Centennial Coal

Response to the Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining Knowledge Report

Temperate Highland Peat Swamps on Sandstone: ecological characteristics, sensitivities to change, and monitoring and reporting techniques

September 2014

Introduction

The following is a response by Centennial Coal to the Independent Expert Scientific Committee on Coal Seam Gas and Coal Mining Knowledge Report: Temperate Highland Peat Swamps on Sandstone: evaluation of mitigation and remediation techniques (the IESC Report). In general the IESC Report:

- does not consider all of the relevant publicly available information in developing arguments about the effects of longwall mining on Temperate Highland Peat Swamps on Sandstone communities (THPSS).
- Where publicly available data has been used in the preparation of this report, certain data has been excluded where it does not support the position argued in the IESC report.
- Certain reference sources cited in the IESC report contain material which is not based on data and is biased against coal mining.

These general observations are further described in this report. For ease of reference, the structure of this report is based on the structure of the IESC report, and has been appended to the Response to Submissions to add a summary of relevant information from publicly available sources. In some areas this extends to a rebuttal of the data analysis or arguments presented in the report.

Centennial acknowledged in Chapter 2 and Chapter 8 of the Springvale Mine Extension Project Environmental Impact Statement (SVMEP EIS) and the Angus Place Colliery Mine Extension Project Environmental Impact Statement (APMEP EIS) that longwall mining has caused impacts to certain THPSS, however, as identified in these documents, this has not been the case in all instances. Chapter 2 of both the SVMEP EIS and the APMEP EIS acknowledged that subsidence impacts to swamp hydrology have been noted at two swamps (Kangaroo Creek Swamp and East Wolgan Swamp). Where impacts to certain THPSS on the Newnes Plateau have occurred, Centennial has conducted extensive research to understand the causes of the impacts. Centennial has used the findings of the research to avoid and mitigate both past and future impacts of longwall mining and related activities to THPSS on the Newnes Plateau.

Extensive research and investigation, lead primarily by work commissioned by the then DEWHA (the Goldney 2010 Report), has shown that impacts to THPSS on the Newnes Plateau have been caused primarily by:

- Licenced discharge of mine water through THPSS
- Changes to swamp hydrology caused by cracking of rock substrate beneath THPSS as a result of mine subsidence

The Goldney 2010 Report found that *the principal cause of impacts* to East Wolgan Swamp and Narrow Swamp was mine water discharge. This finding has been reinforced by research conducted by the University of Queensland. Neither these reports, nor Centennial's response to the findings, have been referenced in the IESC Report. The finding of major impacts caused by mine water discharge is not acknowledged in the IESC Report. As a result of the finding, Centennial has not discharged mine water through THPSS on the Newnes Plateau since 2010 and is committed to managing mine water through the Water Transfer Scheme (WTS), which transfers mine water off the Newnes Plateau.

Following completion of the DEWHA investigation and the Goldney 2010 Report, in November 2011, Centennial (through its Joint Venture) and the Minister for the Environment entered into an Enforceable Undertaking under section 486DA of the Environment Protection and Biodiversity

Conservation Act 1999. Under this Enforceable Undertaking, the Joint Venture entered into a research agreement with the Australian National University to undertake a comprehensive research program into THPSS[1].

With the conclusion of these investigations, in 2011, Centennial made applications to the Minister for the Environment to extract coal from Springvale Mine longwall 415 to 417 (EPBC2011/5949) and from the Angus Place Colliery longwall 900W and 910. In 2012, the Minister for the Environment conditionally approved these applications. The primary condition of approval was the need to demonstrate that sub-critical longwall panel design would not result in anomalous subsidence impacts to THPSS.

To demonstrate this, changes to the mine design were are based on reduced mining void widths and increased chain pillar widths. The changes have been made in the context of cover depths in proposed future mining areas in the vicinity of THPSS and are designed to a criterion of sub-critical panel geometry. Subsidence modelling indicates that the design changes will result is very significant reductions to total subsidence and differential subsidence movements. These changes were made specifically to reduce the environmental impacts of longwall mining under the Newnes Plateau, and demonstrate Centennial's commitment to sustainable mining practices.

This mine design approach for all future longwall mining described in the SVMEP EIS and the APMEP EIS in the vicinity of THPSS is consistent with that approved for longwall mining beneath THPSS by DotE under EPBC2011/5949.

All documentation supporting this research, investigations, outcomes is available on the Centennial Coal website, www.centennialcoal.com.au.

[1] In should be noted that in this report, a reference to the federally listed endangered ecological community Temperate Highland Peat Swamps on Sandstone, includes a reference to the State listed endangered ecological communities incorporating the Newnes Plateau Shrub Swamps and Newnes Plateau Hanging Swamps. The extent to which these communities have been described under these listings is discussed further in response to the IESC Report on ecological characteristics of THPSS.

Overview and Summary

Mining and Subsidence

In 2008 and 2009, monitoring at Angus Place and Springvale Collieries detected impacts attributable to mining-related activities at two THPSS. Centennial Coal launched an extensive investigative program to determine the factors causing these impacts. Specific investigations were targeted to determine the hydrogeological characteristics of THPSS. The purpose of these investigations was to ascertain the coincident characteristics which lead to THPSS formation and to understand the sensitivity of those characteristics to mine subsidence behaviour.

These investigations include:

- Aurecon Report Ref:7049-010 Newnes Plateau Shrub Swamp Management Plan Investigation of Irregular Surface Movement in East Wolgan Swamp (2009)
- 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, Goldney et at, 2010 (a report prepared for the then Department of Environment, Water, Heritage and the Arts)
- Aurecon Report Ref: 208354, Geotechnical Investigation Report East Wolgan Swamp Investigation, 2011
- Geophysical Survey Ground Penetrating Radar and Resistivity Investigation of East Wolgan Swamp on the Newnes Plateau, Speer (2011)
- 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 LW416 to 1418, Ditton 2013The Geology of the Shrub Swamps within Angus Place/Springvale Collieries, McHugh 2013
- Assessment of Flora Impacts Associated with Subsidence, Fletcher et at, 2013
- EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 to 3 and Appendices, Corbett et all, 2013
- Monitoring Surface Condition of Upland Swamps Subject to Mining Subsidence with very high resolution imagery, Fletcher et al, 2014
- DgS Report No SPV-003/7B Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls, Ditton, 2014
- Hydrogeological Characterisation of Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau, Corbett et al, 2014
- Case Studies of Groundwater Response to Mine Subsidence in the Western Coalfields of NSW, Corbett et al, 2014
- Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps, Brownstein et al, 2014

The results of these investigations, described further in the SVMEP EIS, the APMEP EIS, the respective Response to Submission Reports and this report, have allowed Centennial Coal to understand the multiple co-incident factors that led to historical mining-related impacts and implement management practices to ensure mining impacts will be avoided in the future or can be appropriately mitigated.

Since the investigations were conducted, Centennial Coal has been proactive in avoiding or minimising potential subsidence impacts to the geodiversity and biodiversity of the mining area using a comprehensive multi-disciplinary risk-based approach to mine planning and mine design in conjunction with a rigorous monitoring program.

The monitoring techniques employed are wide-ranging and complementary and the combined results provide insights into the role those factors such as geology, hydrogeology and topography play in THPSS formation and the effects of mine subsidence on these.

The extensive monitoring and investigation process employed by Centennial Coal, which utilised multiple lines of evidence to support the management decisions, created the foundations for an adaptive management outcome. Mine design changes (in the form of reduced longwall void width and increased chain pillar width) were implemented in 2011 and are planned in all Mine Extension Project (MEP) areas where THPSS are present.

Based on the results of the investigation and changes implemented in response to the investigation, the Federal DotE gave approval to mine beneath THPSS under EPBC2011/5949 in October 2013.

Monitoring

There is no evidence to support the statement of limited onsite monitoring data to determine the effect of longwall mining subsidence on upland peat swamps on the Newnes Plateau. There are 36 swamp piezometers installed in Newnes Plateau shrub swamps over the Angus Place and Springvale MLs. They were installed over the period 2005-2011 (Corbett et al 2014).

Groundwater aquifer monitoring commenced at Springvale Mine in 2002. The are currently 28 open hole aquifer monitoring piezometers and 26 multi-level vibrating wire piezometers at Springvale and Angus Place.

The results of these monitoring points are described further in the SVMEP EIS, the APMEP EIS (specifically Chapters 2 and 8), the respective Response to Submission Reports and this report.

The peer reviewed THPSS Monitoring and Management Plan (THPSS MMP) which has been approved by the Federal Department of the Environment (DotE) is aligned with **Before-After/Control-Impact (BACI)** design.

Mitigation

The primary mechanism to mitigate potential impacts to THPSS is mine design. The mine design for the SVMEP and APMEP is described in detail in the respective Environmental Impact Statements (specifically, Chapter 8).

Major design changes have been made to the Springvale and Angus Place 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

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. No subsidence effects to swamp hydrology or flora communities have been identified in areas where sub-critical mine design have been used in the past (refer to Chapter 2 and Chapter 8 of the respective EIS).

The mine design approach for all future longwall mining in the Springvale and Angus Place MEP areas is consistent with that approved for longwall mining beneath THPSS by DotE under EPBC2011/5949.

Future mine dewatering systems have been designed to ensure that discharge of mine water to Newnes Plateau Shrub Swamps is avoided. No mine water discharges into Newnes Plateau THPSS have occurred since April 2010.

Remediation

To date, there has been no requirement or need to undertake hard engineering mitigation on a THPSS on the Newnes Plateau. Regardless, there are examples from other regions where hard engineering mitigation has been successful.

A specific example of where PUR grouting has been shown to successfully repair a rock substrate can be seen at Helensburgh Coal Pty Ltd (HCPL) in the NSW Southern Coalfields. Experience at HCPL has shown that grouting using PUR can be used to successfully fill cracks ranging from small sub millimetre sized cracks to open fractures greater than 100 mm.

A trial was conducted at HCPL on the WRS4 rock bar in the Waratah Rivulet and was followed by a remediation report (Waratah Rivulet Remediation Trial Activities – Completion Report (2007)). The main findings of the remediation report were:

· PUR is non-toxic.

· PUR injection can be conducted in an environmentally acceptable fashion.

· PUR injection is suitable for sealing cracking in rocks from less than 1mm to greater than 100 mm.

· Pre and post permeability testing showed that permeability was reduced by several orders of magnitude following PUR injection.

· The PUR injection process was transferrable to other areas where cracking of rock had occurred.

The HCPL PUR grouting programs are used to seal cracking in outcropping rock bars. However, it is considered that this technology is transferrable and can be used to seal cracks in swamp bases as a swamp base is analogous to a rock bar, albeit one covered with peat and sand.

The use of cementitious grouts has also been used to successfully remediate subsidence induced cracking which led to water loss in watercourses in the Southern Coalfield. Injection grouting with cementitious grouts was successfully used for rock bar rehabilitation in the Georges River.

Where alluvial material overlies sandstone, injection grouting though drill rods has also been used successfully to seal void under the alluvial material (soil / peat). This technique was also used in the

Georges River, where 1-2m of loose sediment was grouted through using purpose designed grouting pipes.

2 Overview of Temperate Highland Peat Swamps on Sandstone

2.1 Location

THPSS Communities in the Blue Mountains / Newnes Plateau

Centennial Coal has acknowledged the importance of the THPSS in the landscape. Research conducted over the last 5 years (2009 to 2014) by the University of Queensland has worked towards quantifying the nature and extent of the community across the Newnes Plateau. Further work undertaken through the Enforceable Undertaking has been targeted towards:

- The nature and extent of THPSS
- THPSS water balances
- Functionality of swamps
- Environmental history and origins
- Ecology/biodiversity of major structural species
- Contribution to the landscape
- Condition status/mapping
- Monitoring of selected reference sites
- Thresholds for recovery

The University of Queensland is currently conducting research on communities identified as temperate treeless palustrine swamps in a 268 square kilometre area which includes the Newnes Plateau. Based on publicly available combined mapping from the temperate zone of New South Wales and manual interpretation of the numerous vegetation classifications used, a region containing more than 1000 shrub swamp communities per degree of latitude/longitude was identified which contained the communities mapped as Newnes Plateau shrub swamps. A report based on the research will be published and finalised in 2014.

2.2 Geology

Newnes Plateau Geology / Hydrogeology Related to THPSS Formation

Centennnial Coal has conducted detailed studies into the geology and hydrogeology of the Newnes Plateau, as outlined in the following excerpts from Corbett et al (2014).

Detailed analysis of the lithology was undertaken and the data was incorporated into the Minex geological database to allow three-dimensional modelling of correlatable stratigraphic units (i.e. stratigraphic units that are present on a regional scale). The analysis of the near surface stratigraphy also involved the use of geophysical data from 84 exploration boreholes (i.e. a total of 101 exploration boreholes).

A key finding of the study (McHugh, 2013) was the identification and detailing of the stratigraphyof the Burralow Formation, which overlies the Banks Wall Sandstone. Most previous studies of the Angus Place Colliery and Springvale Mine areas do not typically include the presence of the Burralow Formation, and instead refer to the Banks Wall Sandstone as the uppermost outcropping unit.
At a maximum thickness of approximately 110m, the Burralow Formation above Angus Place and Springvale is thicker than previously proposed in the general Lithgow region.

The Burralow Formation consists of medium- to coarse-grained sandstones interbedded with frequent sequences of fine-grained, clay-rich sandstones, siltstones, shales and claystones.

From the 101 bores, the Burralow Formation was determined to contain multiple fine-grained lithological units, which can be several metres thick: their presence differentiates the Burralow Formation from the underlying Banks Wall Sandstone. Correlation of the finer-grained units within the Burralow Formation identified at least seven units, as described in Palaris (2013). 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. These aquitards retard the vertical movement of groundwater into underlying strata. Instead, much of the groundwater present within the Burralow Formation is redirected laterally down-dip to discharge points in nearby valleys (valley wall seepage), which creates a permanent water source for the formation and maintenance of the NPHS. In the case of NPSS, precipitation is 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.

This is presented in Figure 3, whereby the brown contours show the outcropping Burralow Formation units where groundwater seepage would occur. Valley wall seepage, together with direct in-gully input of groundwater via aquitards, permits continuity of hydration for the THPSS during periods of drought. The presence of the Burralow Formation is essential to the formation and persistence of both hanging and shrub swamps (McHugh, 2013). Figure 3 presents a three-dimensional representation of the topography over the eastern area of the Springvale Mining lease. Steep changes in topography occur at the downstream of the THPSS often in the form of water falls.

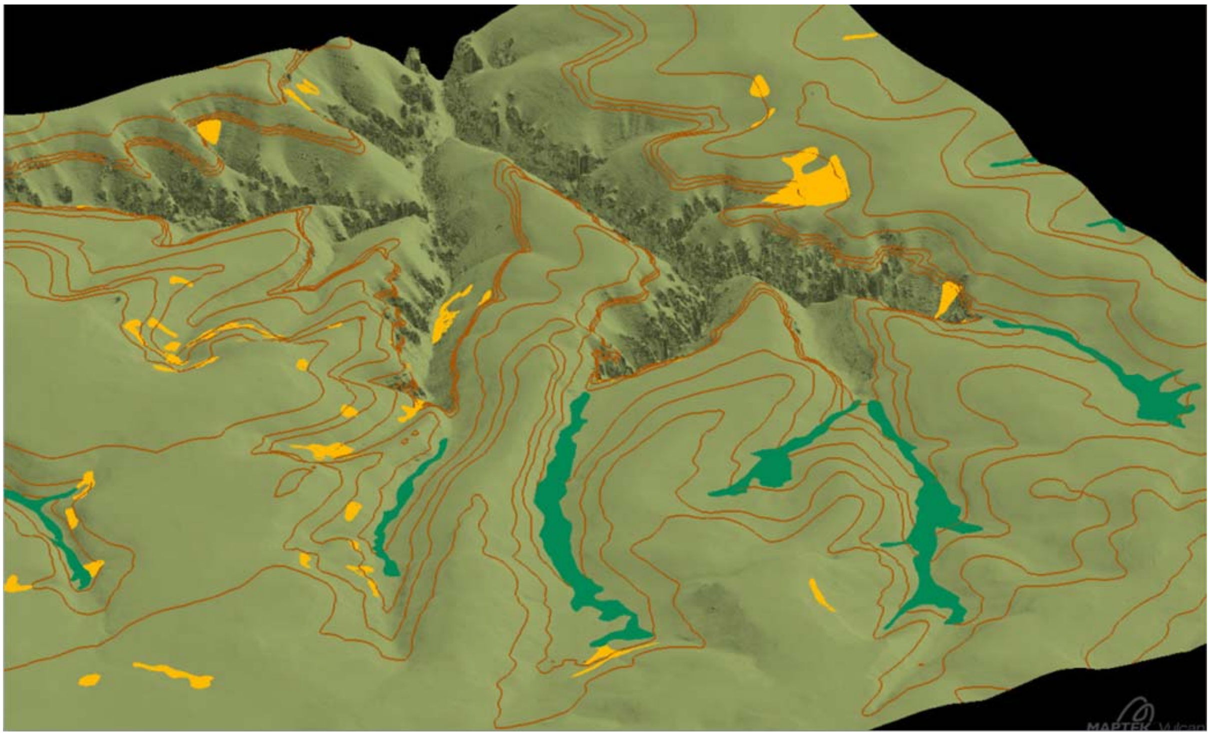

Figure 3 View of shrub swamps in headwaters of Carne Creek from 3-D geology model

Figure 4 presents the interpreted extent of the Burralow Formation in both lateral (spatial) and vertical (thickness) extent in relation to the Angus Place and Springvale Mining Leases. Figure 4 also shows the location of swamps in relation to the Burralow Formation and it can be concluded that the majority of the major swamp formations are located in this Formation. The extensive 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.

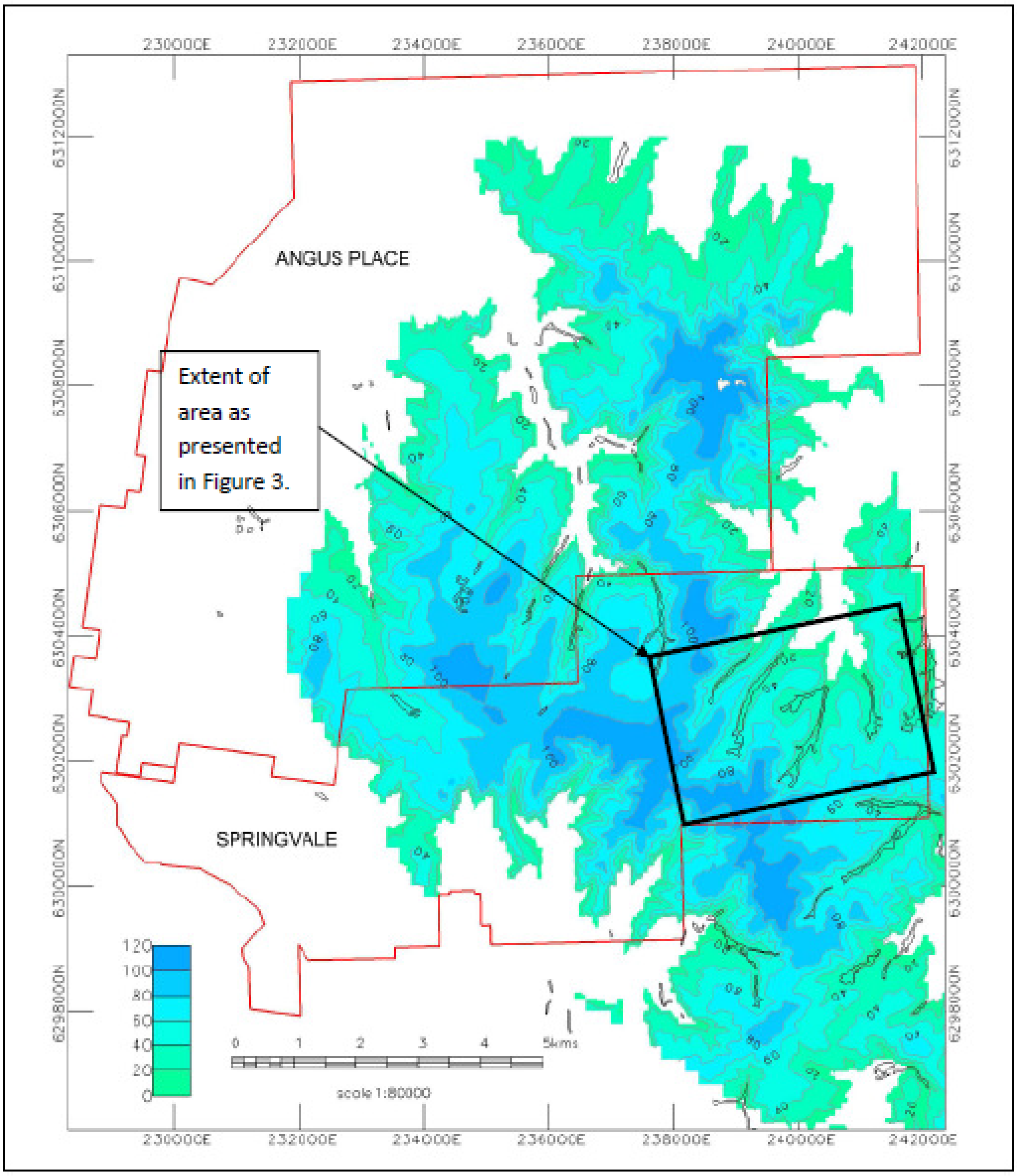

Figure 4 Isopach drawing of the Burralow Formation in the Angus Place and Springvale Mining Lease Areas together with shrub swamp locations (black outline)

Peer review comments on Chapter 2

Existing damage to upland swamps

Investigations of the Drillhole and Flat Rock Swamps identified that impacts had developed at these swamps prior to mine subsidence and that they were also affected by physical disturbances. Tomkins and Humphreys (2006) were engaged by the Sydney Catchment Authority to assess the erosion in swamps on the Woronora Plateau, including Flat Rock and Drill Hole Swamps, and concluded that:- "Human disturbance in the catchment, particularly direct physical disturbance such as at Drillhole Swamp has been found to be an important trigger of erosion of swamps. The impact of mine subsidence, however is less clear. Both Swamp 18 and Flat Rock Swamp featured scour pools and gully erosion well before any direct effects of mining were observed. It may be likely that dewatering of swamps due to mining increases the sensitivity of swamps to other influences such as wildfires.";

and that "The impacts of mining on erosion of Swamp 18 and Flat Rock Swamp is less clear as both swamps were already in the process of erosion prior to the commencement of known mining and ground subsidence."
The findings were supported by the Southern Coalfields Inquiry (DP&I, 2008) which stated that:-
"Most impacted swamps that the Panel was made aware of were valley infill swamps (e.g. Flatrock Swamp and Swamps 18 and 19). However, at all sites inspected by the Panel, there had been a range of other environmental factors in play, including evidence of pre-existing scour pools, previous initiation of erosion, concurrent drought, and subsequent heavy rainfall and/or severe bushfires. The sequence of events was not clear in relation to the swamp impacts (drying, erosion and scouring, water table drop, burning, vegetation succession, etc)."; and that in relation to Drill Hole Swamp:
"gully erosion was not directly caused by mining subsidence, per se. Significant site disturbance took place as a result of site clearing, soil disturbance and erosion associated with the drilling of a stratigraphic drillhole in 1976 for the Reynolds Inquiry. Tomkins and Humphreys conclude that the cause of the gully erosion was this site disturbance, coupled with an extreme rainfall event."
Flat Rock and Drillhole Swamps should not be used as examples of how swamps recover from mine subsidence related impacts, as these swamps showed existing erosion and scouring prior to mining and had physical disturbances from natural causes (i.e. fire, heavy rainfall and drought) and human activities (i.e. construction of roads and installation of monitoring boreholes).

3 Peat swamp conceptualisation

3.1.1 Headwater swamps

3.1.1.1 Geology/substrate

See 2.2 (Geology) above

3.1.1.2 Water regime

See 3.3 Swamp Hydrology (below)

3.1.1.3 Groundwater connection

See 3.3 Swamp Hydrology (below)

3.1.1.5 Threats to swamps from longwall mining

Mine water discharge from Springvale and Angus Place impacted on Headwater Swamps on the Newnes Plateau as documented by Goldney et al (2010) and UQ (2014).

3.1.3 Hanging swamps

3.1.3.1 Geology/substrate

See 2.2 (Geology) above

3.1.3.2 Water regime

See 3.3 Swamp Hydrology (below)

3.1.3.3 Groundwater connection

See 3.3 Swamp Hydrology (below)

3.1.3.5 Threats to swamps from longwall mining

Despite the statement CoA (2014) “Hanging swamps are expected to be more vulnerable to subsidence impacts than headwater and valley infill swamps, due to their location in steep topography where natural stresses are highest”, there are no documented cases of impacts to Newnes Plateau Hanging Swamps in the history of mining at Angus Place and Springvale since 1979.

3.2 Swamp stratigraphy

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."

3.2.1 Swamp sedimentation

As part of the investigation into impacts at East Wolgan Swamp, an investigation of the soil profile present was undertaken as follows:

Soil profile description

An open cut at the central slump location was used to assess the soil profile as a representative for the type of soils, which can be expected.
Table 1 summarises the profile description and Fig. 4 shows the soil profile at the southern end of the slump.

Soil Profile:

Fig 4: Soil profile at central slump

Tab. 1 Soil profile description in central slump area

Depth	Horizon	comments
0-40	A-horizon/peat	densely rooted
40-60	(bleached) sand	
60-65	Wet organic matter enriched layer	densely rooted
65-90	(brown) sand	
90-95	organic matter enriched layer	densely rooted
95-110	Sand enriched with organic matter	

The soil profile at the slump shows well developed root layers and relatively dense root distribution up to the max. investigated depth of 1.1m. The rooting depth may be potentially deeper.

3.2.2 Erosion

Major incisions have been recorded in pre-mining surveys of swamps including Sunnyside East Swamp (McTaggart 2013). Major incisions were recorded prior to a bushfire in 2010 which burnt through the middle reaches of the swamp, however records indicate that the bushfire did cause additional incisions to be caused to Sunnyside East Swamp in the period between 2010 and 2013.

Incisions which pre-dated mining were also identified by Goldney et al (2010) at Junction Swamp, Kangaroo Creek North, Kangaroo Creek (Mid), Narrow Swamp South and Sunnyside East (Burnt) Swamp.

3.3 Swamp hydrology

In the case of Newnes Plateau Shrub Swamps, baseline data from the piezometers indicates that swamp hydrology is variable along individual swamps, and standing water levels are typically influenced by rainfall in the upper reaches and by groundwater in the lower reaches. This demonstrates the increasing groundwater contributions from the multiple outcrops of the Burralow Formation aquitards.

The data from the swamp monitoring has shown that the hydrology of an individual swamp can be 'periodically waterlogged' or 'permanently waterlogged' or can vary along its length from 'periodically waterlogged' to 'permanently waterlogged', with transitional behaviour between (Corbett et al 2014).

Monitoring of piezometers in Sunnyside, Sunnyside East, Tri-Star and Carne West swamps indicates that variable hydrology (between periodically waterlogged in the upper reaches and permanently waterlogged in the lower reaches) occurs for swamps to the East of the Newnes Plateau in swamps previously identified as entirely permanently waterlogged.

3.4 Groundwater interaction

Hydrogeological models for Newnes Plateau swamps have been developed through detailed investigation and research since 2010 (detailed in McHugh (2013) and Corbett et al (2014)). These models are described in detail in the SVMEP EIS, the APMEP EIS (specifically Chapters 2 and 8), the respective Response to Submission Reports.

A key finding of the study (McHugh, 2013) was the identification and detailing of the stratigraphy of the Burralow Formation, which overlies the Banks Wall Sandstone. Most previous studies of the Angus Place Colliery and Springvale Mine areas do not typically include the presence of the Burralow Formation, and instead refer to the Banks Wall Sandstone as the uppermost outcropping unit.

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. These aquitards retard the vertical movement of groundwater into underlying strata. Instead, much of the groundwater present within the Burralow Formation is redirected laterally down-dip to discharge points in nearby valleys (valley wall seepage), which creates a permanent water source for the formation and maintenance of the Newnes Plateau Hanging Swamps (NPHS).

In the case of Newnes Plateau Shrub Swamps (NPSS), precipitation is 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. Valley wall seepage, together with direct in-gully input of groundwater via aquitards, permits continuity of hydration for the THPSS during periods of drought. The presence of the Burralow Formation is essential to the formation and persistence of both hanging and shrub swamps (McHugh, 2013).

4.2 Sensitivity to mine waste water discharge

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."

The findings of the Goldney et al (2010) report are supported by further research by University of Queensland. An extract from ACARP Project - C20046 Report (Monitoring surface condition of upland swamps subject to mining subsidence with very high-resolution imagery) is included below:

"Imagery collected by the small-UAS clearly show spatially discrete impacts on the vegetation within a shrub swamp associated with mine discharge flow channel (Fig. 21a,d), including slumping and scouring of peat and underlying sand (Fig. 21b) and trampling as a result of subsidence monitoring (Fig 21e). Mine water discharge rates were as high as 240l.sec-1 which, combined with a continuous slope of 1.53 degrees along the length of the shrub swamp (25m decline over 960m), resulted in a channel up to 28m wide. Vegetation outside the flow path of the mine associated water is still intact present (Fig. 22). As imagery was collected in mid-June (late autumn) condition is difficult to assess from imagery.

To allow classification of shrub swamp impacts a 15cm GSD orthophoto product was segmented using multi-resolution segmentation algorithm (eCognition Developer v8.7 scale 30, shape 20, compactness 30) resulting in recognizable features in the image. The segments were converted to polygon features and exported to ArcGIS (v10.1, ESRI, CA, U.S.A.). Manual interpretation was then applied to each segment to assign a class of shrub vegetation, bare ground/dead vegetation or other. Dead vegetation was characterized by high reflectance while bare peat in eroded areas was dark in colour. Shrub vegetation was defined by a combination of colour, surface elevation and texture. The imagery detected both live vegetation and areas of bare ground allowing the spatial extent of disturbance to be classified in two categories (Fig. 22). Waypoints (Fig. 22; e.g., 14 and 15) could be separated in two categories even if they had similar estimates of bare ground (10-25 percent), high estimates of leaf litter (55-80%), and differed only in low percentage cover estimates of vegetation. For example, waypoint 14 had cover from a common shrub swamp species Leptospermum obovatum (7%), while waypoint 15 had small low growing species, including Baumea rubiginosa (6%) and Centella asiatica (5%). In contrast to ground surveys, the classification process utilized surrounding information to quantify natural breaks in shrub swamp habitat and disturbed areas over a broad geographic area. The utility of small UAS can bridge the gap between data collected from the ground (local) and information captured using remote sensing tools (regional), to provide broad landform assessments covering key conservation concerns in protected and threatened ecosystems (Kerr and Ostrovsky, 2003; Turner et al., 2003).

The primary cause for vegetation loss appears to be the flow path of mine discharge water through the studied shrub swamp community. This conclusion is supported by the presence of shrub swamp species surrounding impacted areas caused by discharge events which ended in March 2010. The extensive areas of dead vegetation and bare ground remaining more than three years later demonstrates a sustained and extensive degradation of this community. UAS

imagery combined with field survey demonstrates the capacity for assessment of impacts at an actionable scale by applying ground derived knowledge to spatial extents.
Manual delimitation of extent and context of spatially discrete impacts to vegetation is not necessarily quantitative but provides coverage of entire shrub swamp communities at a known date without impact to the community.

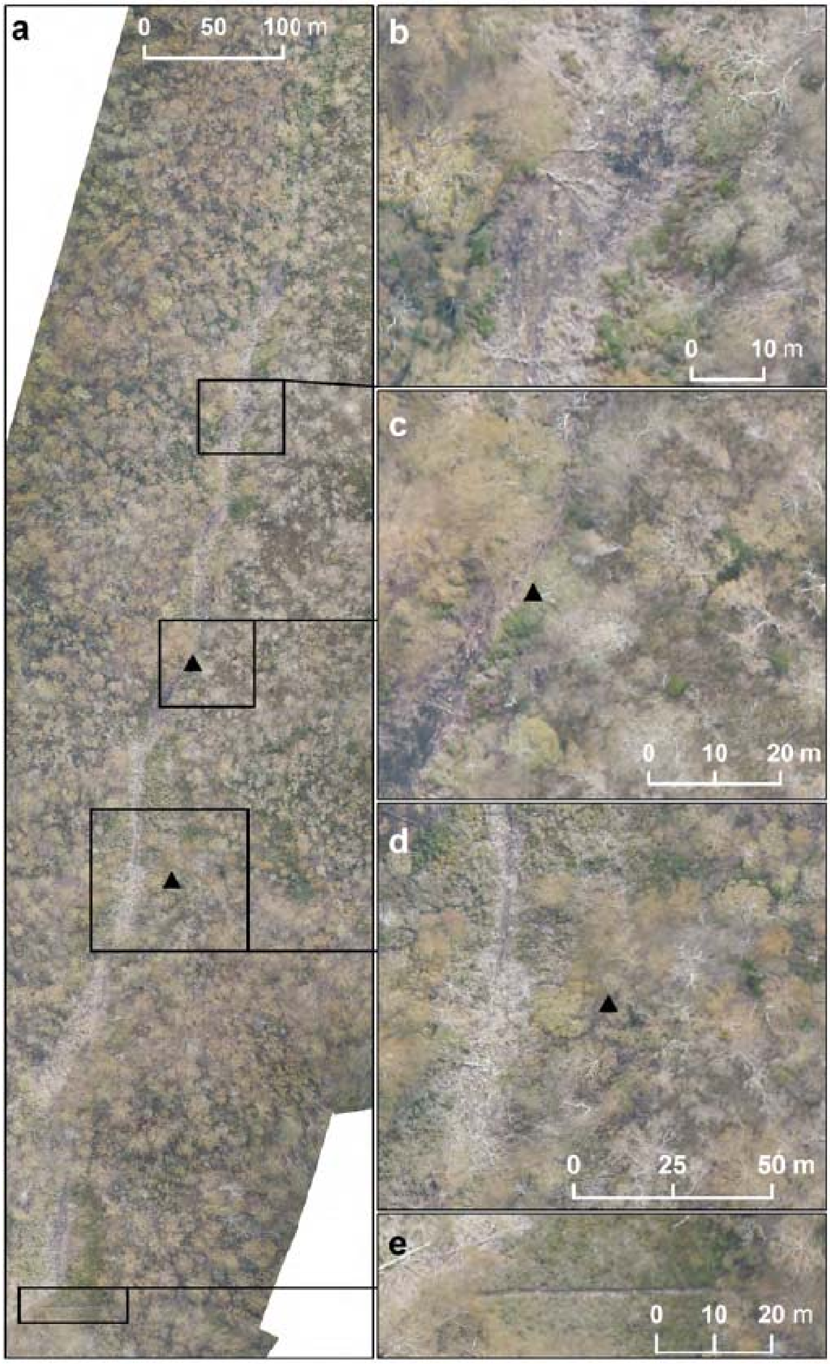

Figure 21: (a) UAS orthophoto mosaic of a shrub swamp collected in June 2013 showing outline of community as described in VISmap 2231 by New South Wales Office of Environment and Heritage. (b). Detail of slump towards downstream end of swamp caused by preferential flow of mine discharge water to below ground strata. (c) Detail image of location of monitoring plot EW01. (d) Detail image of location of EW02 monitoring plot. (e) Upstream end of shrub

swamp community showing trampling impact of subsidence monitoring line.

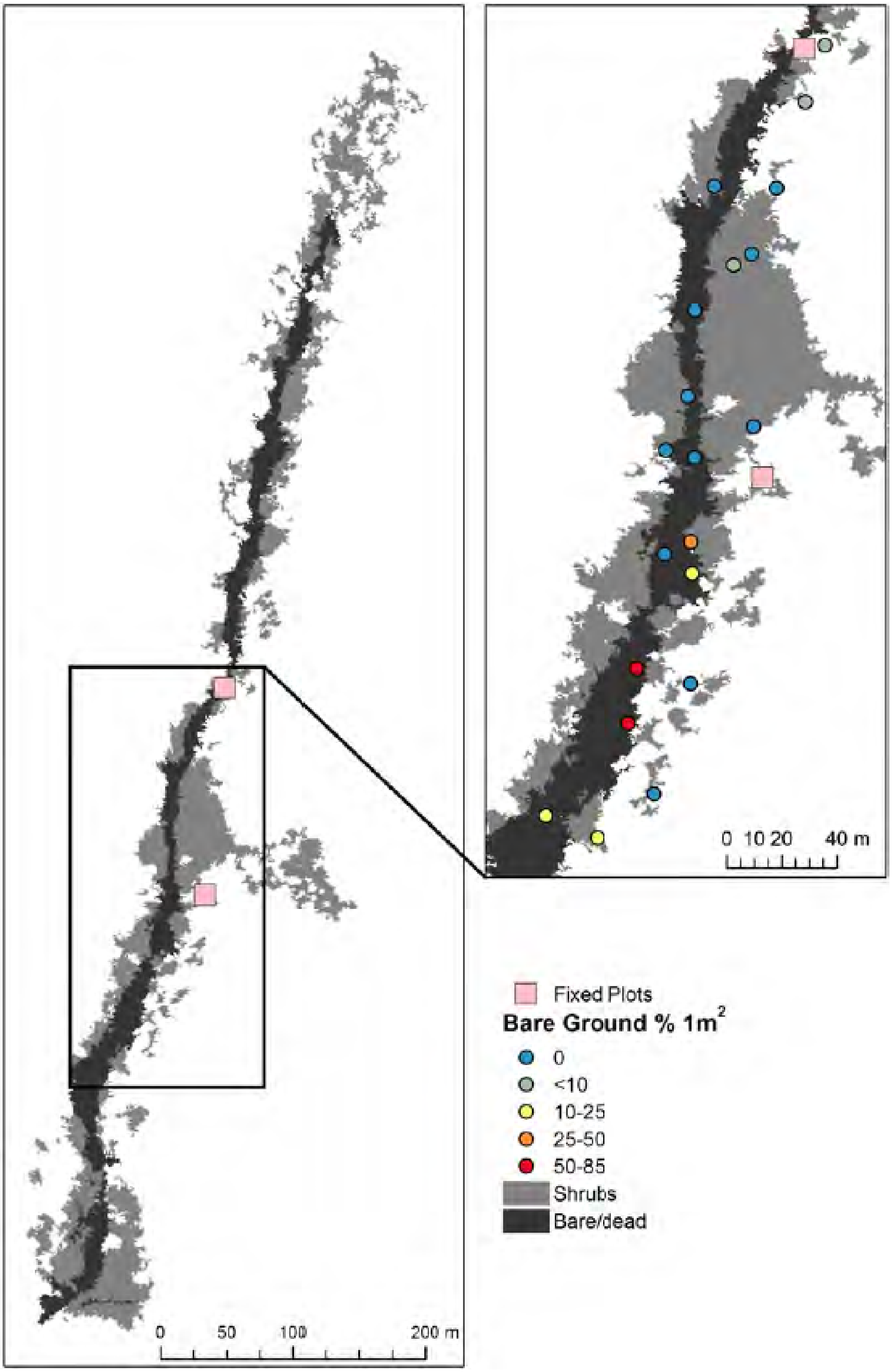

Figure 22: (main) Thematic map of a shrub swamp describing shrub vegetation and dead or bare ground. (inset) Area of mini-plot vegetation assessment ranked by proportion of bare ground identified in 1m2 plot."

Springvale Coal Pty Ltd (2013) reported the following in terms of investigations into the role of mine water discharge in impacts to East Wolgan Swamp. "Figures 1.20 to 1.25 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."*

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.

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.

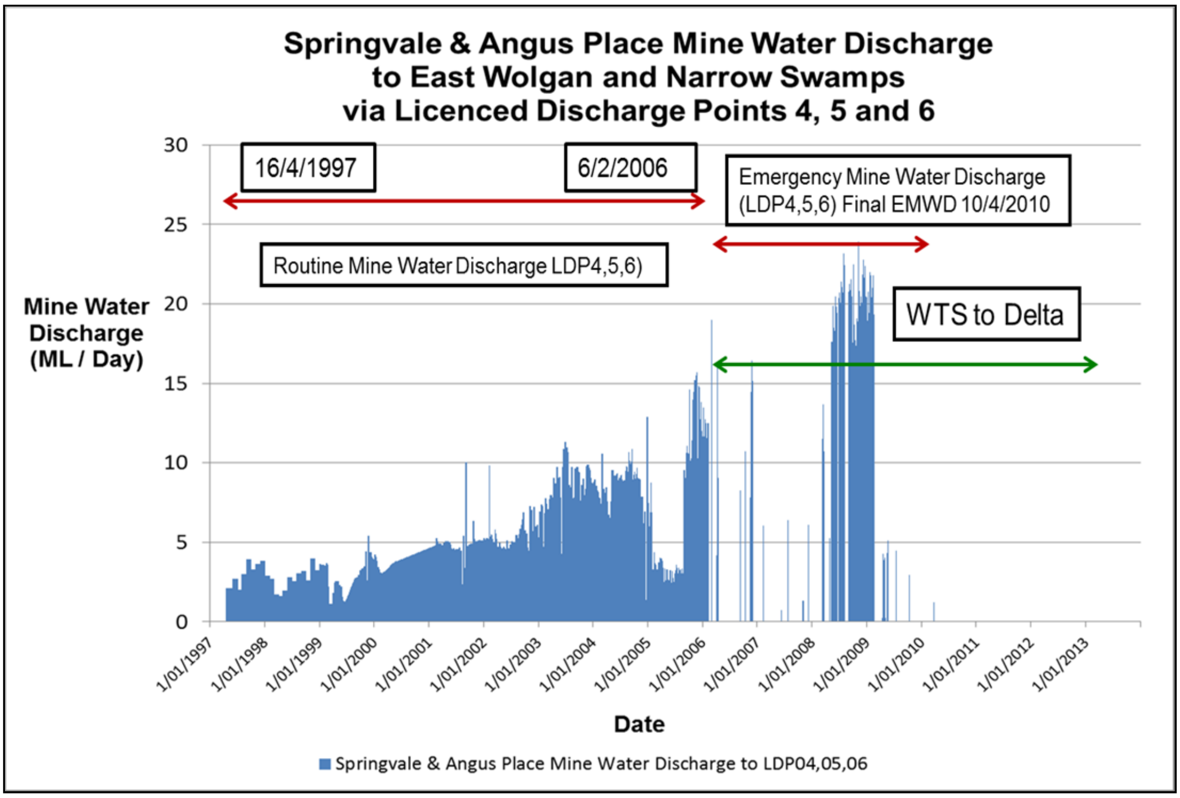

Figure 1.26 Mine Water Discharge to East Wolgan and Narrow Swamps via Licenced Discharge Points 4, 5 and 6 – first discharge 16/4/1997, no discharges since 10/4/2010

Figure 1.27 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.

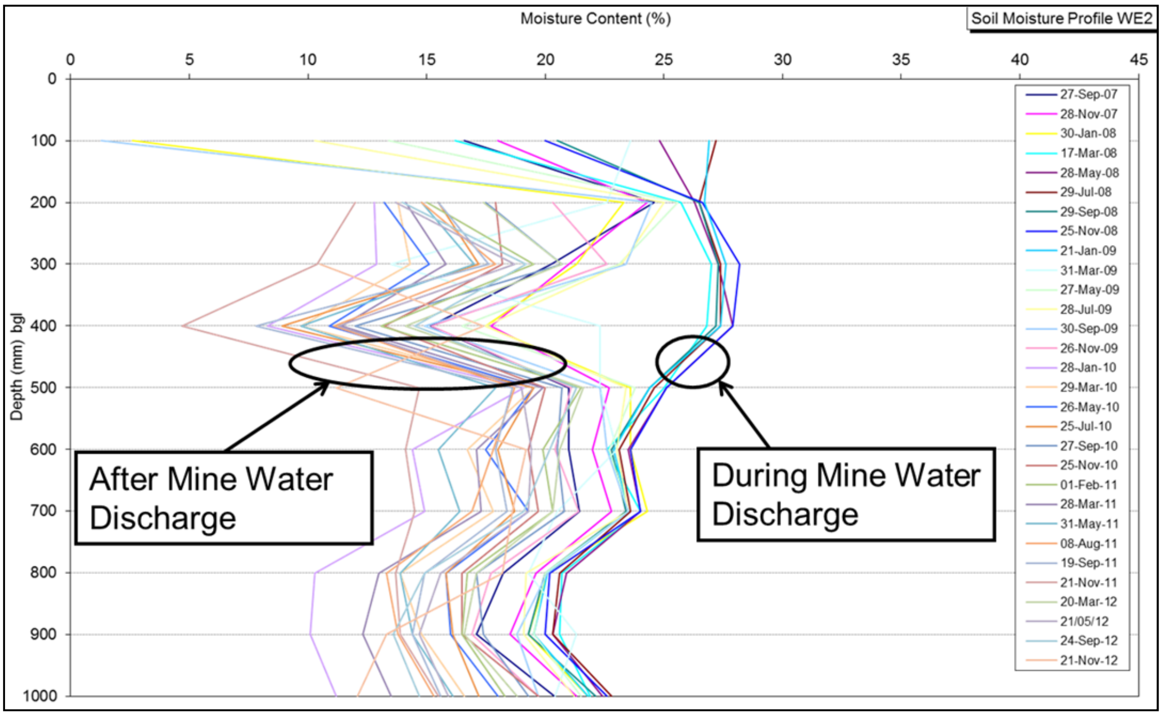

Figure 1.27 Soil Moisture Monitoring Data from WE2 Piezometer Location in East Wolgan – Showing Differences Between Results During and After Mine Water Discharge

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.

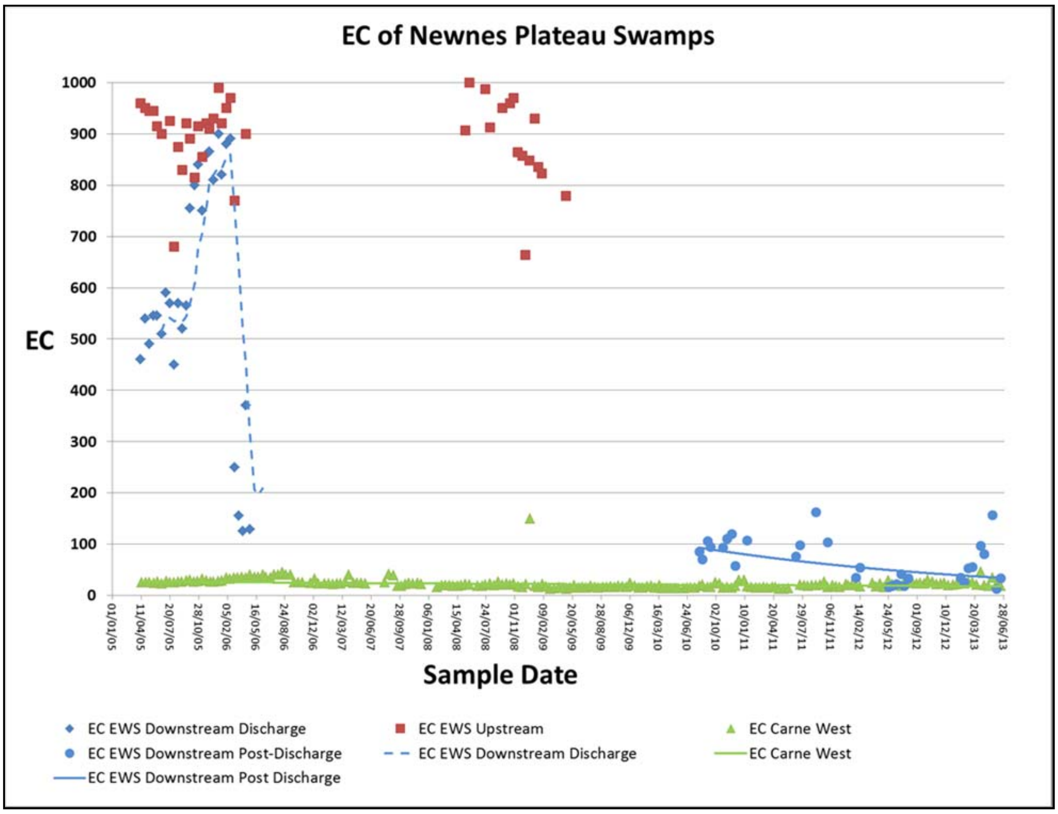

Figure 1.28 Electrical Conductivity (EC) Water Quality Data from Newnes Plateau Swamp Sampling Sites – showing significant differences between measured EC at swamps impacted by mine water discharge compared to typical Newnes Plateau swamp (Carne West). NB Elevated EC values are still being recorded at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

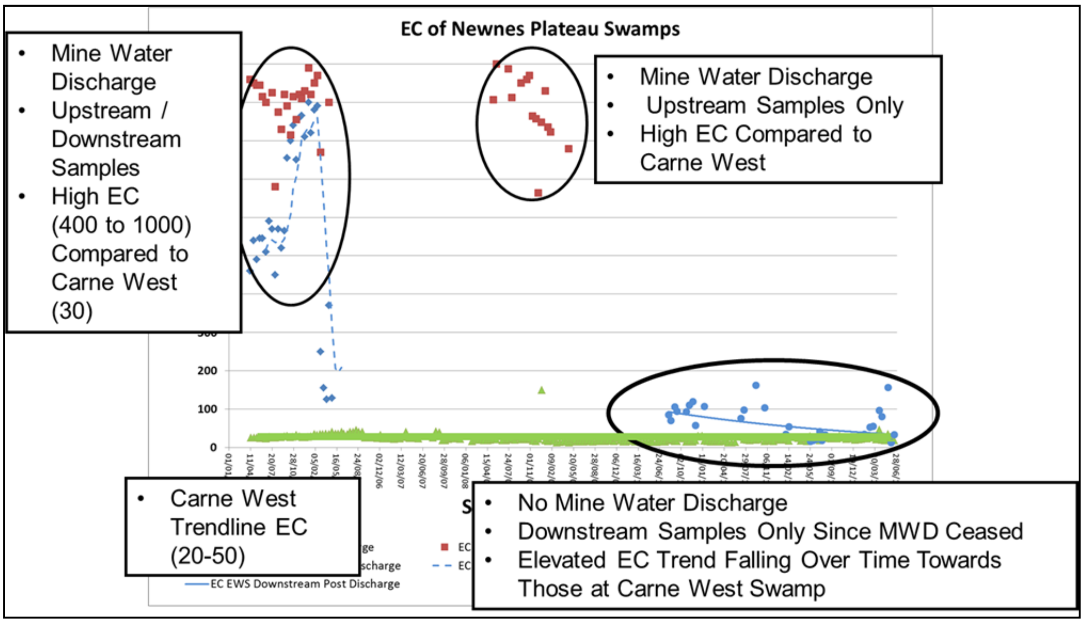

Figure 1.28(a) As per Figure 1.28 with Explanation of Interpretation of Data

Figure 1.29 Water Quality Data (pH) from Newnes Plateau swamp sampling sites, showing significant differences between measured pH at 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.

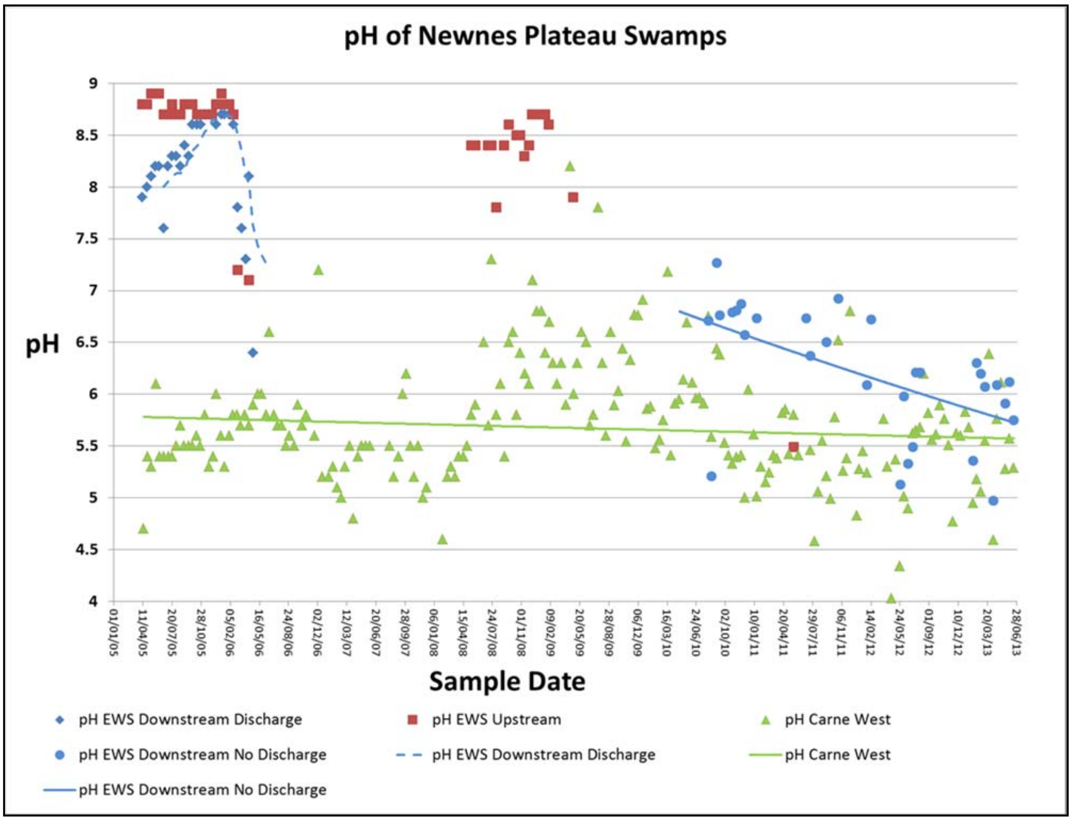

Figure 1.29 Water Quality Data (pH) from Newnes Plateau Swamp Sampling Sites – showing significant differences between measured pH at swamps impacted by mine water discharge compared to typical Newnes Plateau swamp (Carne West). NB Elevated pH values are still being recorded at swamps impacted by mine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

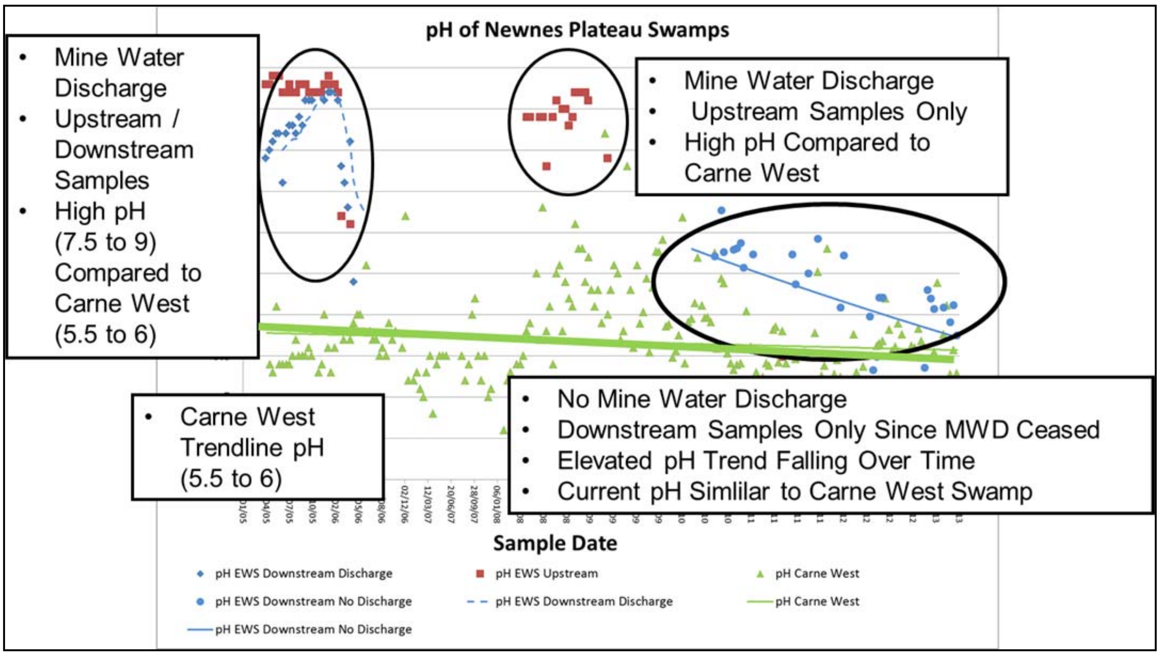

Figure 1.29(a) As per Figure 1.29 with Explanation of Interpretation of Data

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*."

Investigations into soil water chemistry were undertaken at East Wolgan Swamp, with soil samples taken at multiple horizons within the peat. 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.

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 humus containing horizon is acidic."

6 Evaluation of monitoring techniques

7 Ecological monitoring and reporting approach

8 Recommended monitoring methods

Monitoring programs have been established in accordance with NSW State and Federal requirements in order to determine if mining related impacts from longwall mining activities on the Newnes Plateau.

The Springvale THPSS Monitoring and Management Plan was approved by DotE in October 2013 following peer review by two independent reviewers. It is based on BACI design within statistically calculated triggers for the following parameters:

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

Time series analysis processes have been built into the development of trigger values, to identify short and long term mining related impacts, should any occur. The Springvale THPSS Monitoring and Management Plan is appended to this review report.

9 Knowledge gaps

In order to further improve understanding of the impacts of longwall mining on Newnes Plateau THPSS, Centennial implemented research programs in conjunction with the University of Queensland with the following key outcomes:

- Development of a statistically robust ecological change methodology for flora monitoring of THPSS and an associated Monitoring Methodology handbook. This handbook outlines the datasets, analyses and reporting required to conduct a statistically rigorous and sensitive flora monitoring program to detect change in Newnes Plateau Shrub Swamps and Hanging Swamps, at an individual swamp community scale, due to underground mining. It contains the following improvements, relative to current monitoring programs in use: 1) sufficient replication at the swamp scale such that analysis of key indicators of community composition and health can be assessed in a statistically rigorous manner, 2) clearly defined and ecologically meaningful trigger values and 3) a clear framework outlining required. The Monitoring Methodology handbook - Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps is appended to this review report.

- The University of Queensland is currently conducting research on communities identified as temperate treeless palustrine swamps in a 268 square kilometre area which includes the Newnes Plateau. Based on publicly available combined mapping from the temperate zone of New South Wales and manual interpretation of the numerous vegetation classifications used, a region containing more than 1000 shrub swamp communities per degree of latitude/longitude was identified which contained the communities mapped as Newnes Plateau shrub swamps. A report based on the research will be published and finalised in 2014.

References

A number of relevant publicly available references were not used in the preparation of these reports. These include:

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

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

Springvale Coal Pty Ltd (2013) EPBC Approval 2011/5949 Application to Allow Longwall Mining Under Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau – Supplementary Data Volume 1 – 3 and Appendices

Fletcher, A. and Erskine, P. (2014) Monitoring surface condition of upland swamps subject to mining subsidence with very high-resolution imagery (ACARP Project - C20046)

DgS Report No. SPV-003/7b (2014) Subsurface Fracture Zone Assessment above the Proposed Springvale and Angus Place Mine Extension Project Area Longwalls

Corbett, P., White, E., Kirsch, B., (2014) Hydrogeological Characterisation of Temperate Highland Peat Swamps on Sandstone on the Newnes Plateau

Corbett, P., White, E., Kirsch, B., (2014) Case Studies of Groundwater Response to Mine Subsidence in the Western Coalfields of NSW

Brownstein, G., Johns, C., Blick, R., Fletcher, A., Erskine, P., (2014) Flora monitoring methods for Newnes Plateau Shrub Swamps and Hanging Swamps