Centennial Coal

SUPPLEMENTARY DATA

Volume One

EPBC Approval 2011/5949

Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau

Springvale Colliery

August 2013

Information Request Regarding Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau (EPBC Approval 2011/5949)

Background

On 30 April 2013 Centennial Coal representatives met with SEWPaC Post-Approvals Compliance Section representatives and gave a presentation on Centennial's Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau (the Application), which is required to be approved by the Minister under EPBC Approval 2011/5949 before mining beneath THPSS within the Controlled Action Area (CAA). Following the presentation, feedback was provided by SEWPaC to Centennial and specific information was requested to supplement the information provided in the Application.

- Information is required about the findings of East Wolgan Swamp (EWS) investigations.
    - Circumstances related to damage to East Wolgan Swamp
    - Reasons why similar event will not occur in the future
    - Reasons why East Wolgan Swamp has not been remediated yet

- Prepare detailed Case Studies for other swamps previously undermined, with relevant data for each location.

- Compare data in Case Study areas with proposed mining activities in the CAA

- Supply additional data regarding remediation case study (Metropolitan Colliery – Waratah Rivulet Rockbar remediation) including:
    - specific reports supporting case study
    - analysis of data (i.e. graph showing water level in pools pre and post PUR injection)
    - additional data regarding reduction in permeability since 2008

Scope Of Supplementary Data Submission

This submission is a summary of relevant data and analysis and references specialist reports where relevant. Relevant specialist reports are appended. Volume 1 (below) includes the East Wolgan and Narrow Swamp Case Studies and also the additional data regarding the Metropolitan Colliery – Waratah Rivulet Rockbar remediation. Volume 2 contains case studies of other previously undermined swamps and the Sunnyside East and Carne West case studies.

East Wolgan and Narrow Swamp Case Studies

1. East Wolgan Swamp and Narrow Swamp Location and Monitoring

Figure 1.1 shows East Wolgan Swamp and Narrow Swamp and associated watercourses, surface topographic contours and environmental monitoring locations and types, together with the location, dimensions and timing of mine workings. It also shows the locations of peat slumping events which were identified following mining activities in the area.

Figure 1.2 contains a summary of environmental monitoring within East Wolgan Swamp and the neigbouring Narrow Swamp, including the type and number of monitoring locations together with the frequency of sampling and the duration over which monitoring has been conducted.

Where relevant, this case study references Narrow Swamp due to it's similarity in terms of geology, topography, hydrology and the fact that it was also subjected to similar mine water discharges.

2. Impacts to East Wolgan Swamp Due To Mining Related Activities

Aurecon (2009) reported the following in terms of the monitoring results which triggered investigations into impacts caused to East Wolgan Swamp by mining related activities.

"Subsidence Status Management Reports (SMSR) compiled by Springvale in 2008, indicated that discharge waters were not being recorded at the downstream monitoring location. It was originally contemplated that the discharge waters were being absorbed into the peat material as it had dried out following the cessation of continuous discharge from LDP004. This behaviour continued into late 2008 and a site inspection in December 2008 was carried out. At this inspection, it was found that mine water discharge was flowing into a cavity at the base of the swamp.

Accordingly, Springvale committed to carrying out a detailed investigation to determine the cause of this phenomenon.

A later inspection carried out in early April 2009 (after the discharge had ceased) found that there had been some irregular movement within East Wolgan Swamp. This included erosion, siltation and surface slumping of the peat material. Shortly after this finding, Springvale Mine and Angus Place notified the relevant Government Departments."

2.1. East Wolgan Swamp Investigations

The following investigations have been conducted at East Wolgan Swamp since 2009:

- Aurecon (2009) and Specialist Consultants (Groundwater / Surface Water / Mine Water Discharge / Structural Geology / Subsidence / Flora)
- Alpha Geoscience (2011) Geophysical (Ground Penetrating Radar, Resistivity)
- Aurecon (2011) Geotechnical / Geophysical
- Bush Doctor (2011) Swamp Remediation
- DgS (2013) Subsidence
- UQ (2013) Swamp Hydrology and Rehabilitation

In addition to investigations conducted by Centennial, the Federal Government Department of the Environment, Water, Heritage and the Arts (DEWHA) also commissioned an investigation in 2010 (Goldney, D., McTaggart, B., and Merrick, N. (2010) Determining Whether Or Not A Significant Impact Has Occurred On Temperate Highland Peat Swamps On Sandstone Within The Angus Place Colliery Lease On The Newnes Plateau).

Other detailed investigations related to Newnes Plateau swamps have also been conducted and have also informed the East Wolgan Swamp investigations. These include the following:

- Palaris (2013) – Near Surface Geology of the Newnes Plateau
- RPS Aquaterra / CSIRO (2013) – Groundwater / Surface Water Impact Assessments
- RPS (2013) Swamp Delineation Study
- McHugh, E. (2013) – Geology of Newnes Plateau Shrub Swamps

2.2. Summary of Impacts to East Wolgan Swamp

Based on previous investigations conducted and recent studies, there are a number of changes to East Wolgan Swamp which have resulted from mining related activities.

- Dieback of Vegetation (along path of mine water flows)
- Changes to swamp Soil Water Chemistry (changes due to elevated EC and high pH of mine water flows)
- Changes in Swamp Hydrology (wetting / drying cycles due to mine water discharge)
- Erosion (along path of mine water flows)
- Elevated sediment loads (along path of mine water flows)
- Slumping of peat due to erosion of sub-surface sediments (two locations)
- Cavity Beneath Swamp (where loss of mine water discharge occurred)

2.3. Goldney et al (2010) – Assessment of East Wolgan Swamp

Goldney et al (2010) concluded the following with regard to East Wolgan Swamp:

"Site 10 (East Wolgan Samples a and b): There has been a significant and catastrophic impact on this swamp, where ecological and geomorphic thresholds have been exceeded. Shrub components had disappeared, a significant thickness of peat had been washed away and a heavy deposit of patchy sand of unknown origin was deposited over what remains of the swamp bed. ***We attributed this swamp's destruction principally to mine water discharge.*** *However, we are unable to determine the role of longwall mining as a contributing factor since mine water discharge impacts have very likely masked the longwall mining impacts. We have determined that these impacts were very likely significant.*

Normal flood hydrographs generated from rainfall are expected to rise and fall reasonably rapidly in response to rainfall events, and thereafter, to feed low baseline flows maintained by a combination of valley-side and in-stream seepage. Mine discharge flows are of the order of 2 - 20ML/day. From the available data we are unable to determine the length of time over which such flows were maintained. ***In the absence of sufficient data we have hypothesised that lengthy time periods of flow, combined with high alkaline relatively deep flows, and possibly higher flow regimes from emergency releases could account for the impacts described above.***

Changes in water quality

Water quality monitoring has been carried out on Angus Place and Springvale. While there have been changes to stream water quality recorded, these changes are unlikely to account for the measured impacts on THPSs undermined by LWM.

*However, mine discharge water is released into a limited number of streams with THPSs namely sites 5, 9 and 10. Swamps are in the acid range around 4-5 pH units whereas mine discharge water is alkaline and around 8 - 9 pH units**. It is likely that extended flows of alkaline water within streams and over swamps could and would adversely impact stream ecology and in particular THPSs. The level of impact would depend on the frequency and extent of flow, water temperature and whether or not there were any adverse synergistic effects with other chemicals within the system."***

2.4. Photographic Monitoring of East Wolgan Swamp

Figure 1.3 shows photographic monitoring locations along East Wolgan Swamp, together with position of mine workings, location of monitoring points, timing of mining and slumping locations.

Figures 1.4 to 1.24 are photographs of East Wolgan Swamp at monitoring locations.

Figure 1.4 is a photo showing mine water discharge from Licenced Discharge Point 4 at the upstream end of East Wolgan Swamp.

Figures 1.5 to 1.7 are photos taken upstream of the Southern slumping location, showing the area during mine water discharge, soon after cessation of mine water discharge and at 28 June 2013 (three years post mine water discharges). The photos appear to show major dieback / loss of vegetation in the flowpath of the mine water discharge during and following mine water discharge and limited regrowth in the three years following cessation of mine water discharge.

Figures 1.8 to 1.10 are photos taken between the Southern and Northern slumping locations, showing the area during mine water discharge, soon after cessation of mine water discharge and at 28 June 2013 (three years after mine water discharges). These photos also appear to show major dieback / loss of vegetation in the flowpath of the mine water discharge during and following mine water discharge and limited regrowth in the three years following cessation of mine water discharge.

Figures 1.11 to 1.13 are photos taken at the Southern slumping location, showing the area during mine water discharge, soon after cessation of mine water discharge and at 28 June 2013 (three years post mine water discharges). Figure 1.11 shows inflow of water from upstream, pooling of water at the slump location and downstream flow of water from the slump location (with no apparent water loss). Figures 1.12 and 1.13 show the Southern slumping location following cessation of mine water flows and three years after cessation of mine water discharge. Minor erosional infilling is evident at the site, with very limited vegetation regrowth.

Figures 1.14 to 1.17 are photos taken at the Northern Slumping and Cavity Site, showing the area during mine water discharge, soon after cessation of mine water discharge and at 28 June 2013 (three years post mine water discharges). Figure 1.14 shows the area during mine water discharge, with complete water loss into the cavity and no downstream flow. Figure 1.15 shows the hole in the peat where water loss occurred (note limited area of hole). Figures 1.16 and 1.17 show the Northern slumping and cavity location following cessation of mine water flows and three years after cessation of mine water discharge. A significant erosional headcut is present in the swamp peat to the South of the original slumping location, which has progressed approximately five metres upstream in the period since the slumping was identified in 2009. Limited vegetation regrowth is evident. Rehabilitation of this site is required to prevent further erosion of the swamp peat.

Figure 1.18 and 1.19 are photos taken immediately to the North (upstream) of the cavity location on 28 June 2013 (three years after mine water discharge). Figure 1.18 shows healthy swamp vegetation downstream of cavity. The swamp narrows downstream due to topography (swamp lies within a narrower, steeper valley downstream). The condition of the swamp vegetation downstream of the cavity is important in the context of discussions regarding swamp hydrology i.e. the good condition of the vegetation is indicative that there has been an ongoing supply of water to the swamp downstream of the cavity. This will be discussed in more detail later.

Figure 1.19 shows defined erosion channel in peat downstream of cavity which allowed a concentrated flow path for mine water discharge and thus minimised its impact on swamp vegetation.

Figures 1.20 to 1.24 were taken in areas of East Wolgan Swamp affected by mine water discharge. These photos show the following trends:

- surface erosion and remnants of topsoil secured from erosion by dead root biomass (hummocky surface)
- erosion channels caused by mine water flows
- sediment deposition caused by mine water flows
- healthy swamp vegetation outside of mine water flow path
- limited regrowth of sedges and weeds within flow path

Aurecon (2009) reported *"The photographic monitoring has shown that the discharge from LDP004 has had some visible impact on vegetation within the East Wolgan Swamp. Significant surface flows through the swamp have been continuous, and groundwater levels have been raised for extended periods. The most obvious disturbance to the swamp vegetation from the discharge is where the creek channel is not well defined, and discharge flows have spread out over the swamp vegetation in a broad area across the width of the swamp and resulted in slumping of the peat deposit and dieback of some species over limited areas, most probably due to water logging and the force of the elevated volumes flowing through the swamp. Three primary sites have been identified where this has occurred. In these areas the swamp flora have been disturbed, silt has been deposited due to the slowing of the flow velocity, and the vegetation condition is relatively poor, after being inundated for extended periods. At these sites, it appears that the vegetation associated with the swamp was protecting the peat substrate from disturbance. As the vegetation has been affected by water logging and water flows, the peat structure/complex has also been disturbed. The bare peat material has not been able to retain its integrity most* *probably due to its low shear strength (in the absence of root matter holding it together) and the force of the water flow. This disturbance is probably a recent phenomenon, as the flow rates from the prolonged emergency discharge down the East Wolgan watercourse from LDP004 in 2008 were significantly greater than previous discharges."*

2.5. Surface Water Flow and Quality

Figure 1.26 shows mine water discharge to East Wolgan and Narrow Swamps via Licenced Discharge Points 4, 5 and 6. The first licenced discharge occurred on 16/4/1997. In February 2006 the Water Transfer Scheme was commissioned and mine water was pumped to Delta Electricity's Wallerawang Power Station. Due to issues with infrastructure and management of the system, licenced emergency discharges to Narrow and East Wolgan Swamps via Licenced Discharge Points 4, 5 and 6 were required to ensure the safety of mine workers when the system was not available. These issues have been resolved over the life of the WTS and there have been no discharges since 10/4/2010.

Figure 1.27 shows soil moisture monitoring data from WE2 piezometer location, showing significant differences between results during and after mine water discharges. The wetting / drying cycles of Narrow and East Wolgan Swamps due to mine water discharge are evident in the data.

Figure 1.28 shows electrical conductivity (EC) water quality data from Newnes Plateau swamp sampling sites, showing significant differences between measured EC at Narrow and East Wolgan Swamps (which were impacted by mine water discharge) compared to Carne West Swamp, which is unaffected by mine water discharge. Elevated EC values are still being recorded at Narrow and East Wolgan Swamps three years after cessation of mine water discharge, but the trend is back towards normal levels. Some change in soil water chemistry at these sites may have occurred as a result of mine water discharge. Further investigation through soil sampling and testing is currently underway to quantify these effects.

Figure 1.29 Water Quality Data (pH) from Newnes Plateau swamp sampling sites, showing significant differences between measured pH at Narrow and East Wolgan Swamps (which were impacted by mine water discharge) compared to Carne West Swamp, which is unaffected by mine water discharge. Elevated pH values are still being recorded at Narrow and East Wolgan Swamps three years after cessation of mine water discharge, but the trend is back towards normal levels. Some change in soil water chemistry at these sites may have occurred as a result of mine water discharge. Further investigation through soil sampling and testing is currently underway to quantify these effects.

Figure 1.30 shows the timing of mine water discharges into East Wolgan Swamp along with recorded upstream and downstream flows. From this data it can be deduced that water loss into the cavity at the Northern slumping site in East Wolgan Swamp started at some time between April 2006 and May 2008. Downstream of the cavity it was not possible to take water quality or flow samples between 9 May 2006 and 4 August 2010 with the comments "Dry, no flow, no sample" recorded by sampling personnel throughout this period. This reflects the re-routing of mine water discharges and surface water flows from major rainfall events into the cavity during this period. After 4 August 2010 samples have consistently been taken at the East Wolgan Downstream (EW-DS) surface water monitoring location (shown on Figure 1.1). The sample data is presented on Figures 1.28 and 1.29, where the gap in the downstream water quality data is clearly evident. The availability of surface water for sampling after 4 August 2010 is also evidence of recovery of swamp hydrology.

Baumgartl (2013) wrote the following regarding East Wolgan Swamp: "*At locations where linear erosion and sheet erosion occurred, vegetation has died back. It is currently unknown whether vegetation initially died as a result of water saturated conditions and lack of oxygen for plant growth or altered chemical conditions impacting on plant health. As a result topsoil could have been eroded due to the loss of a surface near stabilizing root mat. Alternatively, high flow rates may have eroded the topsoil and caused the vegetation to die subsequently*."

As noted above, investigations into soil water chemistry are currently underway, with soil samples taken at multiple horizons within the peat of East Wolgan Swamp. These samples were tested to determine if any contaminants from mine water discharge remain in the peat and soils of the swamp.

Figure 1.56(a) is a table showing soil testing results from Southern slumping location in East Wolgan Swamp. A "control" sample was taken from outside of the path of mine water flows and appears to have relatively normal EC and pH values for a Newnes Plateau Shrub Swamp. The samples taken at various depths within the soil profile exposed within the Southern Slumping Location (in the path of the mine water flows) show relatively normal EC values for a Newnes Plateau Shrub Swamp. The pH values, however, are significantly higher than those typical for a Newnes Plateau Shrub Swamp i.e. the pH in the soil profile from within the slump is slightly alkaline at the top and alkaline towards the depth where expected range for an organic rich humous containing horizon is acidic. The reason for elevated pH levels in the soils adjacent to the Southern Slumping Location may be related to mine water discharge.

The proposed remediation strategy for East Wolgan Swamp is discussed later in this case study and includes measures to assist with the "flushing" of contaminants remaining in the peat / soil through retention and spreading of surface water flows from rainfall.

2.6. Investigation into Causes of Peat Slumping / Cavity Formation

As shown on Figure 1.1, two areas of slumping were identified in the East Wolgan Swamp investigations.

2.6.1. Southern (Upstream) Peat Slumping Location

Aurecon (2009) reported that: "*The reason for the slumping is uncertain, although one of the areas has the appearance of a sinkhole which is indicative of subsurface piping. The piping may have initiated in a former channel that was filled with loose* *sand or low density material. There are often channels through the surface peat deposits, which become overgrown with vegetation and could eventually become buried under more recent peat deposits, and possibly fill with sand. This would leave a subsurface channel in the peat in which piping could initiate and progress, especially if the peat became saturated during high surface flows. Sinkhole formation would occur when the pipe became sufficiently large that the roof collapsed."*

This assessment was in terms of the upstream (Southern) slump area. As shown in Figure 1.11, there was no observed loss of surface water flows (mine water discharge) at this site with flows from upstream pooling of water at the slump location and continuing to flow downstream from the slump location with no apparent water loss.

Aurecon conducted a geotechnical investigation in 2011 to further investigate the causes of the peat slumping and cavity formation at East Wolgan Swamp. Aurecon (2011) reported *"The upstream (Southern) slump area was not observed to be draining any water and was not discovered until some time after the downstream slump, as the mine water discharge was flowing over the top of the slump. Evidence suggests that this slump has formed by the relict channel erosion mechanism outlined above, with no assistance from any mining-induced fractures or cavities. The conclusion is drawn that the underlying sand has simply been deposited and disbursed downstream of the slump area. (Some evidence of recent sand deposits has been located in the swamp downstream of the slump.) Once the erosion reached the denser sand layer beneath the loose material, the progression of the erosion ceased."*

2.6.2. Northern (Downstream) Peat Slumping and Cavity Location

Aurecon (2009) reported the following in the context of the Northern (downstream) slumping location. "*Another possible mechanism for the formation of the sinkhole involves subsidence cracking. If a longitudinal crack formed at the base of the peat in the rock foundation, it is possible that longitudinal flow along the crack could result in piping in the peat above the crack. This again could lead to sinkhole formation."*

At Northern (downstream) slumping location, Aurecon (2009) concluded that it was likely that mine subsidence had contributed to the cavity formation and that this in turn had caused the peat slumping.

Aurecon (2009) investigated the contribution that mine subsidence had on the cavity formation event. Their conclusions are shown below (italicised):

Since normal mine subsidence-related strains over longwall 411 do not appear to be responsible for the dislocation of the structure and the formation of the cavity, it is theorised that there may be a combination of one or more other factors that resulted in the abnormal movement. That is, there must be some other coincident contributing condition(s), otherwise this would be a common occurrence. What this infers is that one or more additional factors are acting to exacerbate movement on the pre-existing structure to produce the cavity.

Simple physics dictates that for movement to occur on a planar structure, it is necessary for the normal stress on the structure to be reduced and/or the shear stress along the plane to increase. In an effort to better define the mechanism responsible for the abnormal movement, all possible contributing factors which would produce conditions that are conducive to changes in the stress conditions (either normal or parallel to the structure) were listed.

These possible coincident conditions which may have contributed to the formation of the cavity include the following:

- ***Intersection of major structures** - Intersecting structures can produce conditions conducive to cavity formation, since the wedge of rock between the two structures (especially where they intersect at an acute angle) only needs to move slightly for one of the structures to be propped open permanently. There may also be a zone of weakness formed at the intersection of the structures.*

- ***Orientation of the longwall panel relative to the major structures** - one of the structures is located sub-parallel to and vertically above the edge of the longwall panel, which is in a zone of tensile strain produced by the extraction of the panel. This will serve to reduce the normal stress on the structure. In addition, when the structure is sub-parallel to the longwall, the tensile stresses operate over a much longer length of the structure than if the panel crossed it perpendicularly.*

Figure 1.31 is a plan of Angus Place and Springvale Mine workings relative to interpreted major geological zones – note that the Eastern Wolgan Lineament Zone crosses Springvale Mine's Longwall 411 at the cavity location.

- ***Steepness and depth of the East Wolgan watercourse at its northern end** - the steepness and depth of the valley increases the potential for valley closure and bulging effects. Horizontal compressive stresses in the floor of the valley are generally relieved by heaving of the valley floor, but, depending on the dip and orientation of the structure, these may provide the shear stress required to produce lateral/vertical movement on the structure. Where the panel is sub-parallel to the valley, these stresses will operate over a longer distance than if the valley is perpendicular to the panel.*

Figure 1.32 shows valley profiles of East Wolgan Swamp compared to Carne West Swamp – at East Wolgan Swamp there are steeper valley wall gradients and generally greater depth of the valley compared to Carne West Swamp.

Figure 1.33 is a cross section of mine workings, surface topography and measured subsidence on the EWS Survey Line at East Wolgan Swamp (adjacent to the Southern Slumping Area) showing the subsidence mechanism at East Wolgan Swamp – note valley rotation leading to increased compressive horizontal stress in valley floor resulting in buckling strata.

- ***Prevailing in-situ stress direction and magnitude*** *- The magnitude and orientation of the in-situ horizontal stress is important, as it can provide the shear stress required to produce movement on the structure. This of course depends on the orientation and dip of the structure (which is currently unknown) relative to the stress direction.*

- ***Location of the structure close to the permanent barrier pillar*** *- It is a fact that residual tensile strains generally occur over the unmined barrier (which is the transitional point between mined and unmined areas), unlike over the chain pillar between longwall panels where the residual tensile strains are lower. The location of a geological structure over the barrier pillar in an area of residual tensile stress will provide conditions that will serve to reduce the normal stress on the structure, where it is sub-parallel to the panel.*

Figure 1.34 is a plan of predicted cumulative strains for the current and proposed mine workings at Springvale and Angus Place mines – note that cavity formation occurred at the location of the greatest predicted strains in the Springvale mine workings.

Figure 1.35 is a graph of measured and predicted strains relative to mine workings on the M Line at Springvale Mine – note the greater measured strains adjacent to large “barrier pillars” and the development of compressive strains (above large barrier pillars) rather than tensile strains (above smaller chain pillars) in valleys

Further to Aurecon’s investigation, subsequent analysis by DgS (2013) has identified the following additional factors which may have contributed to the formation of the cavity:

- **315 m void width in Springvale LW 411** - this represents a critical width panel with significantly higher measured subsidence in comparison to the earlier sub-critical width panels.

Figure 1.36 is a graph of measured subsidence at Springvale Mine (B-Line) showing differences in subsidence for sub-critical panels widths (Longwalls 1 and 401-409) where measured subsidence was around 1m compared to critical panel widths (Longwalls 410-412) where measured subsidence was around 1.4m.

- **Overburden influenced by two different mines (within each other’s angle of draw) drawing towards different goaf voids and away from each other** – DgS (2013) reported “*The strain profile after LW412 and 950 were commenced shows a reversal from a compressive strain of 12 mm/m to a tensile strain of 1 mm/m. This change was probably caused by the development of 250 mm to 300 mm of subsidence over the barrier pillar under additional loading between LW411 and LW950. Normal convex bending deformations would have occurred in response to the strata cantilevering out across the two adjacent goaves.”*

DgS (2013) further reported **“It is noted that the slump features did not occur until after LW412 and 950 had increased the initial LW411 panel subsidence of 0.9m to 1.3 m.”**

Figure 1.37 is a cross section of mine workings, surface topography and measured strains on the EWS Survey Line at East Wolgan Swamp (adjacent to the Southern Slumping Area). The key point to note is the horizontal strain reversal in the valley floor due to buckling of near surface strata, which occurred after the commencement of Angus Place’s Longwall 950.

Aurecon (2009) concluded: *“As a result of the co-incident factors noted above it is considered likely that the formation of a cavity has occurred below East Wolgan Swamp due to shear failure on a pre-existing, sub-vertical planar geological structure. If the structure had any asperities on its surface, a translational movement could have resulted in the structure being propped open so that a cavity was formed during mine subsidence development.”*

Aurecon (2009) reported that the slumping phenomenon **due to mining** has not occurred elsewhere on the Newnes Plateau above Angus Place or Springvale workings.

DgS (2013) reported “*It is important to note that similar 'piping' features have also developed naturally outside the limits of longwall extraction within the mining area. A slumping feature 8 m in diameter and 1.8 m deep was noted by DgS on Kangaroo Creek above the unmined LW960 in 2010. Several ‘piping’ features have also developed naturally within Sunnyside East Swamp*”.

2.6.3. Comparison with Narrow Swamp

Aurecon (2009) conducted the following comparison of Narrow Swamp with East Wolgan Swamp:

Although, it is unsurprising that the cavity has formed in an area that has the highest probability of anomalous subsidence effects, it is considered improbable that the conditions that caused the abnormal movement will reoccur coincidentally in the lease area. This is supported by the monitoring data at Angus Place, which show that the three longwall panels that have passed under the Narrow Swamp have caused no significant loss of flow in the watercourse. Flow monitoring carried out in this swamp prior to the extraction of longwall 950 has shown that approximately 91% of the discharge from LDP005 reached a weir (NSW1) in the centre of the Narrow Swamp. The deficit in flow volume is apparently taken up in the peat deposits in the swamp (which is normally periodically waterlogged). After undermining by longwall 950 in February 2009, the monitoring indicated no change in the percentage of the discharge that reached NSW1. In addition, the percentage of discharge from NSW1, which reached a weir at the northern end of the swamp (NSW2), was coincidentally 91%. Two longwall panels have undermined the Narrow Swamp in the section of the watercourse between NSW1 and NSW2, and so the flow monitoring indicates *conclusively that the mining to date has not resulted in any significant cracking in the base of the swamp.*

Figure 1.38 is a graph of mine water discharge at Licenced Discharge Point 5 compared to downstream flow monitoring at Narrow Swamp – note similarity of trend of discharge flows compared to upstream and downstream flow monitoring i.e. similar losses through monitoring period from pre-mining to post-mining period.

It is unknown why longwall mining has been successfully completed beneath the Narrow Swamp, with no mining-induced cracking within the drainage line or associated loss of flow, while mining in longwall 411 at Springvale has produced the abnormal subsidence impacts observed in East Wolgan Swamp. However, some of the contributing factors noted above are not relevant or active in the vicinity of Narrow Swamp. These include the following:

- *The orientation of the longwall panels to the watercourse is near perpendicular, which is more favourable than at the East Wolgan watercourse where the orientation produces a large area of increased tensile stress across the valley;*
- *The chain pillars between longwall panels are designed for plastic deformation, so that there are lower residual strains in evidence over the pillars beneath the Narrow Swamp, than over the barrier pillar between Angus Place and Springvale, which is designed not to fail. As a result, the residual tilts and strains over the Narrow Swamp are less likely to produce structural instability than at the East Wolgan Swamp;*
- *Although there are major structures which are aligned with the Narrow Swamp watercourse, they cross the longwall panels at a more favourable angle, and are not exposed to a significant tensile stress regime like the structure over longwall 411, which is near-parallel to the panel.*
- *The valley supporting the Narrow Swamp is not as steep or deep where it has been undermined, as that containing the East Wolgan watercourse beneath the northern end of longwall 411. As a result, the potential for valley closure and uplift is reduced in the Narrow Swamp.*

All of this data supports the conclusion that any future recurrence of the coincident conditions favourable to abnormal subsidence damage within the Springvale lease area is unlikely."

2.6.4. Summary of Co-Incident Factors Related to Cavity Formation

In summary, the key co-incident factors related to cavity formation at East Wolgan Swamp are listed below:

- Mine Water Discharge
- Intersection of major geological fault structures
- Orientation of the longwall panel sub-parallel to the major structures
- Steepness and depth of East Wolgan Swamp valley at Northern end
- Prevailing in-situ stress direction and magnitude
- Critical width longwall panel design

- Location of the geological structure close to the permanent barrier pillar (at location of cavity formation)
- Two mines adjacent to each other drawing overburden in opposite directions

It must be noted that this combination of factors does not occur elsewhere on the Springvale or Angus Place mine plans.

2.7. Baseline Hydrology of East Wolgan and Narrow Swamps

In order to understand the baseline hydrology of Newnes Plateau Swamps, relevant data is gathered, trended and interpreted by expert personnel. This data includes rainfall, standing water levels, surface water flow and quality, soil moisture and monitoring of swamp flora and fauna.

Monitoring related to mining activities including the position of mine working and the timing of mining, mining related subsidence and mine water discharges (where relevant) is also conducted.

The monitoring programs allow an understanding of how mining influences the pre-mining baseline hydrology. This is discussed below in the context of East Wolgan and Narrow Swamps

2.7.1. Newnes Plateau Swamp Piezometer Installations

There are currently 40 swamp piezometers installed in Newnes Plateau Swamps which are associated with Centennial Coal’s monitoring programs.

Piezometers are installed in swamps on the Newnes Plateau in hand augered boreholes to minimise environmental impacts associated with their installation. The boreholes are drilled using the hand auger to a point of “refusal”, where it is not possible to continue drilling. This point is often reached at the bedrock at the base of the swamp (although there are examples where dense clays or coarse gravels cause refusal). The peat / soil material excavated from the boreholes are logged in terms of soil type and other installation details, including location, relative level (RL), bore depth, instrument type are recorded. Figure 1.41 shows an example of information recorded at each installation. The piezometer instrument is installed at the base of the borehole and thus usually measures the standing water level above the bedrock beneath the swamp (although this depends on whether the borehole refused on bedrock). Hydrographs are prepared based on trending of standing water levels (below the ground surface) over time at the instrument locations. Technically, the flat horizontal lines in the hydrographs do not represent the standing water level, as this may be anywhere below the base of the bore. They are included in the figures in this report to indicate continuity of monitoring at the instrument location. It is important to understand that where the hydrographs show a flat horizontal line trend (which is at variable depths below ground level due to variable depths of the peat / soil profile at different locations within the swamps), the standing water level is at or below the base of the borehole (which generally represents the bedrock of the swamp).

2.7.2. Timing of Mining

The time when mining occurs under a particular monitoring location is recorded on the hydrograph in order to determine if there is any immediate response to mining activities. It also allows a division between all pre-mining and post-mining data to establish longer term data trends.

2.7.3. Mine Water Discharge

Mine water discharge into East Wolgan Swamp and Narrow Swamp was conducted at Licenced Discharge Points 4, 5 and 6 in accordance with the conditions of Springvale EPL 3607 and Angus Place EPL 467. Figure 1.26 shows the timing and volume of mine water discharges. The timing of mine water discharge is recorded on the hydrographs to determine correlations with standing water levels recorded at the monitoring locations.

2.7.4. Cumulative Rainfall Deviation Trend

The CRD trend is calculated from difference between the measured rainfall and the long term average rainfall. Where the trend is negative, measured rainfall is less than average and where it is positive measured rainfall is greater than average. The CRD trend is calculated from the commencement of groundwater level monitoring activities on the Newnes Plateau in 2002.

2.7.5. East Wolgan and Narrow Swamp Hydrographs

The hydrographs for East Wolgan and Narrow Swamps are presented in Figures 1.42 to 1.52 with additional data presented to assist with understanding of key influences on swamp hydrology as measured by the piezometers. Discussion of the data is included below each figure. Below is a summary of the data and conclusions from the hydrograph analysis.

2.7.5.1. East Wolgan Swamp Hydrographs

Figures 1.42 to 1.46 are hydrographs of East Wolgan Swamp piezometers WE1 and WE2 with additional data presented to assist with understanding of key influences on swamp hydrology as measured by the piezometers. Key points are summarised below:

Figure 1.42 is a hydrograph of East Wolgan Swamp Piezometers WE1 and WE2 with no other data presented.

Figure 1.43 shows time when Angus Place Longwall 960 undermined WE1 piezometer, establishing that there is no relationship between piezometer response and timing of undermining.

Figure 1.44 shows times when mine water discharges from LDP04 were released into East Wolgan Swamp, establishing a strong relationship between piezometer response and timing of mine water discharges.

Figure 1.45 shows the periods (in excess of two years) during which pre-mining data was not influenced by mine water discharge, which may be used to characterise the pre-mining hydrology of East Wolgan Swamp. It is important to note that at both piezometer locations, the data shows that the standing water level was at or below the piezometer instrument (indicated by the flat horizontal line in the hydrograph trend) for most of the periods not influenced by mine water discharge. Based on this baseline data it is reasonable to conclude that East Wolgan Swamp was a periodically waterlogged swamp before commencement of mining activities.

Figure 1.46 Hydrograph of East Wolgan Swamp Piezometers WE1 and WE2 showing the timing of mine water discharge and longwall mining as well as the Cumulative Rainfall Deviation (CRD) trend. Following the cessation of mine water discharges, the hydrograph trends can be seen to be strongly influenced by rainfall. The Standing Water levels rise in response to rainfall events which are in excess of the long term average trends and fall in response to less than average rainfall trends. The responses are typically immediate and of short duration, indicated by the "spikes" in the hydrograph trends. When the data recorded during mine water discharged is removed, the same trend can be seen in the pre-mining baseline data.

2.7.5.2. Narrow Swamp Hydrographs

Figures 1.47 to 1.52 are hydrographs of Narrow Swamp piezometers NS1, NS2, NS3 and NS4 with additional data presented to assist with understanding of key influences on swamp hydrology as measured by the piezometers. Key points are summarised below:

Figure 1.47 is a hydrograph of Narrow Swamp Piezometers NS1 and NS2 with no other data presented.

Figure 1.48 shows the timing when Angus Place Longwall 950 undermined NS1 and NS2 piezometers. Although there is a drop in standing water level recorded by the piezometers near the time of undermining, it is necessary to look at Figures 1.49 to 1.52 for detail of major factors influencing hydrograph behaviour.

Figure 1.49 shows times when mine water discharges from LDP05 were released into Narrow Swamp, establishing a strong relationship between piezometer response and timing of mine water discharges.

Figure 1.50 shows the periods (approximately 12 months) during which pre-mining data was not influenced by mine water discharge, which may be used to characterise the pre-mining hydrology of Narrow Swamp. It is important to note that at both piezometer locations, the data shows that the standing water level was at or below the piezometer instrument (indicated by the flat horizontal line in the hydrograph trend) for most of the period not influenced by mine water discharge. Based on this baseline data it is reasonable to conclude that Narrow Swamp was a periodically waterlogged swamp before commencement of mining activities. Piezometers NS3 and NS4 were not installed until 2008 and cannot be used to establish pre-mining swamp hydrology.

Figure 1.51 shows times when mine water discharges from LDP05 and LDP06 were released into Narrow Swamp, establishing a strong relationship between piezometer response and time of mine water discharges. Piezometers NS1and NS2 are positioned upstream of LDP06 and are not influenced by mine water discharge from this point. All Narrow Swamp piezometers are positioned downstream of LDP05 and are influenced by mine water discharge from this point. The timing of mining was similar to that of the cessation of mine water discharges at LDP05 in February 2009, but the dominant influencing factor can be seen to be mine water discharges.

Figure 1.52 is a hydrograph of Narrow Swamp piezometers NS1, NS2, NS3 and NS4 showing the timing of mine water discharge and longwall mining as well as the Cumulative Rainfall Deviation (CRD) trend. Following the cessation of mine water discharges, the hydrograph trends can be seen to be strongly influenced by rainfall. The standing water levels rise in response to rainfall events which are in excess of the long term average trends and fall in response to less than average rainfall trends. The responses are typically immediate and of short duration, indicated by the “spikes” in the hydrograph trends. When the data recorded during mine water discharged is removed, the same trend can be seen in the pre-mining baseline data.

It should be noted that there are six piezometers installed in East Wolgan Swamp and Narrow Swamp, and that these piezometers have been subjected to different mining effects. Four have been undermined at different times (due to different locations) and two have not and will not be undermined. Despite the differences in mining effects upon the piezometers, the trends exhibited between the piezometers are very consistent.

Figure 1.53 is a plan showing the position of Narrow and East Wolgan Swamps and piezometers relative to mine workings together with summary of baseline data gathering duration prior to mining

Figure 1.54 is a summary table of piezometers installed in Narrow and East Wolgan Swamps, together with pre-mining baseline duration and hydrology classification based on piezometer hydrographs and other influencing factors.

2.8. Influence of Cavity at Northern Slumping Location on East Wolgan Swamp Hydrology

East Wolgan Swamp is a periodically waterlogged swamp and Figure 1.30 shows the timing of mine water discharges into East Wolgan Swamp along with recorded upstream and downstream flows. From this data it can be deduced that water loss into the cavity at the Northern slumping site in East Wolgan Swamp started at some time between April 2006 and May 2008. Downstream of the cavity it was not possible to take water quality or flow samples between 9 May 2006 and 4 August 2010 with the comments "Dry, no flow, no sample" recorded by sampling personnel throughout this period. This reflects the re-routing of mine water discharges and surface water flows from major rainfall events into the cavity during this period. After 4 August 2010 samples have consistently been taken at the East Wolgan Downstream (EW-DS) surface water monitoring location (shown on Figure 1.1). The sample data is presented on Figures 1.28 and 1.29, where the gap in the downstream water quality data is clearly evident. The availability of surface water for sampling after 4 August 2010 is also evidence of recovery of swamp hydrology.

2.9. Summary of Hydrological Influences on East Wolgan and Narrow Swamp

The following points summarise the key Hydrological Influences on East Wolgan and Narrow Swamps based on the data analysis.

- Mine Water Discharge was the dominant influence on swamp hydrology between 2005 and 2009
- There is a strong relationship between piezometer behaviour and Cumulative Rainfall Deviation after cessation of Mine Water Discharge (since 2010)
- There is no obvious relationship between piezometer behaviour and timing of Longwall Mining
- The pre-mining hydrology of East Wolgan and Narrow Swamps can be classified as periodically waterlogged (Type A).
  - Pre-mining baseline data show water table typically below bottom of borehole (base of swamp) at greater than 1.2m to 2.75m below surface
  - All piezometers exhibit similar behaviour – whether undermined or not
  - Only major rainfall events cause water table to rise above base of swamp
- Consistent surface water sampling at downstream sampling point evidence of recovery of swamp hydrology downstream of the Northern Slumping and Cavity location
  - Recorded as "dry, no sample" 9 May 2006 to 20 July 2010 (all 101 sample dates)
  - Recorded as "clear, pooled water" since 4 August 2010 (31 samples taken)

2.10. East Wolgan Swamp Cavity Investigation Findings

The following section summarises investigations conducted at East Wolgan Swamp cavity and it's apparent impacts to swamp hydrology and flora.

2.10.1. Geophysical Investigation Into East Wolgan Swamp Cavity

In 2011 a geophysical investigation using Ground Penetrating Radar (GPR) and Resistivity Survey (RS) techniques was conducted adjacent to the two slumping locations at East Wolgan Swamp.

Figure 1.39 is a plan showing geophysical and geotechnical investigation transect locations relative to the Northern peat slumping location – note similar investigation was conducted at the Southern peat slumping site. Investigations conducted included Ground Penetrating Radar, Resistivity, Peat / Soil Geotechnical Sampling & Testing and Dynamic Cone Penetrometer testing.

Figure 1.40 shows the ground penetrating radar interpretation plotted over inverted resistivity plots. AGS (2011) concluded "The use of resistivity profiling has mapped a deeper conductive zone at a number of locations. These deeper features may be the result of a minor fault or fracture zone carrying water".

If the fault zone is carrying water, that means it is NOT draining it away from the base of the swamp and these transect study locations are in close proximity upstream and downstream of the cavity. The field work for the geophysical investigation was conducted in October 2010, and thus occurred after the restoration of surface water flows in East Wolgan Swamp (as shown in Figure 1.55)

2.10.2. Evidence of Recovery of East Wolgan Swamp Hydrology Downstream of Cavity

Figure 1.30 shows the timing of mine water discharges into East Wolgan Swamp along with recorded upstream and downstream flows. From this data it can be deduced that water loss into the cavity at the Northern slumping site in East Wolgan Swamp started at some time between April 2006 and May 2008. Downstream of the cavity it was not possible to take water quality or flow samples between 9 May 2006 and 4 August 2010 (even in periods of mine water discharge) with the comments "Dry, no flow, no sample" recorded by sampling personnel throughout this period. This reflects the re-routing of mine water discharges and surface water flows from major rainfall events into the cavity during this period. After 4 August 2010 samples have consistently been taken at the East Wolgan Downstream (EW-DS) surface water monitoring location (shown on Figure 1.1). The sample data can be seen on Figures 1.28 and 1.29, where the gap in the downstream water quality data is clearly evident. Figure 1.55 is a graph of surface water monitoring (EC) results for East Wolgan Swamp upstream (EW-US) and downstream (EW-DS) monitoring points. Of critical importance is the availability of surface water for sampling at the East Wolgan Downstream (EW-DS) sampling point – indicative of restoration of surface water flows downstream of the Northern slumping area and cavity in East Wolgan Swamp in the period since 4 August 2010. **The availability of surface water for sampling after 4 August 2010 is specific evidence of recovery of swamp hydrology.**

2.10.3. Infilling of Cavity Through Natural Processes

The following refers to photographs of the East Wolgan Swamp cavity location at times since the cavity was identified and provides evidence of infilling through natural processes.

Figure 1.57 shows the cavity site during mine water discharge on 20 April 2009. At this time there was complete water loss into the cavity, with no downstream flow.

Figure 1.58 shows the cavity site with no mine water discharge on 1 May 2009, showing the hole in the peat where water loss occurred.

Figure 1.59 shows the cavity site on 28 June 2013 showing the infilling of the hole where water loss occurred through natural processes.

2.10.4. Effect of Cavity on Downstream Vegetation

The following refers to photographs taken on 28 June 2013 of the East Wolgan Swamp at the cavity location as well as upstream and downstream of the cavity. They show significant impacts to vegetation upstream and at the cavity location, with impacts downstream of the cavity limited to a deep, narrow channel in the peat. These photos are consistent with mine water discharge being the main cause of impacts to swamp vegetation.

Figure 1.10 is a photo of East Wolgan Swamp on 28 June 2013 Upstream of Northern Slumping / Cavity Location. Vegetation impacts from mine water discharge are obvious.

Figure 1.17 is a photo of East Wolgan Swamp on 28 June 2013 at the Northern Slumping / Cavity Location. Vegetation impacts from mine water discharge are obvious.

Figure 1.18 is a photo of East Wolgan Swamp on 28 June 2013 Looking Downstream (North) from the Northern Slumping / Cavity Location. The photo shows **No Apparent Effect of Cavity on Downstream Vegetation (apart from a deep, narrow channel in the peat).**

Figure 1.19 is a photo of East Wolgan Swamp on 28 June 2013 Looking Downstream (North) from the Northern Slumping / Cavity Location. It shows a defined erosion channel in peat downstream of cavity, which allowed concentrated flow path for mine water discharge (and prevented impacts to vegetation outside the flow path). The cavity also prevented high volume emergency discharge flows from reaching vegetation in the period between May 2008 and March 2009**.**

2.10.5. Summary of East Wolgan Swamp Cavity Impacts to Swamp Hydrology and Flora

Key points from available data regarding impacts of cavity at East Wolgan Swamp to swamp hydrology and flora are as follows:

- Photos of cavity show infilling through natural processes
- Surface water flows restored since August 2010
- Geophysical investigation found that fault zone adjacent to cavity was "carrying water" i.e. not draining water
- Vegetation downstream of cavity not affected (discussed later in "Swamp Hydrology Study")

The available evidence indicates that swamp hydrology has been restored through natural processes, and that it has had no impact on swamp flora. The reasons for not impacting on swamp flora are discussed in the Swamp Hydrology section below.

3. East Wolgan and Narrow Swamp Rehabilitation Proposal

Gingra (2009) made the following recommendations regarding East Wolgan and Narrow Swamp remediation. "*The areas of slumping and dieback need to be stabilised to prevent further erosion and movement of swamp sediments and to prevent weed invasion.*

Rehabilitation works need to be of minimal impact and un-invasive to avoid disturbance elsewhere in the swamp and surrounding vegetation. Some soft engineering can be utilised using local and/or sterile materials. The rehabilitation works should aim to stabilise swamp sediments, to limit the possibility of channelisation of water flow through the affected areas and to prevent weed invasion.

A suitable approach could involve use of local material such as dead tea tree branches and dead sedge clumps to stabilise sediments and impede water flow, combined with hand removal of weed species germinating within the areas of exposed soil. Use of weed free straw or mulch may also be appropriate. These techniques have been applied by bush regeneration teams working for Blue Mountains City Council.

Infestations of Blackberry may need to be treated with appropriate herbicides to ensure adequate control. Control of Blackberry should extend upstream of the affected areas as these may be transported along the creek during periods of high water flow. Control in early summer (December) is recommended, given normal climatic conditions.

Rehabilitation works, including stabilisation of the soil surface and weed control, may require a licence under section 91 of the Threatened Species Conservation Act. Advice from DECC should be sought regarding any requirements of that Act when working in an area which supports the Newnes Plateau Shrub Swamp endangered ecological community."

The Bush Doctor (2011) prepared a remediation proposal for East Wolgan and Narrow Swamps. The Bush Doctor (2011) stated "*Issues identified at East Wolgan Swamp include slumping and channelisation along with minor weed invasion. The aim of the East Wolgan Swamp project is to reinstate the natural hydrological processes of the swamp through the replacement of lost soil and organic material. Narrow Swamp will have a rock ramp constructed to prevent the head cutting that is active in the area at present.*"

Key elements of the proposed remediation strategy are as follows:

3.1. East Wolgan Swamp Remediation Proposal

3.1.1. Slump Remediation Strategy

- Use of geotextile around work area for storage of sand bags and to reduce to impact on soils and vegetation.

- Use of the following materials (air lifted in and stored as close as possible to the work area to reduce the foot damage of carrying heavy materials across the swamp).
  a. Coarse washed river sand delivered on site in large bales,
  b. Coir logs will be 300 X 300mm square logs of an assortment of sizes
  c. Sand bags mad of hessian
  d. Jute mesh
  e. Jute matting

- Removal of the upper soil profile that has slumped into the depressions. This will be hand dug and placed in sand bags to be used in the final remediation process. This will ensure that the upper profile containing the native seed bank and vegetative propagules is retained and placed back in their correct profile. The bags then break down over a twelve months period.

- Coir logs laid in the excavated areas level, the sand will then be use to pack voids and cover logs. Jute mat will be placed over the top. Alternate layers of coir logs, sand and jute laid in alternative direction. The sand will be used in conjunction with the coir to reintroduce a medium of organic and sand material representative of the natural soil composition. This construction is intended to create anaerobic conditions that with allow for the slow deterioration of materials.

- Reintroducing the top soil back into the area, covered with jute mesh.

- Brush matting of area to prevent some of the animal grazing on regenerating plants (which is apparent throughout the area is a factor impeding the natural regeneration of the swamp).

- Use of level spreader structures in the deeper areas of channelisation present in the swamp to spread some of the surface flows out over the swamp rather than concentrated flows.

- Brush matting and direct seeding of the areas surrounding the slumping sites. This seed will be collected from the adjoin swamp vegetation. Only species from the swamp vegetation composition will be used.

- On the completion of these works a regular weed control and regeneration program will occur to monitor the establishment of both annual and perennial weed establishment and control these if they are hindering the regeneration processes. Monitoring of the natural regeneration should asses the need if any for supplementary planting of indigenous species.

Figure 1.60 is a cross section of proposed slump remediation methodology

3.1.2. Swamp Rehydration and Flushing of Residual Peat / Soil Contaminants

Use of level spreader structures in the deeper areas of channelisation present in the swamp to spread some of the surface flows out over the swamp rather than concentrated flows.

Figure 1.61 is a photo of Braeside Swamp at time of Remediation works using similar techniques to those proposed for channelised areas in East Wolgan Swamp

Figure 1.62 is a photo of Braeside Swamp approximately 12 months after remediation works using similar techniques to those proposed for channelised areas in East Wolgan Swamp

3.2. Narrow Swamp Remediation Proposal

1. This section of swamp will be addressed with a rock lined channel creating a stable rock ramp between the swamp and the creek bed.

2. The rock ramp will be constructed using sandstone rip rap a suitable size to with stand high flows in the system.

3. Prior to installing the ramp the area will be sculptured using a small excavator to (3-5 tonne) to create a ramp.

4. Once the ramp is constructed the area will then be covered in geo textile fabric.

5. Rock will then be transported down to the area with the excavator and placed into position.

6. Access to the work are will be through the woodland, the work area is at the end of the swamp and access with the machine would be through an area of approximately 10 metres.

7. On the completion of work all soil disturbance will be jute meshed and brush matted with material found on site.

4. Actions By Centennial To Prevent Impacts To Swamps

Following extensive investigations to determine impact causes to East Wolgan Swamp, the following actions have been completed to prevent impacts to swamps on the Newnes Plateau.

4.1. Mine Re-Design To Reduce Subsidence

Major design changes have been made to the Springvale mine plan in order to reduce subsidence from longwall mining. These changes are based on the following dimensional changes.

- Void width reduced from 315m to 261m
- Pillar width increased from 45m to 58m

Figure 1.63 is a Springvale Mine Plan illustrating changes to mine design to reduce subsidence

Figure 1.64 is a cross section showing mine subsidence across 13 longwalls at Springvale and indicating evidence base for reduced void width leading to reduced subsidence.

Figure 1.65 is a cross section showing predicted mine subsidence across Longwalls 412 to 417 at Springvale (including Longwalls 415 – 417 in the Controlled Action Area for EPBC 2011/5949) showing reduced void width leading to reduced subsidence for Longwalls 416 and 417.

These changes have been made specifically to reduce the environmental impacts of longwall mining under the Newnes Plateau, and demonstrate Centennial's commitment to sustainable mining practices. The changes have been made in good faith and at significant cost to the business at a time when there was no guarantee of approval for ongoing mining activities.

4.2. No Further Mine Water Discharges To Swamps

Figure 1.63 is an image of Springvale and Angus Place mine water management system on the Newnes Plateau. Figure 1.63(a) is the same figure with explanatory notes regarding management measures to eliminate mine water impacts to Newnes Plateau swamps. The following are key points related to the elimination of mine water impacts to Newnes Plateau swamps.

- There have been no mine water discharges to Newnes Plateau Swamps since April 2010

- Future bore pump installations are located downstream of swamps (e.g. Springvale Bore 8)
- Re-design of Angus Place mine dewatering infrastructure to allow storage of emergency discharges in Angus Place 900 Area
- Angus Place Emergency Discharge Point (LDP06) has been relinquished in recent modification of EPL467
- Springvale Emergency Discharge Points (LDP04 and 05) will be relinquished as part of the Angus Place and Springvale mine extension projects. It is planned to re-inject any future emergency discharges underground into the Angus Place 900 Area Water Storage (as shown on Figure 1.63). Prior to relinquishment, the following processes must be completed:

    - Development Consent for Angus Place and Springvale mine extension projects
    - Aquifer Injection Licence to allow re-injection into mine workings voids
    - Testing of current infrastructure and design / build of additional required infrastructure

4.3. Studies To Understand Swamp Formation And Interactions With Mine Subsidence

Studies have been conducted by Centennial in the following areas to improve understanding of swamp formation are interactions with mine subsidence.

- Geology and Hydrogeology
- Swamp Hydrology
- Mine Design and Subsidence
- Swamp Flora

Reports based on the findings of these studies are included in the Appendices to this report. Summaries of the main findings are included below.

Other studies including the modelling of water flows within swamp peat / soils are currently underway.

4.3.1. Newnes Plateau Geology and Relationship to Newnes Plateau Swamp Formation

Centennial has also sought to gain a deeper understanding of swamp hydrology through studies into Newnes Plateau geology.

McHugh (2013) wrote that "*Previous studies of the Angus Place/Springvale area do not typically include the presence of the Burralow Formation, and instead refer to the Banks Wall Sandstone as the uppermost outcropping unit. Figure 1.67 is an isopach drawing of the Burralow Formation, which shows maximum thicknesses of approximately 110 metres, principally in the north-east of Angus Place East and the south-eastern extent of Springvale Colliery at the headwaters of East Wolgan, Sunnyside, Sunnyside East, Carne West, and Gang Gang Shrub Swamps. Hence the Burralow Formation, as defined in the study area, is thicker than previously* *proposed in the general Lithgow region in earlier works, for example, Goldbery (1972) and Herbert and Helby (1980).”*

4.3.1.1. Burralow Formation Geology

Mc Hugh (2013) reported “*This formation consists of medium- to coarse-grained sandstones interbedded with frequent sequences of fine-grained, clay-rich sandstones, siltstones, shales and claystones. These latter fine-grained units can be several metres in thickness and their presence differentiates the Burralow Formation from the underlying Banks Wall Sandstone. An example of these differing lithologies can be seen in Figure 1.68 which is a photo of a core drilled from the Burralow Formation on the Newnes Plateau.*

McHugh (2011) studied the upper stratigraphy of the Angus Place/Springvale leases, in particular the Burralow Formation, and identified both a lithological and topographic link between the presence of the Burralow Formation and the occurrence of the Newnes Plateau Hanging Swamps (NPHS). Several of the claystone horizons, together with clay-rich, fine-to-medium grained sandstones and shales were found to be acting as aquitards, or semi-permeable layers.”

4.3.1.2. Burralow Formation Aquitards

Mc Hugh (2013) reported “*Aquitards are semi-permeable units which permit only relatively small amounts of water to percolate through them into the underlying strata. Aquitards retard water flow underground; that is, they act as a partial barrier to downward groundwater movement. Aquitards separate aquifers and partially disconnect the flow of water underground, directing water downdip to discharge points in nearby gullies.*

These aquitards decrease the hydraulic gradient of rainwater and groundwater movement percolating through the weathered and semi-weathered strata of the Burralow Formation and form a permanent water source for the formation and maintenance of the hanging swamps.”

4.3.1.3. Burralow Formation Geology Related to Newnes Plateau Swamp Formation

Mc Hugh (2013) reported “*Although the Burralow Formation consists of abundant fine grained semi-permeable units, it was determined that only units of approximately two metres or above in thickness would be capable of acting as an aquitard that would alter the hydraulic gradient for a hanging swamp to form.*

In total, McHugh identified seven units, designated YS1 to YS6 which were capable of sustaining the hanging swamps in the area, provided the topographic conditions were amenable to the formation of a hanging swamp.

With seven such identified aquitards in total (YS6, YS5, YS5a, YS4, YS3, YS2 and YS1), there is a significant retardation of water percolation through the Burralow Formation from surface to base to permit the formation not only of the Newnes Plateau Hanging Swamps, but to significantly contribute moisture at outcrop points in *gullies containing the Newnes Plateau Shrub Swamps. Groundwater sourced from the presence of aquitards thus supplements input from precipitation, which assists in maintaining the floristic community of the resultant shrub swamp.*

The sole unconfined aquifer in the study area lies above the YS1, the remainder of the strata between aquitards in the Burralow Formation act as individual "aquifers" at surface points where the coarser sandstone units of the formation crop out on gully sides. The high degree of weathering of many of the sandstone units also assists in this process, and is also indicative of the degree of water movement through these units."

Figure 1.69 shows the distribution of Newnes Plateau Shrub Swamps throughout the study area in relation to Burralow Formation outcrop.

Mc Hugh (2013) reported "*The majority of the shrub swamps are located within the confines of the Burralow Formation, particularly in the Springvale lease. However, some shrub swamps are situated wholly within the Banks Wall Sandstone in the Angus Place lease, while a smaller population comprises "mixed-type" swamps. These latter shrub swamps are located such that their upper reaches are located within the Burralow Formation but terminate in the Banks Wall Formation, as the host creek erodes down into the country rock distally from the watershed areas where these shrub swamps are predominantly located. The underlying lithology of each shrub swamp controls its morphology and often, areal extent. Topography also plays a role in shrub swamp morphology, however the presence or absence of a Burralow Formation substrate largely dictates the shape and extent of a particular shrub swamp. Hence Banks Wall-type and "mixed-type" shrub swamps are generally smaller in area and occur in relatively steep-sided gullies.*

In comparison, the Burralow-type shrub swamps characteristically occur in much broader and gently sloping depressions and are commonly longer and permanently waterlogged in their lower reaches."

4.3.1.4. Valley Wall Seepage as a Mechanism for Swamp Hydration

Figure 1.70 shows a view looking north-west from the direction of the Springvale ridge system. Aquitard horizons which support the shrub and hanging swamps are shown in brown. Shrub swamps are marked in green and hanging swamps in yellow.

This figure illustrates the extensive subcrops of aquitards present in this area of the Angus Place/ Springvale lease.

Aquitard horizons crop out along the sides of valley walls, as well as within gully floors, thus supplying a constant source of groundwater moisture for both the shrub swamps in the gullies and the hanging swamps that occur along cliffs and the steeper upper sections of valley sides.

Mc Hugh (2013) reported "*The presence of hanging swamps throughout the lease area is an important indictor of the amount of groundwater contained within the aquitard/aquifer system operating throughout the vertical extent of the Burralow Formation.*

As can be observed in Figure 1.70, by virtue of the regional dip, the aquitard horizons are often present along the sides of ridges and thus follow the gully sides of the host creek below. The presence of aquitards at these locations leads to the occurrence of valley wall seepage which is an important source of moisture for the shrub swamps in the upper reaches of both Carne Creek and the Wolgan River.

Apart from the seven major aquitards discussed earlier (that is, YS6, YS5a, YS5, YS4, YS3, YS2 and YS1), thinner aquitard unit also are present within the Burralow Formation which, while they may not be capable of forming a hanging swamp, nevertheless supply a constant source of seepage at outcrop localities.

The presence of swamps in catchment headwaters cannot be fully explained by rainfall alone and require an additional continuous source of hydration though periods of restricted rainfall. The presence of the Burralow Formation is essential to the formation of both hanging and shrub swamps. Goldney et al (2010) stated "normal flood hydrographs generated from rainfall are expected to rise and fall reasonably rapidly in response to rainfall events, and thereafter, to feed low baseline flows maintained by a combination of valley-side and in-stream seepage".

Piezometer readings, both in-stream and on ridge locations, record only part of the full hydrological picture for any given swamp system. Valley wall seepage, which occurs however minutely at some locations along aquitards outcrops, still permits continuity of hydration during periods of drought."

4.3.1.5. <u>Summary of Investigation into Geology / Hydrogeology and Mining Related Impacts of Newnes Plateau Shrub Swamps</u>

McHugh (2013) reported "*The occurrence and sustainability of the Newnes Plateau Shrub Swamps are multifactorial, involving a complex interplay between topography, hydrological regimes and geology.*

The formation and persistence of the Newnes Plateau Shrub Swamps and the Newnes Plateau Hanging Swamps are intrinsically associated with the Burralow Formation, that is, without the presence of the latter, the presence of both swamp types would not occur in the study area.

The Burralow Formation with its suite of aquitards decreases the hydraulic gradient and thus reduces the degree of percolation of groundwater through the varying lithologies of this formation to the units below. Instead, much of the groundwater present within the Burralow Formation is redirected laterally down-dip to discharge points in nearby gullies. Precipitation is thus supplemented by moisture from groundwater sources to form several discharge horizons along the course of the host creek in which a shrub swamp is located.

In the Burralow Formation, where aquitard units are relatively plentiful, the opportunity for groundwater supplementation via valley wall seepage is common. Groundwater supplementation also occurs when aquitards outcrop within the floor of *creeks, thus providing a direct means of groundwater input into the host creek. Valley wall seepage together with direct in-gully input of groundwater via aquitards permits continuity of hydration during periods of drought.*

The presence of numerous hanging swamps throughout the study area is also an important indicator of the amount of water contained within the aquifer/aquitard systems within the Burralow Formation.

The Newnes Plateau Shrub Swamps are reliant on the Burralow Formation for their presence and development, although the study area does contain shrub swamps which are stratigraphically located solely within the Banks Wall Sandstone. This latter shrub swamp subtype displays an areally restricted morphology and occurs primarily in steep-sided, narrow gullies due to the underlying Banks Wall Sandstone substrate, which is less easily eroded than the lithologies which comprise the overlying Burralow Formation.

In general, shrub swamps occurring wholly within the Banks Wall Sandstone have less access to seepage at discharge points along creek beds due to the absence of aquitard horizons. Consequently this restricts the size and breadth of this shrub swamp type. Significantly, however, with the exception of shrub swamps in the Wolgan River, the Banks Wall-type shrub swamps are invariably adjacent to subcrops of the lower Burralow Formation aquitard sequence and therefore receive substantial groundwater seepage from these horizons.

Burralow-type shrub swamps are typically more areally extensive than the Banks Wall equivalents, with generally longer and broader morphologies. This is due not only to the presence of the Burralow aquitards, but the lithological differences between the Burralow Formation and the Banks Walls Sandstone. The former promotes more areally extensive swamps while the latter, with its sandstone-based lithology, encourages steeper and deeper gullies due to its relative resistance to erosion.

In Banks Wall and "mixed-type" swamps, the lack, or partial lack, of aquifers respectively, inhibits the potential groundwater input and results in smaller, drier and narrower swamps. However, it is important to note that Banks Wall-type shrub swamps, and the "mixed-type" swamps which occur at subcrop boundaries between the Burralow Formation and the Banks Wall Sandstone, still receive seepage from the aquitard/"aquifer" sequences located stratigraphically above them.

Even in shrub swamps located solely within the Burralow Formation, the thickness of the latter can influence the extent of the size of the resultant shrub swamp. High elevation Burralow-type shrub swamps, that is, those in the upper reaches of a particular swamp, may gain groundwater solely from an unconfined aquifer and may be generally smaller in size, unless they are located adjacent to a large recharge area.

Hence, the extensive 1150+ metre ridge system in the Springvale lease, where the Burralow Formation is at its thickest, provides both a substantial precipitation recharge zone plus an array of aquitards to promote groundwater retention in the streams which flow from this watershed area, both to the north and south of the ridge *line. It is for this reason that shrub swamps in the south-east of the Springvale lease are, in general, wetter and broader than those in the remainder of both leases.*

Floristic differences are also apparent between the upper reaches of Burralow-type shrub swamps, where there is less opportunity for sequential aquifers to supply seepage as the gully moves lithologically downwards, as compared to the lower reaches of these swamps which are typically permanently waterlogged. Similarly, vegetation species differ between Burralow-type and Banks Wall-type shrub swamps due to varying availabilities of groundwater. This, along with hydrological inputs into the shrub swamps and hanging swamps will be discussed in a subsequent report.

Longwalling has resulted in groundwater level changes in the lower reaches of Kangaroo Creek due to mining-induced cracking. It is expected that over time any cracks present will gradually infill with sediment and that these effects will be temporary. However, the perennial spring which is fed by the aquifer-aquitard systems within the Burralow Formation was unaffected by mining and the creek remained permanently wet below the spring. This, together with the presence of healthy hanging swamps along the valley walls surrounding Kangaroo Creek shrub swamp, indicates that the water supply from the spring and valley wall seepage has not been interrupted by longwall mining and that groundwater inputs to the swamp hydrological system remain intact. The available evidence indicates that underground mining has not resulted in any long-term negative effects on Kangaroo Creek Shrub Swamp.

It is obvious from the hydrographs presented for Narrow and East Wolgan Swamps that mine water discharge had major impacts on the hydrology of these swamps over an extended period. It is also clear that mine water discharge caused impacts to Narrow and East Wolgan Swamp vegetation and that the combination of mine water discharge and mine subsidence caused localised swamp peat slumping events and cavity formation in East Wolgan Swamp in an area where a combination of contributing factors were present (including mine water discharge, topography, structural geology and mine design).

In the locations where the piezometers are installed, the baseline swamp hydrology at East Wolgan and Narrow Swamps has been established as periodically waterlogged, when the influence of mine water discharge is removed. Based on the hydrographs, the post-mining/ post-mine water discharge swamp hydrology appears to be consistent with the periodically waterlogged baseline hydrology.

By contrast, West Wolgan, Junction, Sunnyside West and Sunnyside swamps, all subjected to longwalling, display no indications of mining-induced effects to the groundwater system on which these swamps are reliant.

Finally, the presence of the Newnes Plateau Shrub Swamps are dependent on topographic, lithological and hydrological factors, which are subsequently reflected in the morphology, floristics and hydrology of the resultant shrub swamp. The manifestation of these complex interacting factors is most readily observable in the change in swamp appearance and swamp vegetation from the northern extension of the Angus Place lease through to the south and east of the Springvale Colliery lease."

4.3.2. Swamp Hydrology Study

Various studies and monitoring data analysis have been conducted to understand the hydrology of swamps on the Newnes Plateau. These include the following:

- Characterisation of Geology and Importance to Swamps
- Hydrology Study - Sunnyside East and Carne West Swamps
- Characterisation of Standing Water Level based on swamp piezometer behaviour
- Flora mapping ~50 “mini-plot” locations along length of Sunnyside East Swamp
- Soil Moisture Characterisation at ~50 “mini-plot” locations along length of Sunnyside East Swamp
- Soil sampling and testing to determine if soil water chemistry has been changed by mine water discharge (EWS)
- Water flow modelling within swamps (understanding different of water flows in sub-surface sands / surface peat layer)

4.3.2.1. Hydrograph Data Analysis

Figure 1.73 shows hydrographs of Newnes Plateau Shrub Swamp piezometers, noting the highly variable depth of the Standing Water Level and long duration between rainfall induced “spikes” in many of the hydrographs.

Goldney (2010) stated “Normal flood hydrographs generated from rainfall are expected to rise and fall reasonably rapidly in response to rainfall events, and thereafter, to feed low baseline flows maintained by a combination of valley-side and in-stream seepage.”

Figure 1.74 shows hydrographs of periodically waterlogged swamp piezometers. There is a strong correlation between piezometer response and Cumulative Rainfall Deviation (CRD) Trendline (in Black). Of the 40 piezometers installed in Newnes Plateau Shrub Swamps by Centennial, 20 are classified as displaying periodically waterlogged behaviour.

Figure 1.75 is a plan of Sunnyside East and Carne West Swamps showing different hydrological classifications within each swamp for the MU50 shrub swamp community.

Figure 1.76 shows hydrographs of 16 permanently waterlogged Newnes Plateau Shrub Swamps. Some of the hydrograph trends show distinct negative spikes which reflects water quality sampling at these locations on a regular basis.

4.3.2.2. Soil Sampling and Analysis

Baumgartl (2013) wrote the following regarding swamp hydrology "*The EWS like most of the other shrub swamps within the Newnes plateau are situated at or associated with a drainage face from the lowest aquitard units of the Burralow formation at locations where these units are intersected by a valley or exposed as outcrop through regressive erosion along a valley upstream. The drainage originates from groundwater within the Burralow formation, which drains from the interstitial space of aquitards or high permeable aquifers above aquitards. Drainage from these units is not specifically localised, but is diffuse along this aquitard-unit exposed to the land surface. The drainage from these units occurs along some length of the valley either at the valley floor or from the sides of the valley. The flows concentrate in a relatively narrow valley, but are in principle identical to the type of drainage as can be found at the hanging swamps on steep slopes at higher stratigraphic locations. From a brief visual assessment of the local environment at three swamps (East Wolgan, Kangaroo Creek and Carne West) typical swamp vegetation communities could be identified at locations above the valley floor and at some distance from the direct swamp influence, which are unmapped. The expression of water seeping from outcrops of aquifer/aquitard units seems to be not uncommon at the steeper flanks of the valleys.*

Constant drainage along those drainage faces allowed the establishment of a specific swamp vegetation community. In the EWS, this vegetation can be found along the central parts of the valley, but also upslope along a contributory valley (and higher in topographic elevation compared to the valley) at the central part of EWS. The soil profile in this region of the swamp is well drained to below 1.2m for most of the time of the year 2012 and piezometer measurements have shown that this reflects the general trend of the pre-mining groundwater baseline. Drained conditions of the swamp can be also assumed from the comparably high slope of the EWS-valley. While at the downstream parts of EWS the soil moisture within the first 0.2m of the soil is higher, the soil upstream can be considerably drier once any major rainfall, which contributed to soil moisture, has drained downstream or within the soil profile. The existence of swamp vegetation, which usually is dependent on extended periods of water logged conditions, also at those drier regions of the swamp may be enabled through deep rooting of the typical species into (or close to) the aquifer. As has been shown, the distance to the aquifer from the surface at the upstream location of the swamp is much higher than downstream as the topographical elevation is markedly higher upstream, but at the same time the strike direction of Burralow formation is quite similar to the orientation of the EWS valley, i.e. there are only small changes in elevation of the formation over the length of the swamp.

From the soil profile description it can be deduced that plants are developing roots to a depth of at least 1.1m, i.e. they may be able to reach depths (even beyond the depth of 1.1m) of the soil, which are permanently moist as they lie in the vicinity of units feeding groundwater, whereby the origin of the water may be from valley side seepages, subsurface flow in the valley and deeper draining rainfall. This would *allow this water dependent vegetation to sustain periods of dry conditions within the soil profile.*

The soil profile description at the central slump location showed a top soil horizon, which was enriched in organic matter, but may not suffice the classification of peat. The topsoil within the existing swamp vegetation upstream of the slump location is overlain by a layer of organic matter. Due to the elevated position of the investigated vegetation outside of the central part of the valley, this organic horizon will always be drained and not water logged."

4.3.2.3. The Importance of "Valley Wall Seepage" for Newnes Plateau Swamps

As noted in the summary of investigation into geology / hydrogeology of Newnes Plateau Swamps above, valley wall seepage is a critical mechanism for hydration of Newnes Plateau swamps for the following reasons:

- Swamp rainfall catchment areas are limited
- Swamps on the Newnes Plateau are mostly located in the upper headwaters of their catchment – not a typical location for swamp formation
- Swamp grades of 3-6% facilitate rapid drainage and only periodic waterlogging in many cases
- Water input critical to maintaining adequate hydration is highly dependant upon the extent of valley wall seepage (Burralow Formation Aquifer-Aquitard system)
- Case studies (including Kangaroo Creek Swamp) indicate that valley wall seepage including Hanging Swamps have not been impacted by mine subsidence on the Newnes Plateau

Figure 1.70 shows how multiple aquitards outcrop longitudinally along each swamp and provide a mechanism for valley wall seepage hydration along the entire length of swamp.

Figure 1.77 is a photo of an unmapped hanging swamp on the Western side of Kangaroo Creek Swamp – illustrating valley seepage mechanism continuing post-longwall mining.

4.3.2.4. Water Flow Modelling in Swamps

It is apparent that there are different behaviours in terms of swamp water flow

- Variable soil profile with sand beneath peat. Figure 1.78 shows a typical Newnes Plateau Shrub Swamp peat / soil profile – showing sand overlain by peat

- Variable water level / moisture content. Figure 1.73 and 1.74 show hydrographs displaying highly variable water levels over time.
- Standing water level often not near peat layer (as shown in Figure 1.74)
- Slow flow rates within peat layer can be seen from the recharge rates at water quality sampling points. Figure 1.79 shows hydrographs of swamp piezometer sampling points in several Newnes Plateau Shrub Swamps – note common sampling dates and slow recharge rates indicative of slow flow rates with swamp peat / soil

Further investigations being conducted, including numerical modelling of flow rates in peat and underlying sand are currently being conducted. These results are not yet available.

4.3.2.5. Subsidence Effects to Groundwater Systems

RPS (2013) summarised the key points with regard to the influence of proposed longwall mining at Springvale and Angus Place mines on the groundwater systems of the Newnes Plateau. This assessment was based on a thorough hydrogeological modelling process by CSIRO and RPS between 2011 and 2013. RPS (2013) stated **"Longwall mining leads to localised disruption of the deep groundwater system as well as subsidence induced changes in overlying strata. The magnitude of influence on overlying strata declines with increasing height above the mined coal seams. Due to the multiple layers of aquitards and aquifers in overlying strata there is minimal change to the perched system that supports hanging swamps and shallow system that supports shrub swamps."** Figure 1.71 is a conceptual model of mine subsidence impacts to groundwater systems. The key elements illustrated in the drawing in summary are as follows:

- Stacked and segregated groundwater systems recharged by rainfall – locally in the case of shallower systems and regionally in the case of the deeper systems.
- Deep regional flow essentially isolated from the shallow and perched groundwater systems;
- Perched water systems, supported on low permeability aquitard layers.
- Shrub swamps fed partially by groundwater originating from the perched groundwater systems and partially from surface water run-off.
- The Mount York Claystone acting as a significant regional aquitard isolating the shallow and perched groundwater systems from the deep groundwater system.
- The deep interbedded and interbanded aquitard (mudstones) and aquifer (sandstone and coal) units present beneath the Mt York Claystone strongly influence the deep regional groundwater flow pattern at depth.
- Groundwater flow is dominated by both porous media flow (dominantly horizontal) and to a much lesser extent, fracture flow associated with the joint, fracture and fault conduits.
- Variably enhanced groundwater flow through the lithological pile affected by subsidence induced permeability zones.
- Extensive aquifer interference in the Deep Groundwater System aquifers due to subsidence induced goaf formation, collapse and fracturing affects.

- Shallow formation sagging, induced by subsidence, gives rise to enhanced horizontal permeability in the Shallow Groundwater System (permeability enhancements decreasing closer to the ground surface).
- Disconnected vertical permeability enhancements are inferred in the shallow surface zones.

Detailed groundwater and surface water modelling has been conducted for Angus Place and Springvale Mine Extension Project Environmental Impact Statements.

4.3.2.6. Swamp Hydrology Study Findings

The following are summary points about swamp hydrology which have been established through swamp hydrology investigations on the Newnes Plateau.

- Similar Flora community (MU50) exists in Newnes Plateau Shrub Swamps

- Soil Moisture is variable along individual swamps. Soil moisture is lower in the upper reaches and soil moisture is higher in the lower reaches

- Swamp Hydrology is variable along individual swamps and standing water level are typically influenced by rainfall in the upper reaches and by groundwater in the lower reaches

- Geology (Burralow Formation) Critical in Swamp Formation. All swamps were formed due to the presence of a permanent water source from the Burralow Formation (or within perennial watercourses)

- Valley Side water input along entire length of swamp (from rainfall and groundwater). There are two principal mechanisms of swamp hydration
  - Groundwater Valley Side Seepage Along Length of Swamp
  - Rainfall Runoff from Valley Sides Along Length of Swamp

  Note: Longitudinal surface (and sub-surface) flows are not common in periodically waterlogged swamps.

- Burralow Formation water output not impacted by mine subsidence (e.g. Kangaroo Creek Swamp)

- Minor cracking in swamp base has localised effects – no evident effects to downstream vegetation at East Wolgan Swamp as shown in Figure 1.18. This is consistent with the findings of Goldney (2010) "*Swamp cracking where it does occur is unlikely to cause other than short-term impacts to particular swamps. In-stream sediment is likely to rapidly in-fill such cracks – in effect they are likely to rapidly self-repair.*" Goldney (2010) also reported "*Subsurface flows are not necessarily continuous along a streambed and result in no net loss of water within the catchment (Gilbert and Associates 2008; Merrick 2008). In the southern coalfields this phenomenon has been modelled and observed in tributary and major streams (Gilbert and Associates 2008; Merrick 2008). However, there have been little adverse impacts observed in undermined upland valley swamps in the southern coalfields.*"

4.3.3. Investigation into Mine Design and Mine Subsidence and Monitored Subsidence Impacts to Swamps

As detailed above there were several co-incident conditions which occurred at East Wolgan Swamp and contributed to cavity formation. The following section reviews the differences between longwall mining beneath East Wolgan Swamp and longwall mining proposed for Sunnyside East and Carne West Swamps i.e. why proposed longwall mining will not cause impacts similar to those seen at East Wolgan Swamp.

4.3.3.1. Prediction of Anomalous Subsidence

A thorough review of subsidence data over history of mining at Springvale and Angus Place was conducted to determine factors which had caused anomalous subsidence in the history of the mine.

Surface cracking locations were mapped and correlated with measured subsidence and strain anomalies.

It was found that recorded subsidence impacts had occurred only at locations with both **Major Fault Zones AND Incised Valleys (with Slope Gradients > 18^o).**

These locations have been identified as ‘moderate to high’ potential subsidence effect increase zones, which exist in the lower reaches of Kangaroo, Narrow and East Wolgan watercourses (as shown on Figure 1.72).

No “moderate to high’ potential subsidence effect increase zones have been identified in the Eastern Mining Areas at Springvale (including Sunnyside East and Carne West Swamps).

4.3.3.2. Comparison of Proposed Mining at Sunnyside East and Carne West Swamps with Mining Beneath East Wolgan Swamp

DgS has stated the following with regard to differences between longwall mining beneath East Wolgan Swamp and that proposed for Longwalls 416 and 417 beneath Sunnyside East and Carne West Swamps.

“There are three notable differences between the East Wolgan Creek case and the proposed longwall geometries for LWs 416 to 417 that are likely to result in lower impacts to the eastern valleys and their interaction with Type 1 geological structures:
(i) Firstly, the angle of orientation between the valleys and the proposed panels will increase to 24^o for Carne West and 51^o for Sunnyside East. The East Wolgan Creek was orientated at 22^o to the side ribs, meaning the potential for increased subsidence and interaction with geological structures is higher. The benefit is more pronounced for Sunnyside East and only marginally improved for Carne West.
(ii) Secondly, the proposed chain pillars for the future sub-critical longwalls have been increased from 42 m to 58 m (a 38% increase), which will increase the supporting capacity of the overburden over multiple panels and reduce tensile strains above the pillars, panels and solid coal at the leading goaf edge due to the reduction in differential subsidence generally.
(iii) Thirdly, the spanning capacity of the strata potentially affected by geological

structure has been improved by the reduction in panel width from 315m to 262m to ensure sub-critical 'arching' behaviour and keeping the planes of weakness in compression. The critical panel width for LW411 would have introduced tension zones due to bending action into the rock mass and may have increased the potential for planes of weakness to slip due to mine subsidence."

DgS (2013) concluded "It is assessed from the results that the development of a peat slump along Sunnyside East and Carne West Creeks due to LWs 416 to 417 is unlikely because of the following factors:

- The valleys above the proposed longwalls 416 to 417 are broader and shallower than East Wolgan Creek valley.
- All of the impacts observed to valleys have occurred above panels with W/H ratios > 0.75. The peat slumping features occurred above a 'critical' width longwall panel with a W/H ratio of 0.93. Zones of tension in the rock mass due to bending action would have increased the potential for planes of weakness in the overburden to slip due to mine subsidence.
- The proposed panels beneath the eastern valleys are 'sub-critical' panels with W/H ratios ranging from 0.73 to 0.69. Arching action in the overburden will enhance stability of geological structure by maintaining compressive forces on the planes of weakness.
- The proposed narrower panels will have significantly wider chain pillars (e.g. 58 m v. 42 m) than previous longwall layouts and will reduce subsidence and strains above the panels and potential interaction with geological structure. The differential subsidence (and strains) above the panel adjacent to the solid coal (i.e. the leading goaf edge) will also be reduced.
- The predicted valley closure and observed uplift along the valleys above Springvale and Angus Place indicate near surface voids of between 15 mm and 112 mm are likely to have developed.
- Apart from the peat slumps, the measured impacts along valleys to-date ranged from 30 to 100 mm of buckling of rock bars, 10 mm to 110 mm wide tension cracks to side slopes or no impact. It is assessed that the impact to the eastern valleys will be similar based on the predicted subsidence, valley closures, strains and buckling due to LWs 416 to 417.
- Despite the similarity in valley depth and higher valley closure and buckling predictions for the proposed longwalls 416 to 417, it is assessed that the likelihood of a peat slump or significant impact occurring to the TPHSS in the Sunnyside East and Carne West Valleys is 'low' provided mine water discharges are excluded from these areas."

4.3.4. Investigation into Swamp Flora and Monitored Subsidence Impacts to Swamps

An intensive flora monitoring program is maintained by Centennial Coal and since 2009 has been conducted by the Centre for Mined Land Rehabilitation at the University of Queensland. The monitoring methodology, commencing in 2003, involved the use of 400m^2 fixed monitoring plots assessed by a modified Braun-Blanquet cover abundance ordinal categorisation using expert estimation. Monitoring is conducted seasonally excluding winter when dormancy and frost prevent identification of species and result in significant damage to vegetation respectively.

4.3.4.1. East Wolgan Swamp Flora

Figure 1.80 to 1.84 relate to flora monitoring at East Wolgan Swamp. A brief summary of the monitoring results and interpretation for East Wolgan Swamp is included below and the report "Assessment of Flora Impacts Associated with Subsidence" is appended to this report.

East Wolgan swamp has been affected by a series of mining related activities including subsidence by both Angus Place and Springvale Collieries and discharge of mine water. As a result, this swamp has a number of highly visible impacts including extensive areas of bare peat and slumping of swamp substrate and cracking of the surrounding sandstone slopes. The condition of swamp vegetation in East Wolgan swamp has shown significant changes related to mining activity, primarily mine water discharge (Figures 1.81 and 1.82) when cessation of mine water discharge in early 2006 coincided with below average rainfall. This condition change is expected as mine water discharge activity in this swamp had been ongoing for almost a decade and was stopped immediately. This will have drastically altered the hydrological conditions experienced by vegetation present at this time. With return of mine discharges in 2008 condition of vegetation present improved somewhat but is only recently achieving a health assessment of five. Composition of vegetation in East Wolgan is influenced by the presence of weedy species (Figure 1.90) but to a lesser extent than Narrow swamp, due in part to the broad extents of bare peat which are not actively measured in the current monitoring program. East Wolgan consistently has high weedy species richness which is unsurprising given available habitat for opportunistic species. The composition of East Wolgan monitoring plots does not indicate a sustained change although plot EW01 location is variable, likely the result of variable weed presence (Figure 1.83).

4.3.4.2. Narrow Swamp Flora

Figure 1.85 to 1.90 relate to flora monitoring at Narrow Swamp. A brief summary of the monitoring results and interpretation for Narrow Swamp is included below and the report "Assessment of Flora Impacts Associated with Subsidence" is appended to this report.

Narrow shrub swamp community has been exposed to multiple mining related activities in a similar manner to East Wolgan Swamp. Long-term discharge of mine water resulting in drastically altered hydrology and hydrochemistry. Condition and abundance of monitored species declined markedly with the initial cessation of long-term minewater discharge in mid 2005 (Figures 1.85, 1.86, 1.87). Condition and abundance of swamp community species improved during the period of emergency minewater discharge from 2008 to 2010 and remained healthy with the subsequent cessation of mine water discharge into this community. As noted for East Wolgan shrub swamp community the initial cessation of discharge in 2005 coincided with a prolonged period of below average rainfall extending into 2008. Weedy species richness in monitoring plots of Narrow shrub swamp is the highest recorded for any monitored plot. The abundance of weeds contributes to the overall location of Narrow shrub swamp in the 2D nMDS plot of vegetation composition (Figure 1.90). While structural swamp species were more strongly correlated with the direction of Narrow swamp eg. Leptospermum obovatum (Figure 1.89) the variation and distance of this community is clearly affected by weed abundance (Figure 1.90). The composition of Narrow shrub swamp monitoring plots are highly variable and with few exceptions are represented in 2D nMDS distinctly separate from any other plot assemblages. To date increases in Eucalyptus seedlings and other native non-swamp species from surrounding communities have not been recorded in the monitoring plots.

This indicates that the shrub swamp community structure within monitoring plots is still relatively competent although substantially altered.

Additional Data Regarding Remediation Case Study (Metropolitan Colliery – Waratah Rivulet Rockbar Remediation)

Information was requested on the remediation case study regarding the Waratah Rivulet Rockbar Remediation at Metropolitan Colliery.

- Specific reports supporting case study are included in Appendix 3
- Analysis of data presented in the graph showing water level in pools before and after PUR injection is presented below
- Additional data regarding reduction in permeability since 2008 is presented below

The following is an explanation of "Graph 3" in the Hard Engineering Section of Appendix 6 of EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau, Springvale Colliery, March 2013.

The following is an excerpt from the Helensurgh Coal Pty Ltd Waratah Rivulet Remediation Trial Activities – Completion Report (October 2008), which provides detailed discussion regarding the figure supplied by Centennial Coal in the EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau, Springvale Colliery, March 2013.

"OVERALL HYDROLOGICAL PERFORMANCE

Water levels in Pool F were reportedly first affected during the longwall mining of Panel 12 in October 2005. Pool levels were further affected by mining of Longwall Panel 13.

Water levels in Pool A were also affected by mining. The pool has not been fully remediated and continues to show obvious signs of subsidence induced underflow.

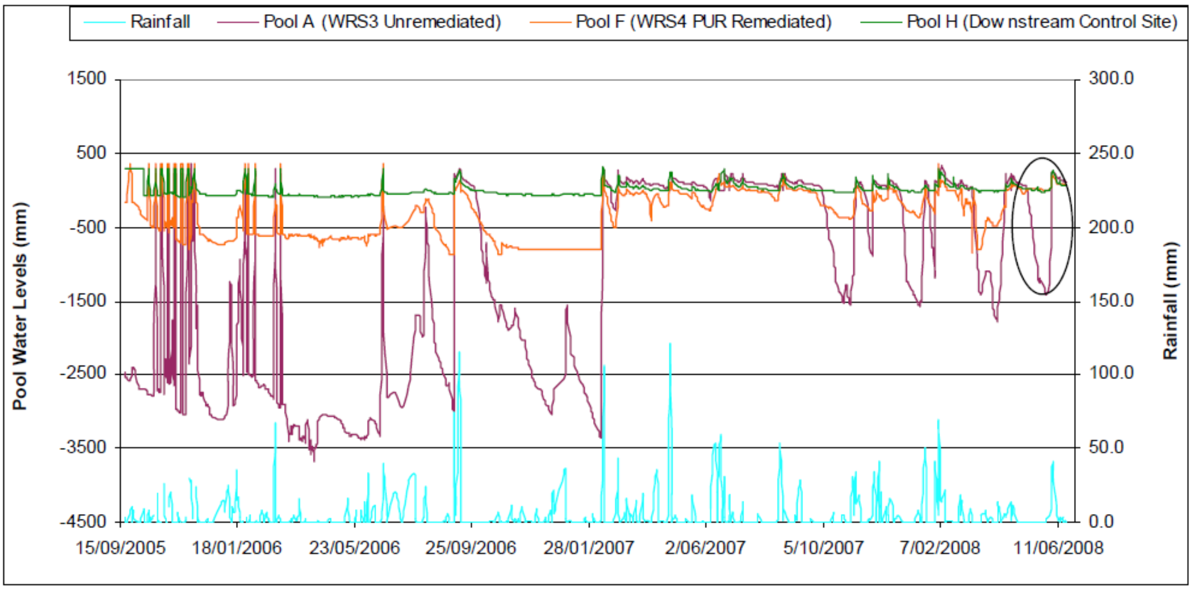
Pool H is located downstream of Pool F and approximately 120m downstream of previous longwall mining activities. The hydrological characteristics of Pool H have not been affected by subsidence. Pool H is a similar size to Pool F and has a similar pool/rock bar morphology.

Comparison of recorded water level behaviour in these three pools, both before and after the remediation trials at Pool F, provides a means of assessing the success of the trial. Specifically, this data allows a comparison of pool water level responses in Pool F (before and after the trial) to those observed in Pool H and Pool A.

During periods of moderate or high flow in Waratah Rivulet, the water level in subsidence affected pools is similar to a pool un-affected by subsidence. During dry periods when flows in the Rivulet are in a low, recessionary regime the water level in pools affected by subsidence recede faster than they do in unaffected pools. Water levels in natural pools will decline below their 'cease to flow' level (ie stop overflowing) if the combined effects of evaporation from the pool surface and slow leakage through the downstream rock is greater than inflow rate.

Graph 1 shows recorded pool water levels in the 3 pools from 20 September 2005 to 20 June 2008. It is readily apparent that water levels in both Pools A and F have regularly declined rapidly during low flow periods whilst water levels in Pool H have generally remained near the CTF (zero) level. Water levels in Pool A have receded further at least in part because the pool is significantly deeper than Pool F.

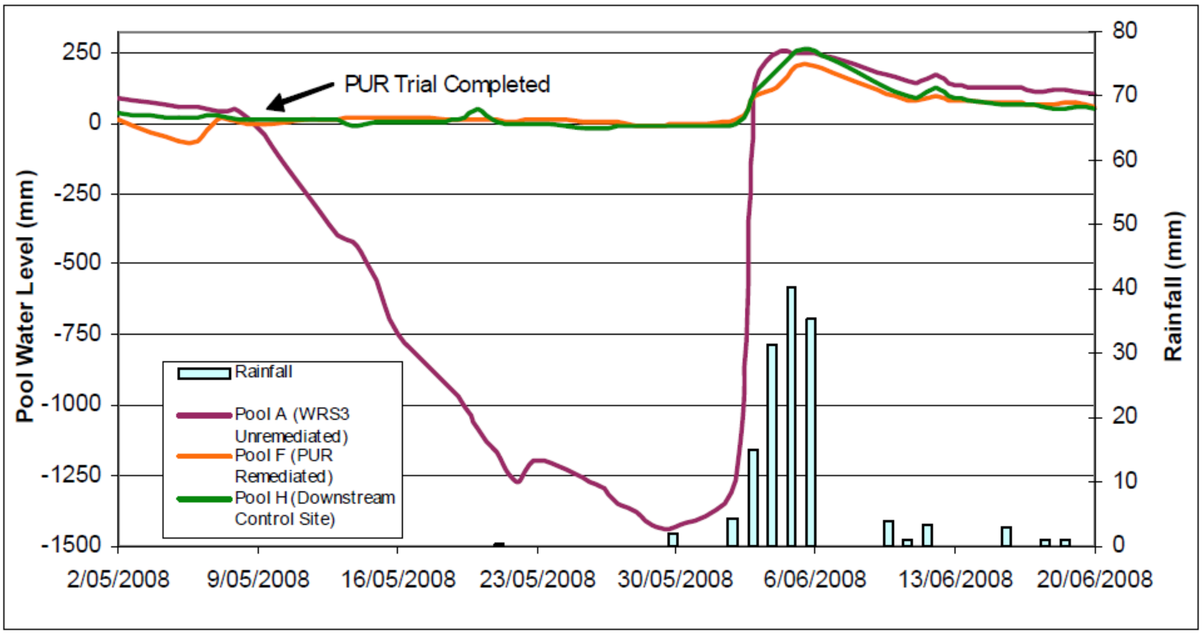
Graph 1 Recorded Pool Water Levels in Pools A, F and H



Note: See Graph 2 for further detail of circled data.

The remediation trial commenced on 17 March 2008 and was completed on the 13 May 2008. There is an obvious comparative difference in water level response in Pool F prior to 18 April 2008 and pool levels after this date. Water levels in pool F have mirrored those in Pool H after 18 April 2008 but not before. Water levels in Pool A continued to show the effects of subsidence during this period.
Graph 2 shows a magnification of the period from near the end of the trial until the 20 June 2008. This clearly shows water level responses in Pool F have mirrored those in Pool H (i.e. have been similar to natural pool behaviour). As indicated above, this behaviour is in stark contrast to the water level responses in Pool A over this period. The rainfall over this period is also shown on Graph 2. There was 138 mm of rainfall recorded in the period 13 May to 13 June 2008 with no rain recorded from the 13 May until the 29 May 2008. This indicates that any residual leakage in Pool F is low relative to low flows which were likely to have occurred over this period.

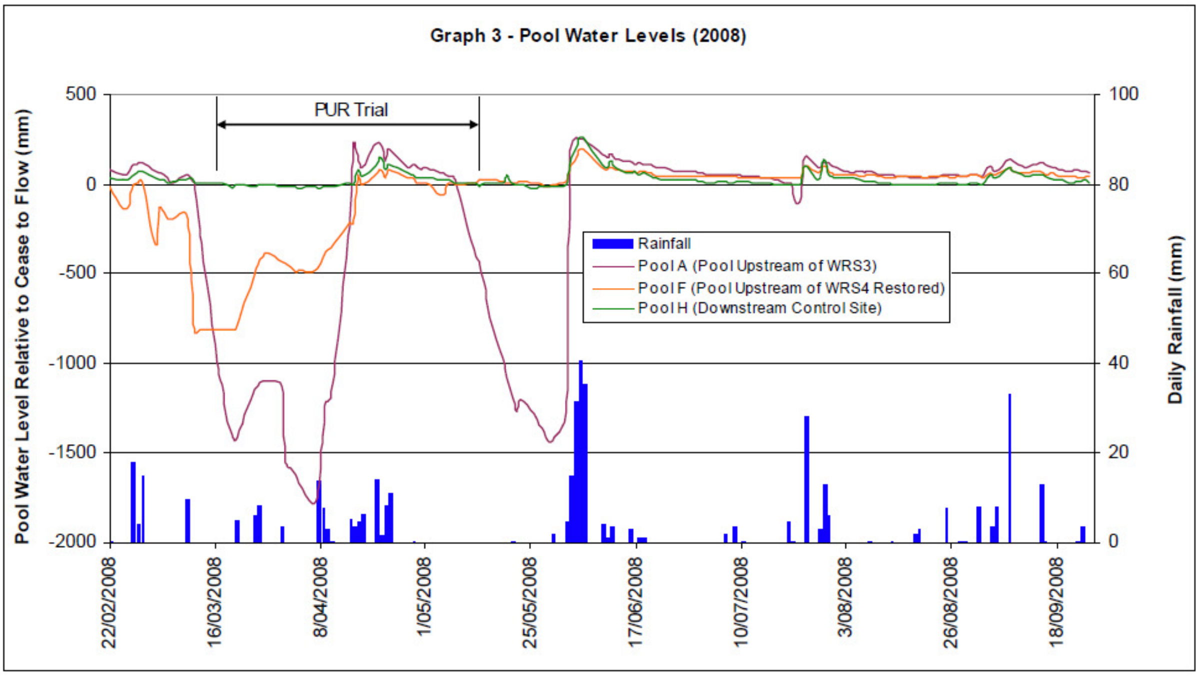
Graph 2 Pool Water Level Responses to PUR Trial



Note: On 5 and 6 June 2008, pool level instrumentation was submerged due to a rainfall event. Pool levels for this period are conservatively assumed to be the highest calibrated pool level measurement.

Graph 3 presents pool water level data to 26 September 2008. There continues to be a clear difference in the water level response in Pool F prior to 18 April 2008 and after this date. Graph 3 indicates that a further recession in the water levels in Pool A occurred in late July 2008, however there was no similar response in Pool F.

HCPL will continue to collect data regarding the remediated hydrological characteristics of Pool F. The current data set enables the conclusion to be drawn that water levels in the pool have behaved in a similar fashion to those in a natural pool after the trial. Flows in Waratah Rivulet since remediation were low during the period from the 13th to the 29th May 2008 – during which time the pool water levels responses in Pool F were indistinguishable from those recorded Pool H (unaffected by subsidence). A further recession in the water levels in Pool A occurred in late July 2008, however there was no similar response in Pool F. Therefore it can be concluded that water level responses in Pool F have changed markedly as a result of the trial, indicating a significant reduction in leakage as a result of successful remediation.



Graph 3 Pool Water Levels to September 2008

5.5 40 DAY TEST WORK

In accordance with Approval Condition 8d, two cored holes were obtained from the grout curtain to recover samples for 40 day test work, including acid digestion, leaching and microscopic characterisation.

The results of the 40 day testing of the grouting product are described in Appendix 3. Comparison of the data for acid digestion of polyurethane with the leached metals shows that the presence of trace metals including iron within the structure of the polyurethane does not result in their leaching in creek or demineralised water. These results indicate that the incorporation of metals from sandstone during mixing of the polyurethane is not a significant inclusion as polyurethane is essentially a very inert material. Downstream TOC and DOC concentrations in Waratah Rivulet waters show no increase associated with grouting activities. Based on the results, there is considered to be no reason to undertake any XRD or XRF analysis of polyurethane.

5.6 SUMMARY

Observation of PUR in core confirmed that the product had infiltrated and filled both the fine and larger void spaces.

The expanded trial further confirmed that the modified drill/injection sequence of drill and inject single holes in turn would be more effective compared with drilling and injecting a series of holes.

The hydraulic conductivity tests further confirmed that the hydraulic conductivity of a PUR filled fracture was of the order of 10^{-7}m/s, at least several orders of magnitude lower than an open fracture network.

HCPL will continue to collect data regarding the remediated hydrological characteristics of Pool F. The current data set enables the conclusion to be drawn that water levels in the pool have behaved in a similar fashion to those in a natural pool after the trial. Flows in Waratah Rivulet since remediation were low during the period from the 13th to the 29th May 2008 – during which time the pool water levels responses in Pool F were indistinguishable from those recorded Pool H (unaffected by subsidence). A further recession in the water levels in Pool A occurred in late July 2008, however there was no similar response in Pool F. Therefore it can be concluded that water level responses in Pool F have changed markedly as a result of the trial, indicating a significant reduction in leakage as a result of successful remediation.

The water quality tests confirmed that PUR injection had no impact on the water quality.

The environmental controls were very effective."

Demonstration of Ongoing Success of Remediation

The following is an excerpt from a report for Helensurgh Coal Pty Ltd by Gilbert and Associates (July 2012) Assessment of the Success of WRS3 Remediation Works in Re-Establishing Surface Flow. This refers to Pool A from the previous section, which is upstream of the WRS3 rockbar, which was also remediated using PUR injection techniques.

"3.1 Assessment of the Behaviour of Pool A over the Period 1/1/2011 to 3/5/2012

The recorded (continuous) and manual (daily) water level observations in Pool A are plotted on Figure 2 relative to the Pool cease-to-flow level (i.e. the pool water level at which it just ceases overflowing the downstream rock bar - WRS3). The continuous data and manual observations cover the period 1 January 2011 to 3 May 2012. The data demonstrates that pool water levels fell below the cease-to-flow level between the 7 February 2011 and 19 March 2011, but have remained above the cease-to-flow level continuously from the 19 March 2011 through to the end of the available data (3 May 2012). There is generally a close correspondence between (manually) observed and recorded water level data. There was however a period of missing data from the continuous record between 21 December 2011 and the 9 February 2012. The manual observations during this period show that water levels in Pool A remained above the cease-to-flow level.

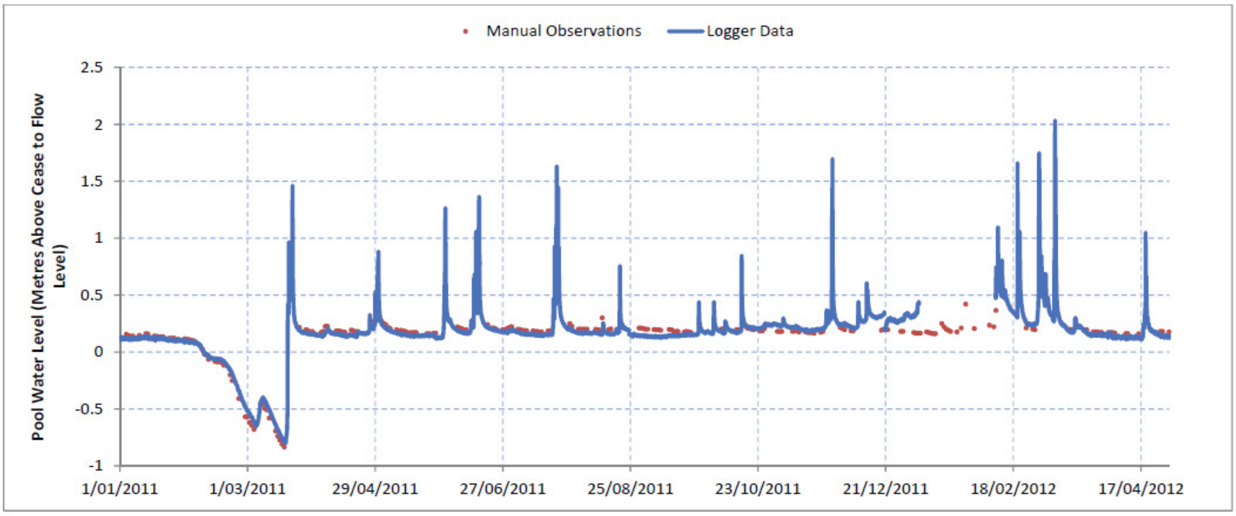


Figure 2 Observed and Recorded Water Level Data for Pool A (1 January 2011 to 3 May 2012)

A comparison was also made between the recorded pool water level behaviour of Pool A and other Pools on Waratah Rivulet downstream of expected mine subsidence effects. Again the pool water level data has been converted to depth above the cease-to-flow levels of the pools – refer Figure 3. It is apparent that Pool A has mirrored the water level behaviour of the other downstream pools indicating that after 19 March 2011 its behaviour has been consistent with un-impacted pools. Because the rate of pool water level recession between rainfall/runoff events is consistent with the downstream pools and it can be concluded that the remediation works have resulted in flow holding capacity in Pool A which is consistent with pools outside the area affected by mine subsidence over this period.

A similar comparison with pools on Woronora River, which is outside the mine affected area, shows that the water level responses in Pool A has been consistent with those measured in the Woronora River pools – refer Figure 4. Again the water level pool holding capacity, as evidenced by the recorded pool water level recessions, are consistent with the pools in Woronora River over this period.

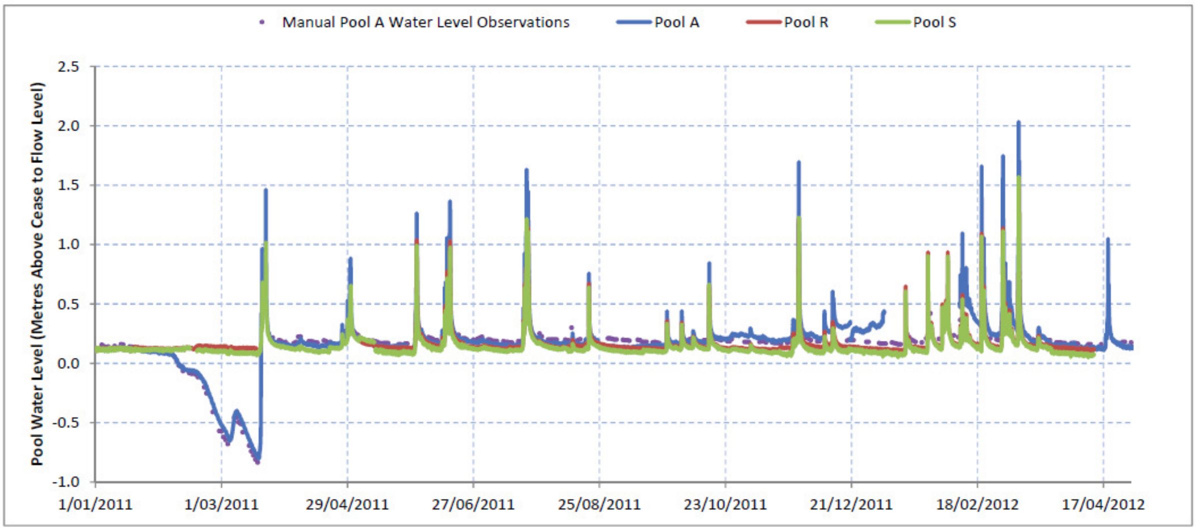


Figure 3 Comparison of Pool A Water Level Hydrograph with Downstream Pools R and S – Waratah Rivulet

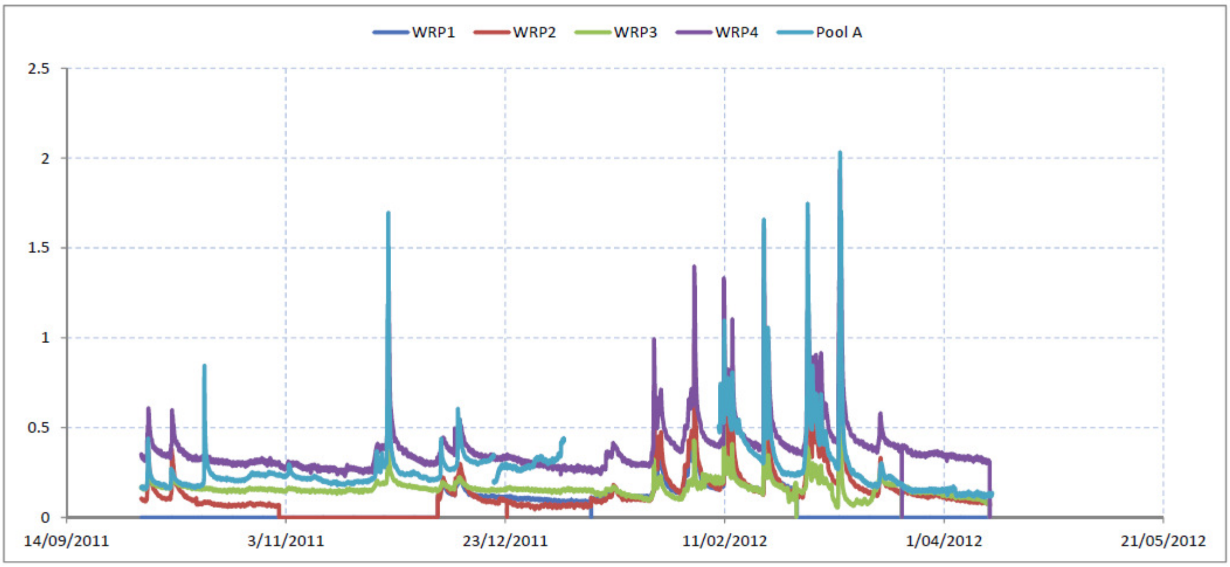


Figure 4 Comparison of Pool A Water Level Hydrograph with Pools WRP1, WRP2, WRP3 and WRP4 on Woronora River"

East Wolgan Swamp Case Study

Figures

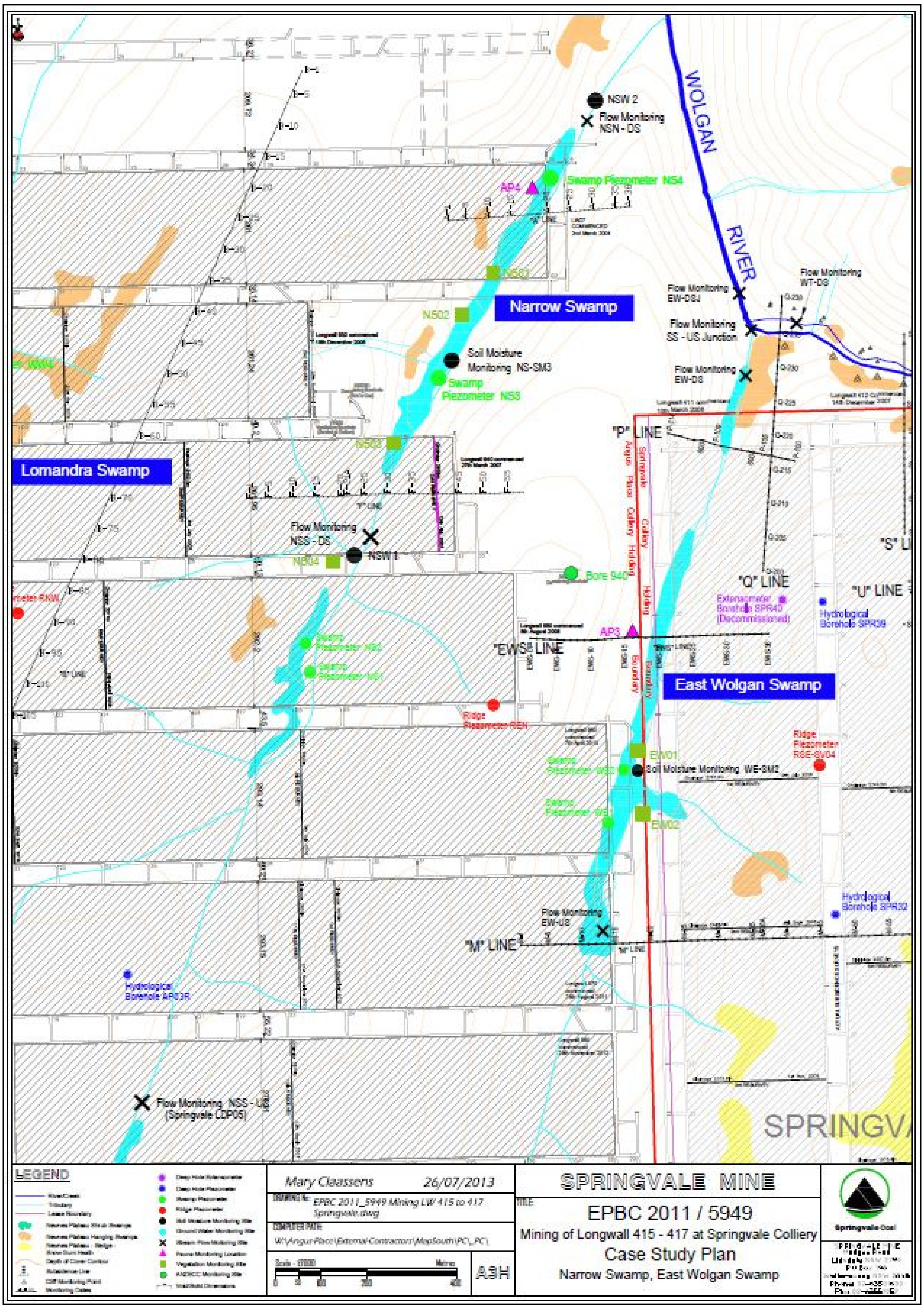


Figure 1.1 - East Wolgan and Narrow Swamp Case Study Plan

East Wolgan & Narrow Swamp Environmental Monitoring			
Number	Monitoring Type	Frequency	Duration (Years)
6	Swamp Piezometers	Continuous	8
6	Surface Water Flow	2 Weekly	9
6	Surface Water Quality	2 Weekly	10
2	Soil Moisture	2 Monthly	6
6	Flora	Quarterly	8
2	Fauna	Annual	8
5	Subsidence Lines	Pre and Post Mining (Up to 15 Surveys each)	9
	LIDAR	Pre and Post Mining (2 Surveys to date)	8
	Photographic	Pre and Post Mining	8
3	Mine Water Discharge	Daily	16

Figure 1.2 East Wolgan & Narrow Swamp Environmental Monitoring Details

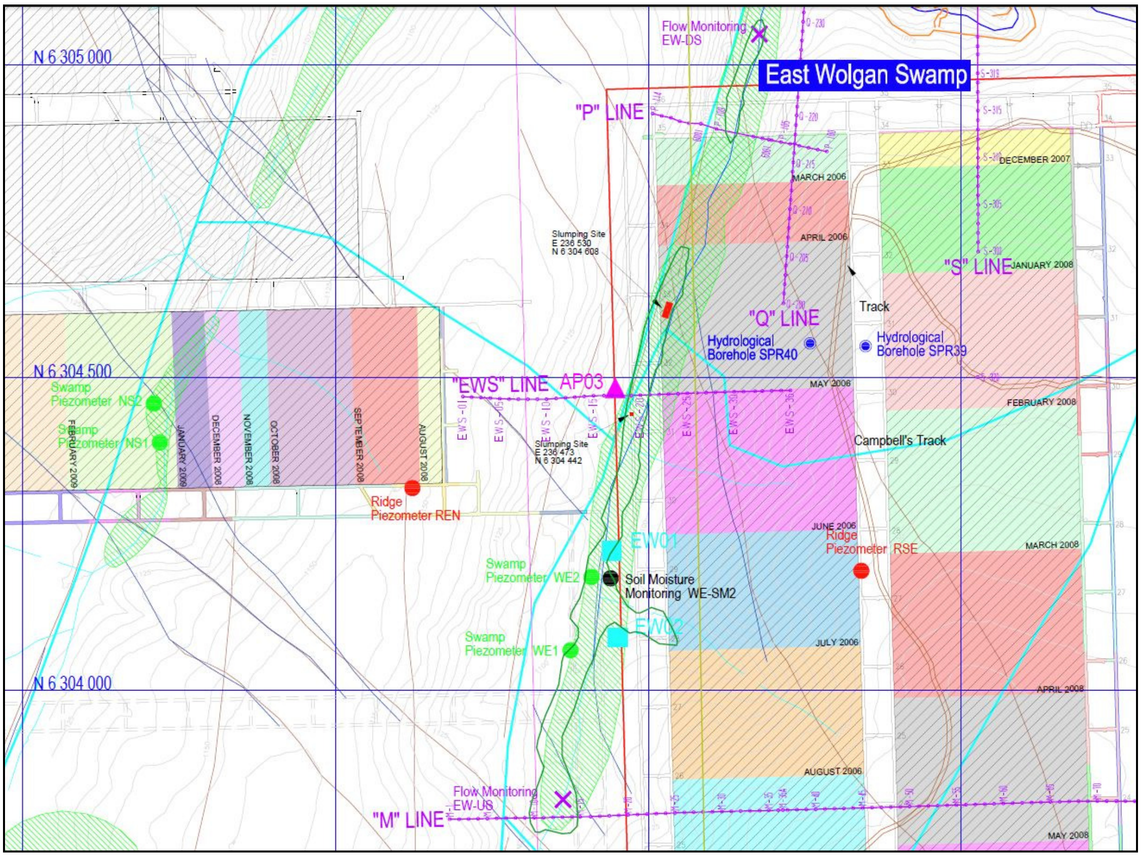


Figure 1.3 Plan of East Wolgan Swamp Showing Timing of Mining, Photographic Monitoring Locations and Slumping Locations

Figure 1.4 - LDP004 water discharge flow downstream 20 April 2009

Photos of EWS From Location 10 (Upstream of Southern Slumping Site)

Figure 1.5-Location 10 Upstream of Southern Slumping Site During Mine Water Discharge 20/04/2009

Figure 1.6 - Location 10 Upstream of Southern Slumping Site No Mine Water Discharge 17/06/2009

Figure 1.7 - Location 10 Upstream of Southern Slumping Site at 28/06/2013

Photos of EWS From Locations 1-3 (Between Slumping Sites)

Figure 1.8 - East Wolgan Swamp at Location 1 on 20 April 2009 (during mine water discharge)

Figure 1.9 - East Wolgan Swamp at Location 1 on 17 June 2009 (no mine water discharge).

Figure 1.10 - East Wolgan Swamp at Location 1 on 28 June 2013 Upstream of Northern Slumping / Cavity Location Note: Vegetation Impacts

Photos at Location 16 – Upstream Slumping Site 1

Figure 1.11 - Location 16 Southern Slumping Site During Mine Water Discharge on 20 April 2009 (No Obvious Water Loss - Upstream Flow Similar to Downstream Flow)

Figure 1.12 - Location 16 Southern Slumping Site - No Mine Water Discharge on 1 May 2009

Figure 1.13 - Location 16 Southern Slumping Site - No Mine Water Discharge on 28 June 2013

Photos at Locations 7-9 Northern Slumping Site and Cavity Site

Figure 1.14 - Location 7-9 Northern Slumping and Cavity Site - During Mine Water Discharge on 20 April 2009 (Complete Water Loss -No Downstream Flow)

Figure 1.15 - Location 7-9 Northern Slumping and Cavity Site - No Mine Water Discharge on 1 May 2009 – Hole Where Water Loss Occurred

Figure 1.16 - Location 7-9 Northern Slumping Site - No Mine Water Discharge on 1 May 2009

Figure 1.17 – Location 7-9 Northern Slumping Site on 28 June 2013 – note vegetation impacts

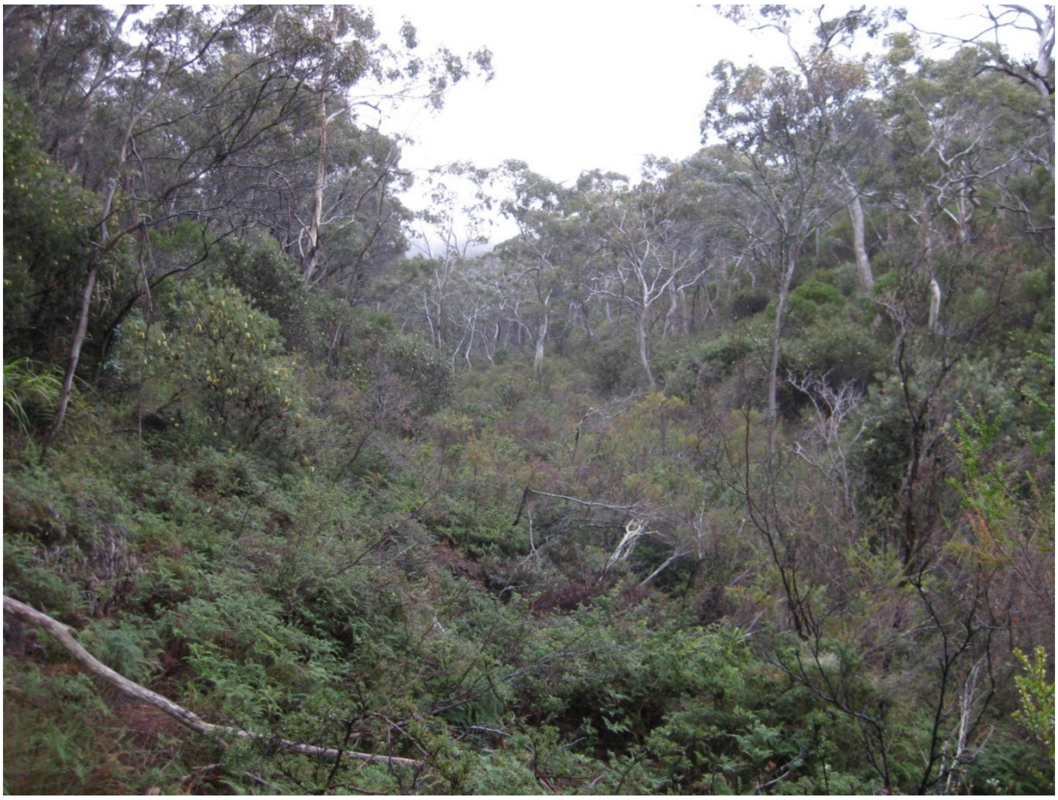


Figure 1.18 - Location 7-9 Northern Slumping Site Looking Downstream (North) on 28 June 2013 – Note that there is **No Apparent Effect of Cavity on Downstream Vegetation**

Figure 1.19 Location 7 Northern Slumping Site Looking Downstream (North) on 28 June 2013 - note erosion channel in peat downstream of cavity (concentrated flow path for mine water discharge)

Other Photos of EWS From Locations 1-3 (Between Slumping Sites)

Figure 1.20 East Wolgan Swamp in Area Affected by Mine Water Discharge. Note surface erosion and remnants of topsoil secured from erosion by (dead) root biomass (hummocky surface)

Figure 1.21 - Looking Across East Wolgan Swamp from the Flow Path of Mine Water Discharge Towards Swamp Unaffected by Mine Water Discharge - Note Limited Regrowth of Sedges and Weeds

Figure 1.22 - East Wolgan Swamp in Area Affected by Mine Water Discharge – Note Limited Regrowth of Sedges Outside of Erosion Channels

Figure 1.23 - East Wolgan Swamp Between Slumping Locations – Note Erosion Channels and Sediment Deposition Caused by Mine Water Discharge

Figure 1.24 Photo of East Wolgan Swamp at WE2 Piezometer location showing vegetation damage along flow path of mine water discharge – not evident outside of flow path

Figure 1.25 Photo of East Wolgan Swamp downstream of WE2 Piezometer location showing vegetation damage along flow path of mine water discharge – not evident outside of flow path.

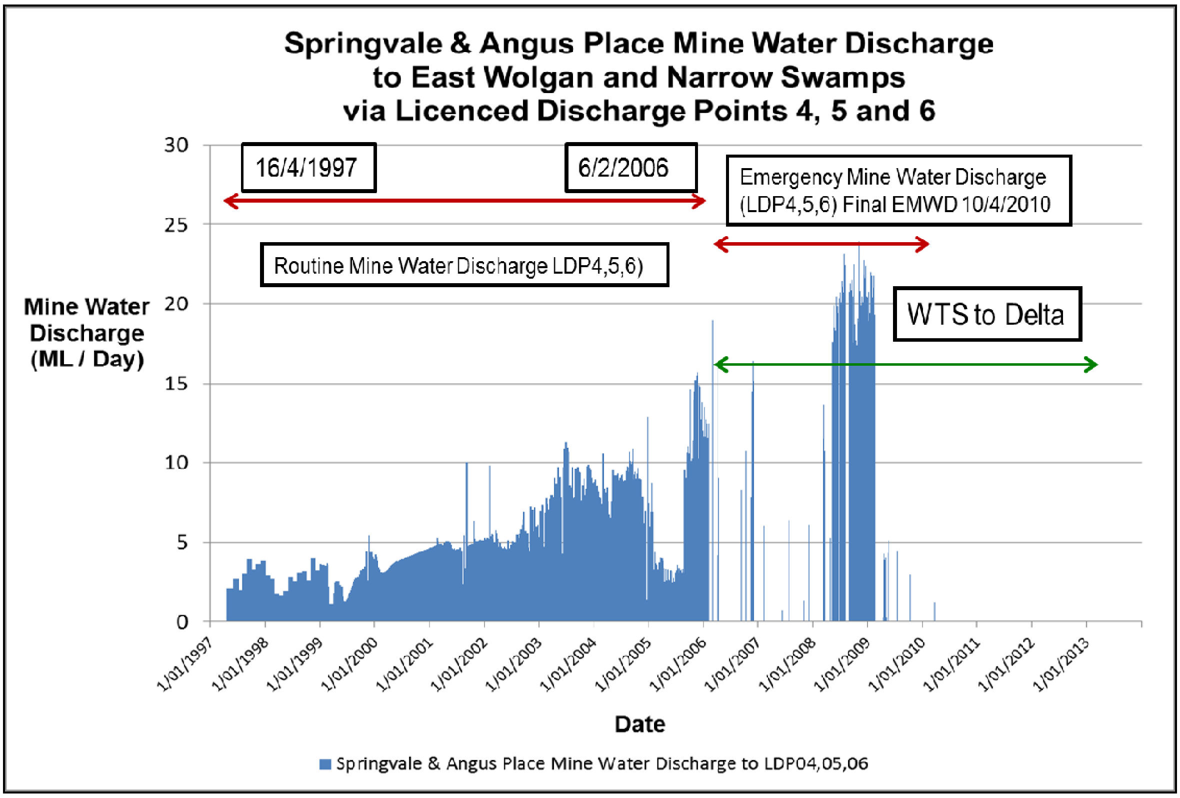


Figure 1.26 Mine Water Discharge to East Wolgan and Narrow Swamps via Licenced Discharge Points 4, 5 and 6 – first discharge 16/4/1997, no discharges since 10/4/2010

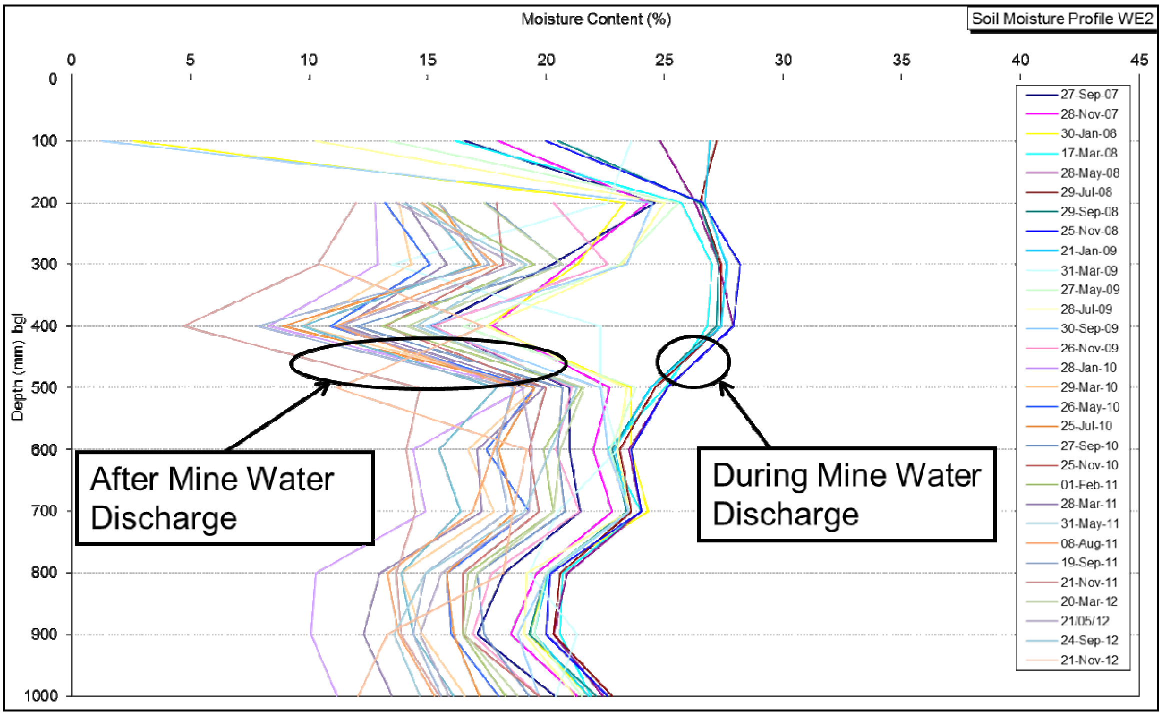


Figure 1.27 Soil Moisture Monitoring Data from WE2 Piezometer Location in East Wolgan – Showing Differences Between Results During and After Mine Water Discharge

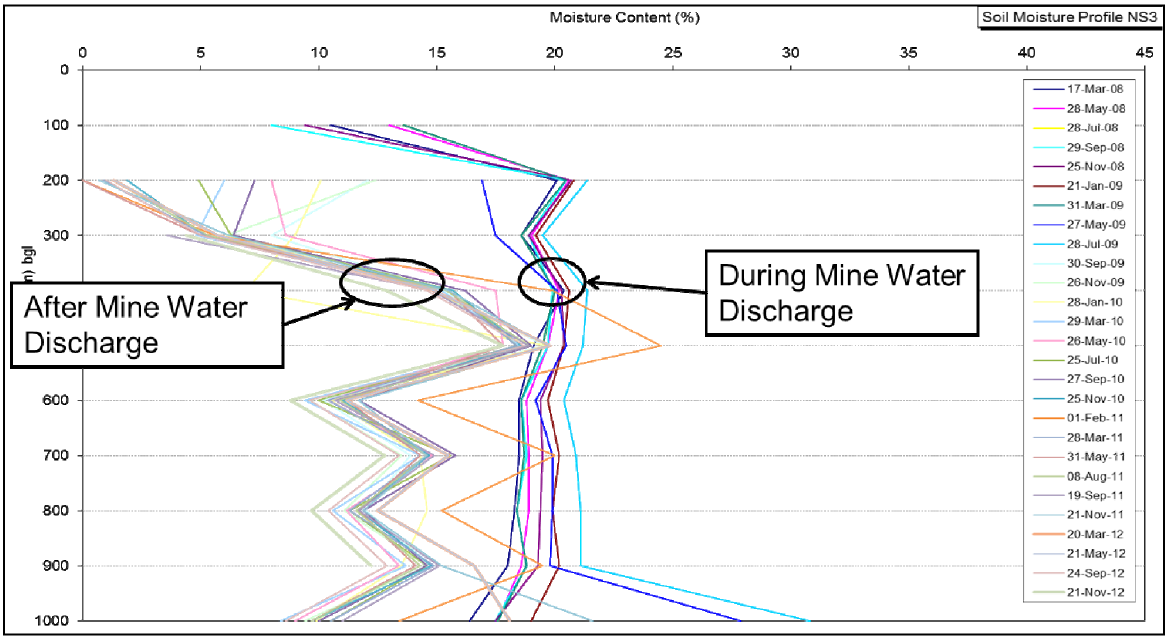


Figure 1.27(a) Soil Moisture Monitoring Data from NS Piezometer Location in Narrow Swamp – Showing Differences Between Results During and After Mine Water Discharge

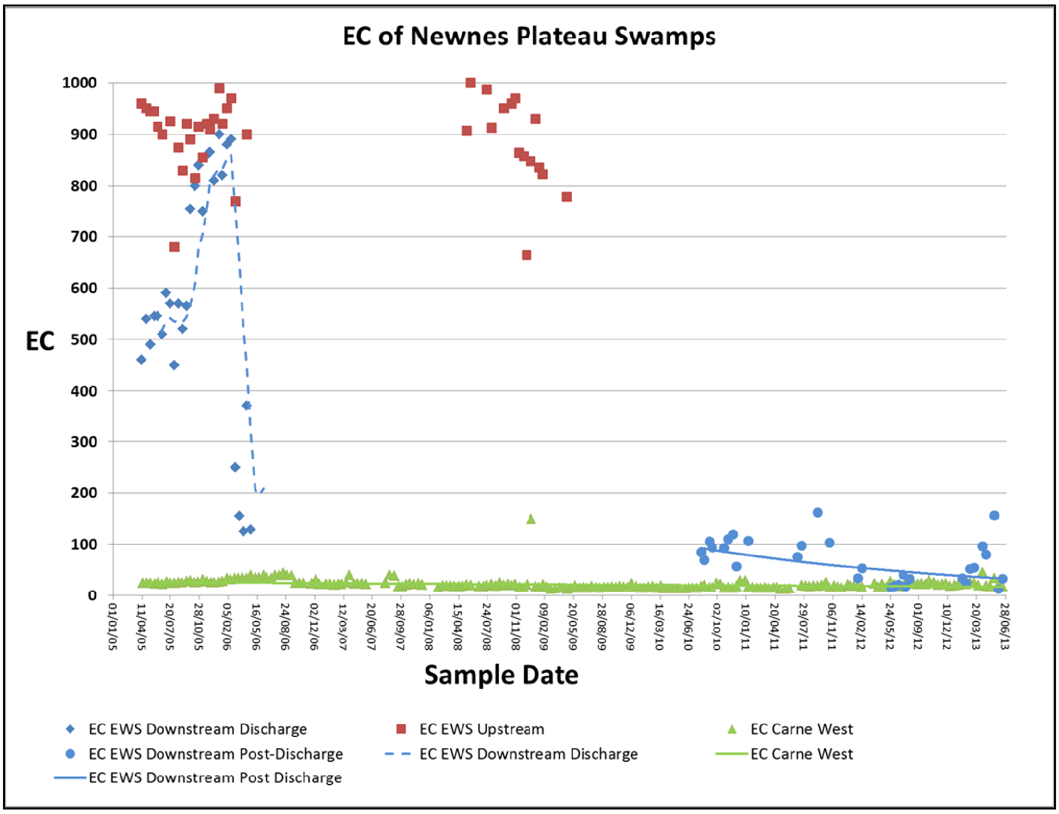


Figure 1.28 Electrical Conductivity (EC) Water Quality Data from Newnes Plateau Swamp Sampling Sites – showing significant differences between measured EC at swamps impacted by mine water discharge compared to typical Newnes Plateau swamp (Carne West). NB Elevated EC values are still being recorded at swamps impacted by mine water discharge three years after cessation of mine water discharge, but the trend is back towards normal levels.

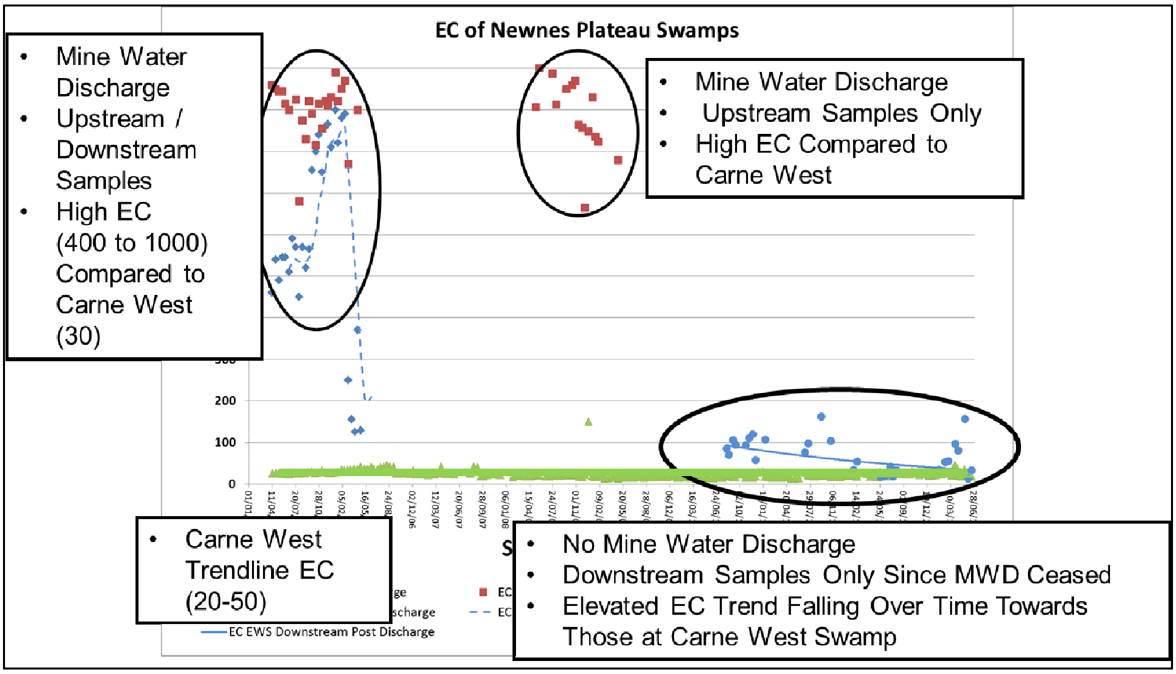


Figure 1.28(a) As per Figure 1.28 with Explanation of Interpretation of Data

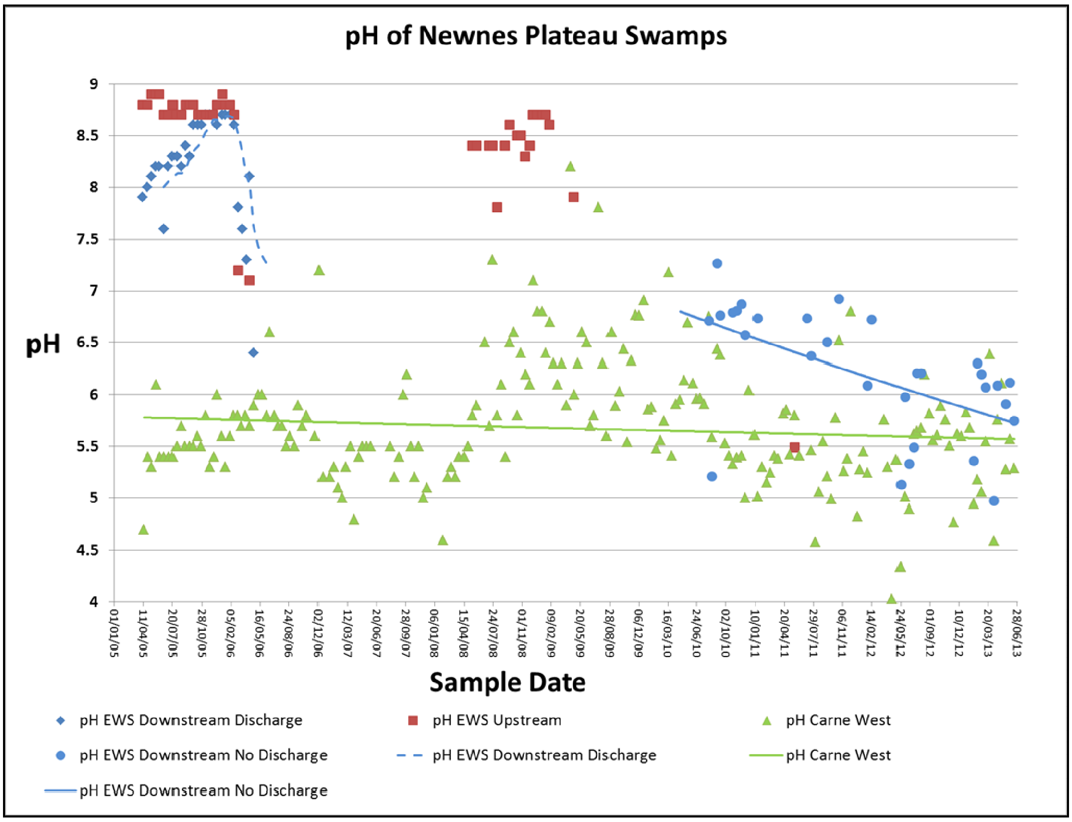


Figure 1.29 Water Quality Data (pH) from Newnes Plateau Swamp Sampling Sites – showing significant differences between measured pH at swamps impacted by mine water discharge compared to typical Newnes Plateau swamp (Carne West). NB Elevated pH values are still being recorded at swamps impacted by mine water discharge three years after cessation of mine water discharge, but the trend is back towards normal levels.

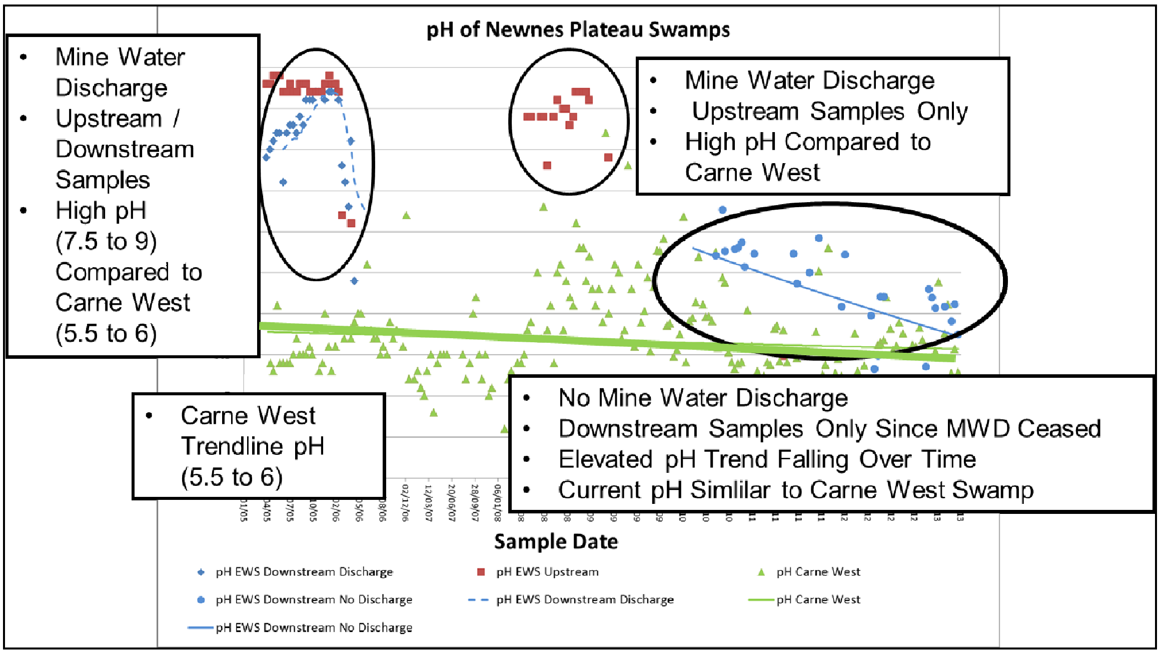


Figure 1.29(a) As per Figure 1.29 with Explanation of Interpretation of Data

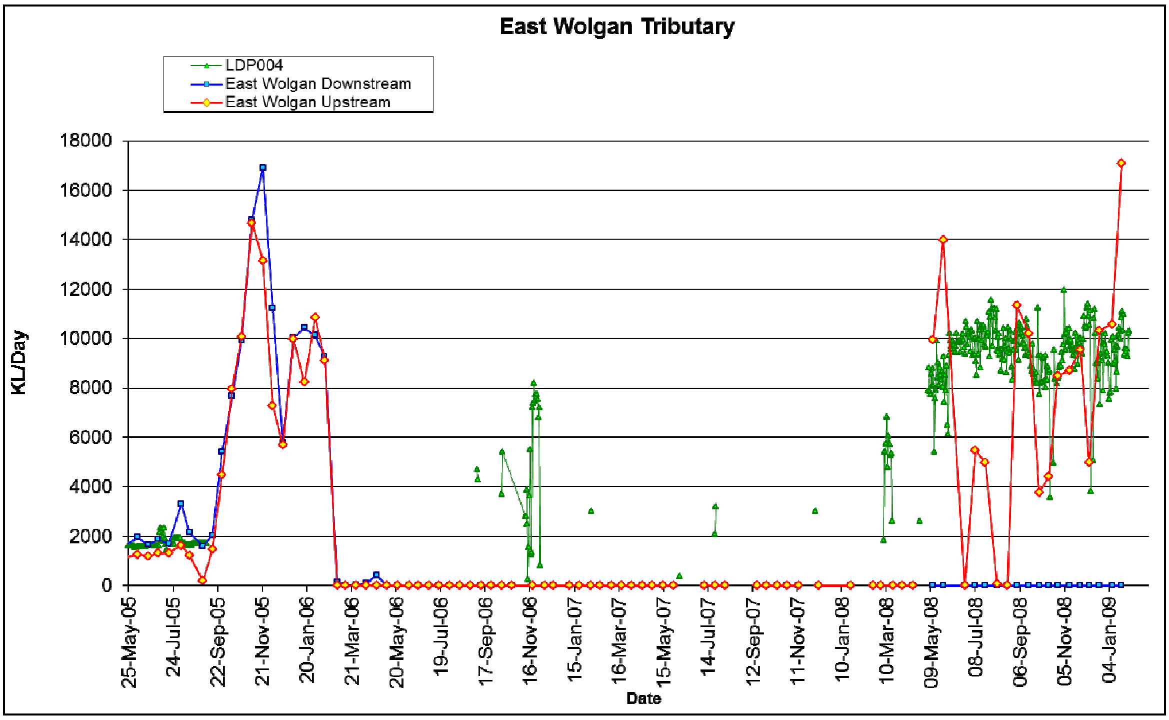


Figure 1.30 Mine Water Discharges into East Wolgan Swamp with Upstream and Downstream Flows – Water loss into cavity occurred at some time between April 2006 and May 2008.

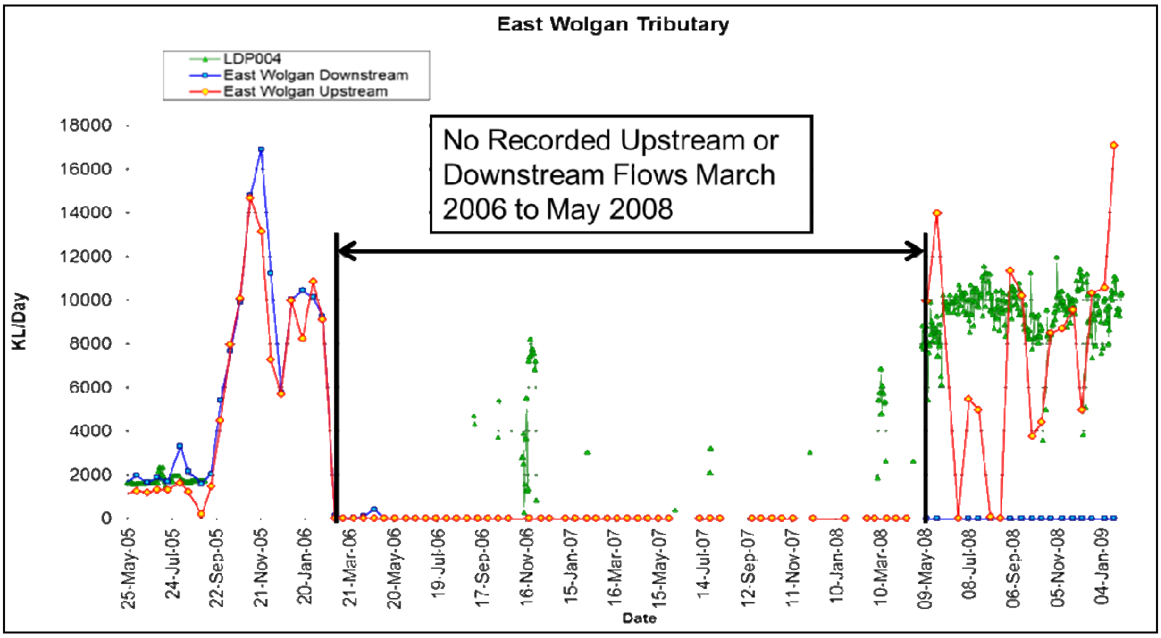


Figure 1.30(a) As per Figure 1.30 with Explanation of Interpretation of Data

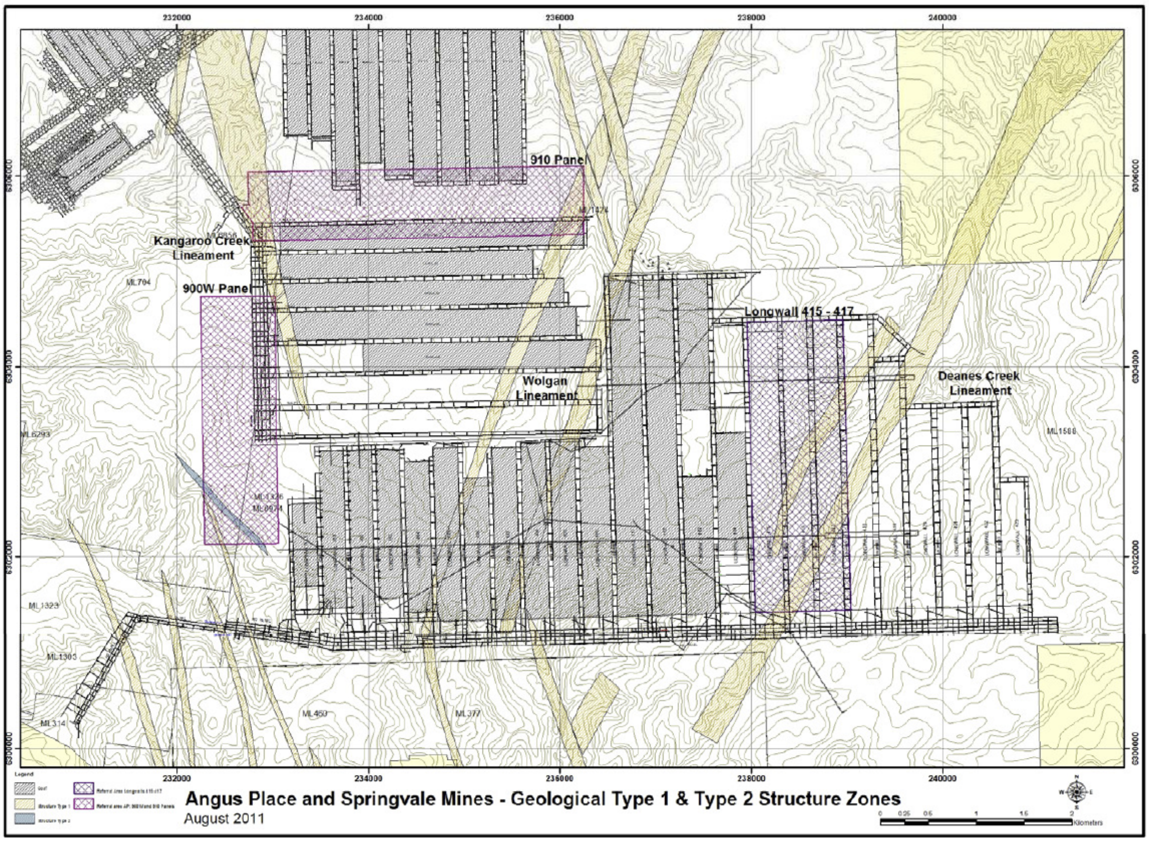


Figure 1.31 Plan of Angus Place and Springvale Mine Workings Relative to Interpreted Major Geological Zones – note that the Eastern Wolgan Lineament Zone crosses Springvale Mine's Longwall 411 at the cavity location

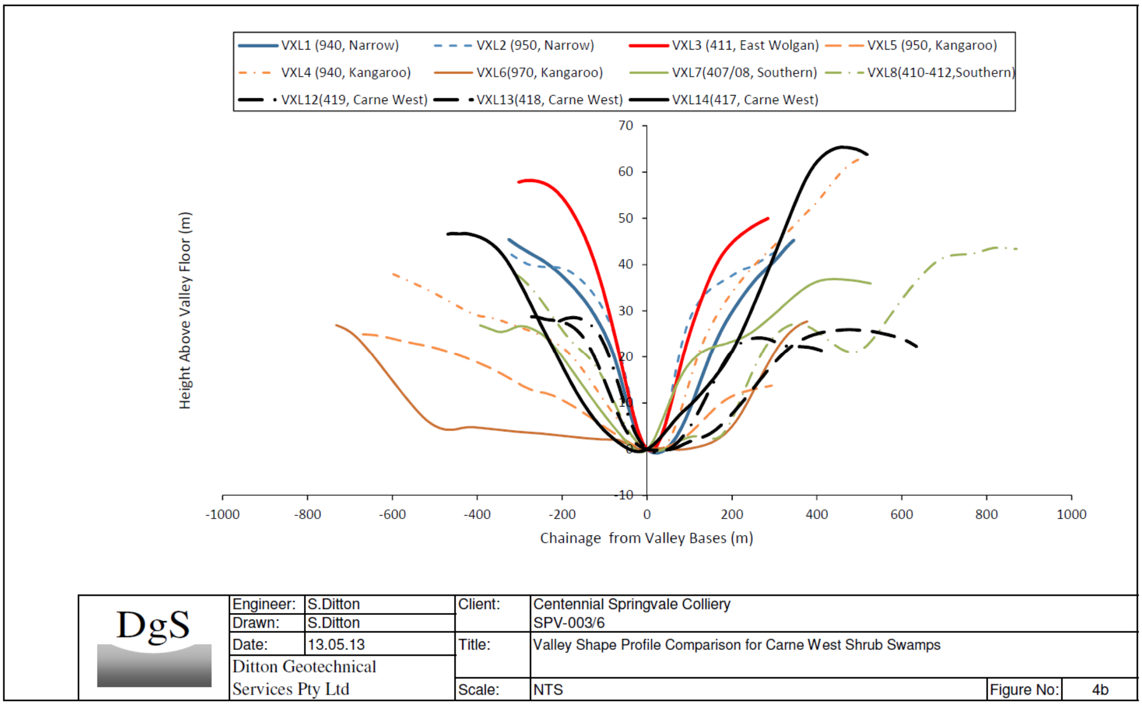


Figure 1.32 Valley Profiles of East Wolgan Swamp compared to Carne West Swamp – note the steeper valley wall gradients and generally greater depth of the valley at East Wolgan Swamp (in red) compared to Carne West Swamp (black)

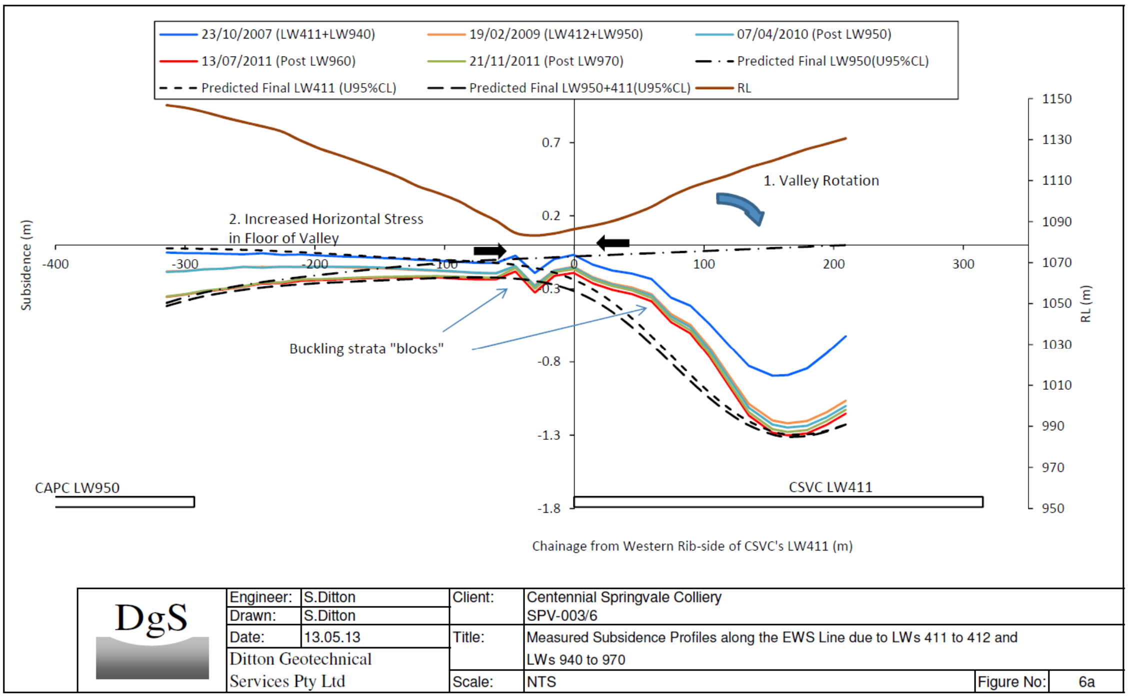


Figure 1.33 Cross Section Of Mine Workings, Surface Topography and Measured Subsidence on the EWS Survey Line at East Wolgan Swamp (adjacent to the Southern Slumping Area) showing the subsidence mechanism at East Wolgan Swamp – note valley rotation leading to increased compressive horizontal stress in valley floor resulting in buckling strata.

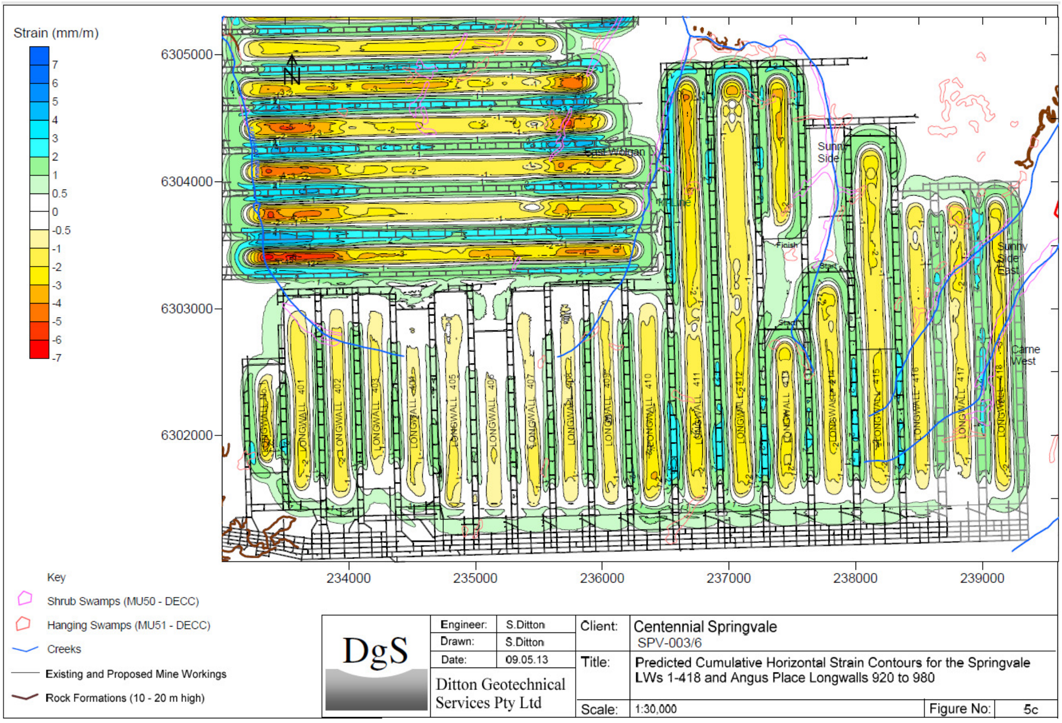


Figure 1.34 Plan of Predicted Cumulative Strains for the Current and Proposed Mine Workings at Springvale and Angus Place Mines – note that cavity formation occurred at the location of the greatest predicted strains in the Springvale mine workings

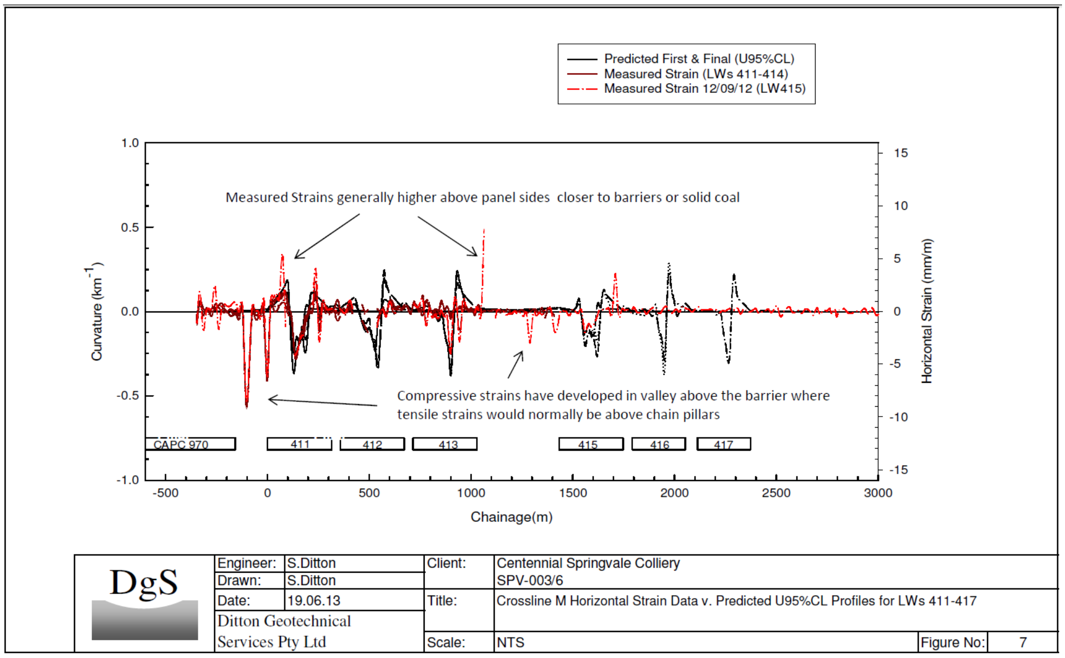


Figure 1.35 Graph of Measured and Predicted Strains Relative to Mine Workings on the M Line at Springvale Mine – note the greater measured strains adjacent to large “barrier pillars” and the development of compressive strains (above large barrier pillars) rather than tensile strains (above smaller chain pillars) in valleys

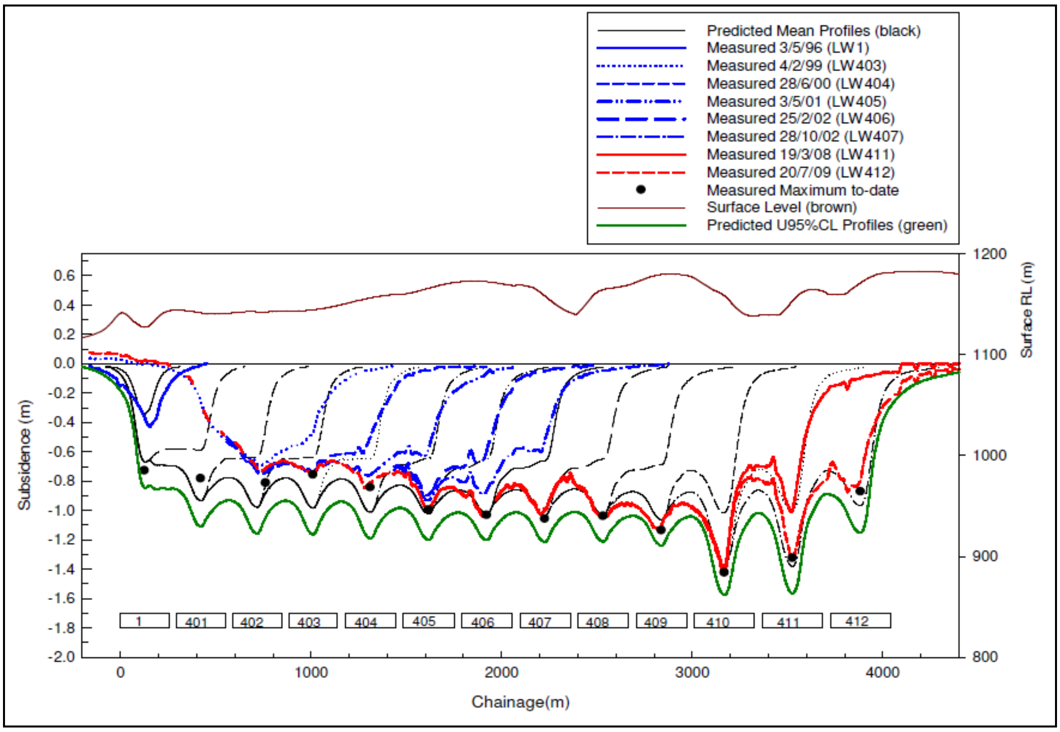


Figure 1.36 Measured Subsidence at Springvale Mine (B-Line) showing differences in subsidence for sub-critical panels widths (Longwalls 1 and 401-409) where measured subsidence was around 1m compared to critical panel widths (Longwalls 410-412) where measured subsidence was around 1.4m.

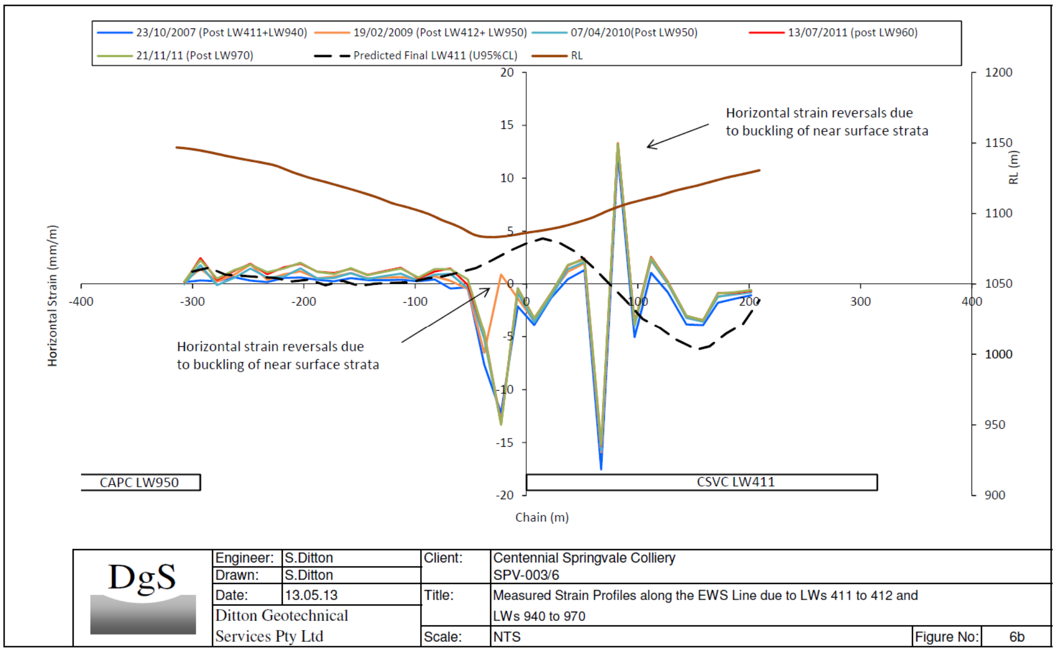


Figure 1.37 Cross Section of Mine Workings, Surface Topography and Measured Strains on the EWS Survey Line at East Wolgan Swamp (adjacent to the Southern Slumping Area) – note the horizontal strain reversal in the valley floor due to buckling of near surface strata, which occurred after the commencement of Angus Place's Longwall 950

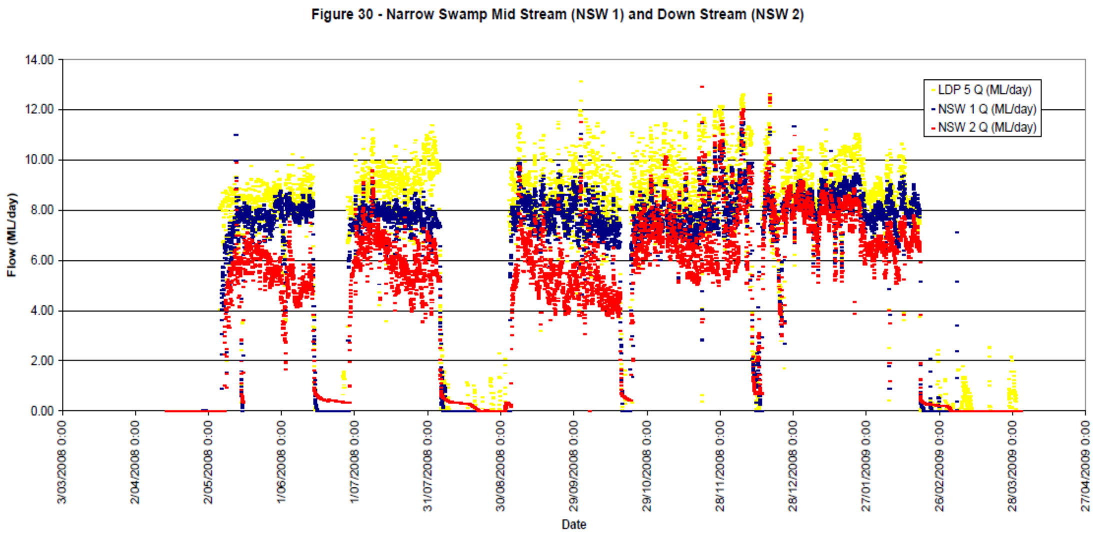


Figure 1.38 Graph of Mine Water Discharge at Licenced Discharge Point 5 compared to downstream flow monitoring at Narrow Swamp – note similarity of trend of discharge flows compared to upstream and downstream flow monitoring i.e. similar losses through monitoring period from pre-mining to post-mining period

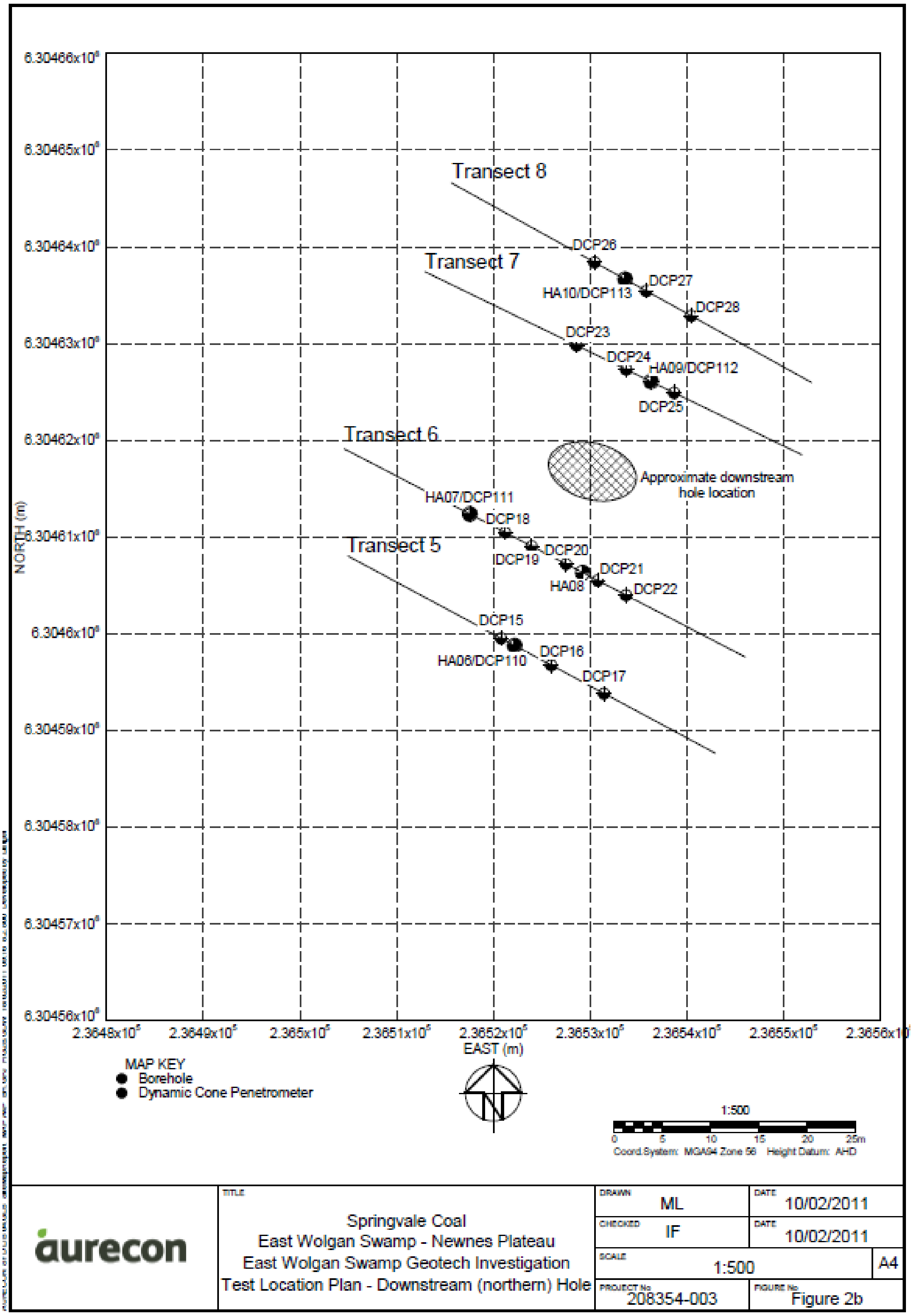
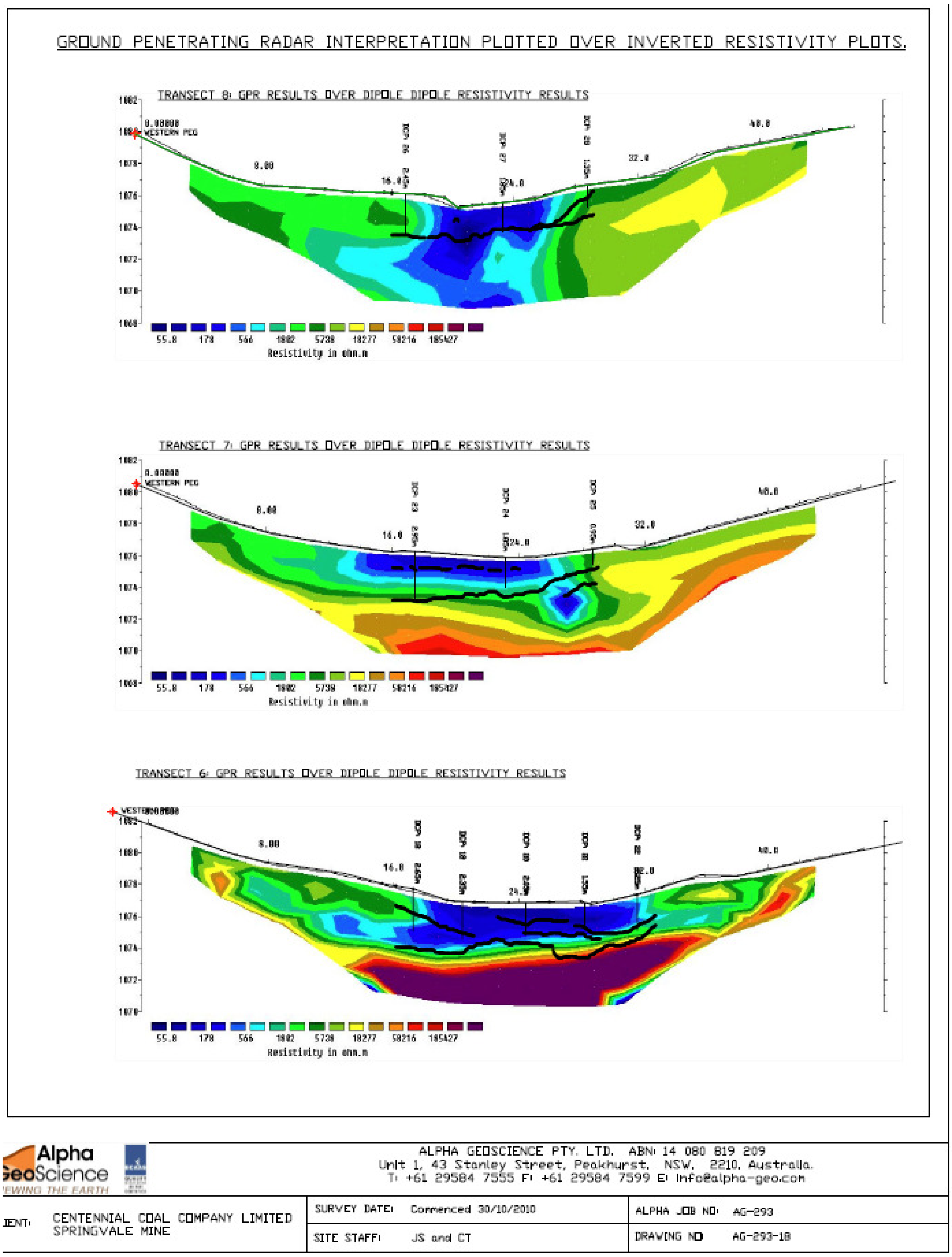


Figure 1.39 Plan Showing Geophysical and Geotechnical Investigation Transect Locations Relative to the Northern Peat Slumping Location – note similar investigation was conducted at the Southern Peat Slumping Site. Investigations Conducted Included Ground Penetrating Radar, Resistivity, Peat / Soil Geotechnical Sampling & Testing and Dynamic Cone Penetrometer Testing



- Figure 1.40 – Ground Penetrating Radar Interpretation Plotted Over Inverted Resistivity Plots "The use of resistivity profiling has mapped a deeper conductive zone at a number of locations. These deeper features may be the result of a minor fault or fracture zone carrying water". This important because if the fault zone is carrying water, that means it is NOT draining it away from the base of the swamp – these transect study locations are in close proximity to the cavity (as shown in Figure 1.39)

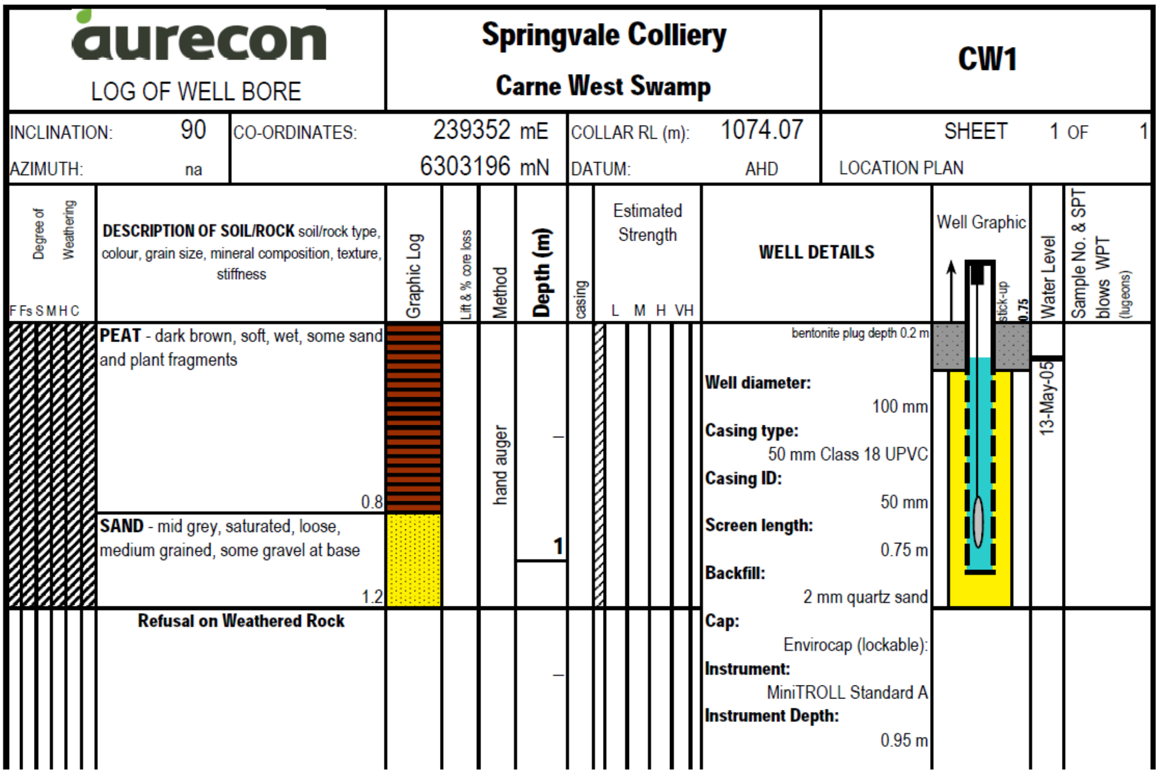


Figure 1.41 Example of Recorded Information at Swamp Piezometer Installations

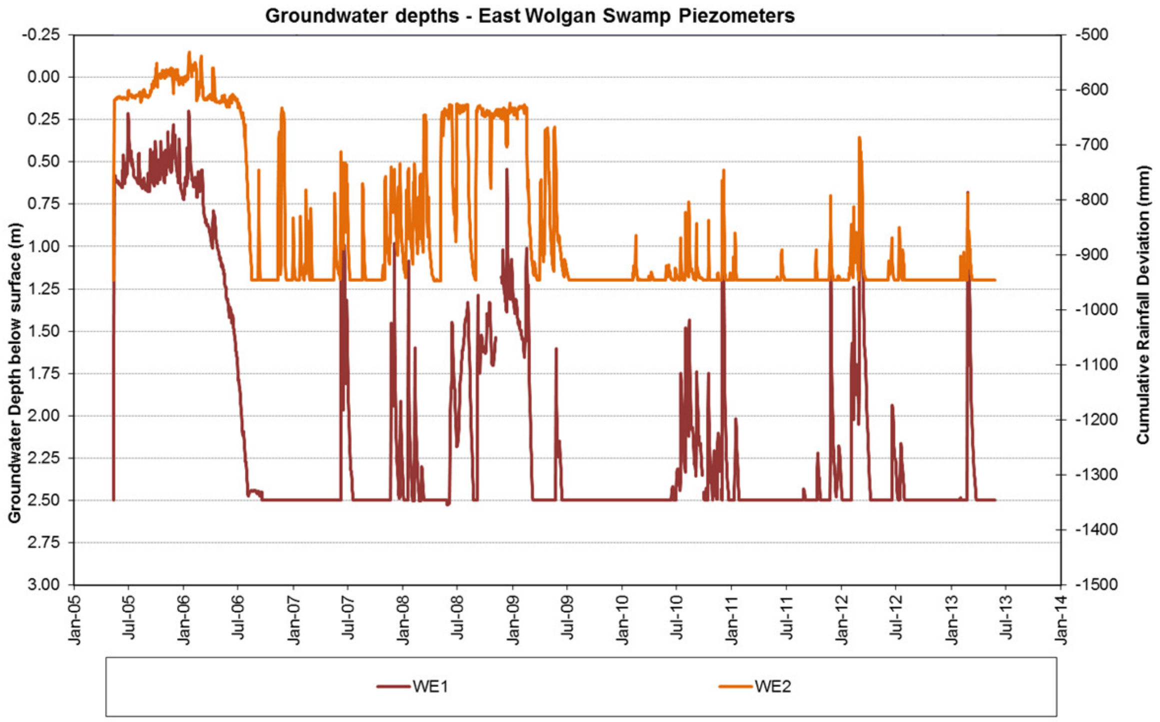


Figure 1.42 Hydrograph of East Wolgan Swamp Piezometers WE1 and WE2

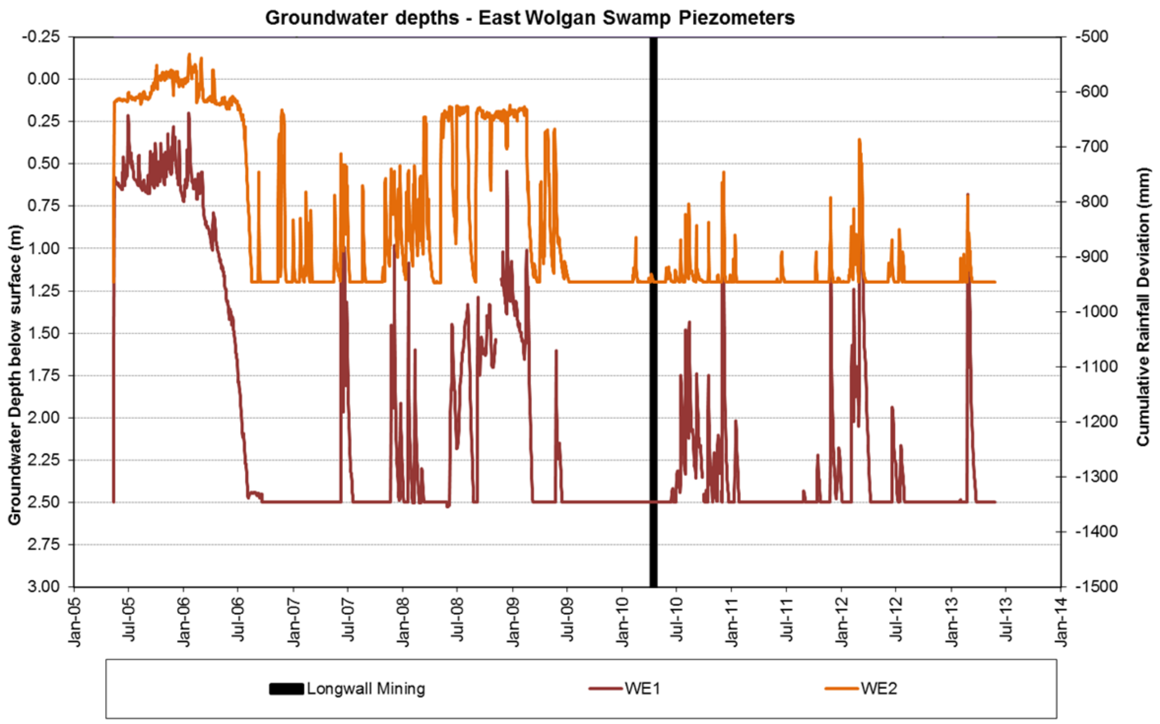


Figure 1.43 Hydrograph of East Wolgan Swamp Piezometers WE1 and WE2 showing time when Angus Place Longwall 960 undermined WE1 piezometer – note no relationship between piezometer response and time of undermining

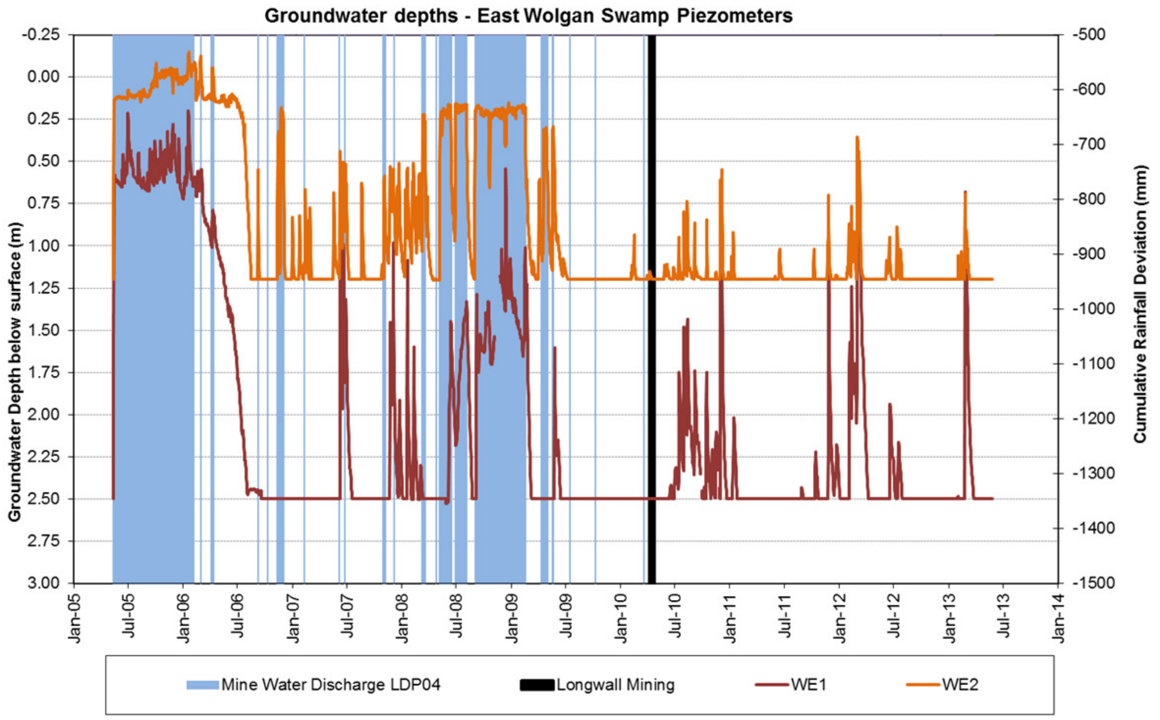


Figure 1.44 Hydrograph of East Wolgan Swamp Piezometers WE1 and WE2 showing times when mine water discharges from LDP04 were released into East Wolgan Swamp – note strong relationship between piezometer response and time of mine water discharges

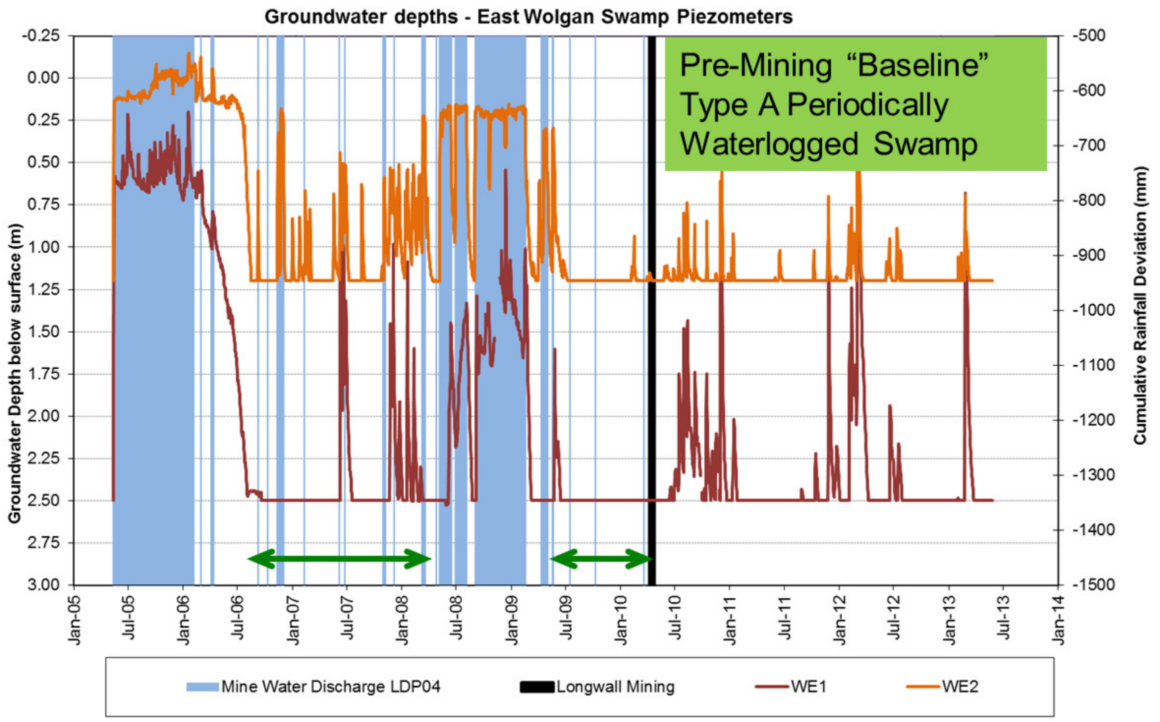


Figure 1.45 Hydrograph of East Wolgan Swamp Piezometers WE1 and WE2 showing the periods (in excess of two years) during which pre-mining data was not influenced by mine water discharge, which may be used to characterise the pre-

mining hydrology of East Wolgan Swamp – note that at both piezometer locations, the data shows that the standing water level was at or below the piezometer instrument (indicated by the flat horizontal line in the hydrograph trend) for most of the periods not influenced by mine water discharge. Based on this baseline data it is reasonable to conclude that East Wolgan Swamp was a periodically waterlogged swamp before commencement of mining activities.

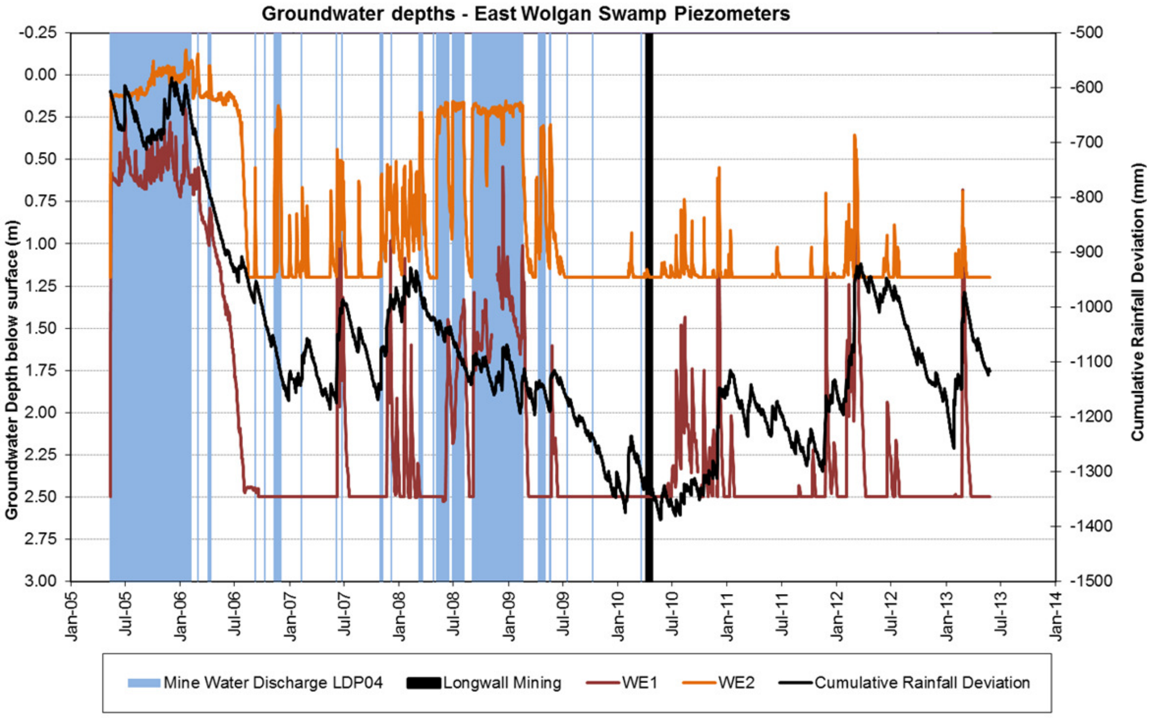


Figure 1.46 Hydrograph of East Wolgan Swamp Piezometers WE1 and WE2 showing the timing of mine water discharge and mining as well as the Cumulative Rainfall Deviation (CRD) trend. Following the cessation of mine water discharges, the hydrograph trends can be seen to be strongly influenced by rainfall. The Standing Water levels rise in response to rainfall events which are in excess of the long term average trends and fall in response to less than average rainfall trends. The responses are typically immediate and of short duration, indicated by the "spikes" in the hydrograph trends. When the data recorded during mine water discharged is removed, the same trend can be seen in the pre-mining baseline data.

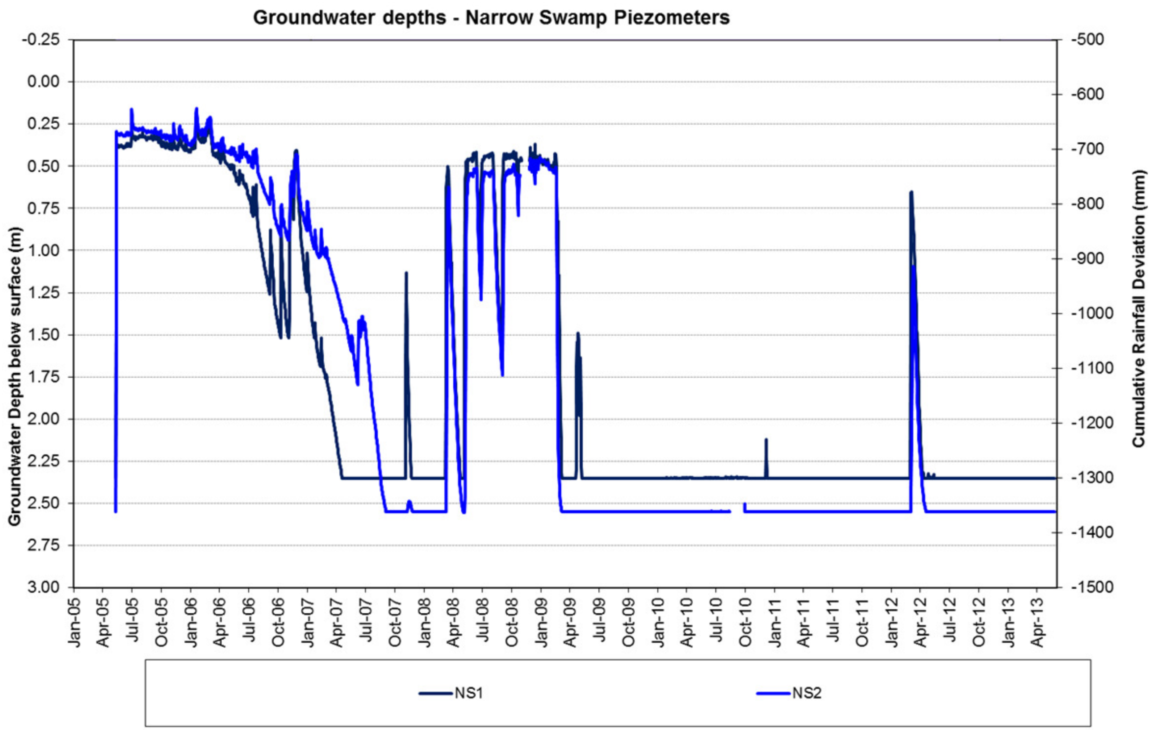


Figure 1.47 Hydrograph of Narrow Swamp Piezometers NS1 and NS2

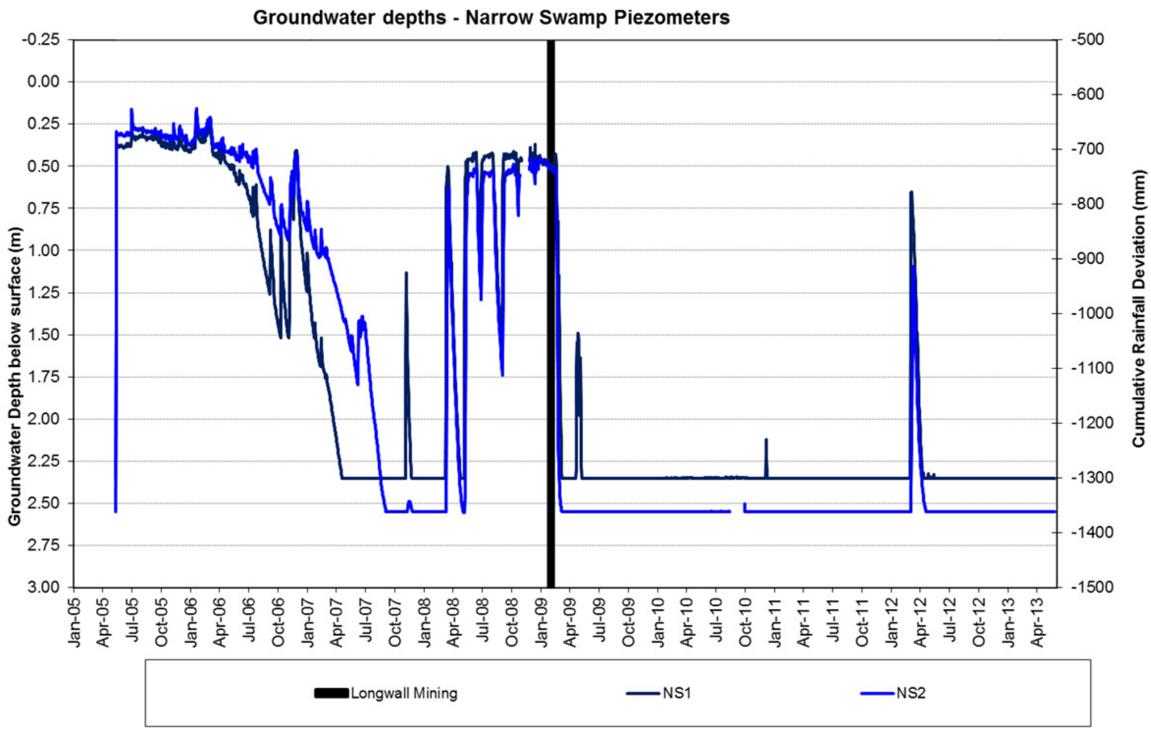


Figure 1.48 Hydrograph of Narrow Swamp Piezometers NS1 and NS2 showing time when Angus Place Longwall 950 undermined NS1 and NS2 piezometers – note piezometer response and time of undermining – see Figures 1.49 to 1.52 for detail of major factors influencing hydrograph

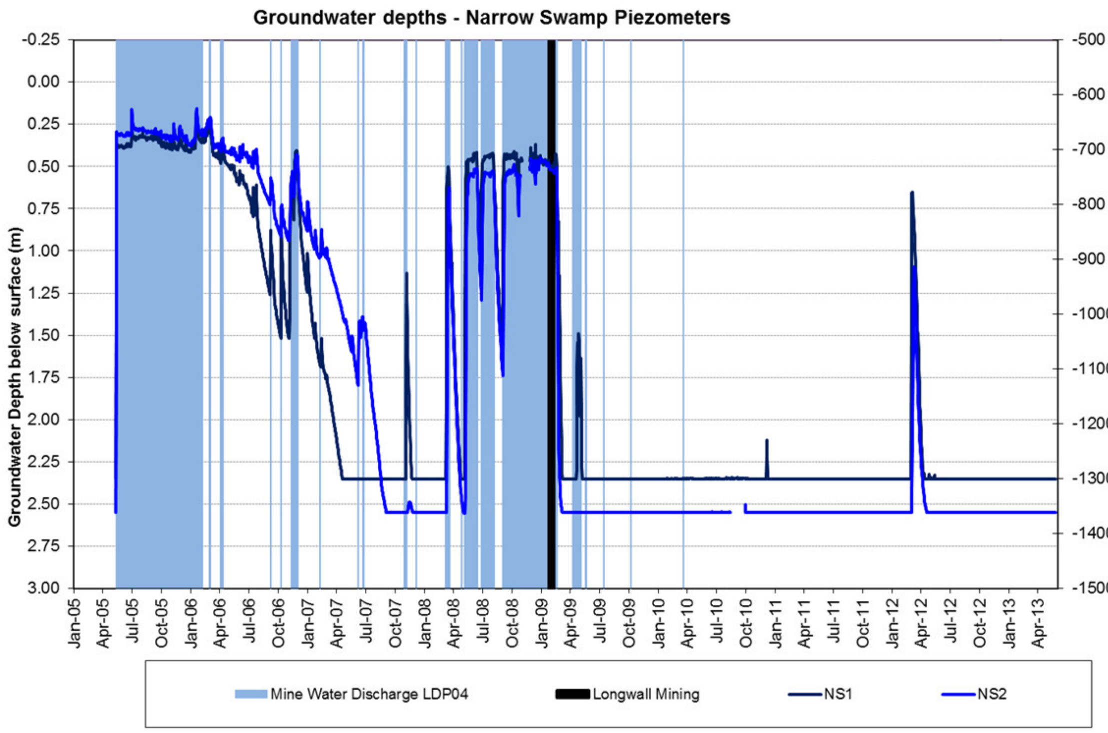


Figure 1.49 Hydrograph of Narrow Swamp Piezometers NS1 and NS2 showing times when mine water discharges from LDP05 were released into Narrow Swamp – note strong relationship between piezometer response and time of mine water discharges

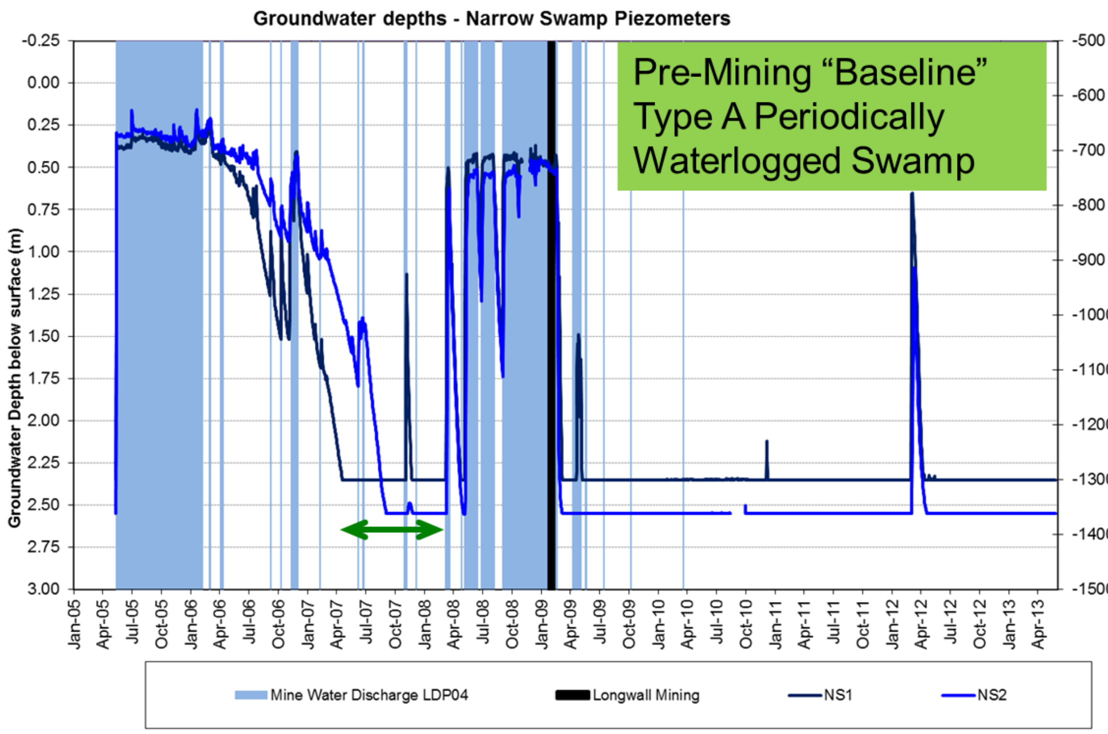


Figure 1.50 Hydrograph of Narrow Swamp Piezometers NS1 and NS2 showing the periods (approximately 12 months) during which pre-mining data was not influenced by mine water discharge, which may be used to characterise the pre-mining

hydrology of Narrow Swamp – note that at both piezometer locations, the data shows that the standing water level was at or below the piezometer instrument (indicated by the flat horizontal line in the hydrograph trend) for most of the period not influenced by mine water discharge. Based on this baseline data it is reasonable to conclude that Narrow Swamp was a periodically waterlogged swamp before commencement of mining activities. Piezometers NS3 and NS4 were not installed until 2008 and cannot be used to establish pre-mining swamp hydrology.

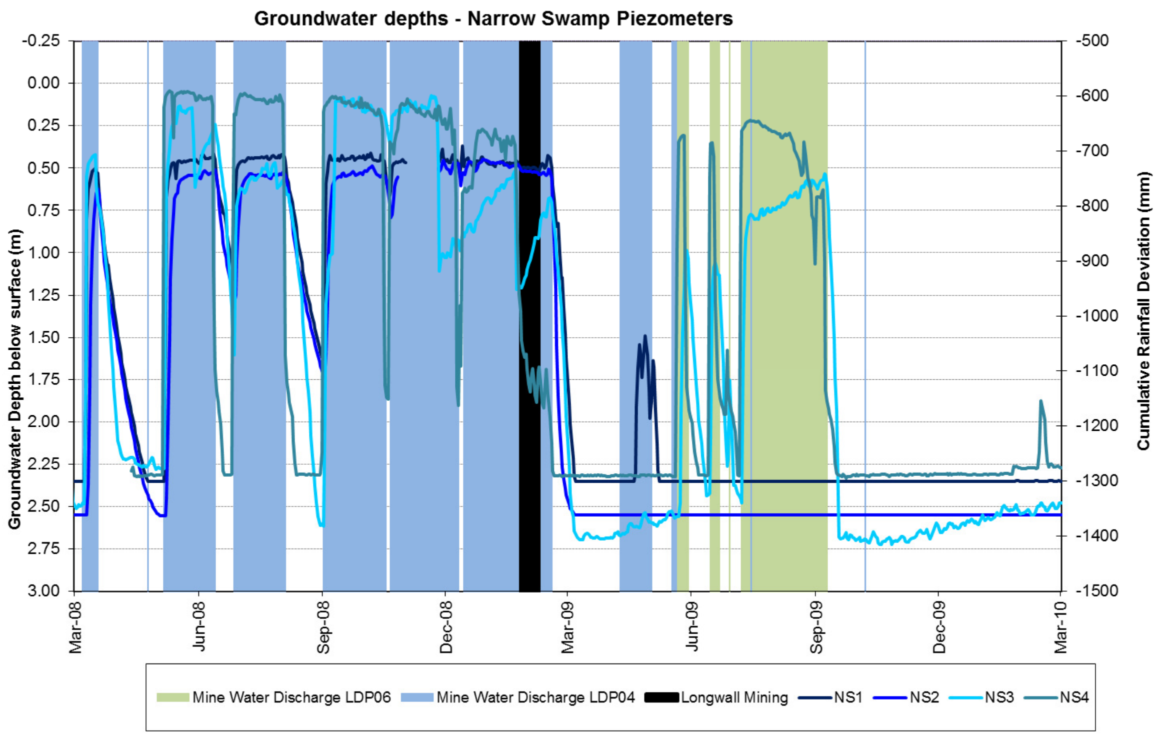


Figure 1.51 Hydrograph of Narrow Swamp Piezometers NS1, NS2, NS3 and NS4 showing times when mine water discharges from LDP05 and LDP06 were released into Narrow Swamp – note strong relationship between piezometer response and time of mine water discharges. Piezometers NS1and NS2 are positioned upstream of LDP06 and are not influenced by mine water discharge from this point. All Narrow Swamp piezometers are positioned downstream of LDP05 and are influenced by mine water discharge from this point. The timing of mining was similar to cessation of mine water discharges at LDP05, but the dominant influencing factor can be seen to be mine water discharges.

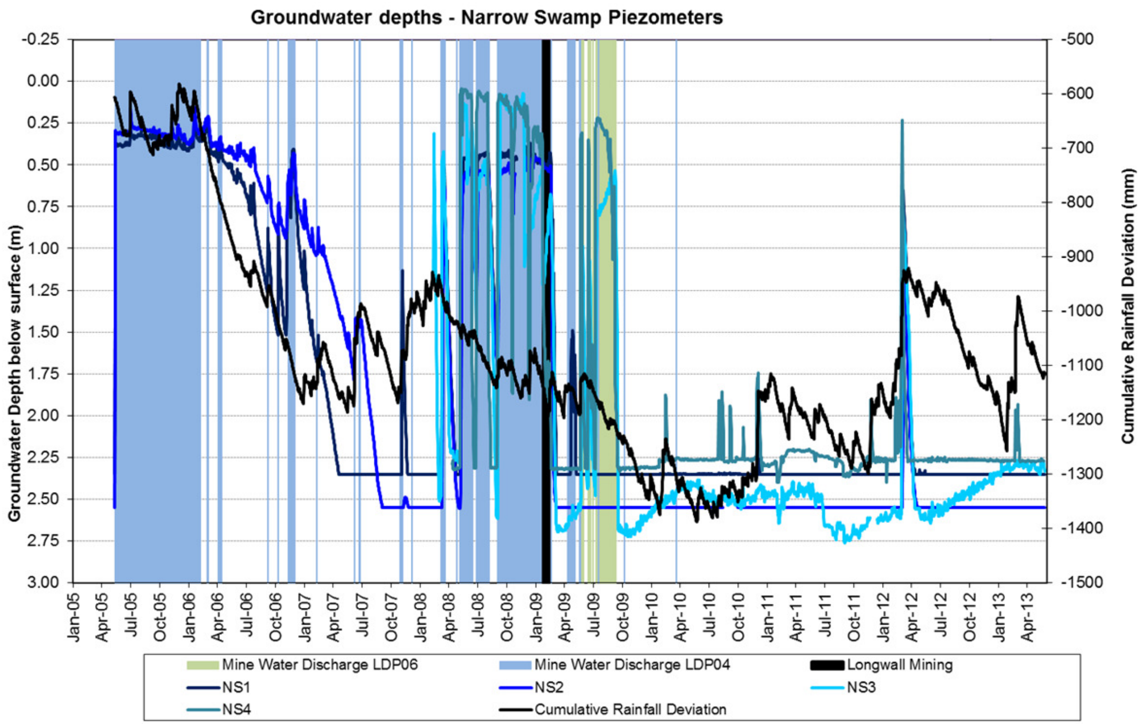


Figure 1.52 Hydrograph of Narrow Swamp NS1, NS2, NS3 and NS4 showing the timing of mine water discharge and mining as well as the Cumulative Rainfall Deviation (CRD) trend. Following the cessation of mine water discharges, the hydrograph trends can be seen to be strongly influenced by rainfall. The standing water levels rise in response to rainfall events which are in excess of the long term average trends and fall in response to less than average rainfall trends. The responses are typically immediate and of short duration, indicated by the “spikes” in the hydrograph trends. When the data recorded during mine water discharged is removed, the same trend can be seen in the pre-mining baseline data.

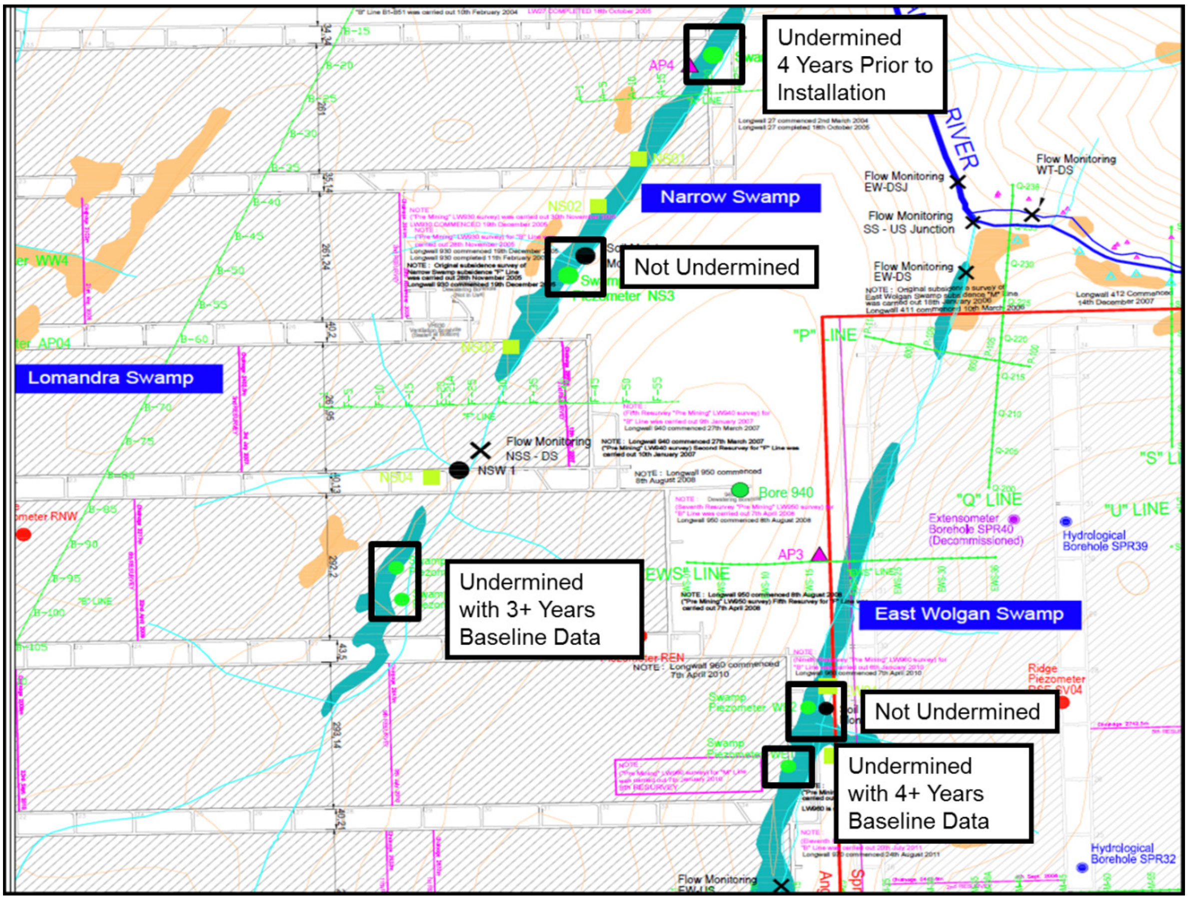


Figure 1.53 – Plan Showing Position of Narrow and East Wolgan Swamps and Piezometers Relative to Mine Workings Together With Summary of Baseline Data Gathered Prior to Mining

Instrument	Pre-Mining Baseline (years)	Hydrology (Waterlogged)	Comments
WE1	4	Periodically	
WE2	8	Periodically	Not Undermined
NS1	3	Periodically	
NS2	3	Periodically	
NS3	8	Periodically	Not Undermined
NS4	(4)	Periodically	Undermined 4 years prior to installation

Figure 1.54 – Summary of Piezometers Installed in Narrow and East Wolgan Swamps, Together With Pre-Mining Baseline Duration and Hydrology Classification Based on Piezometer Hydrographs

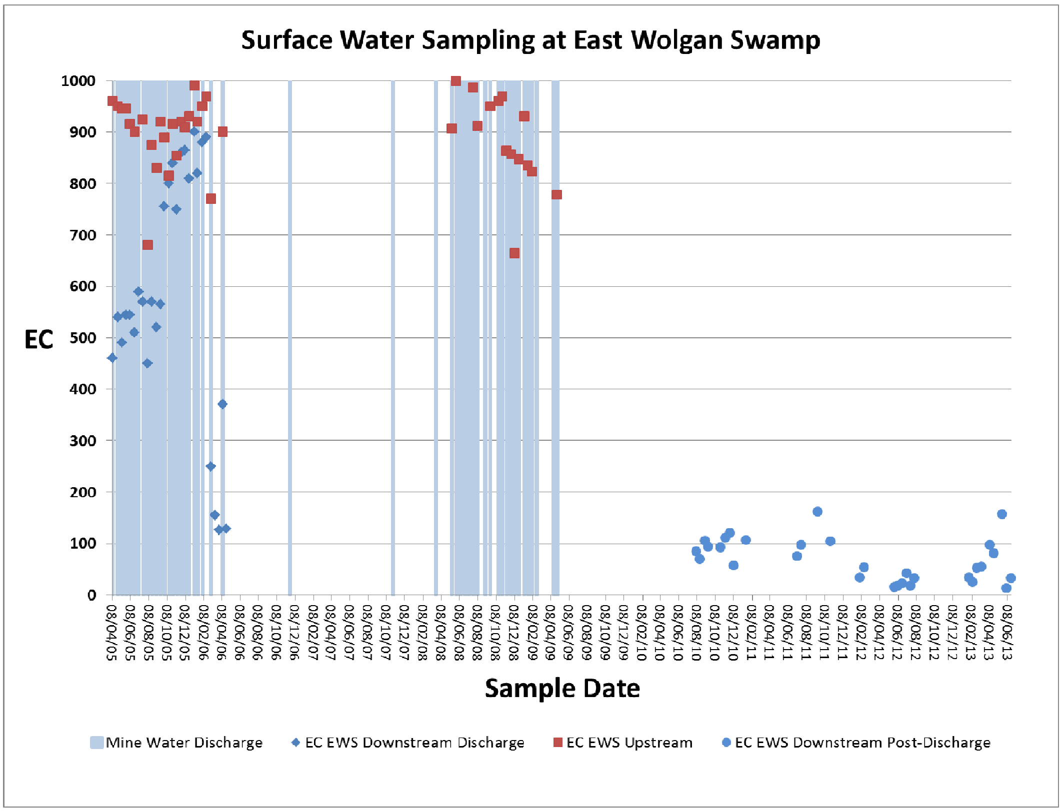


Figure 1.55 - Graph of Surface Water Monitoring (EC) Results for East Wolgan Swamp Upstream (EW-US) and Downstream (EW-DS) Monitoring Points. Of critical importance is the availability of surface water for sampling at the East Wolgan Downstream (EW-DS) sampling point – indicative of restoration of surface water flows downstream of the Northern slumping area and cavity in East Wolgan Swamp in the period since 4 August 2010. Prior to this there had been no recorded downstream sampling able to be conducted since April 2006 (even in periods of mine water discharge) due to loss of surface water flows into the cavity.

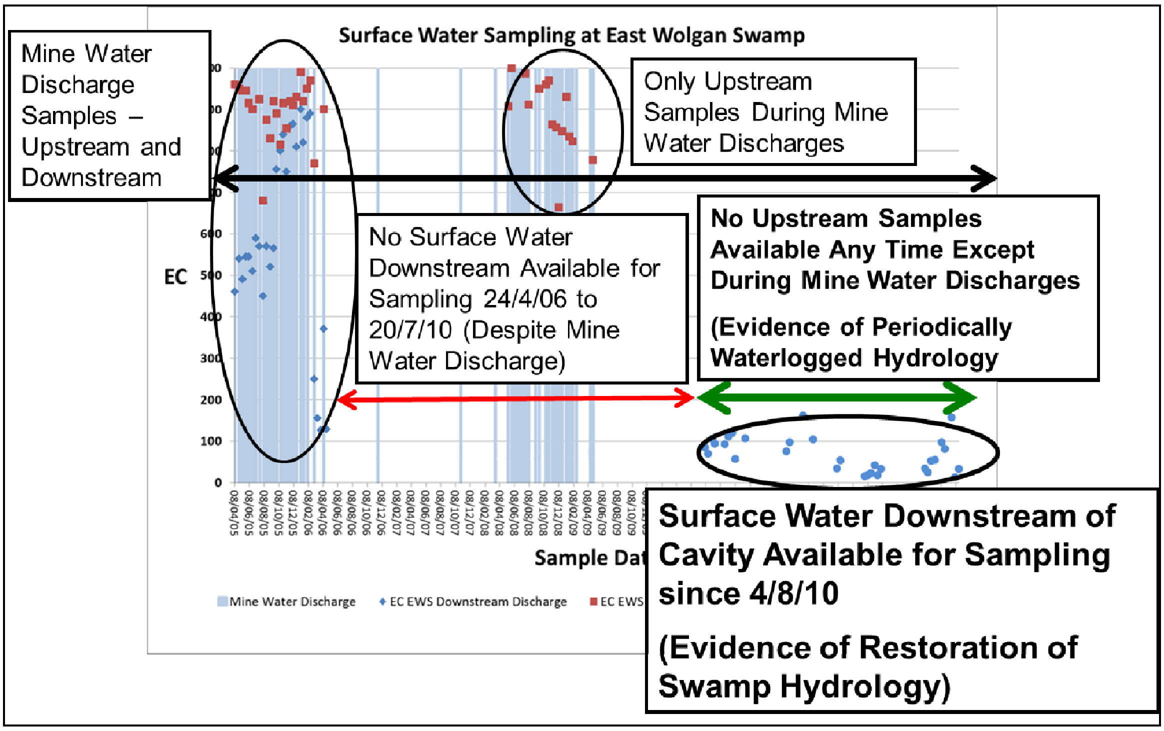


Figure 1.56 - Graph of Surface Water Monitoring (EC) Results for East Wolgan Swamp Upstream (EW-US) and Downstream (EW-DS) Monitoring Points (as per Figure 1.55) – including explanation of different data trends including the restoration of downstream surface water flows in East Wolgan Swamp since April 2010

Samples	pH	EC [µS/cm]
EW SS E	5.2	37
EW SS 0-10	7.37	67.4
EW SS 40-50	8.9	31.8
EW SS 60-70	8.83	51.5
EW SS 100-110	8.57	32.9

Figure 1.56(a) – Table Shows Soil Testing Results from Southern Slumping Location in East Wolgan Swamp – note that EW SS E sample was taken from outside of the path of mine water flows and appears to have relatively normal EC and pH values for a Newnes Plateau Shrub Swamp. The samples taken at various depths within the soil profile exposed within the Southern Slumping Location (in the path of the mine water flows) show relatively normal EC values, but the pH values are significantly higher than those typical for a Newnes Plateau Shrub Swamp i.e. the pH in the soil profile from within the slump is slightly alkaline at the top and alkaline towards the depth where expected range for an organic rich humous containing horizon is acidic.

Figure 1.57 Cavity Site During Mine Water Discharge on 20 April 2009 (Complete Water Loss - No Downstream Flow)

Figure 1.58 Cavity Site - No Mine Water Discharge on 1 May 2009 – Hole Where Water Loss Occurred

Figure 1.59 Cavity Site – 28 June 2013 – Infilling of Hole Where Water Loss Occurred Through Natural Processes

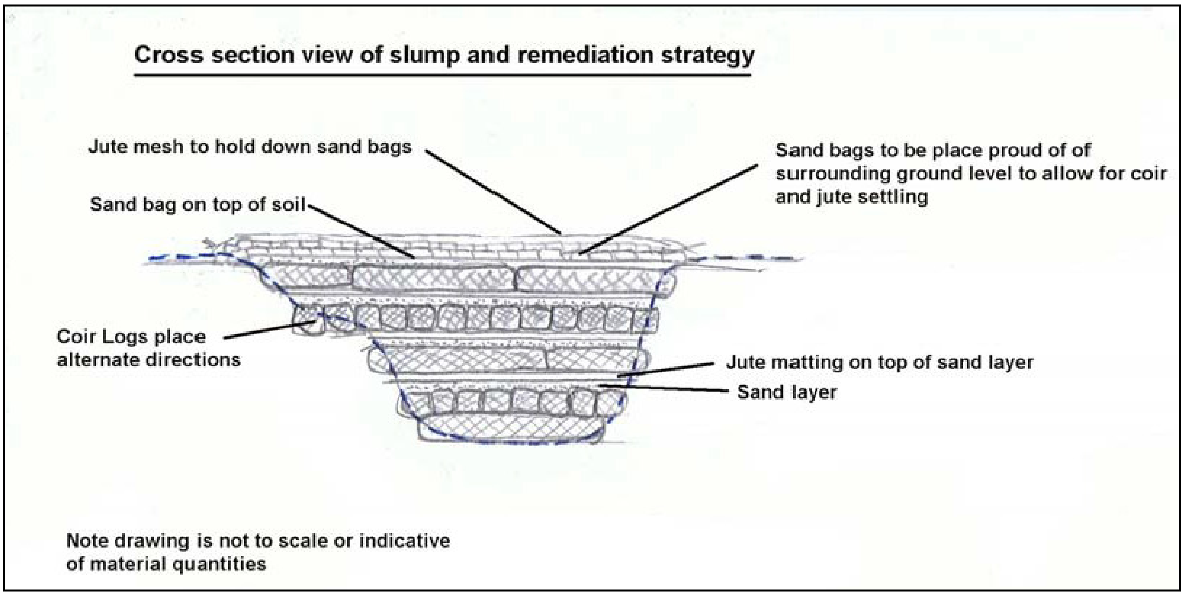


Figure 1.60 - Cross Section of Proposed Slump Remediation Methodology for East Wolgan Swamp

Figure 1.61 – Photo of Braeside Swamp at time of Remediation works using similar techniques to those proposed for channelized areas in East Wolgan Swamp

Figure 1.62 – Photo of Braeside Swamp approximately 12 months after remediation works using similar techniques to those proposed for channelized areas in East Wolgan Swamp

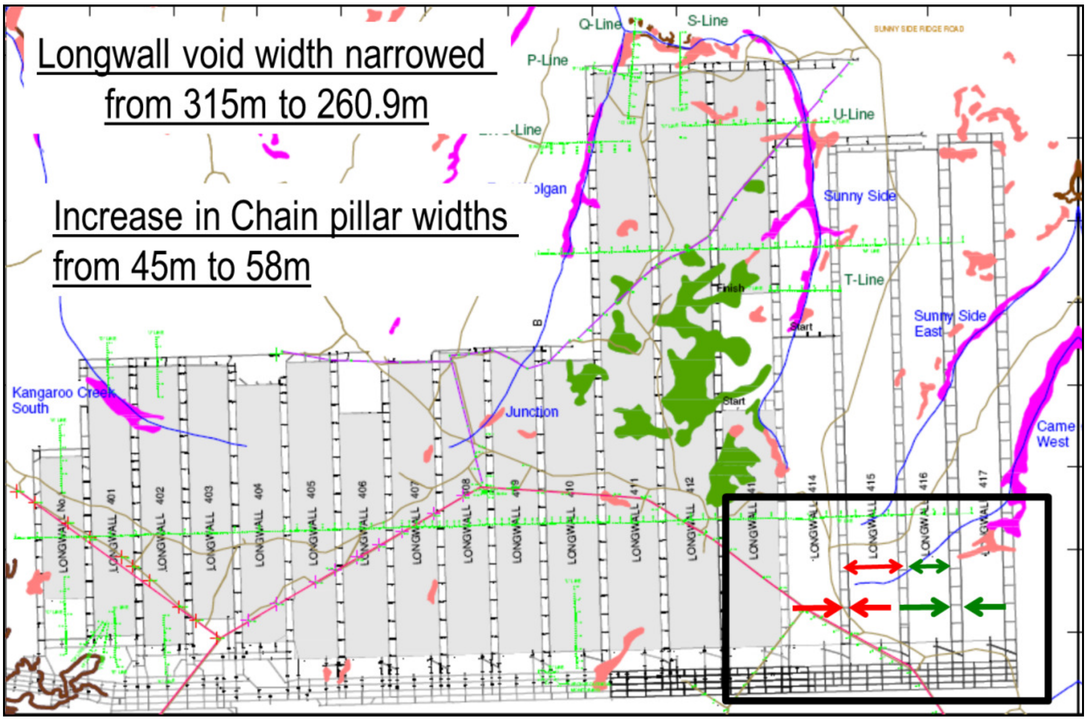


Figure 1.63 – Springvale Mine Plan illustrating changes to mine design to reduce subsidence

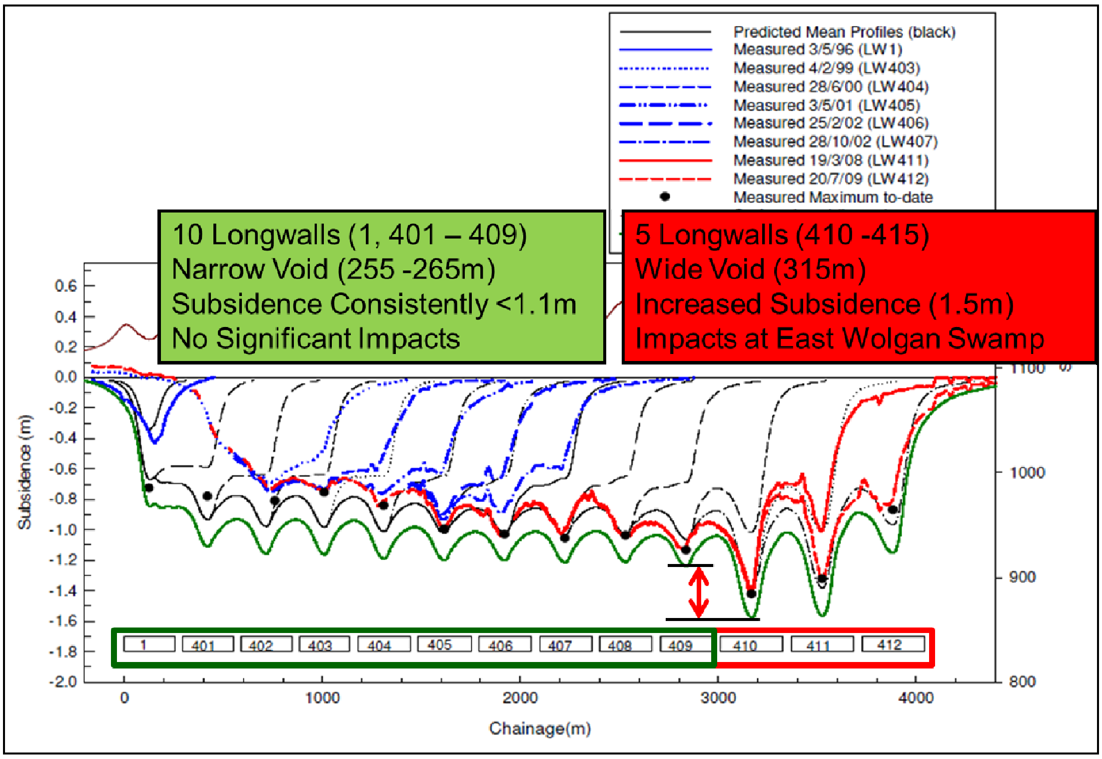


Figure 1.64 – Cross Section Showing Mine Subsidence Across 13 Longwalls at Springvale and Indicating Evidence Base for Reduced Void Width Leading to Reduced Subsidence

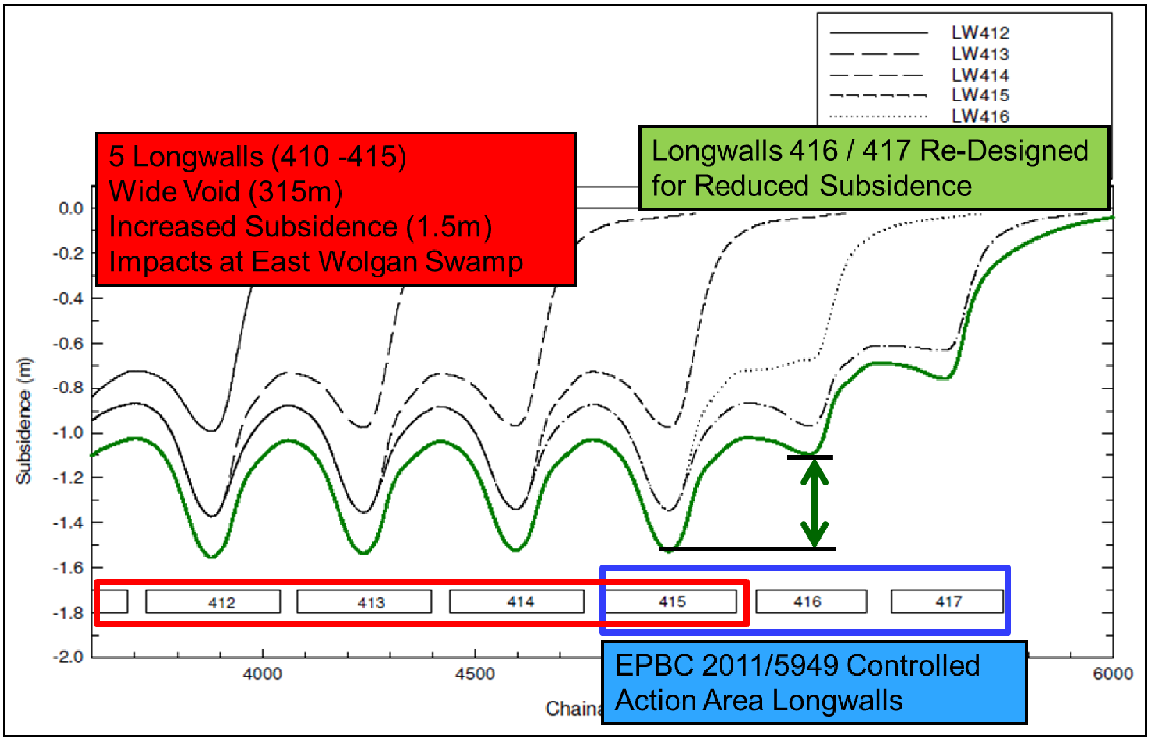


Figure 1.65 – Cross Section Showing Predicted Mine Subsidence Across Longwalls 412 to 417 at Springvale (including Longwalls 415 – 417 in the Controlled Action Area for EPBC 2011/5949) Showing Reduced Void Width Leading to Reduced Subsidence for Longwalls 416 and 417

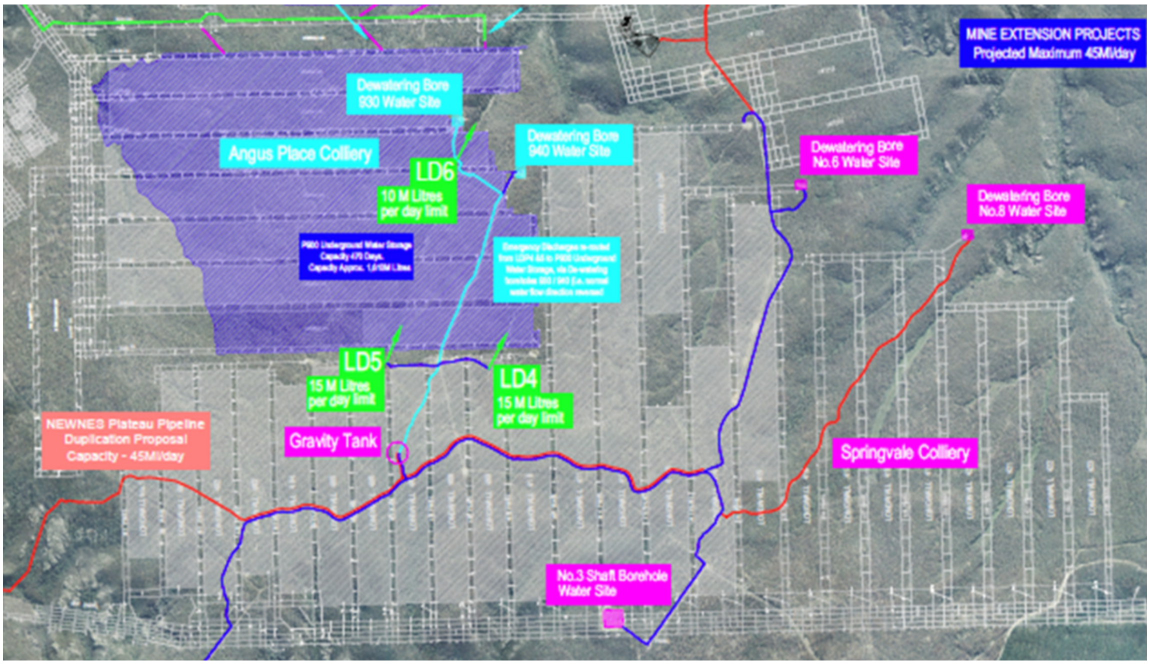


Figure 1.66 – Image of Springvale and Angus Place Mine Water Management System on the Newnes Plateau

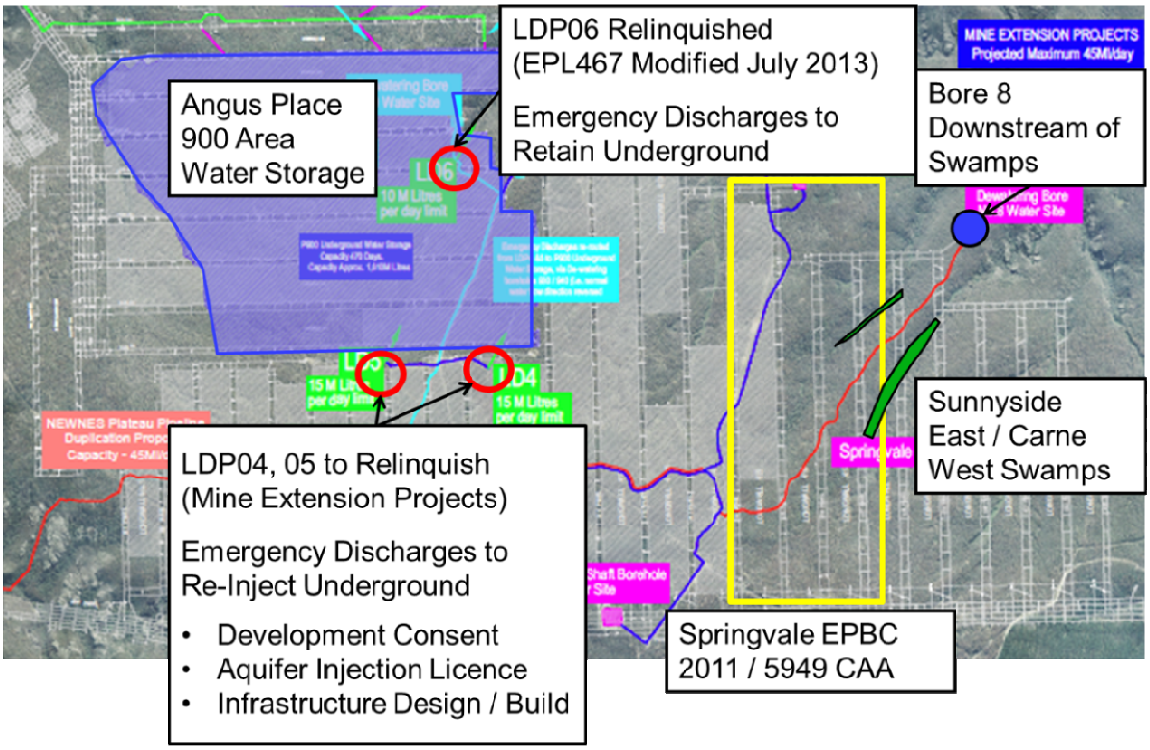


Figure 1.66(a) – This figure is the same as Figure 1.63 with explanatory notes regarding Newnes Plateau mine water management.

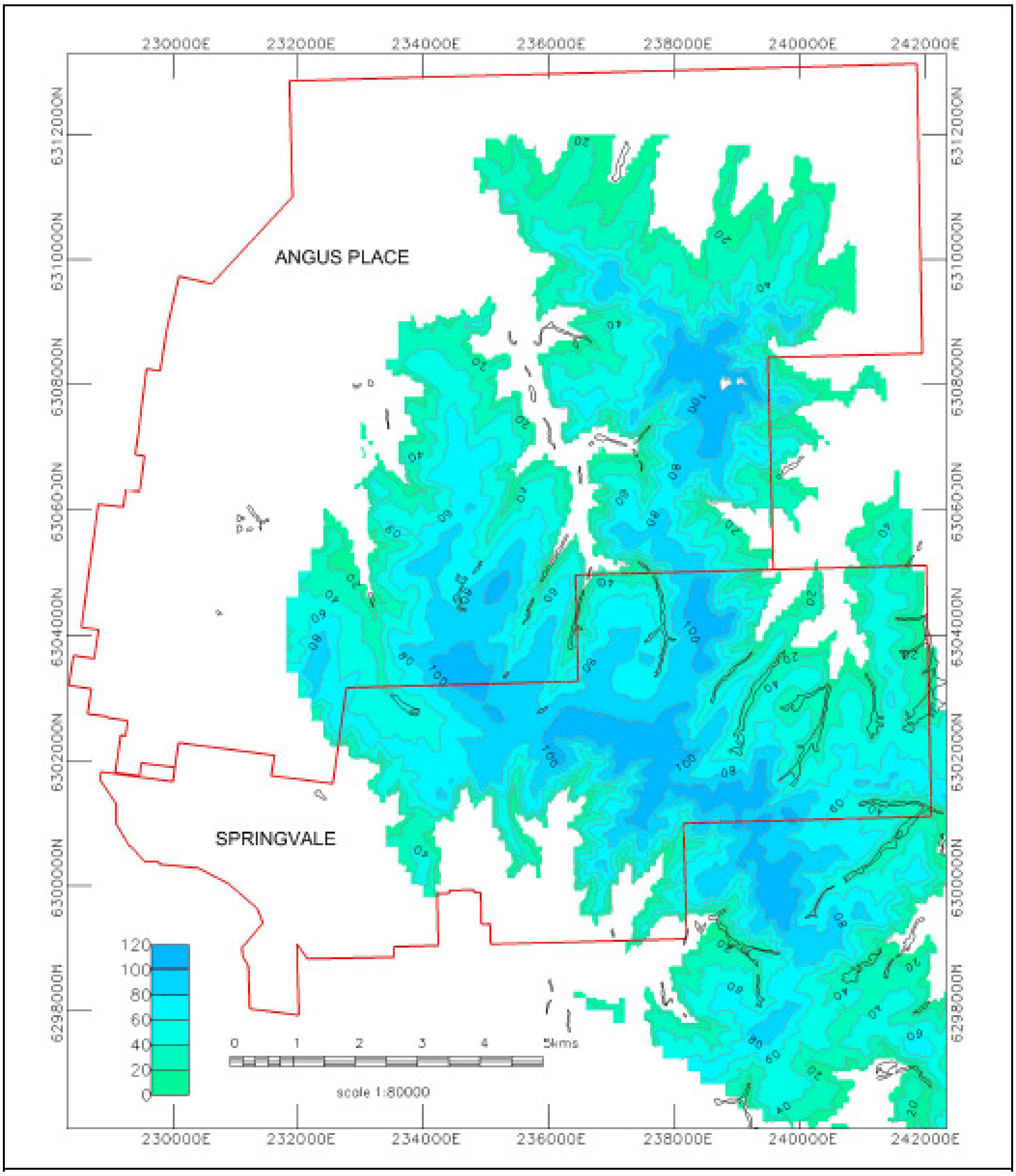


Figure 1.67 Burralow Formation Isopachs - note: shrub swamps shown with black outline shows maximum thicknesses of approximately 110 metres, principally in the north-east of Angus Place East and the south-eastern extent of Springvale Colliery at the headwaters of East Wolgan, Sunnyside, Sunnyside East, Carne West, and Gang Gang Shrub Swamps. Hence the Burralow Formation, as defined in the study area, is thicker than previously proposed in the general Lithgow region in earlier works, for example, Goldbery (1972) and Herbert and Helby (1980).

Figure 1.68 - Photo of a core drilled from the Burralow Formation on the Newnes Plateau showing medium- to coarse-grained sandstones interbedded with frequent sequences of fine-grained, clay-rich sandstones, siltstones, shales and claystones. These latter fine-grained units can be several metres in thickness and their presence differentiates the Burralow Formation from the underlying Banks Wall Sandstone.

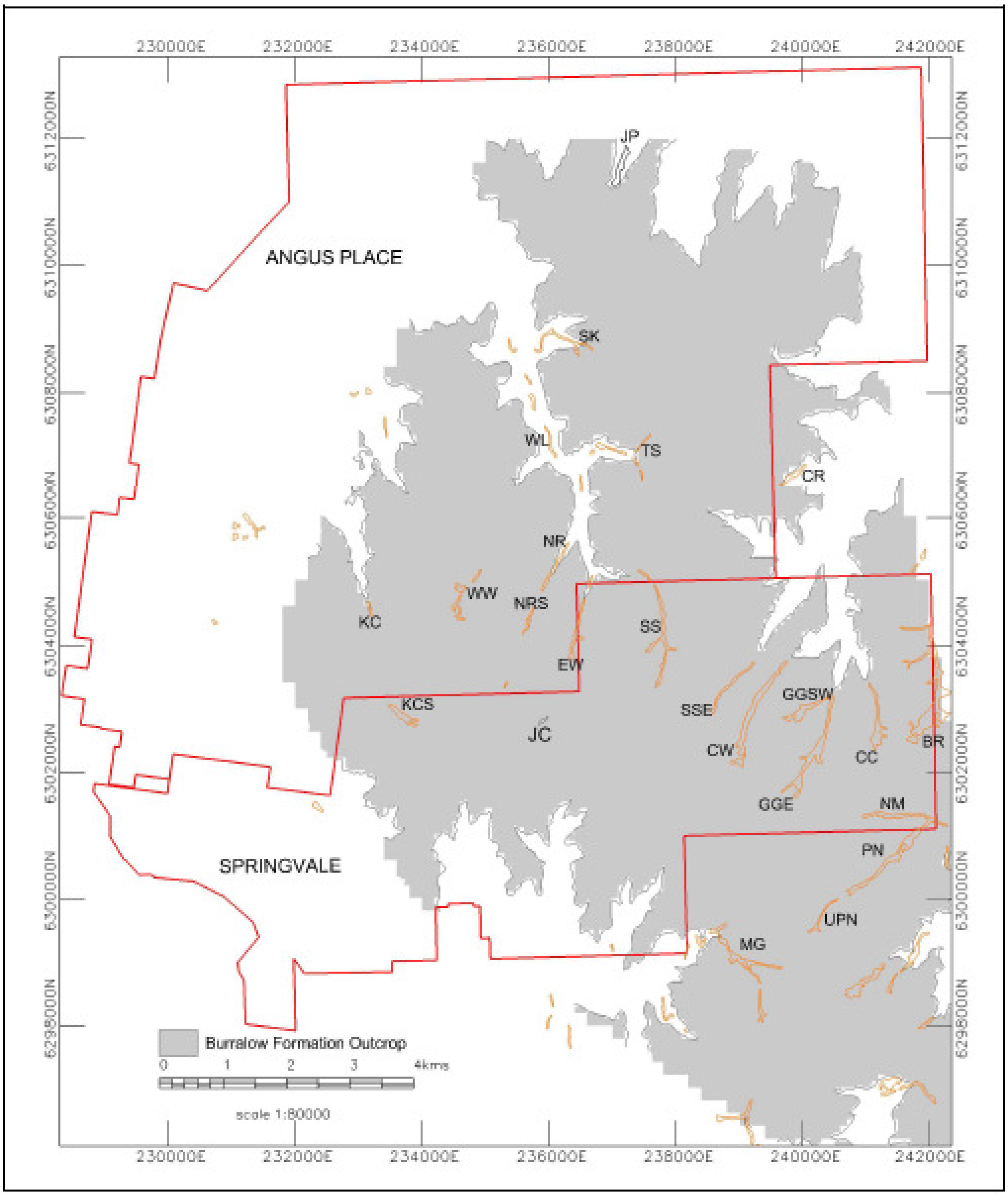


Figure 1.69 Shrub Swamp Locations and Burralow Formation Outcrop
Key to swamp abbreviations:
JP: Japan, SK: Snake, WL: Wolgan, TS: Tristar, CR: Crocodile, NR: Narrow, NRS: Narrow South, WW: West Wolgan, EW: East Wolgan, KC: Kangaroo Creek, KCS: Kangaroo Creek South, JC: Junction, SS: Sunnyside, SSE: Sunnyside East, CW: Carne West, GGSW: Gang Gang Southwest, GGE: Gang Gang East, CC: Carne Central, BR: Barrier, NM: Nine Mile, PN: Pine, UPN: Pine Upper, MG: Marrangaroo Creek

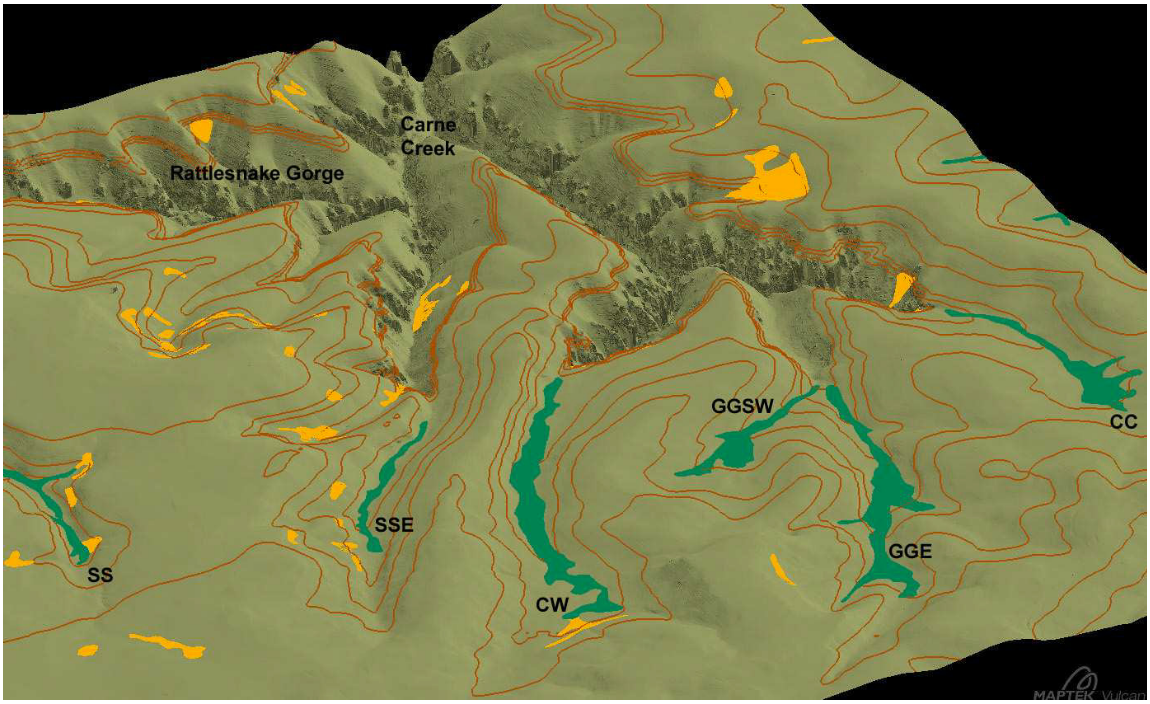


Figure 1.70 shows a view looking north-west from the direction of the Springvale ridge system. Aquitard horizons which support the shrub and hanging swamps are shown in brown. Shrub swamps are marked in green and hanging swamps in yellow.

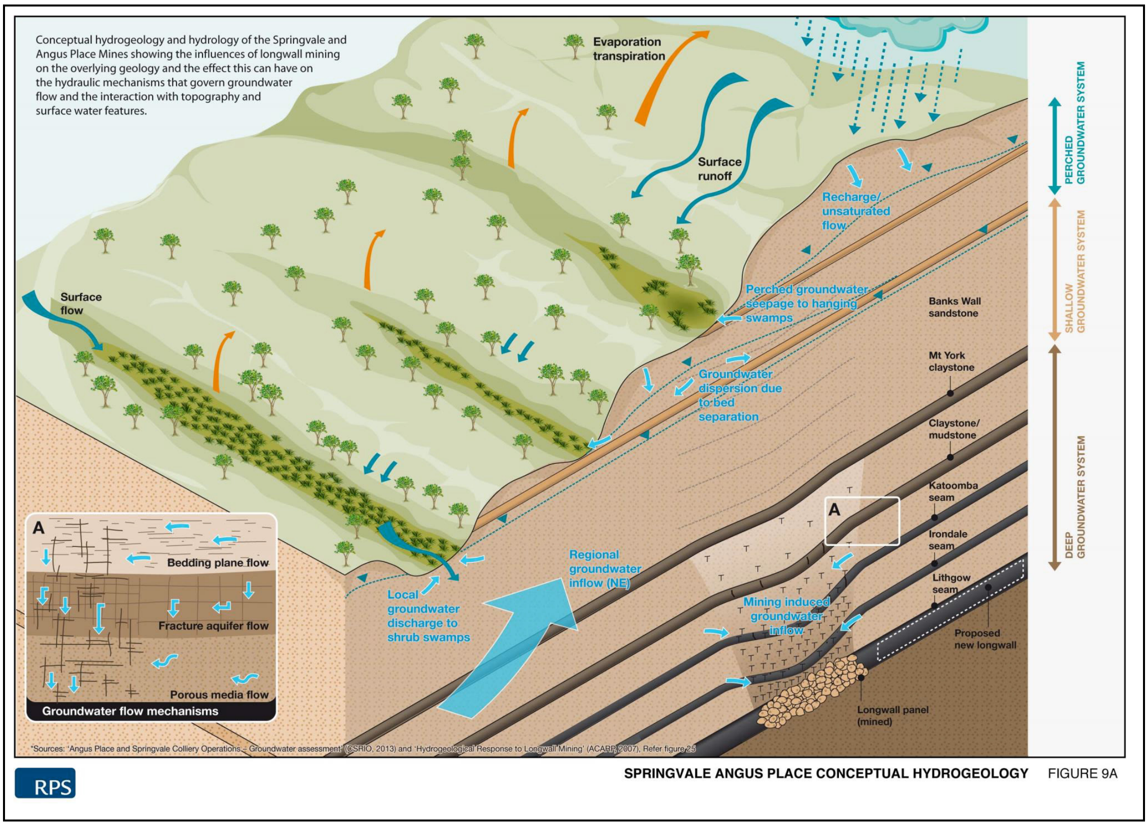


Figure 1.71 Subsidence Impacts to Groundwater Systems - Longwall mining leads to localised disruption of the deep groundwater system as well as subsidence induced changes in overlying strata. **The magnitude of influence on overlying strata**

declines with increasing height above the mined coal seams. Due to the multiple layers of aquitards and aquifers in overlying strata there is minimal change to the perched system that supports hanging swamps and shallow system that supports shrub swamps.

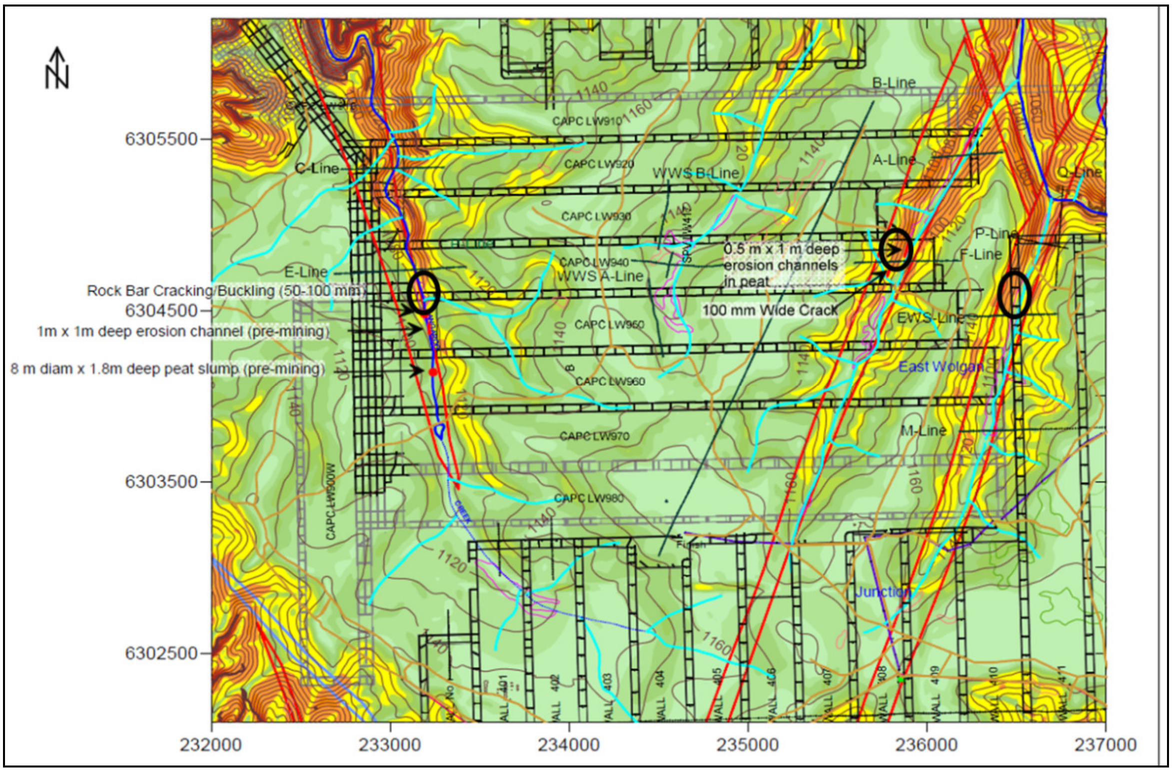


Figure 1.72 Springvale and Angus Place Mine Plan showing Major Fault Zones (Between Red Lines) AND Incised Valleys (Orange Areas on Plan with Slope Gradients > 18^{o}) Together with Subsidence Cracking Impact Locations (Black Circles)

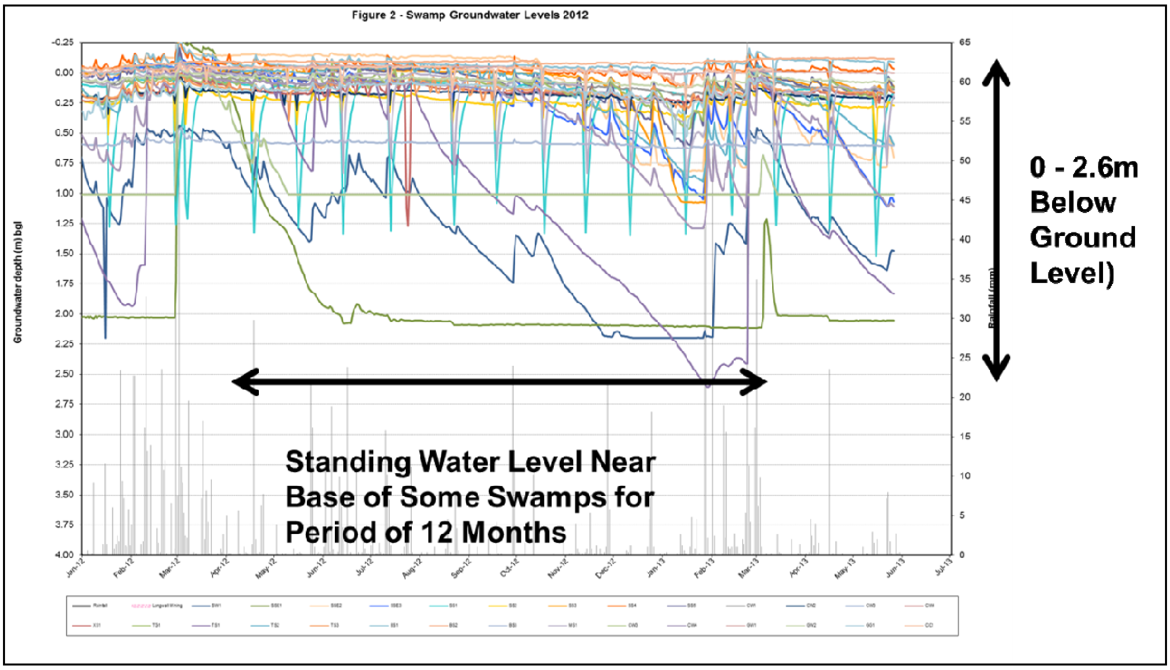


Figure 1.73 Hydrographs of Newnes Plateau Shrub Swamp Piezometers – note the highly variable depth of the Standing Water Level and long duration between rainfall induced "spikes" in many of the hydrographs

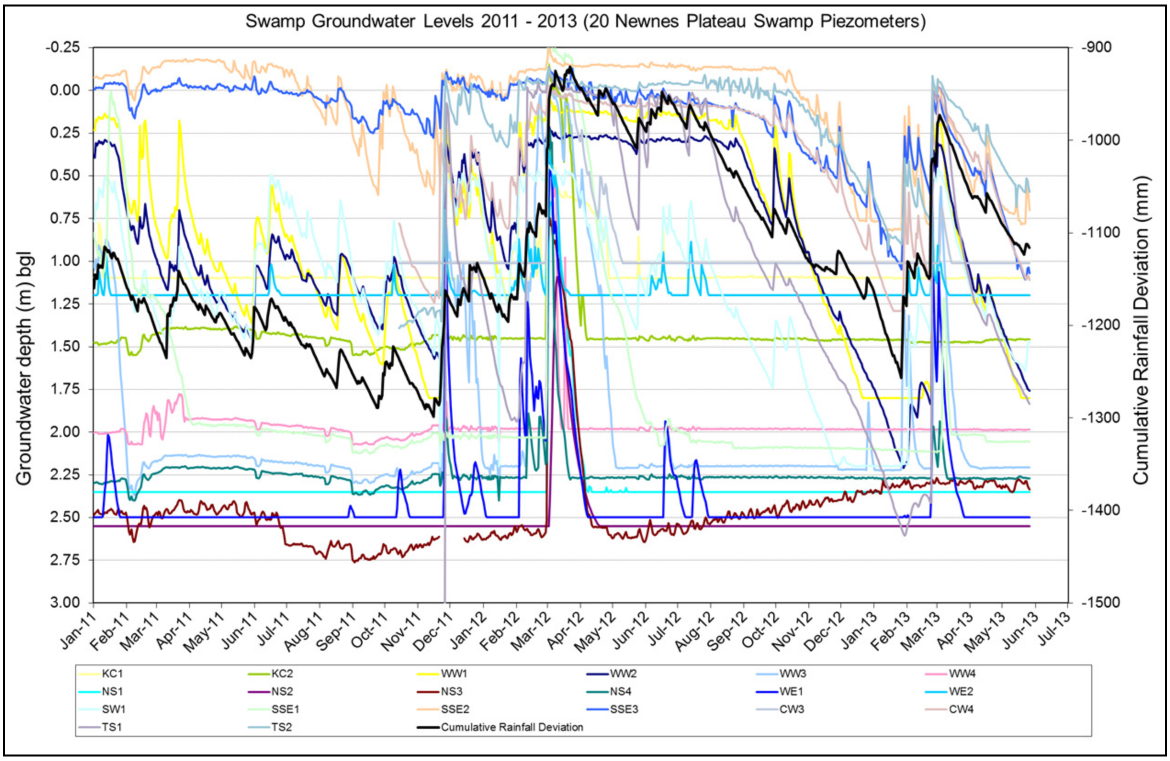


Figure 1.74 Hydrographs of 20 Periodically Waterlogged Swamp Piezometers – note correlation between piezometer response and Cumulative Rainfall Deviation (CRD) Trendline (in Black)

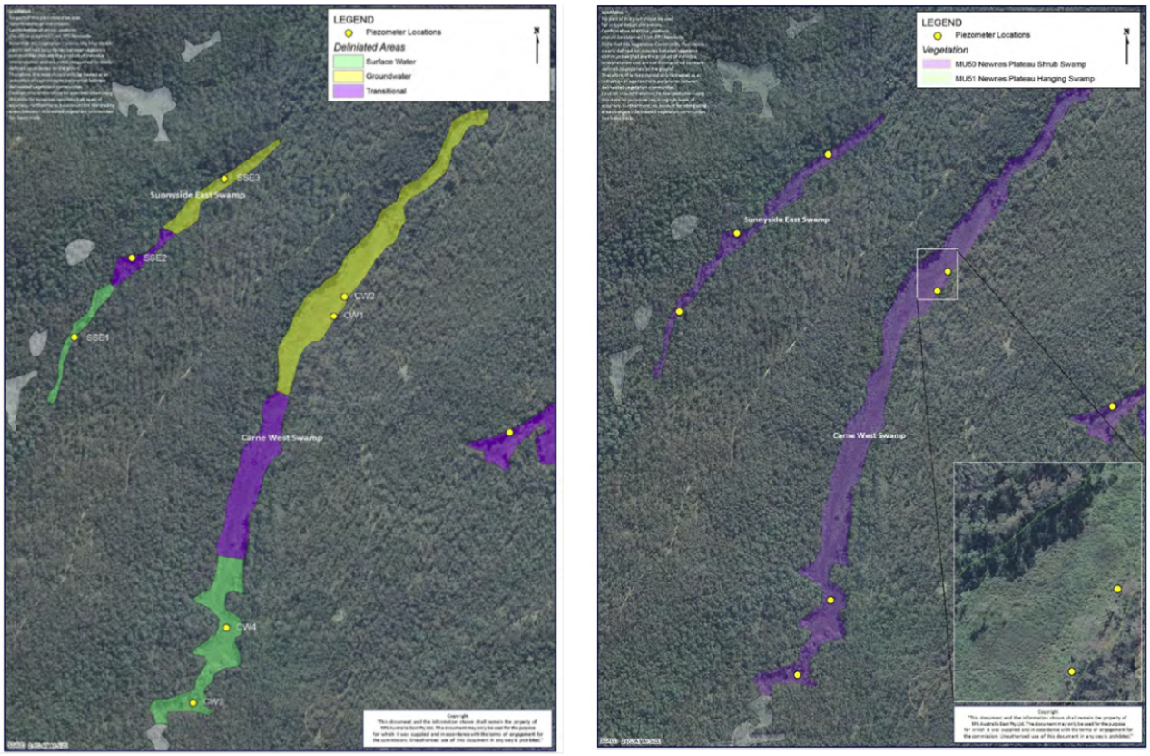


Figure 1.75 – Plan of Sunnyside East and Carne West Swamps Showing Different Hydrological Classifications Within Each Swamp for the MU50 Shrub Swamp Community

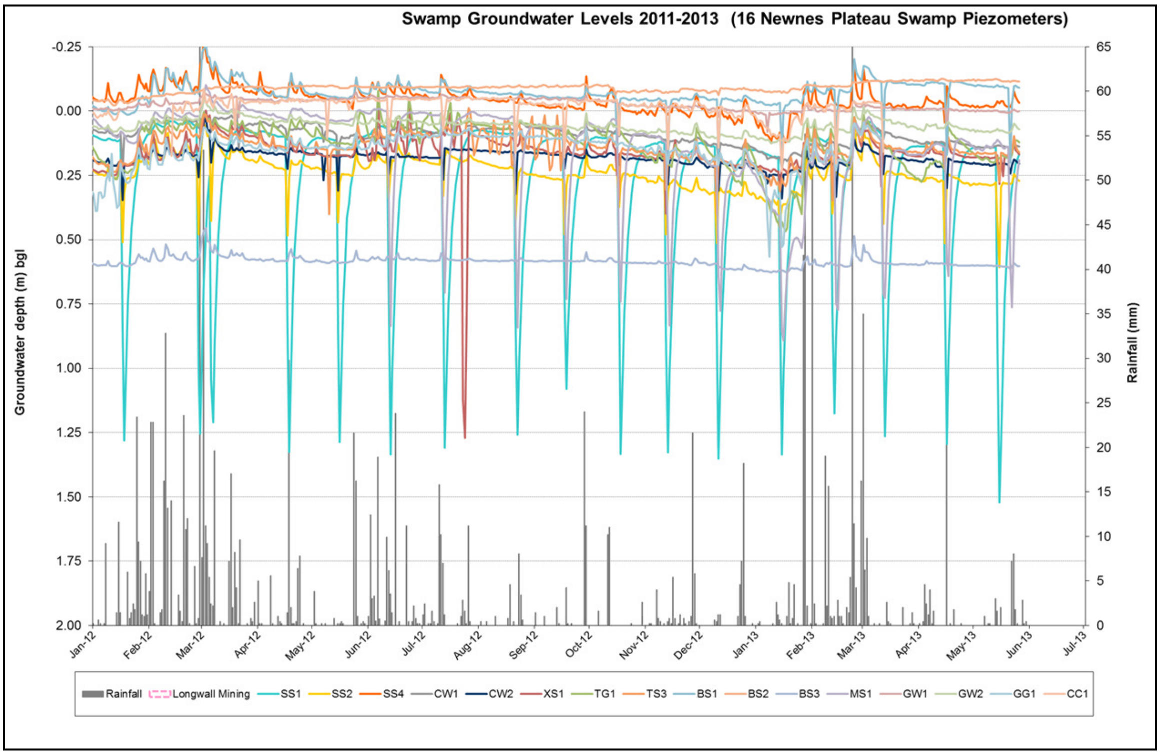


Figure 1.76 – Hydrographs of 16 Permanently Waterlogged Newnes Plateau Shrub Swamps – note distinct negative spikes in hydrograph trends which reflects water quality sampling at these locations on a regular basis

Figure 1.77 – Unmapped Hanging Swamp on the Western Side of Kangaroo Creek Swamp – illustrating valley seepage mechanism continuing post-longwall mining

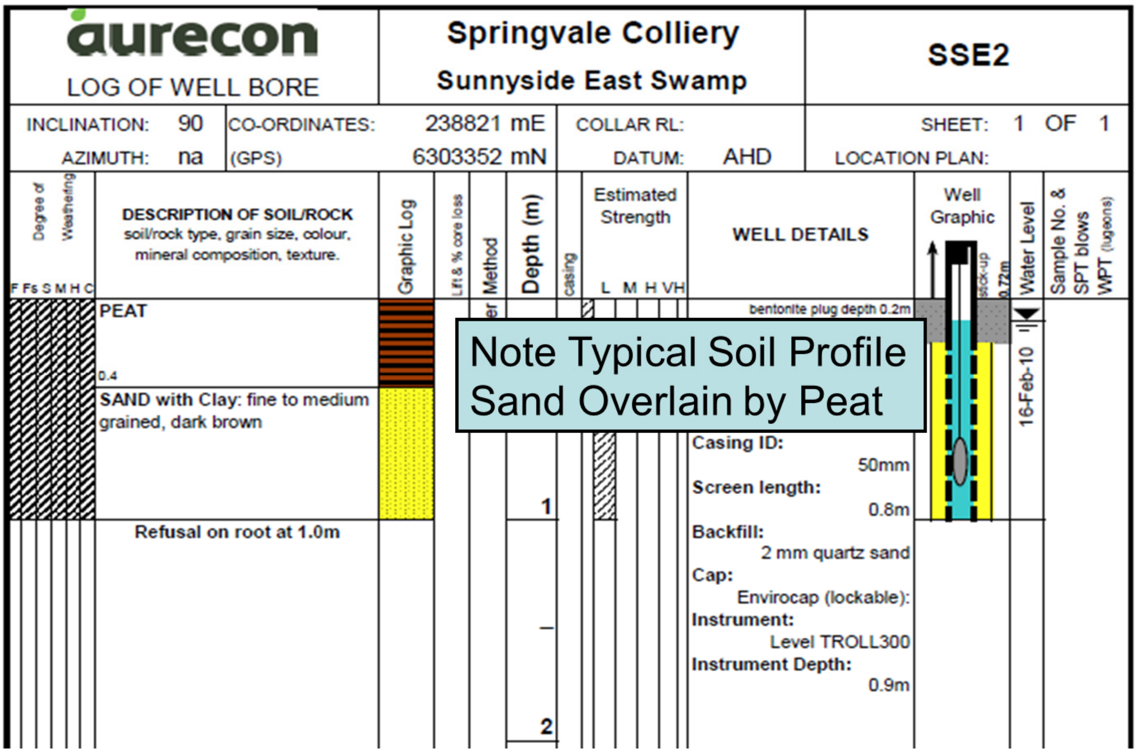


Figure 1.78 – Typical Newnes Plateau Shrub Swamp Peat / Soil Profile – showing sand overlain by peat

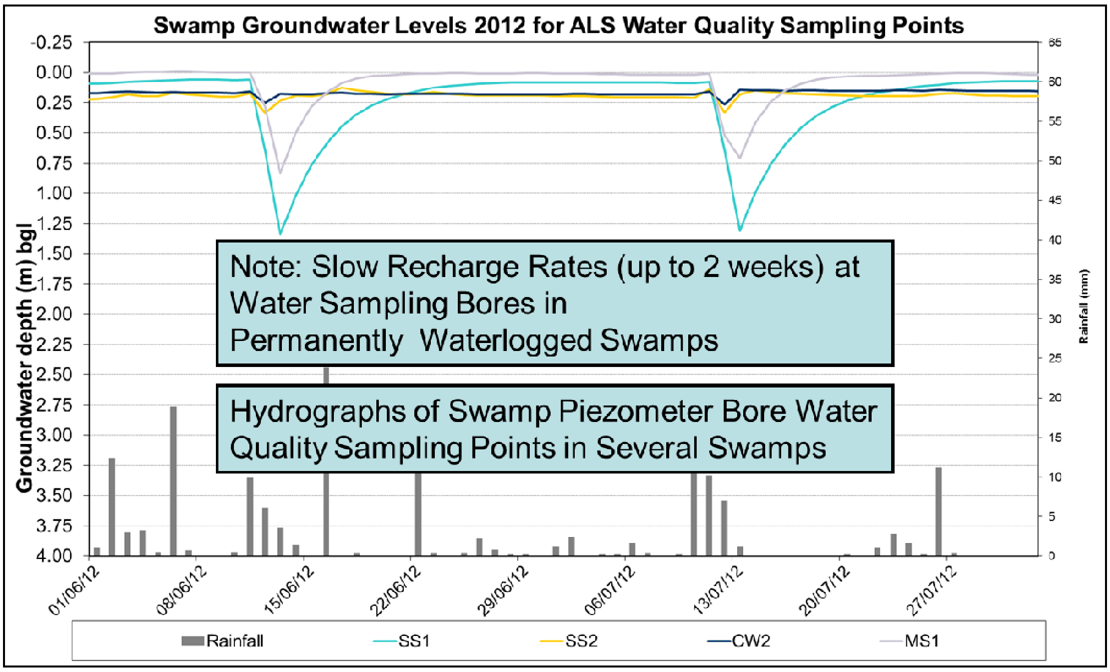


Figure 1.79 – Hydrographs of Swamp Piezometer Sampling Points in Several Newnes Plateau Shrub Swamps – note common sampling dates and slow recharge rates indicative of slow flow rates with swamp peat / soil

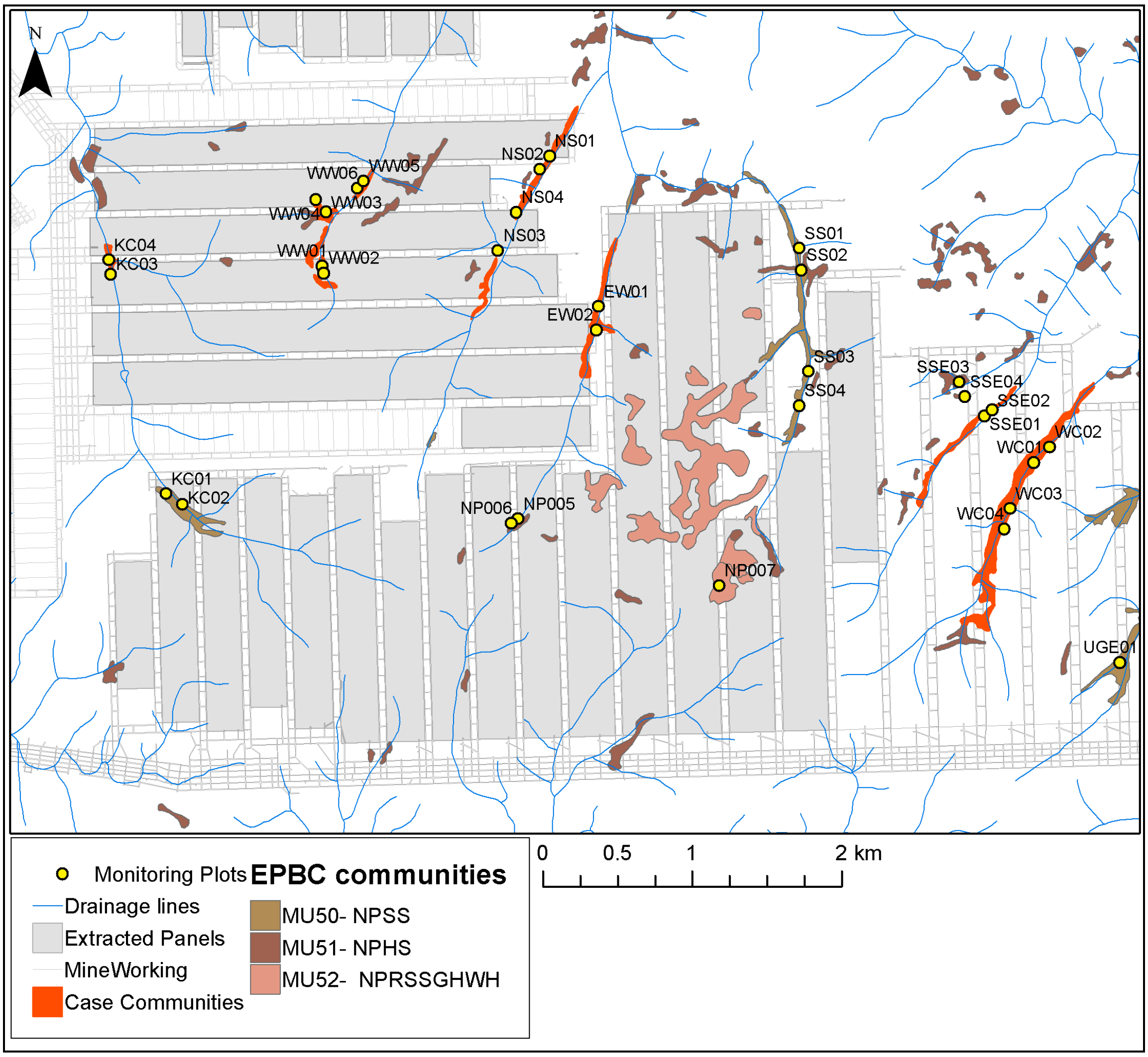


Figure 1.80 Locations of monitoring plots in EPBC listed communities relative to Angus Place and Springvale Collieries longwall panels. Case study communities are highlighted red.

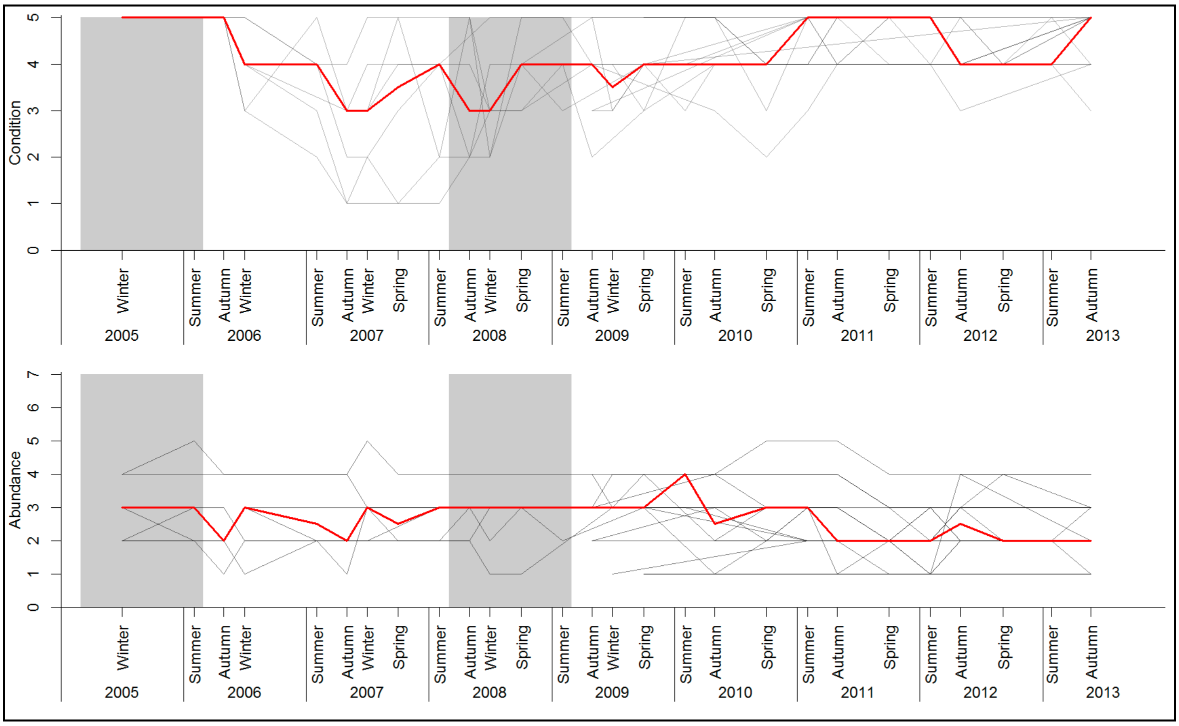


Figure 1.81: Median condition and abundance for East Wolgan 1 flora monitoring plot.

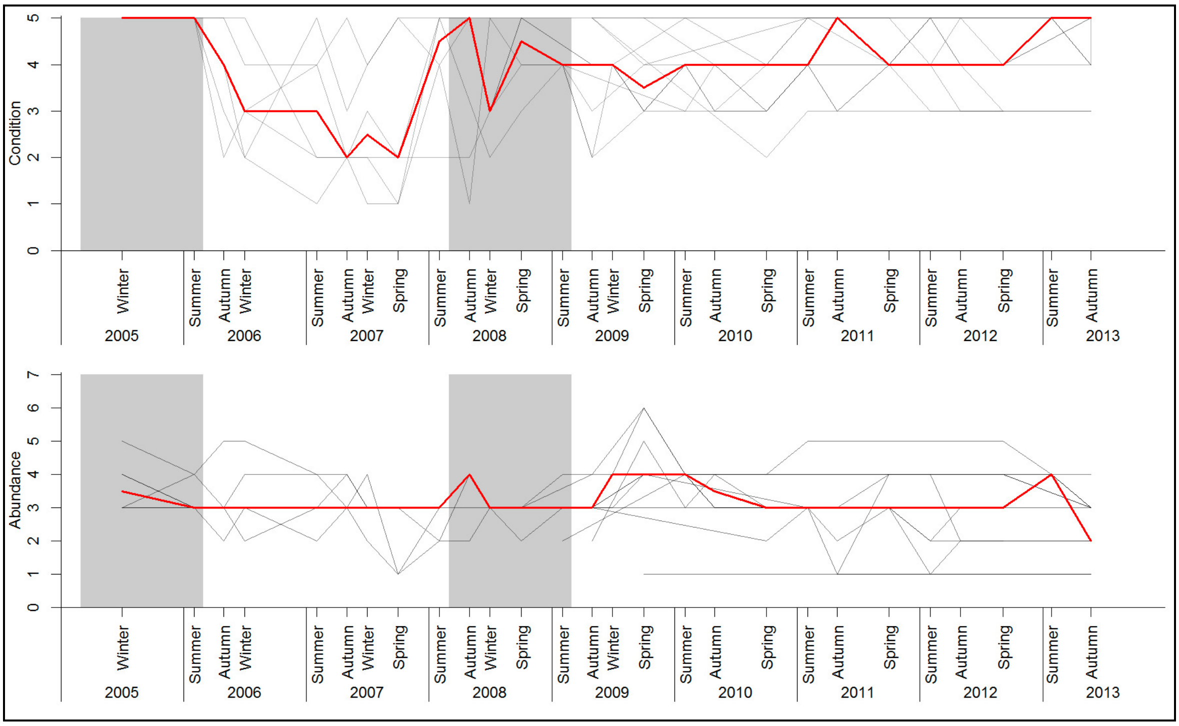


Figure 1.82: Median condition and abundance for East Wolgan 2 flora monitoring plot.

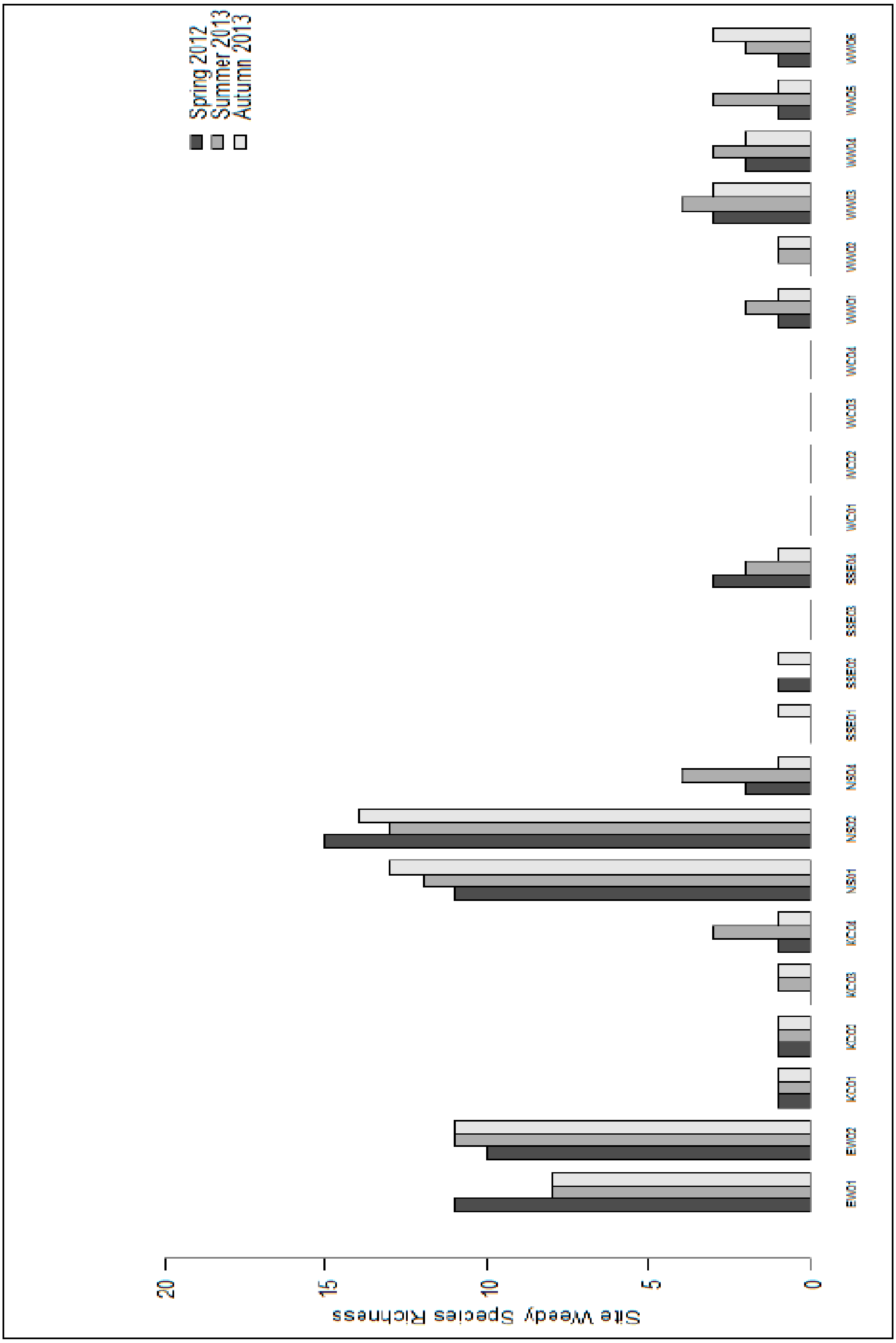


Figure 1.83: Weedy species richness for the case study swamps over the past 12 months.

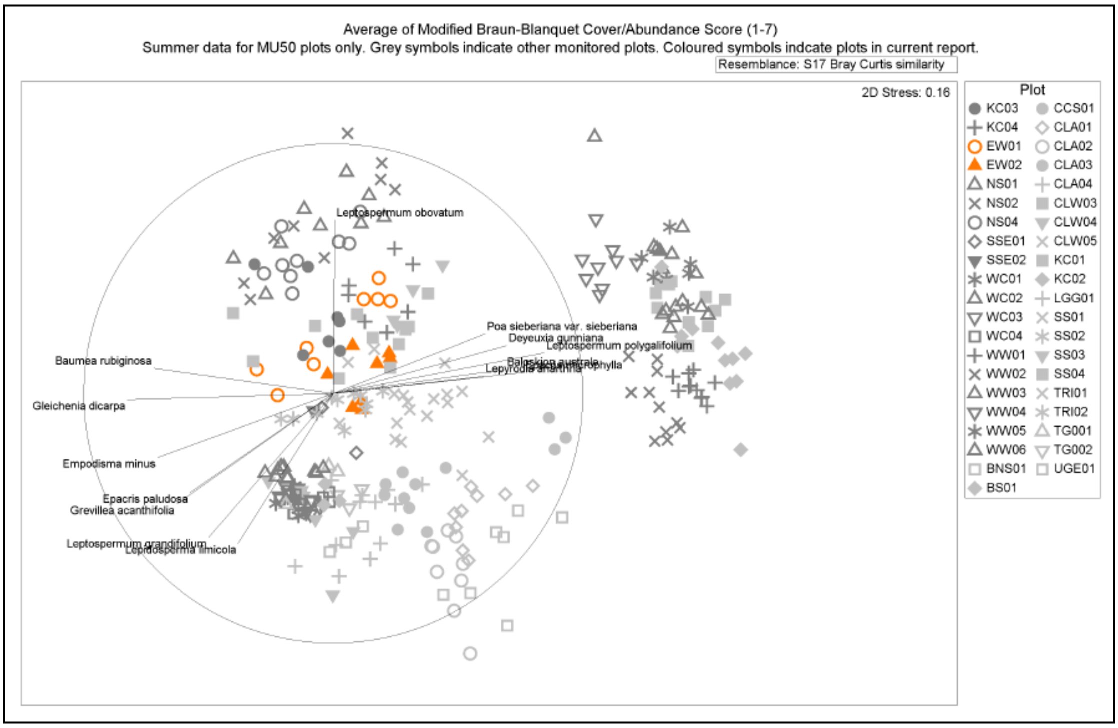


Figure 1.84: nMDS plot of all summer data for monitoring plots in East Wolgan swamp. Summer data for all other MU50 swamps provided for comparison.

Figure 1.85: Median condition and abundance for Narrow Swamp 1 flora monitoring plot.

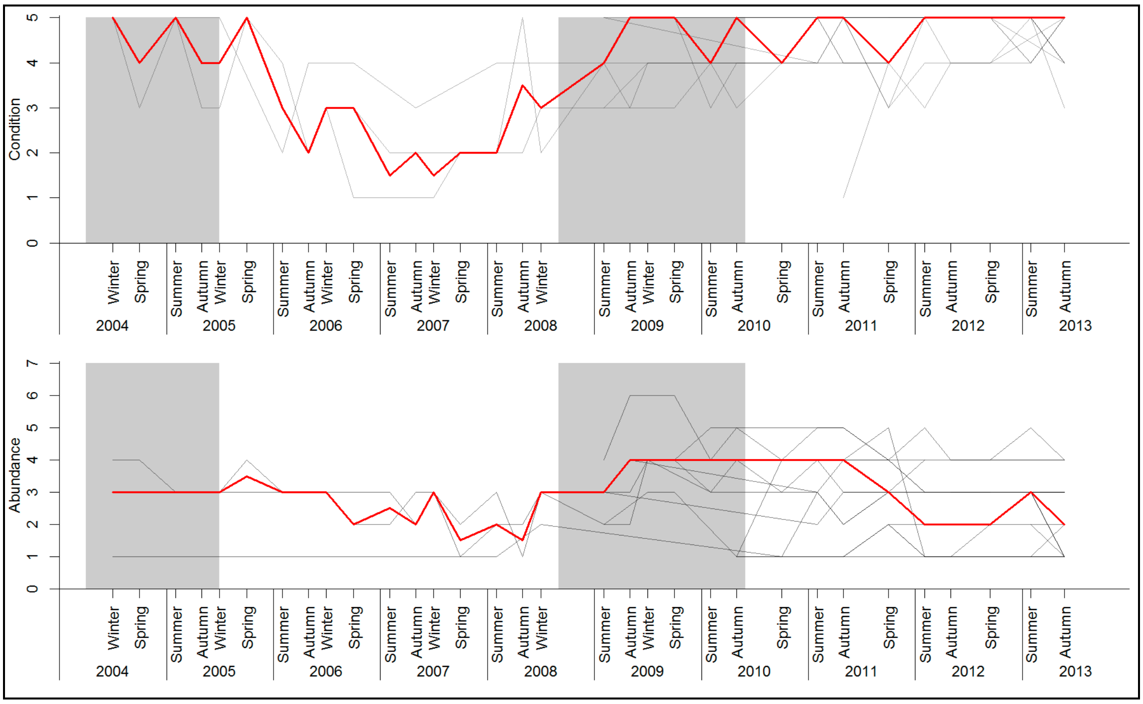


Figure 1.86: Median condition and abundance for Narrow Swamp 2 flora monitoring plot.

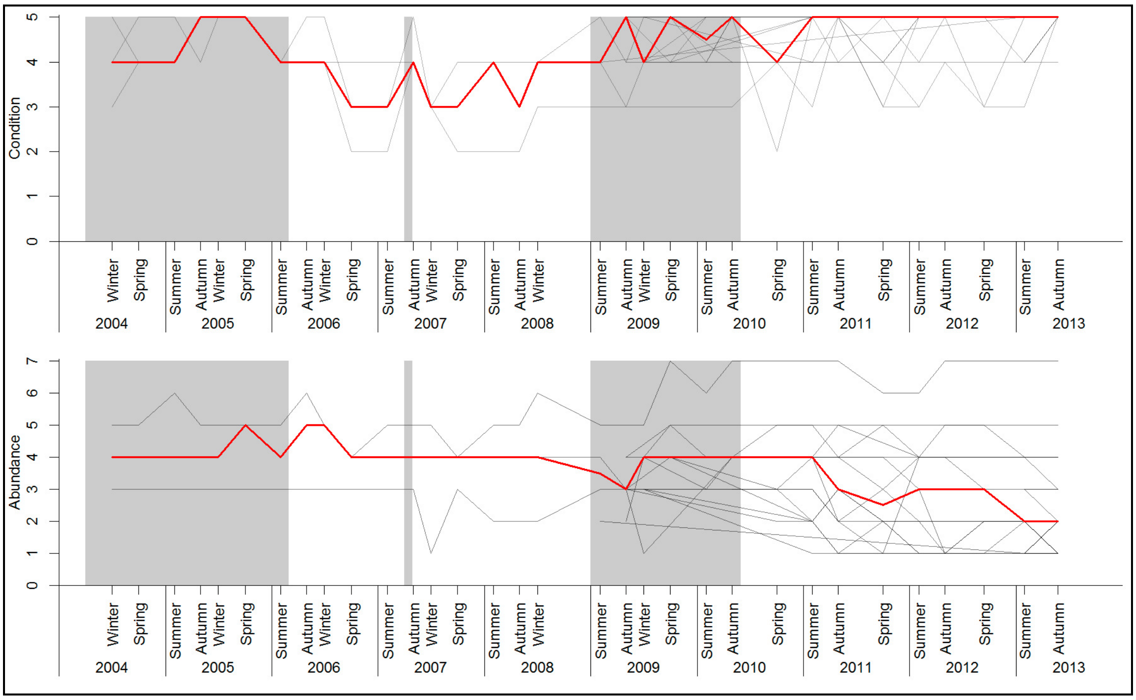


Figure 1.87: Median condition and abundance for Narrow Swamp 4 flora monitoring plot.

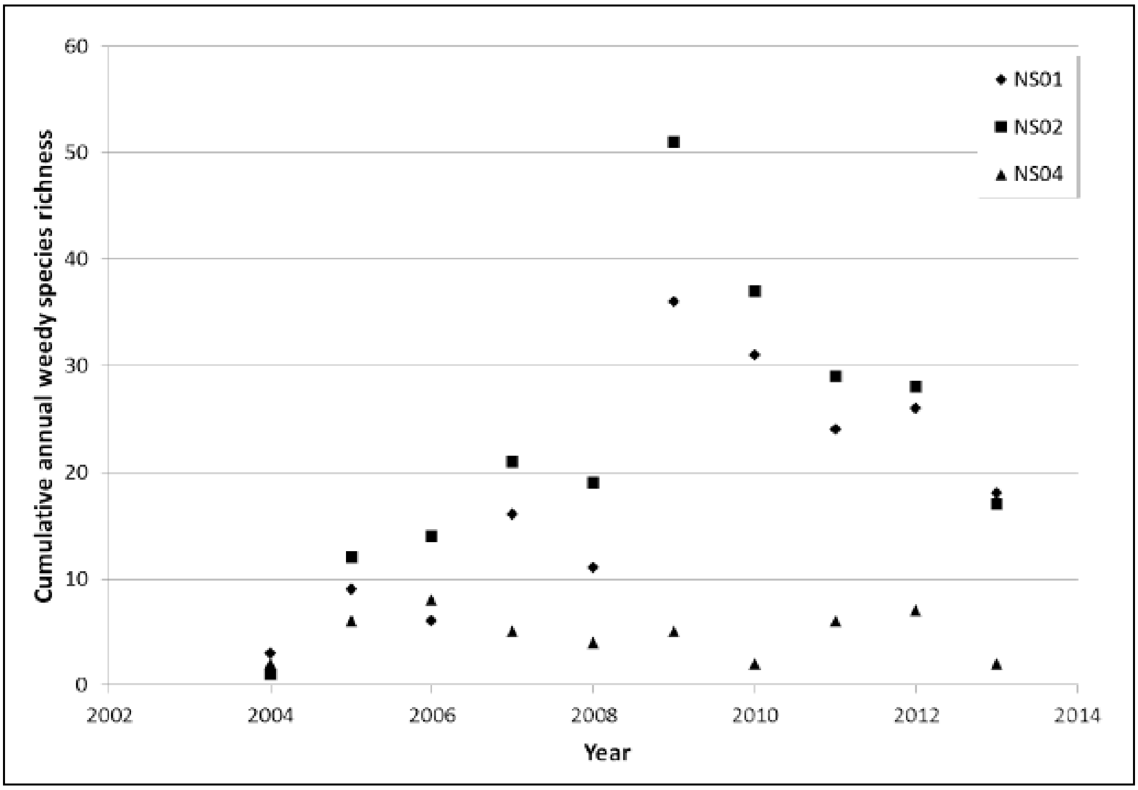


Figure 1.88: Cumulative weedy species richness for Narrow shrub swamp.

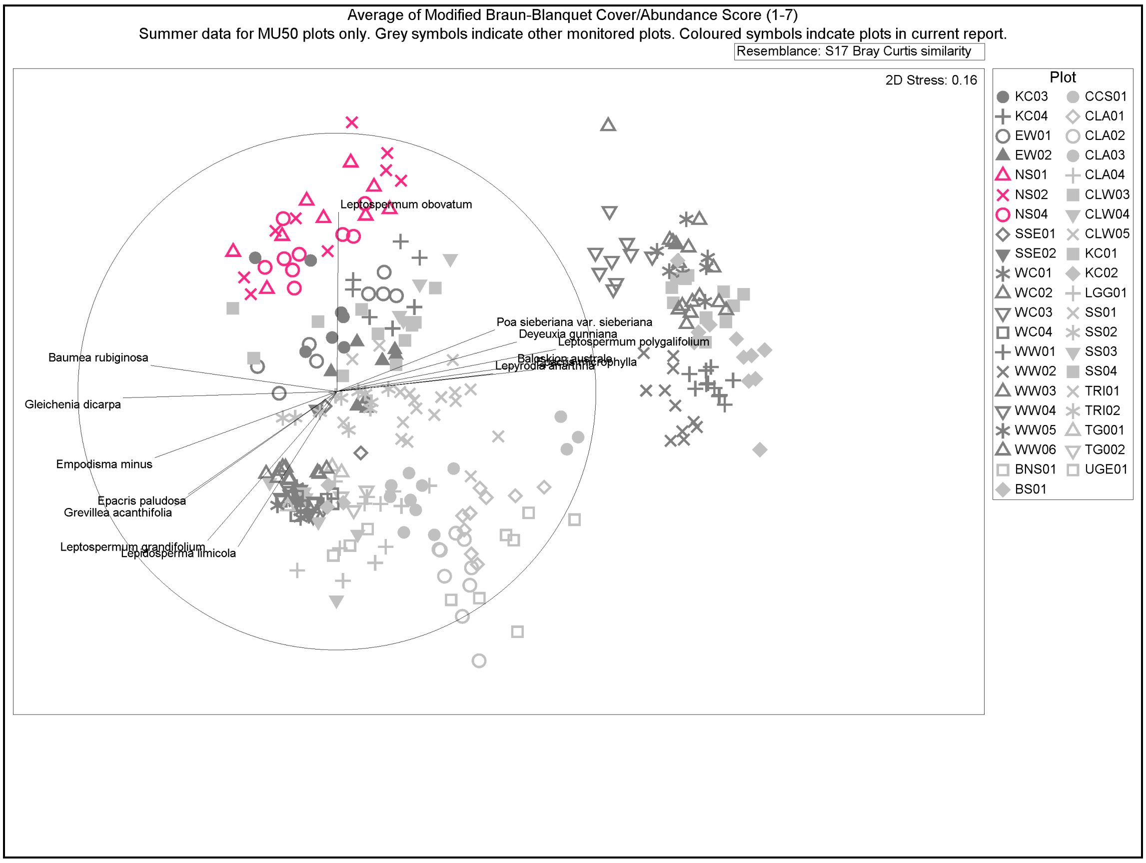


Figure 1.89: 2D nMDS plot showing location and spread of Narrow shrub swamp monitoring plot vegetation assemblage (NS01, 02, 04). Of special note is the location of these plots through time with regard primary correlations of weedy species.

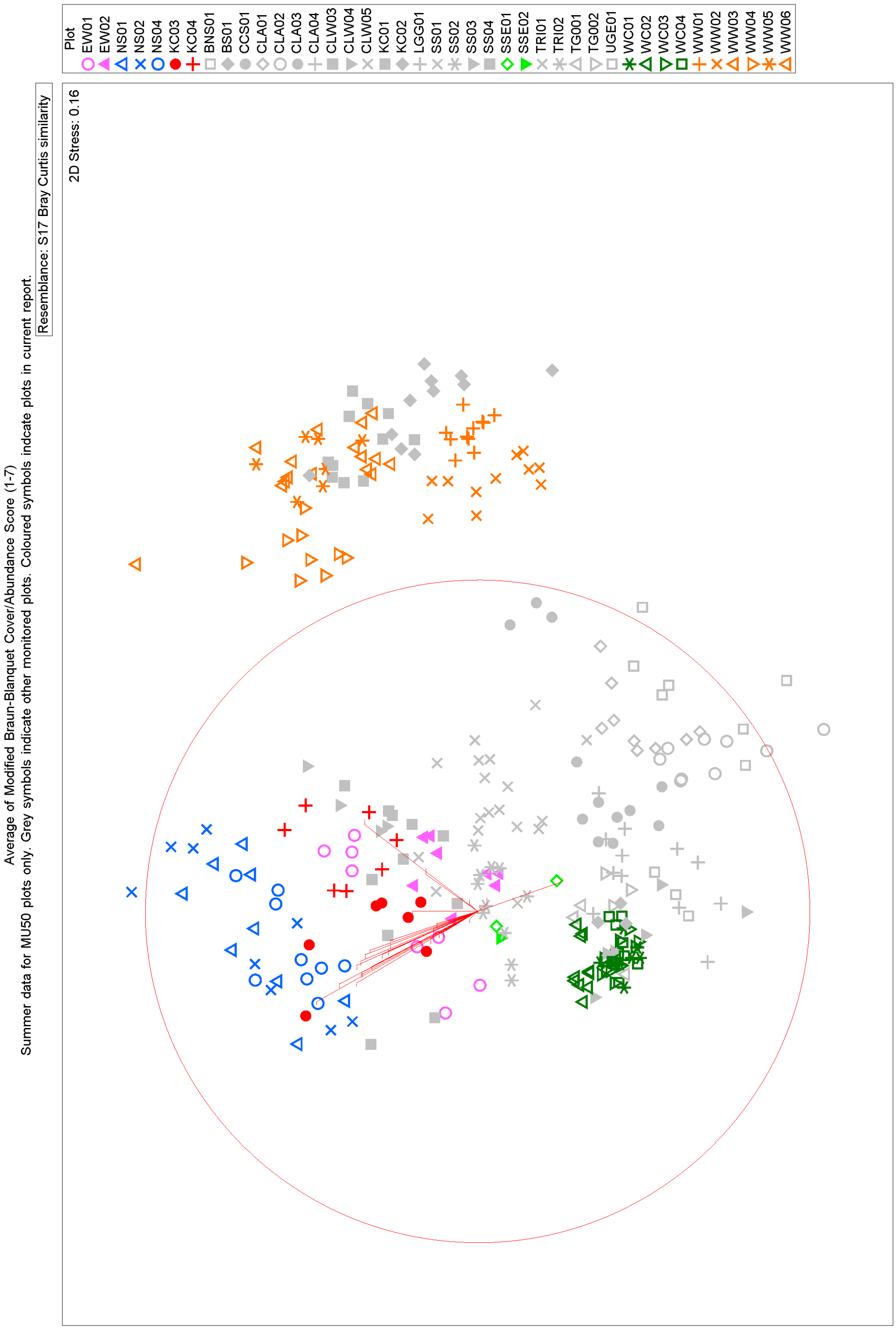


Figure 1.90: Strain directions of weedy species recorded in all plots during summer of all years.

5. References

Forster, I., (2009) Aurecon Report Ref: 7049-010 Newnes Plateau Shrub Swamp Management Plan Investigation of Irregular Surface Movement in East Wolgan Swamp

Goldney, D., Mactaggart B., and Merrick, N. (2010) Determining Whether Or Not A Significant Impact Has Occurred On Temperate Highland Peat Swamps On Sandstone Within The Angus Place Colliery Lease On The Newnes Plateau

Forster, I., (2011) Aurecon Report Ref: 208354, Geotechnical Investigation Report Wolgan East Investigation

Speer, J., (2011) Alpha GeoScience Report, Final Report: AG-293 Geophysical Survey Ground Penetrating Radar And Resistivity Investigation Of East Wolgan Swamp On The Newnes Plateau

Ditton, S., (2013) DgS Report No. SPV-003/6 Further Discussion on the Potential Impacts to Sunnyside East and Carne West Temperate Highland Peat Swamps on Sandstone due to the Proposed Springvale LWs 416 to 418

McHugh, E., (2013) The Geology of the Shrub Swamps within Angus Place/Springvale Collieries

Fletcher, A., Brownstein, G., Blick, R., Johns, C., Erskine, P. (2013) Assessment of Flora Impacts Associated with Subsidence