sites. It is noted that a sufficient number of samples will be collected prior to the commencement of undermining of the first impact site above Longwalls 415 – 417.

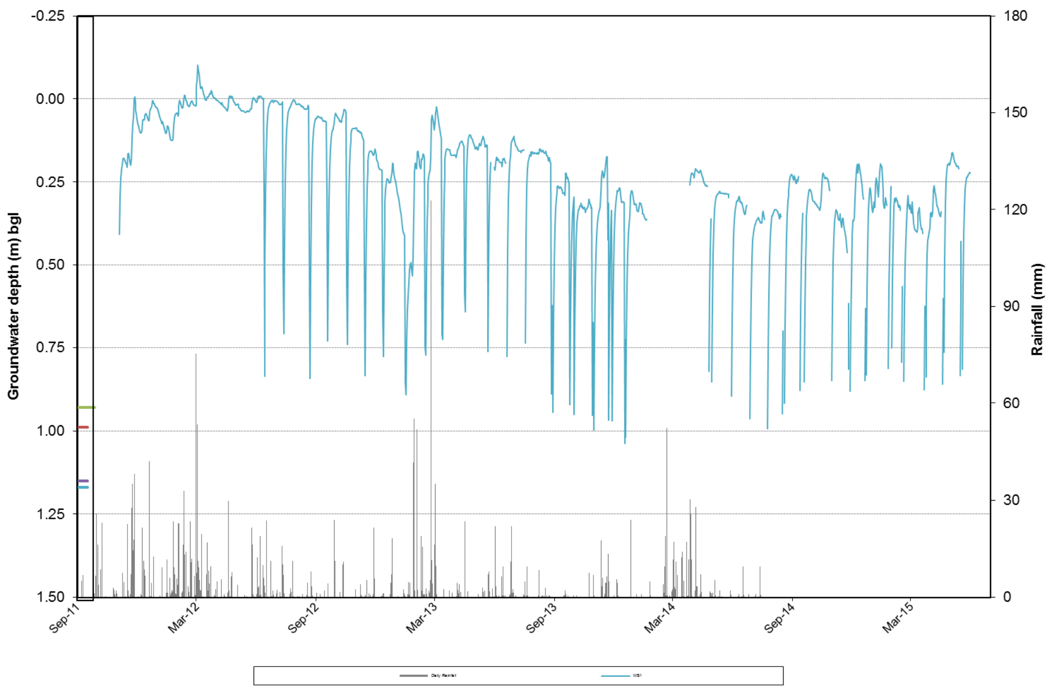


Figure 13.20 - MS1 hydrograph compared with 95 percentile water depth, daily rainfall and rainfall trend [Permanently Waterlogged Swamp]

Tristar Swamp – Reference Site

Groundwater Level

The piezometer in this swamp (TS1) was only installed in October 2011 so that limited baseline data is currently available. Initial monitoring data indicate that this part of the swamp is essentially periodically waterlogged.

The groundwater level measurements show a significant range in level of up to four metres depending on the recent rainfall conditions (**Figure 13.21**). This is typical behaviour for a periodically waterlogged swamp.

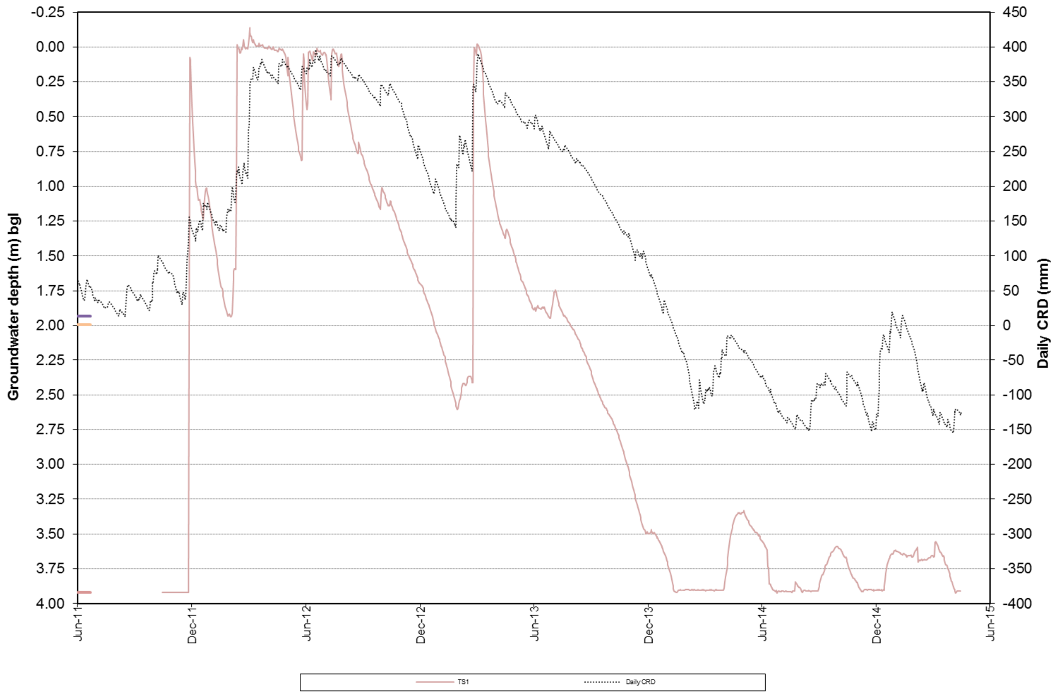


Figure 13.21 - TS1 hydrograph compared with 95 percentile water depth, daily rainfall and rainfall trend [Periodically Waterlogged Swamp]

Twin Gully Swamp – Reference Site

Groundwater Level

The piezometer in this swamp was only installed in October 2011 so that limited baseline data is currently available. The monitoring in the Twin Gully Swamp indicates that, at the site of the piezometer, the swamp displays the hydrogeological characteristics of a permanently waterlogged swamp, with a groundwater table within about 0.5 metres of the ground surface, as well as some response to rainfall events (**Figure 13.22**).

There is an indication from the early data that there may be some rainfall dependence, as the behaviour is similar to the measurements in SSE2 in the centre of the Sunnyside East Swamp, where the swamp transitions from a periodically waterlogged to a permanently waterlogged swamp.

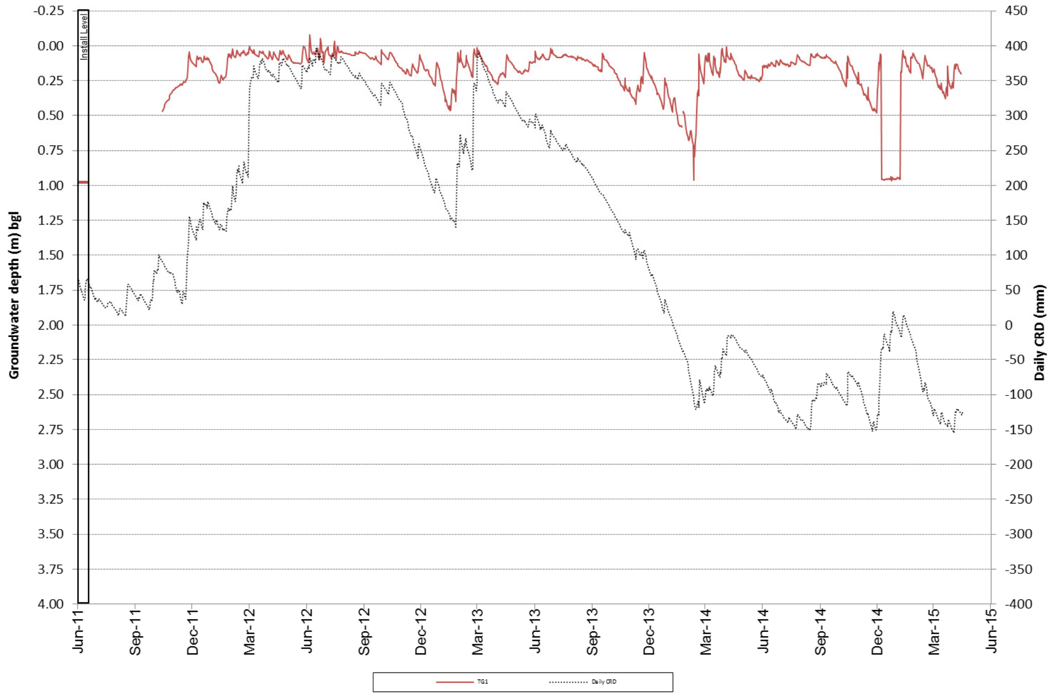


Figure 13.22 - TG1 hydrograph compared with 95 percentile water depth, daily rainfall and rainfall trend [Periodically Waterlogged Swamp]

Baseline Monitoring Data – Aquifer Piezometers

The baseline monitoring data for all of the aquifer piezometers are presented in **Figure 13.**23. Data from individual piezometers are shown on **Figure 13.24** to Error! Reference source not found.**29.**

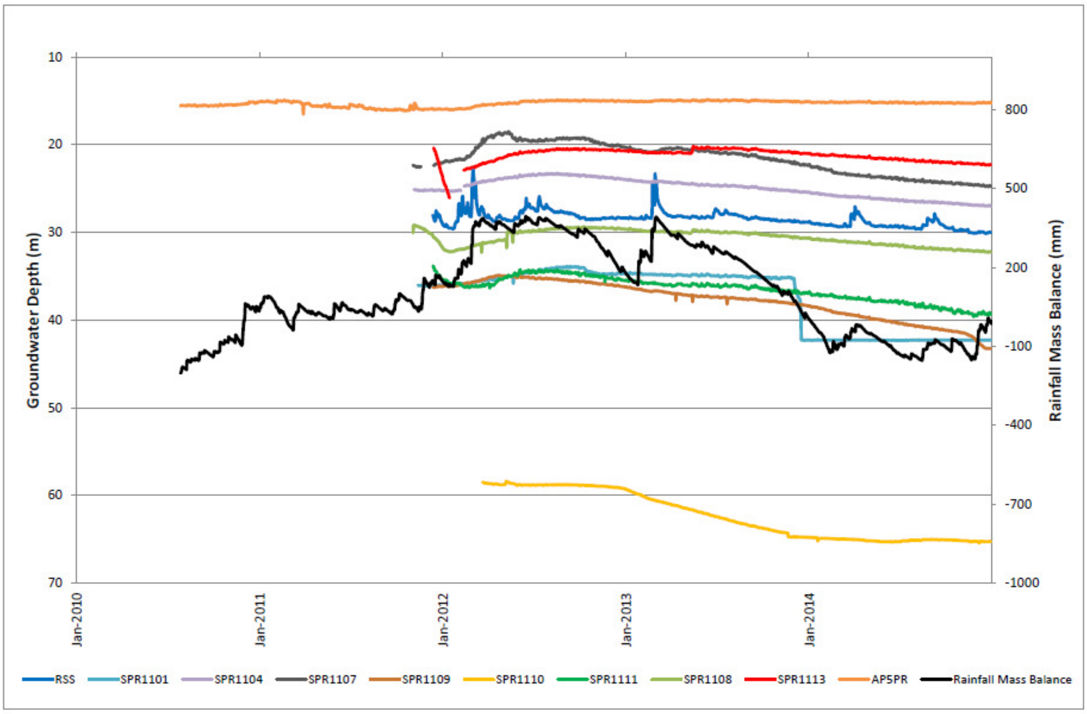


Figure 13.23 - Base line aquifer piezometer data

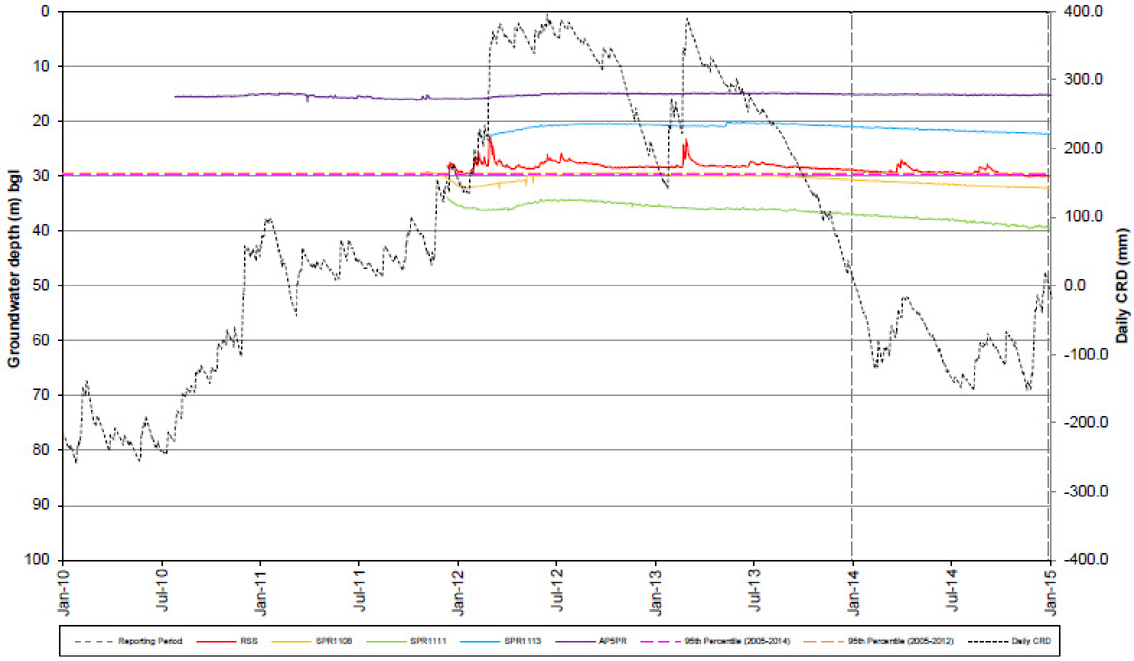


Figure 13.24 - Aquifer piezometer RSS hydrograph compared with 5 and 95 percentile water elevations, daily rainfall and rainfall trend [Over LW415]

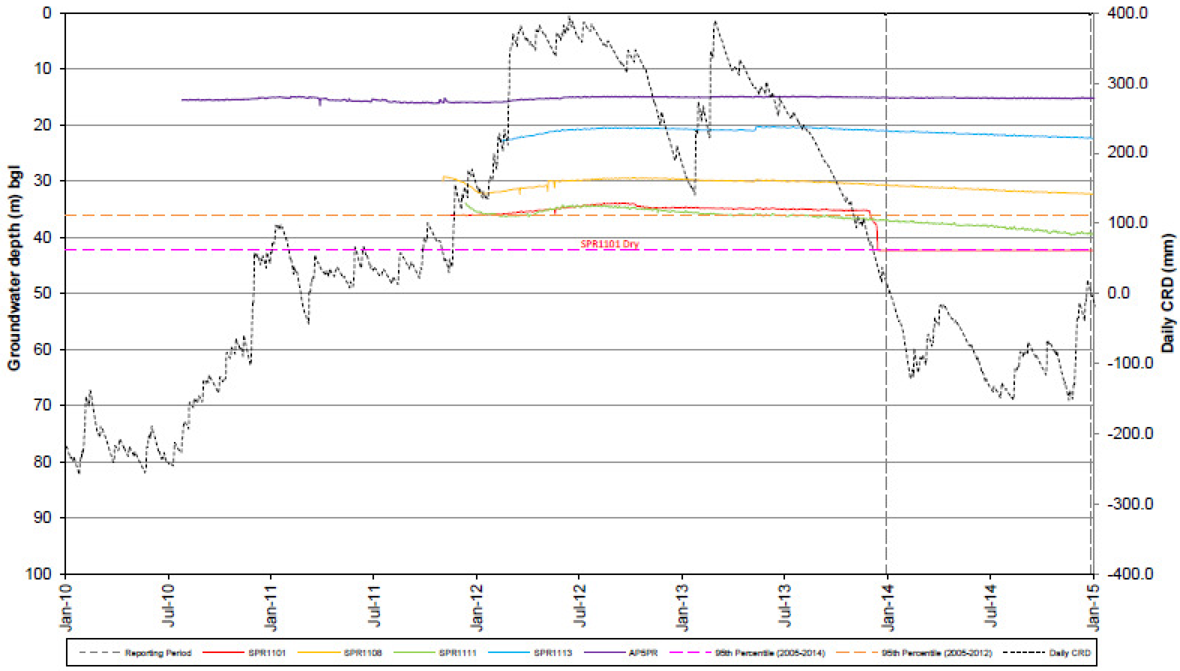


Figure 13.25 - Aquifer piezometer SPR1101 hydrograph compared with 5 and 95 percentile water elevations, daily rainfall and rainfall trend [Over LW416]

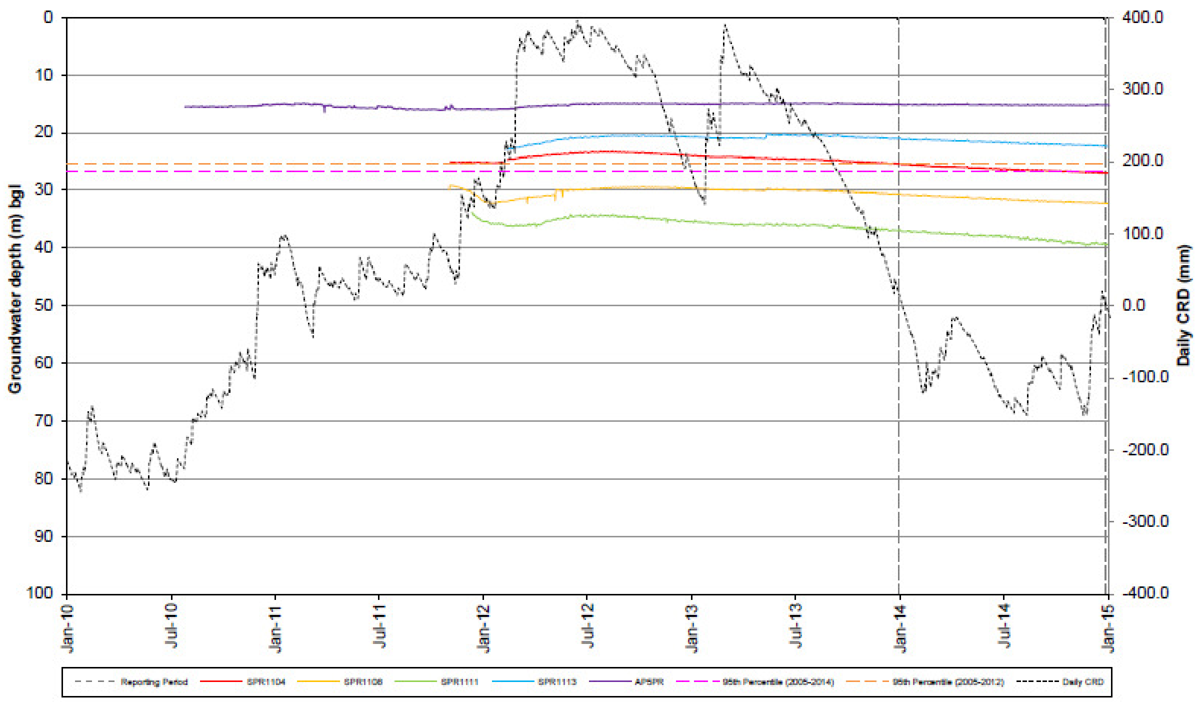


Figure 13.26 - Aquifer piezometer SPR1104 hydrograph compared with 5 and 95 percentile water elevations, daily rainfall and rainfall trend [Over LW420]

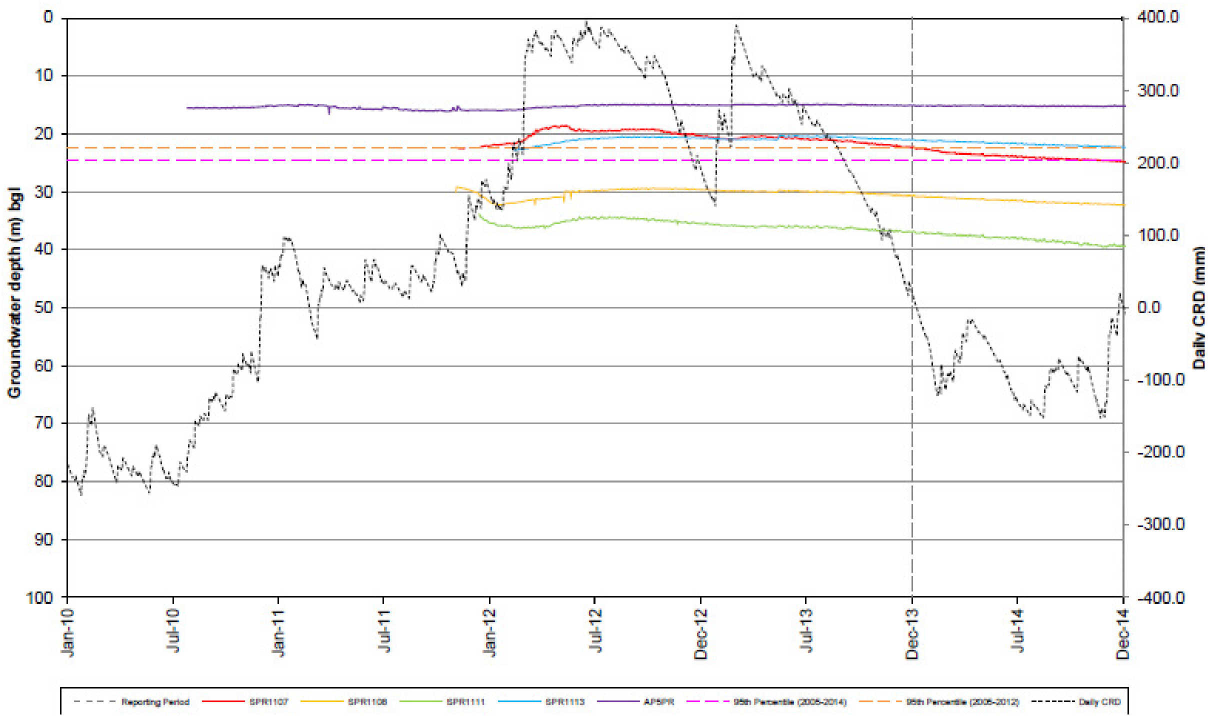


Figure 13.27 - Aquifer piezometer SPR1107 hydrograph compared with 5 and 95 percentile water elevations, daily rainfall and rainfall trend [Over LW420]

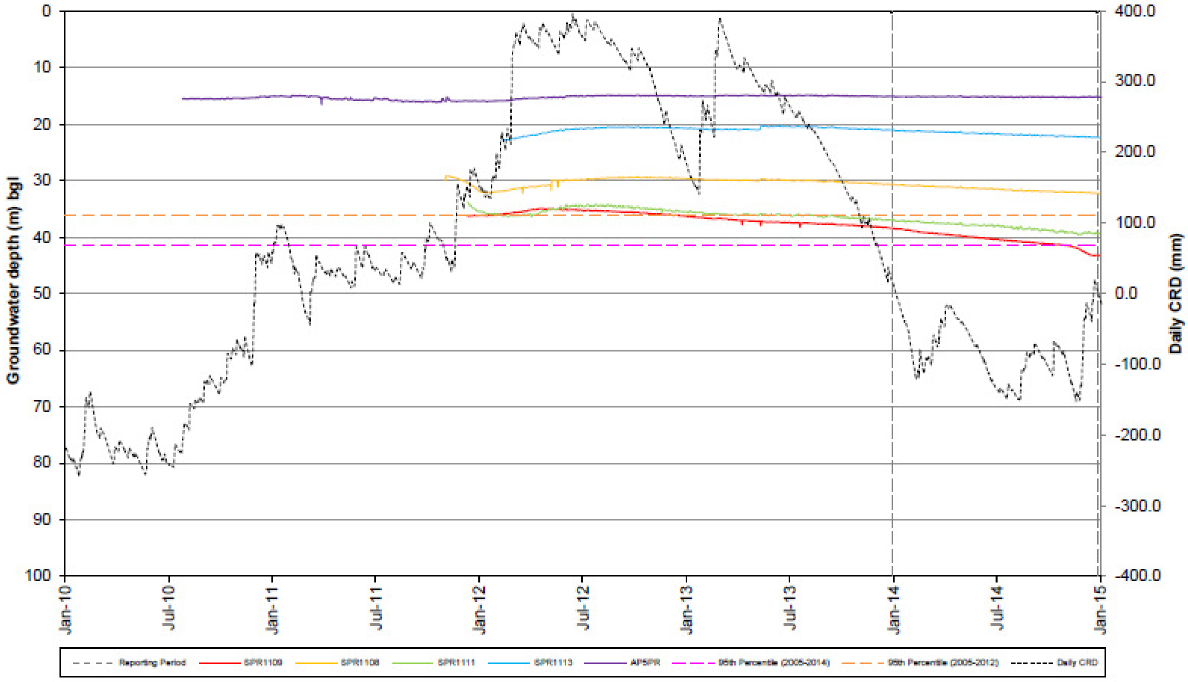


Figure 13.28 - Aquifer piezometer SPR1109 hydrograph compared with 5 and 95 percentile water elevations, daily rainfall and rainfall trend [Over LW418]

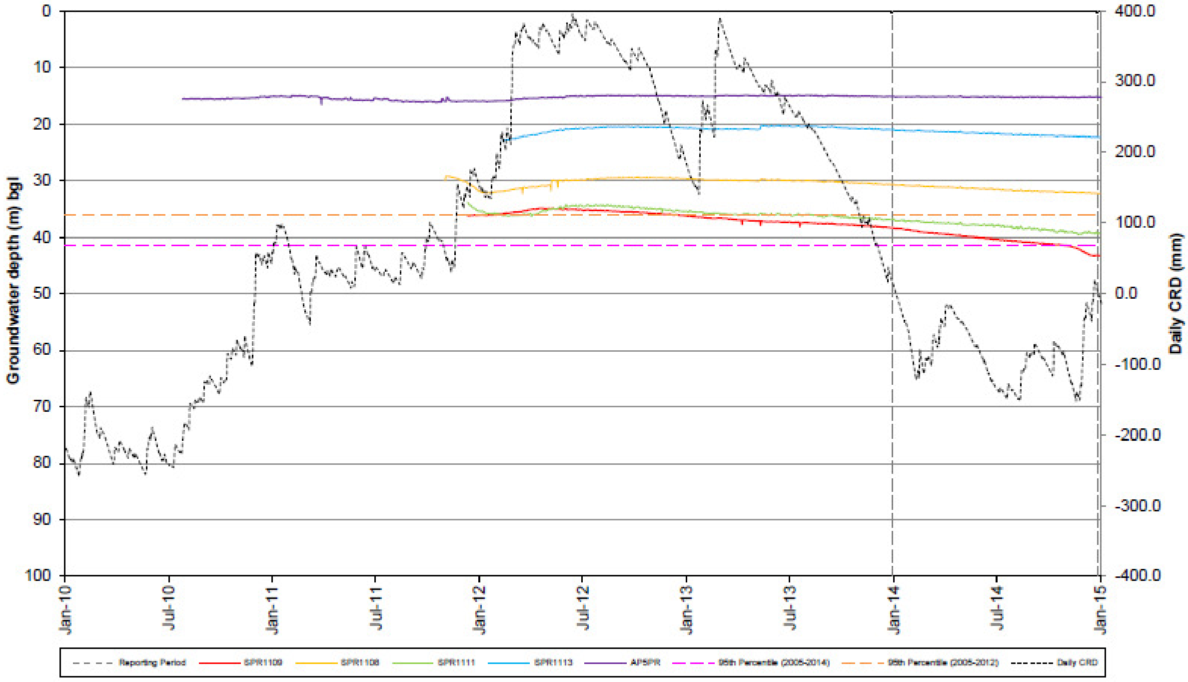


Figure 13.29 – Aquifer piezometer SPR1110 hydrograph compared with 5 and 95 percentile water elevations, daily rainfall and rainfall trend [Over LW417]

APPENDIX F

Baseline Surface Water Monitoring Summary

Flow Rate Monitoring

The water flow rate at the northern end of the Carne West Swamp has been measured fortnightly using a pygmy flow meter since December 2004 and the baseline data have been plotted on Figure 13. Also plotted on this figure is the rainfall mass balance (relative to 12 May 2005), which gives an indication of the climatic conditions relative to average conditions. It is acknowledged that this method of flow rate monitoring has an accuracy of approximately + or – 15% and so it is not accurate enough to set meaningful response triggers. However, this method will be used as an indicative measure until more accurate monitoring can be established.

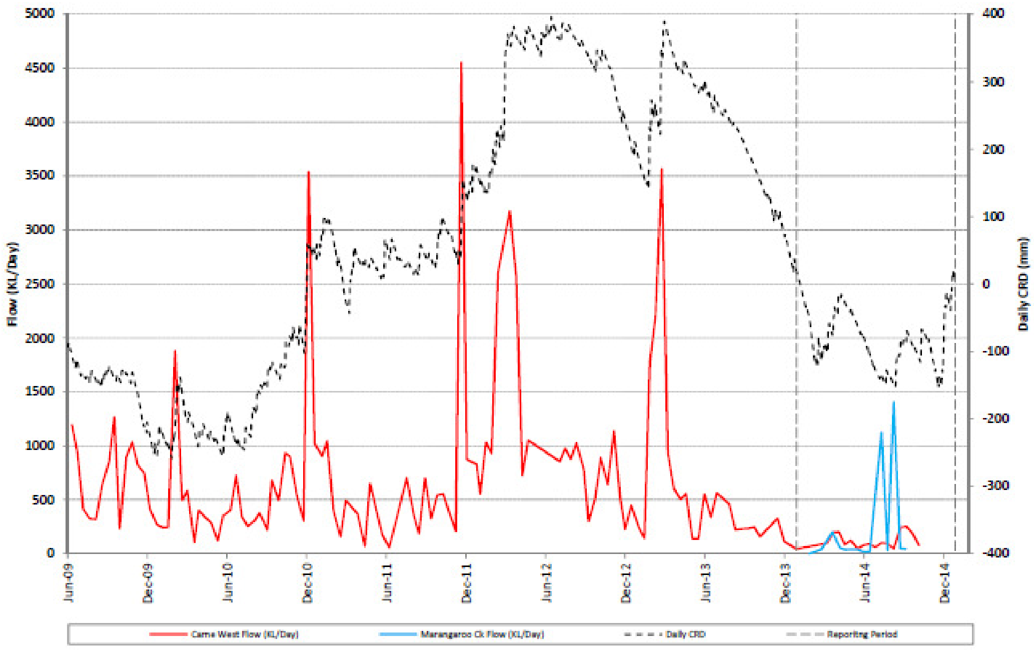


Figure 13.30 – Carne West Swamp and Marangaroo Upstream - flow rates

The data shows that prior to November 2005, the flow rate from the swamp ranged generally between 1,000 and 2,000 kL/day, during a period of generally average rainfall. Over the next 18 months, from early 2006 to mid-2007, during a period of below average rainfall, the discharge rate from the swamp reduced to a base flow of only 200 to 300 kL/day, with a minimum flow rate of 66 kL/day in October 2006. During this period, there were occasional periods of higher flow following rainfall events.

Following a major rainfall event in mid-2007, the base flow increased slightly, but was still less than 1,000 kL/day. Three major rainfall events in 2008 and 2009 raised the flow rate temporarily to more than 5,000 kL/day (maximum 8,600 kL/day), but the base flow returned to about 300 kL/day after each event within a short period. It should be noted that the maximum flow rates above are most likely subject to some inaccuracy due to the measurement method used. Since that time, the base flow rate has remained at this level, and has declined even further during dry periods, with a minimum of 58 kL/day in April 2011. Above average rainfall conditions at the end of 2011 and the beginning of 2012 have increased the rainfall mass balance and raised the base flow to around 700kL/day. Although the base flow is less than when monitoring commenced in 2004, the rainfall mass balance shows that there is still a rainfall deficit since that time so that this is to be expected. The rainfall data prior to 2004 also suggest that the base flow before 2004 would most likely have been higher than 2000kL/day, as there is a rainfall deficit of about 700 mm between early 2002, when rainfall monitoring commenced and December 2004, when flow monitoring commenced.

Since this swamp is far-removed from the mining activity, the flow rates measured show only natural variations, as it is believed that mining activities are far enough away that they do not affect the surface water flows within this swamp. The current low base flow rates from the swamp, compared to the good flow rates during the period when monitoring commenced in 2004, are a result of the prevailing below average rainfall conditions that have produced a rainfall deficit of more than 1,100 mm since 2002.

Despite the severe dry conditions experienced in the past, the swamp has always produced a discharge. This is very good evidence that an efficient aquifer feeds the swamp, and has produced the permanently waterlogged conditions in the swamp.

Pool Water Level

The pool water depth measuring instrument was installed in a pool at the downstream end of Carne West Swamp in May 2012.

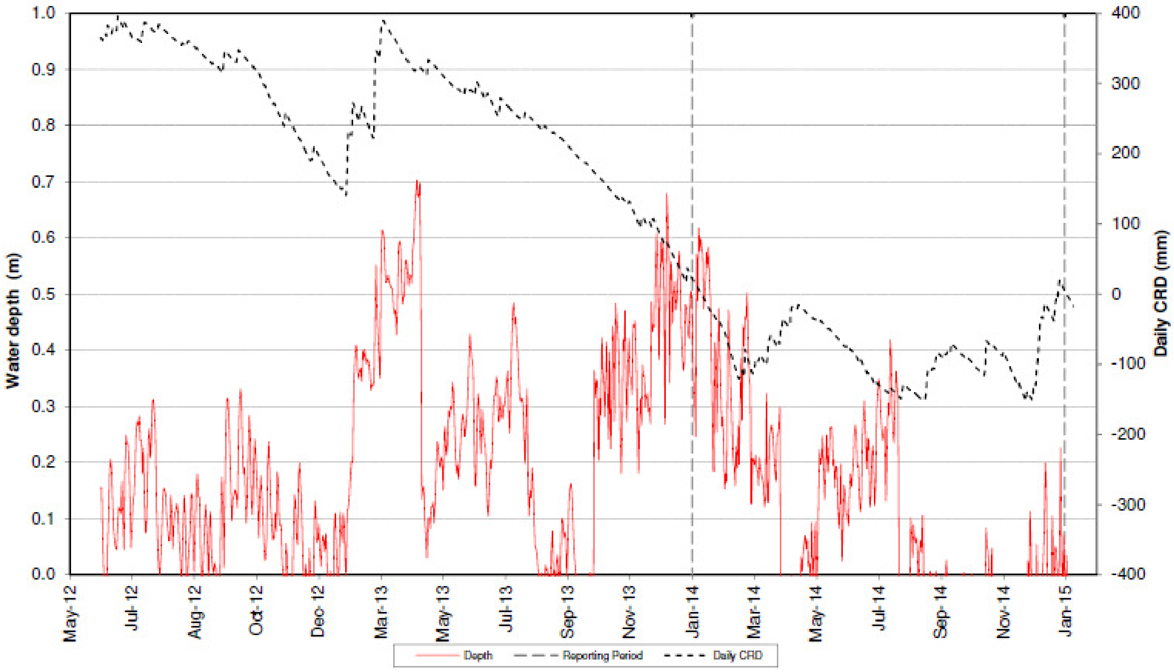


Figure 13.31 – Carne West Pool Water Depth Baseline

Water Quality

Water samples have been collected and analysed from the Carne West flow monitoring site since January 2005, and from the downstream end of the Sunnyside East Swamp since June 2010. The baseline data for each swamp are summarised below.

Carne West Swamp

The baseline data for Carne West Swamp is shown in **Table 13.5**. Changes over time for pH, EC and Iron levels have been compared to the minor and major trigger values in **Figure 13., Figure 13.33, Figure 13.34** and **Figure 13.35,** and discussed in more detail below.

Table 13.5 – Springvale Mine Surface Water Baseline Data Carne West Swamp

Element	Pre-Mining 80th Percentile	Pre-Mining 95th Percentile	Pre-mining average	ANZECC Guideline
pH	5.28	4.83	5.66	6.5 – 8.0
EC (uS/cm)	27	39	24	350
Mn (mg/L)	0.02	0.03	0.02	1.9
Fe (mg/L0	0.39	0.64	0.31	0.3

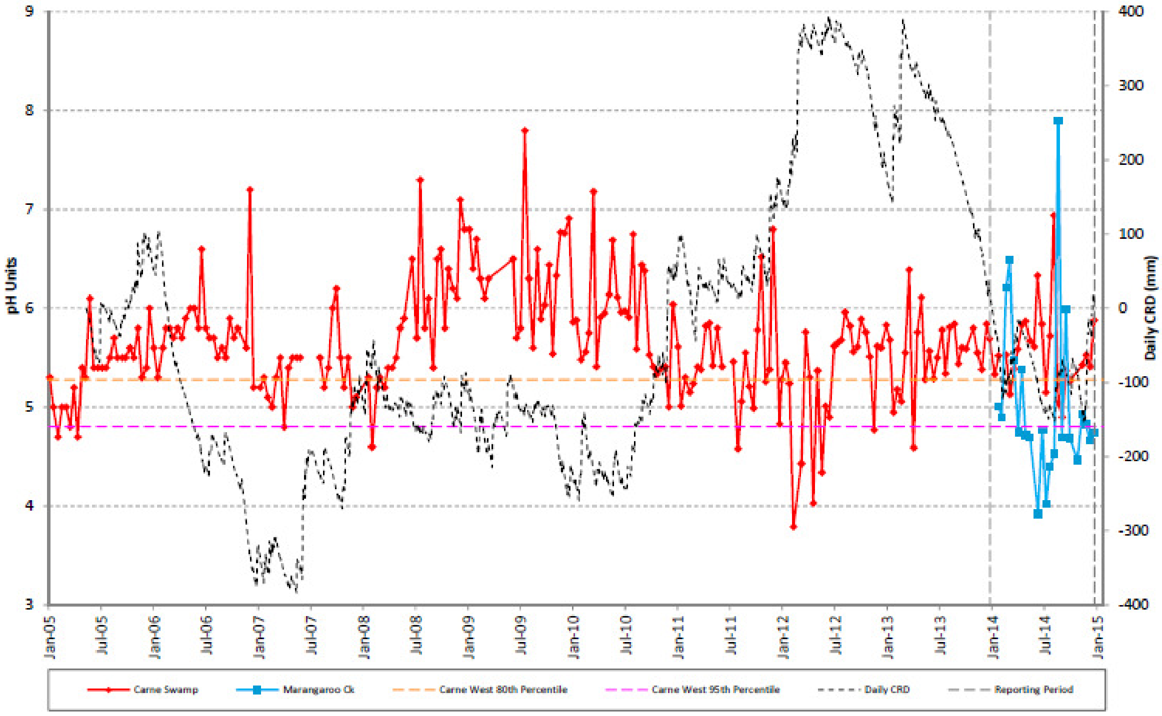


Figure 13.32 – Carne West Swamp Surface Water pH

Carne West Swamp is naturally acid with a pre-mining average pH of 5.66. This is outside the ANZECC guidelines range of 6.5 – 8.0 but is not surprising because organic wetland soils tend to be acidic, particularly in oligotrophic peat. (Maltby 2009).

It is noted that the trigger values for pH are based off the 20th percentile and 20th percentile minus two Standard Deviations.

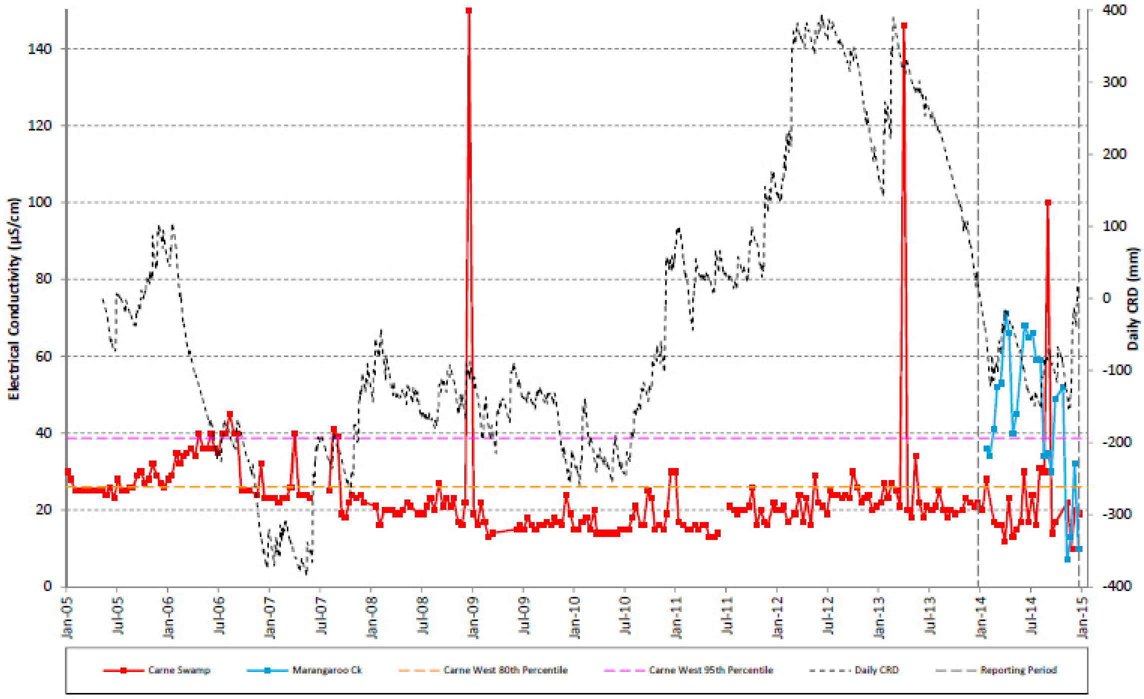


Figure 13.33 – Carne West Swamp Surface Water Electrical Conductivity

Electrical conductivity at Carne West Swamp indicate the waters are very low in salinity content and well below the ANZECC Guidelines for upland rivers trigger value of 350 µS/cm. A spike in conductivity at 150 µS/cm detected on 23 December 2008 was preceded by 51 mm of rain a week before sampling took place. Other rainfall events have failed to reproduce similar spikes.

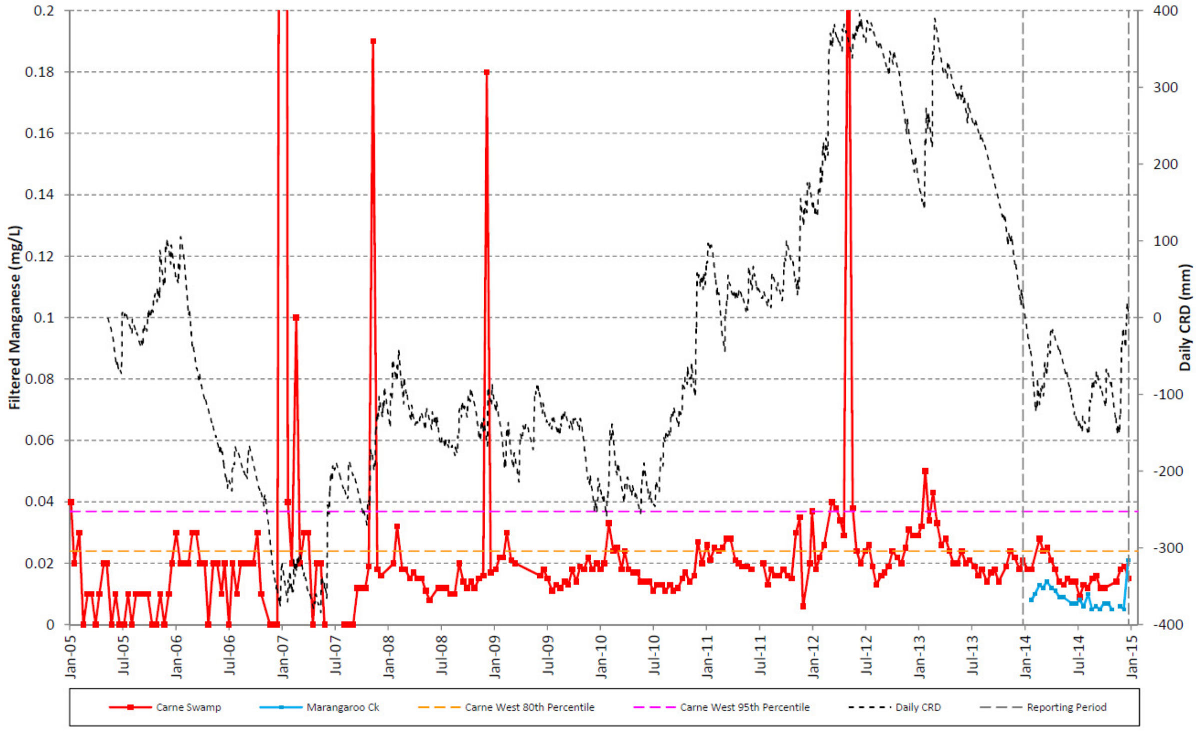


Figure 13.34 – Carne West Swamp Surface Water Manganese Concentrations

Manganese concentrations are well below the ANZECC Guideline limit of 1.9 mg/L.

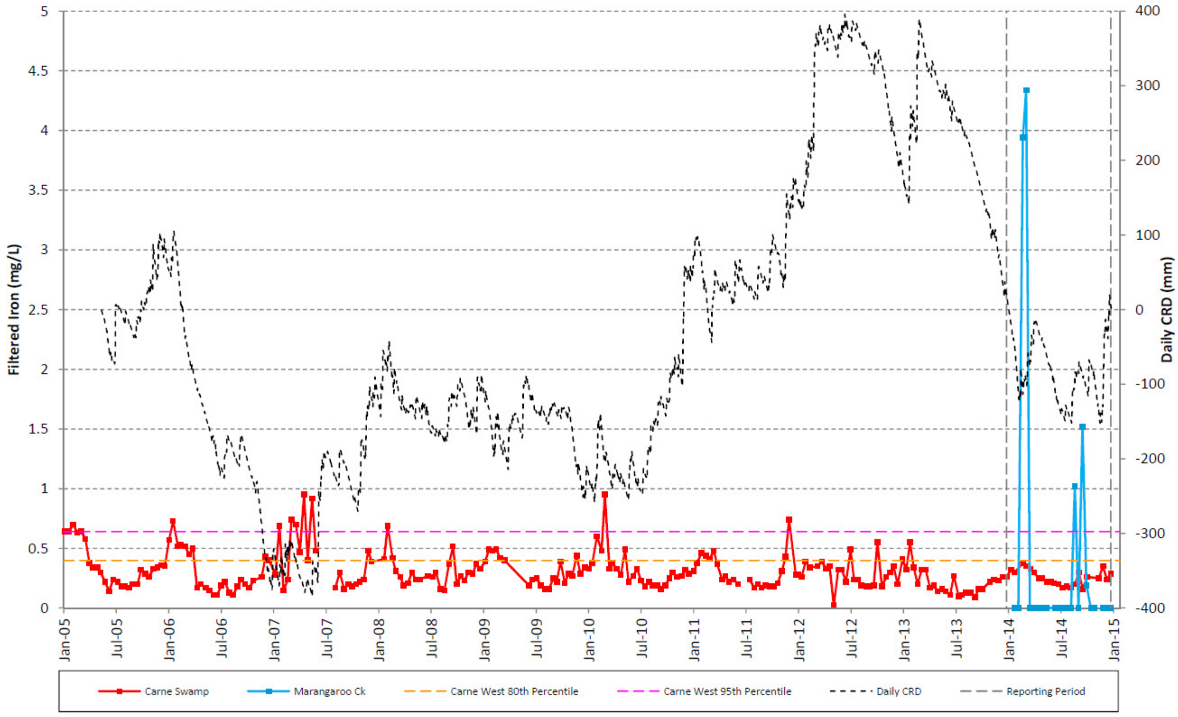


Figure 13.35 – Carne West Swamp Surface Water Iron Concentrations

The pre-mining average concentration of Iron is 0.31 mg/L which is equivalent to the recommended trigger levels prescribed for drinking water in the ANZECC Guidelines (2000). The highest concentration of iron detected is 0.95 mg/L.

Sunnyside East Swamp

The baseline data for Sunnyside East is shown in **Table 13.6**. Changes over time for pH, EC and Iron levels have been compared to the minor and major trigger values in Figure 13.36, Figure 13.37, Figure 13.37 and Figure 13.38, and discussed in more detail below.

Table 13.6 – Springvale Mine Surface Water Baseline Data Sunnyside East Swamp

Element	Pre-Mining 80th Percentile	Pre-Mining 95th Percentile	Pre-mining average	ANZECC Guideline
pH	5.47	4.89	5.81	6.5 – 8.0
EC (uS/cm)	25	40	25	350
Mn (mg/L)	0.03	0.04	0.02	1.9
Fe (mg/L0	0.31	0.42	0.24	0.3

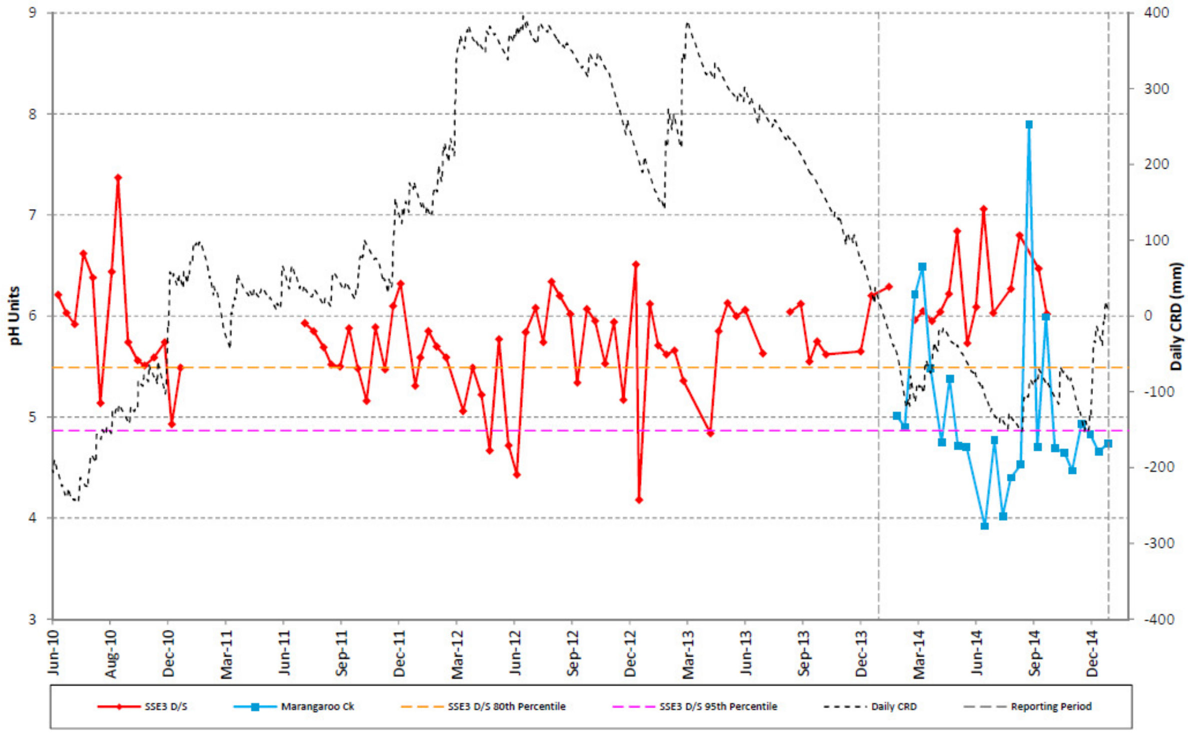


Figure 13.36 – SSE3 DS Surface Water pH

The wetland is naturally acid with a pre-mining average of 5.81 This is outside the ANZECC guidelines range of between 6.5 – 8.0 but is not surprising because organic wetland soils tend to be acidic, particularly in oligotrophic peat. (Maltby 2009).

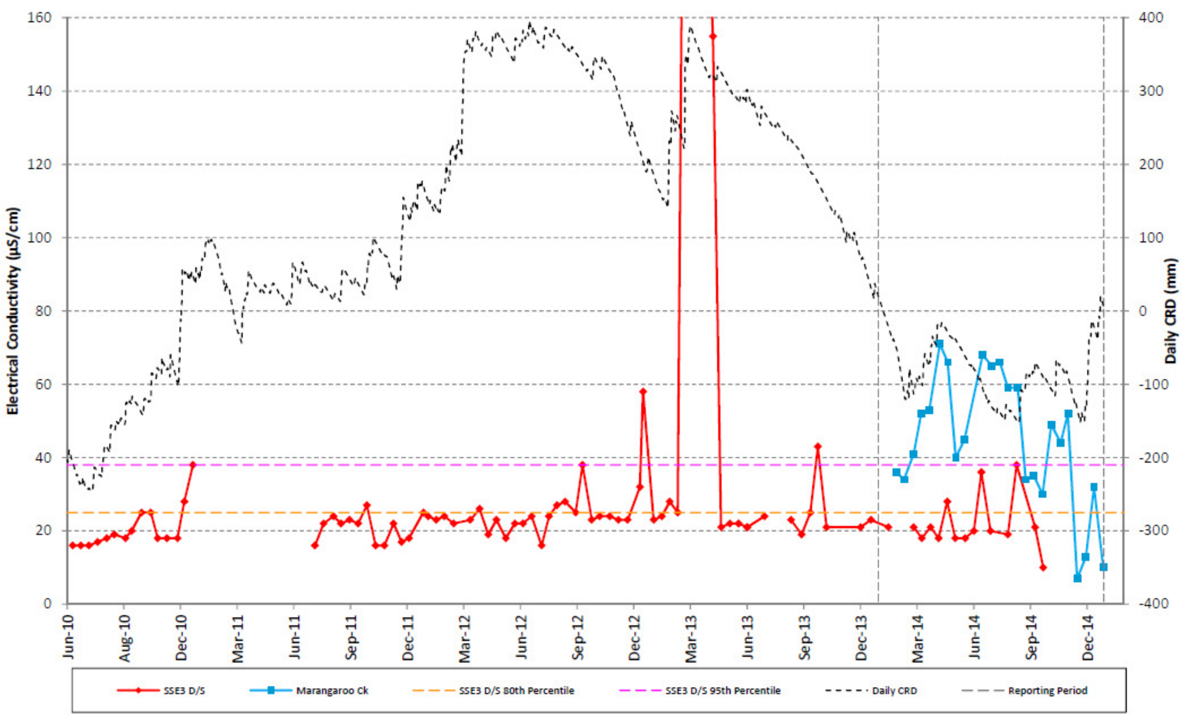


Figure 13.37 – SSE3 DS Surface Waters Electrical Conductivity

The low conductivity at SSE3 DS indicates that the local surface waters has a low salinity content which well below the ANZECC (2000) guideline of 350 µS/cm for upland rivers.

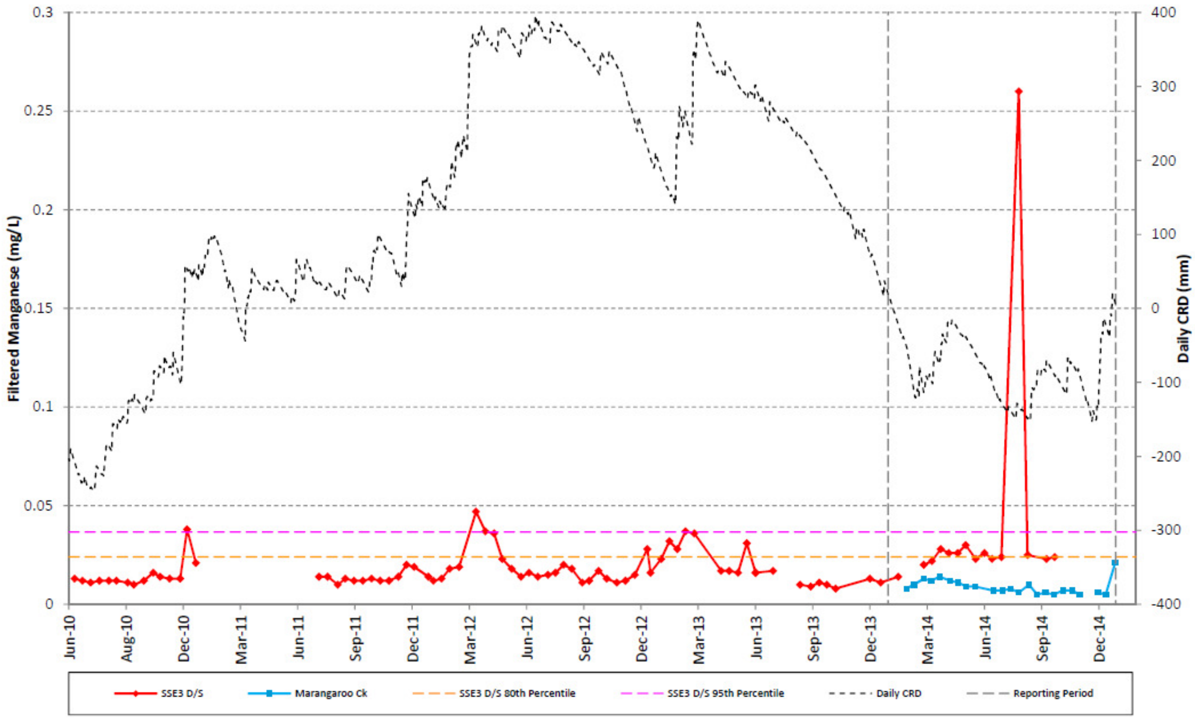


Figure 13.38 – SSE3 DS Surface Water Manganese Concentrations

Pre-mining manganese concentrations are low with a pre-mining average of 0.02 mg/L. This is well below the prescribed ANZECC (2000) guideline limit of 1.9 mg/L.

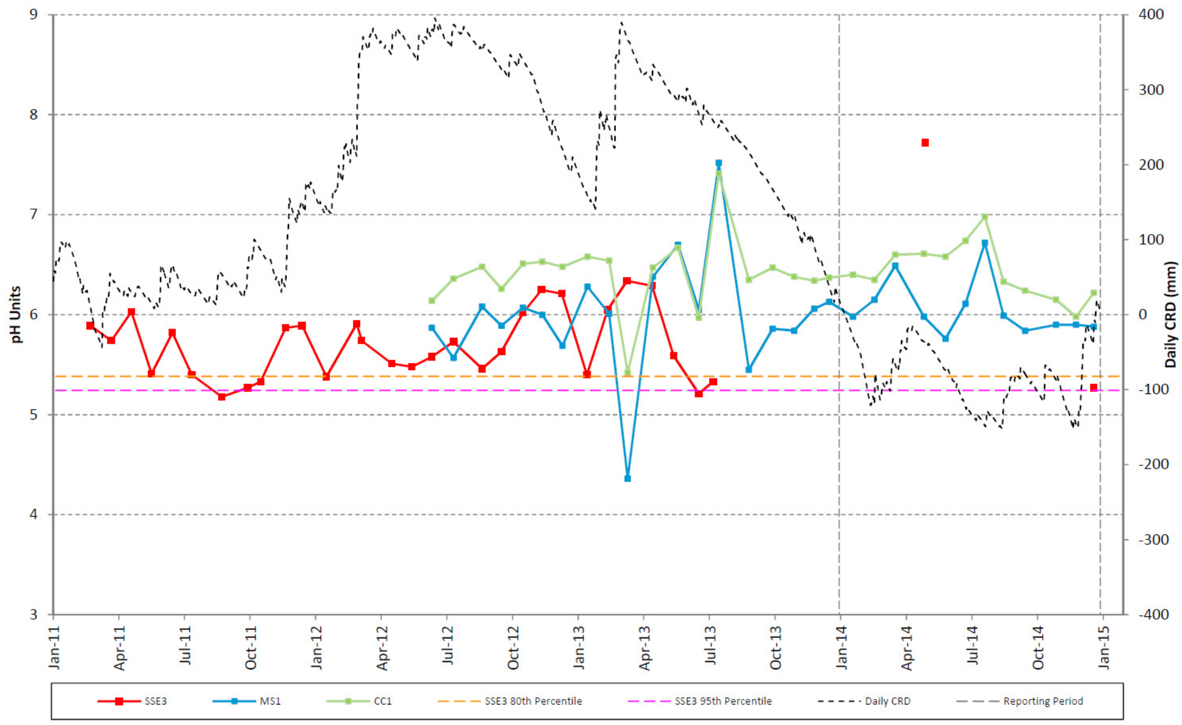


Figure 13.39 – SSE3 DS Surface Water Iron Concentrations

Iron concentrations in the surface waters are fairly low with an average concentration of 0.24 mg/L which is below the ANZECC Guidelines trigger level of 0.300 mg/L for drinking water purposes. These levels have been used as there is insufficient data relating to trigger values for the protection of aquatic ecosystems within the Guidelines.

Marrangaroo Creek Upstream

Water samples have been collected and analysed from the Marrangaroo Creek Upstream flow monitoring site from December 2003 to January 2007.

The baseline data for Marrangaroo Creek Upstream is shown in **Table 13.7** and provides a comparison with the trigger values set out within the ANZECC Guideline. The reference site data has been presented graphically in Figure 13.32 to Figure 13.39

Table 13.7 – Springvale Mine Surface Water Baseline Data Marrangaroo Creek U/S

Element	Pre-Mining 80th Percentile	Pre-Mining 95th Percentile	Pre-mining average	ANZECC Guideline
pH	4.91	4.60	5.58	6.5 – 8.0
EC (uS/cm)	40	62	33	350
Mn (mg/L)	0.01	0.02	0.01	1.9
Fe (mg/L)	0.08	0.27	0.15	0.3

Marrangaroo Creek is slightly acid with an average pH of 5.58 which is typical of the water quality exhibited in this locality.The low conductivity at Marrangaroo Creek indicates that the local surface waters has a low salinity content which fall well below the ANZECC (2000) guideline of 350 µS/cm for upland rivers, with a maximum measurement of 56 µS/cm recorded in December 2003.The average concentration of manganese at Marrangaroo Creek Upstream is 0.01 mg/L fall well below the ANZECC guidelines trigger level of 1.9 mg/L. Iron concentrations are low, averaging 0.15 mg/L which is below the ANZECC Guidelines trigger level of 0.3 mg/L for drinking water.

Data Analysis Methodology

Water Quality Monitoring

Surface water quality data will be assessed in accordance with the ANZECC Guidelines (2000). The analysis of the data will establish site-specific trigger levels for mining impacts on water quality which require actions and responses; including the procedures that would be followed in the event that the monitoring of surface water indicates an exceedence of trigger values. The methodology used for the identification of any anomalies in the data that could indicate mining impacts, as well as establishing trigger values, is outlined below.

The surface water quality monitoring program outlined above will provide data that can be evaluated for any significant changes that may result from the extraction of the longwall panels in the controlled action area. Any mining-induced changes in the water chemistry will be inferred based on a set of trigger values for the concentrations of critical analytes. The trigger values will be determined using the ANZECC (2000) water quality guidelines for protection of aquatic life (95% species protection levels). These will be applied to the available surface water data in the swamps. Minor and major variation/impacts will be assessed by using the ANZECC protocols of comparing the pre-mining 80th percentile baseline with the 50th percentile of the post-mining data and allowing for the effects of short-term spikes due to rainfall runoff events.

The guidelines require 24 measurements to set the baseline 80th and 95th percentiles, so that accurate trigger values can be set to activate appropriate corrective actions. Sufficient data will be available for individual trigger levels to be set for each piezometer prior to the area being undermined, and the preliminary baseline trigger levels shown in the following section will need to be updated accordingly.

The protocol will be applied to key water quality parameters that may indicate effects of cracks in the local rocks due to mining activities. These key parameters were selected on the basis of water quality conditions that may be affected when mining starts. The key parameters for setting trigger values for assessment of cracks in rocks on surface water quality at Springvale Mine are conductivity, pH, and the trace metals manganese and iron. Changes will be tracked in all the water quality parameters monitored using Control Charts, as set out in Standard Methods (e.g. APHA, 1998 or later versions), Section 1020B and the ANZECC guidelines for Monitoring and Reporting.

Minor and major changes will be determined statistically. Minor changes do not require any management or corrective actions, but provide an early warning of potential permanent changes in the water chemistry. Major changes indicate the need for management or corrective actions. The triggers are determined in the following ways:

Type	Description
	Minor Changes
Long-term minor changes	For each analyte, if the post-mining 50th percentile ≤ baseline 80th percentile, the changes are considered minor and would not have an unacceptable impact on aquatic life (i.e. provided the long-term increase in concentrations is such that the 50th percentile does not exceed the baseline 80th percentile, the increase is considered to be minor).
Short-term minor changes –	For each analyte, if any measured parameter greater than baseline 80th percentile, but ≤ baseline 95th percentile (5th percentile for pH) trigger value for ≤ 2 months, the changes are considered minor and would not have an unacceptable impact on aquatic life. It should be noted that about 20% of observations will exceed the 80th percentile and these are usually short-term spikes in concentrations, which are often due to rainfall runoff events. These short-term spikes generally occur for less than two consecutive months.
	Major Changes
Long-term major changes	For each analyte, if the post-mining 50th percentile greater than baseline 80th percentile, the changes are considered major.
Short-term major changes	For each analyte, if any measured parameter greater than baseline 80th percentile by two standard deviations for more than two months, the changes are considered major.

Water Quality Monitoring Reliability

There is a degree of uncertainty when collecting and analyzing water quality parameters for analysis when samples are taken in the field and transported to the laboratory. To this end, the chemical analysis may not always be absolute. There are occasions when errors occur from random fluctuations in the analytical procedure or errors are made in the field. An electrical balance, also known as an ion balance, is used to check the accuracy of analytical results (Department of Water, 2011). The sum of positive and negative charges in water should be equal (Appello & Postma, 2005). That is, the sum of the cations and anions in solutions should be equal and a deviation of more than 5% indicates that both sampling and analytical procedures should be examined (Appello & Postma, 2005).

To this end, water quality samples will be randomly checked for accuracy and precision using this method. In addition, the pH of all water samples will be measured in the field to ensure pH results are not affected by storage errors or extended periods in transit. pH will also be measured in the laboratory. Significant differences between the field pH and laboratory pH may indicate poor handling and may explain anomalous results for other analytes.

APPENDIX G

Rapid Assessment Methodology for Determining Swamp Health

An overview of the 14 condition assessment criteria are presented below:

1. *Location details*

   In this section the date, location, swamp name and GPS co-ordinates of the sample sites(s) were recorded along with monitoring status and the names of people present. A determination was also made as to whether the sampled swamp was a THPS, or other swamp type.

2. *Topography and land surface*

   The landform recorded refers to the landscape context within which a particular swamp is located. The landform abbreviations are UH (undulating hills), RH (rolling hills), UL (undulating low hills), RL (rolling low hills), UR (undulating rises) and RR (rolling rises). Within a swamp it was noted whether the swamp was in a closed (water could not readily escape) or an open depression (water flowed on downstream along a linear drainage depression). Furthermore it was noted if the micro-relief of the swamp floor was 'hummocky' (with plant aggregations rising above the flat surface, mound like and in hummock formation), if debil-debils were present (small hummocks rising above the surface on soil with impeded surface drainage and/or in areas of short seasonal ponding) and the nature of earth micro-depressions (concave, elongate, closed or open). Finally any evidence of subsidence, including surface cracking or bed slumping was noted.

3. *Land use and Longwall Mining*

   The status of the swamp was recorded (permanent or temporary control, undermined, within angle of draw), the year undermined or proposed to be undermined, as well as the nature of the surrounding land-uses.

4. *Fringing vegetation*

   The dominant vegetation community on either side of THPSs was recorded (closed forest, open forest, woodland and heathland) as well as the condition of that community.

5. *Location of swamp within the catchment*

   The location of the sample site was identified as being in the upper, middle or lower reaches of THPSs. The catchment area, swamp length, depth to bedrock (where possible to determine), swamp mean width, elevation, slope and aspect were recorded in the field or assessed via a desktop study.

6. *Geology and soils*

   All THPSs form over Sydney Sandstone formations. The presence of peat was affirmed and where possible, the depth of peat at the drainage line determined utilising incision formations. Usually this was limited to assessments such as peat present, depth of peat > 1 m, since it was not possible to determine the absolute depth of peat in most cases. The nature of the peat present was categorised as 'Fibric' (organic and fibrous), 'Sapric' (organic and non fibrous) and 'Hemic' (between fibric and sapric). An assessment was also made as to peat condition based on peat sponginess and likely changes from optimal peat condition for a particular set of local circumstances. Peat sponginess could be assessed by pressing on the peat surface with hands or boots to detect the capacity of peat to spring back to shape after a short period of deformation. Peat in a THPS, where active but slow formation is still occurring, exhibits varying degrees of sponginess. The arbitrary scale of 1 to 4 identified peat in good condition (4) to bad condition (1) or (0) when peat was absent in the few cases examined where the swamp being assessed was not a THPS.

7. *Geomorphology*

   This section assessed the physical arrangement of a THPS surface with particular attention to:

   - The shape of the swamp cross-section (V, U, convex or other);
   - The presence of continuous streambed incision compared with discontinuous incision as an indicator of an externally or internally induced impact;
   - The presence and severity of internal and external erosion;
   - Other evidence of changes in site geomorphology;

The stability, length and depth of any incision were described and placed in an incision age category (contemporary, a few decades old, many decades etc.). The latter was an informed judgement on our part.

Site and boundary erosion were identified (sheet, rill and gullying) along with an assessment of the degree of erosion present (nil, minor, moderate, severe).

8. *Hydrology*

   Where possible the approximate flow of water in ML/day was estimated, the location and depth of water within the swamp determined and the wetness of the top 10 cm of peat-soil categorised from dry to wet.

9. *Water quality*

   A hand held monitor was used to determine pH and salinity. Eutrophication was scaled 1(bad) to good (4) based on visual presence of green algae. Since water flows were either absent or very low flows in all THPS assessed, the likely sediment loads under medium flow conditions were assessed utilising data from item 7 above. As well, the likely source of sediment flux was identified.

10. *Swamp vegetation*

    Swamps were categorised as varying forms of heath and sedgeland or heath-sedgeland, the presence of the range of vegetation life-forms identified (tree, shrub, grasses, helophyte [water loving plants that have their perennating organs below water level], forbs, moss and liverwort, lichen, sphagnum [a specialised swamp moss capable of forming very thick layers], and litter [detached plant derived matter lying on the swamp surface]).

    The percent ground cover of combined vegetation life forms was assessed and the dominant plant species listed. The condition of the swamp vegetation was assessed as good (4) to bad (1) and where required described in a separate location. For example, a swamp with widespread dead and dying vegetation would be assessed as (1), whereas a large swamp with small isolated patches or individual plants that were dead or dying might be assessed as (4) and minor deviations noted as additional information. Plant structural and species diversity was assessed and the level and life form of invasive species if present.

The heterogeneity (patchiness of vegetation) was also assessed.

11. *Impacts and extent*

    In this section any impacts present within a particular swamp were identified together with a severity rating. Some potential impacts would have been previously identified in items 6-10 above. This section specifically focused on fire, drought, animal tracks, human infrastructure including trails and pine plantations, internal and external sediment sources, changed hydrology and sources of pollution. No attempt is made in this section to necessarily identify the causes of particular impacts.

12. *Fauna observed*

    Any vertebrate fauna or endangered invertebrate species that were located opportunistically were identified and recorded in this section. No time was available for a formal fauna survey at any of the swamps visited, since the focus of this assessment was on vegetation, physical parameters and potential adverse impacts.

13. *Ecosystem condition, thresholds, condition trend*

    In this section an assessment of the condition of a swamp's carbon, water and nutrient cycles was assessed. Under normal conditions, communities and well functioning ecosystems have semi-closed cycles where carbon, water and nutrients cycle through complex food webs and chains via a system of producers, consumers and decomposers. In impacted ecosystems these semi-closed cycles can begin to leak or even completely breakdown, thereby becoming a degraded system (losing resources) compared with the intact system that is in an equilibrium state or gaining resources (aggrading system). Ecosystems that are adversely impacted are always accompanied by biophysical visual cues. In the case of a swamp, loss of surface water would lead to plant death; continuous swamp incision along the major drainage channel would likely lead to lateral drainage across the swamp, drying out of the peat base and eventually the formation of a head cut that could cause the swamp to collapse over time or even very rapidly, although fringing vegetation might be maintained via side valley seepage. Cycles were scored 1(bad) to 4 (good).

    In ecosystems as in all systems, energy cannot be recycled but dissipates in space and time. Plants not only absorb light energy to drive photosynthesis but also act as cooling agents modifying surface temperature. If ground cover is lost then ground surface can heat up and negatively impact on plant production. Degraded ecosystems are often adversely impacted due to ground overheating. This may act synergistically with other adverse impacts. In the case of THPS impacts leading to continuous streambed incision, swamp drainage and the associated death of vegetation are likely to be further adversely impacted by malfunctioning energy interception. Hence the state of energy interception was assessed.

    Resilience is an important attribute of any ecosystem, being the capacity to self-repair following an external or internal perturbation (disturbance). In each swamp both the geomorphic and ecological resilience of the system were assessed.

    An ecological threshold is a point along a continuum where an adverse external impact causes the system to catastrophically collapse and lose resilience. When this occurs a human intervention restoration strategy, usually expensive and time consuming, would be required to restore such a system back to its pre-impacted condition. Such a system may also self-recover over a very long period of time providing adverse anthropogenic influences are constrained. The key THPS feature where the exceedence of an ecological and/or geomorphic threshold is likely to be most damaging is the swamp drainage line, where swamp incision, for example, can lead to the ultimate collapse of the swamp system.

Based on an assessment of ecosystem cycles, geomorphic and ecological thresholds, as well as a consideration of the attributes recorded or assessed in 1-12 above, THPS condition can be determined based on a judgement where all factors are considered together. Furthermore, based on the above understandings it would usually be possible to determine whether THPS condition is stable, improving, worsening or a likely normal stage in the very long term process of a swamp's lifecycle. An informed judgement can only be made by a skilled assessor. However, the process can be readily understood and utilised by other scientists unfamiliar with this approach.

14. *Impact of longwall mining*

A preliminary impact assessment was made at the swamp location based on:

- Data recorded together with assessments in categories 1-13 above;
- Whether or not a particular THPS had been undermined and when;
- Additional information recorded about the swamp not captured within the formal data sheet; and
- Adding an additional sampling site further up or downstream if necessary;

Impact categories ranged from nil to major to those that are, indeterminate (based on field assessment unable to be certain). For others we were unable to differentiate potentially adverse impacts of longwall mining from other impacts or possible impacts. A summary of findings was tabularised and subjected to further scrutiny in Section 6.

Temperate Highland Peat Swamp on Sandstone (Newnes Plateau) – data sheet

1.Location details

Coordinates	E		N	Date		
Swamp name				No.		Sample
Swamp type	NPSS	THPS	Other			
Surveyors present						
Others present						
Monitoring status				Photo		

2.Topography, land surface

Landform	UH	RH	UL	RL	UR	RR	Depression	Open	Closed
Micro-relief	Hummocky	Mounds/depressions	debil-debils						
Subsidence	Surface cracks	Depressions							

3. Land use, LW mining

Relation to mining	Perm control	Temp control	Undermined	Within angle of draw			
Yr undermined		SV/AP	Proposed yr undermined	Never	Year	SV/AP	
Land use	hardwood forestry	pine	both	motorbikes/4WD	other		

4. Fringing vegetation

Structure	closed forest	open forest	woodland	heathland
Condition*	1 (bad)	2	3	4 (good)

5. Site description

Location within swamp	Upper reach	Middle reach	Lower reach		
Catchment area (km^2)		Length (m)		Depth (m)	
Mean width (m)		Elevation (m)			
Valley slope%		Aspect °			

6. Geology, soils

Parent rock	Sydney SS	Soil type					
Peat	p/a	Depth m		Type & ~depth	fibric	hemic	sapric
Condition from natural*	1	2	3	4	Comment		
Peat sponginess	nil	some	very	comment			

7. Geomorphology

Incision	y/n	active	stabilised	partly stabilised

Incision length m	<2	2-20	20-50	>50	Incision depth m	<1.5	1.5-3	>3

~incision age	contemporary	few decades	many decades	many centuries	millennia

X-section	v	u	convex	other

Site erosion	sheet	rill	gullying	nil	minor	moderate	severe
Boundary erosion	sheet	rill	gullying	nil	minor	moderate	severe

8. Hydrology

Water flow	p/a	~ML/day		Depth water cm	nil	<2	2-5	>5

Water flow pattern	within incision	across bed	Recent rain (7 days) mm	
Soil water top 10cm	dry	mod moist	moist	wet

9. Water quality

pH		EC		Eutrophication* 1-4		Sediment load* 1-4	

Sed. source	upstream erosion	forestry trail	hillslope	other

***Ratings 0 – nil, 1 – 4 (bad to good)**

10. Swamp vegetation

Formation	closed heath	open heath	closed sedgeland	sedgeland	open sedgeland	heath sedgeland

Life forms	trees	shrubs	grasses	helophyte	forbs	moss, LW	lichen	sphag	litter
Layer ht m									
% cover									
Condition*									
Dominant spp									

Structural div.	v simple	simple	moderate	complex	v complex
Spp diversity	v few	few	many	diverse	very diverse

Weeds	v few, sparse	few, sparse	many, common	abundant, v common
Invasion non-swamp spp. & type	v few	few	many	Abund.

Life-form of invasive spp	
Succession stage	

Heterogeneity	1 (homogeneous)	2	3	4 (very heterogeneous)

11. Impacts and extent

Rank 0-4 (0 nil, 4 severe) ? – level of uncertainty							
Fire		Drought		Animal tracks		Vehicle tracks	

Swamp cracking		Pine		Infrastructure	
Sediment y/n & source	external		Internal		
Lack water inflow		Other impacts			
Change water inflow y/n & cause					
Pollution y/n & types					
Overall rating & comments					

12. Fauna observed

13. Ecosystem condition, thresholds, condition trend

Cycles (1-4)	Carbon		Water		Nutrient		E. interception (1-4)	
Resilience (1-4)	Geomorph		Ecol					
Geomorph thresholds exceeded	y/n							
Ecological thresholds exceeded	y/n							
Swamp condition assessment 1-4								
Condition trend	stable	improving	worsening	likely natural stage in cycle#				

14. Impact of LW mining

Impact	nil apparent	minor	moderate	major	future impact possible	indeterminate
unable to differentiate LW from LW impacts			requires further exam of data or monitoring			

***Ratings 0 – nil, 1 – 4 (bad to good)**

This data sheet may be changed as the monitoring program progresses

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