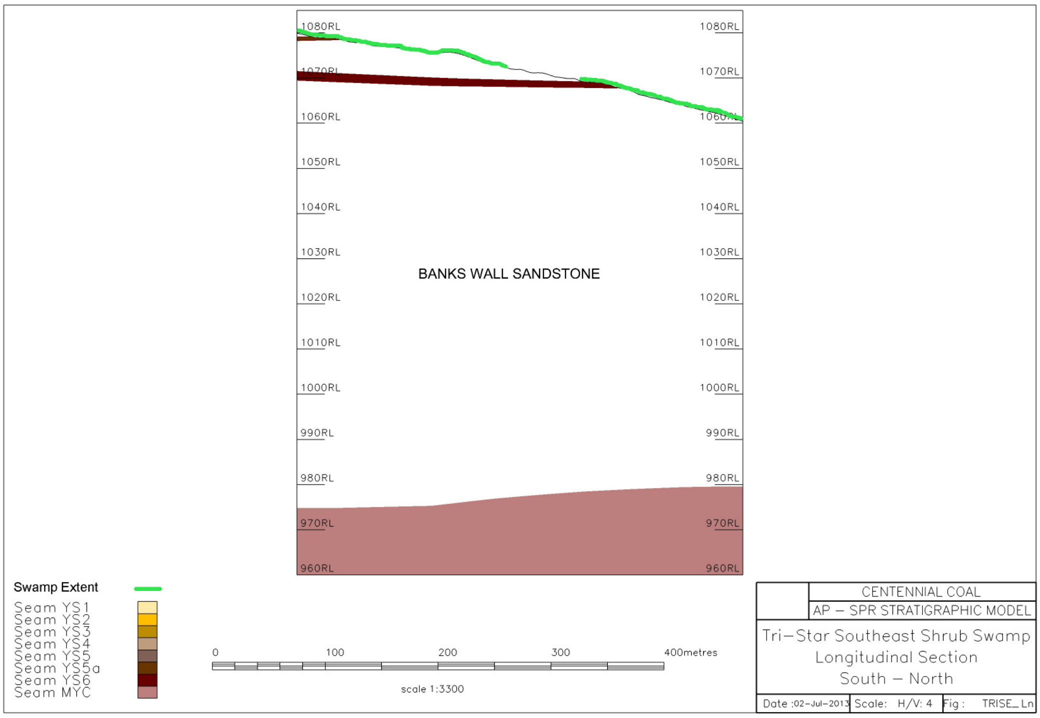

Figure 38 Longitudinal Stratigraphic Section of Tri-Star Shrub Swamp (South-East segment)

Figure 38 shows a south-east to north-west longitudinal cross-section of the south-east tributary of Tri-Star swamp. The upper two-thirds are located within the Burralow Formation and are located stratigraphically between plies YS6 and YS5a. The extreme upper reaches are situated between plies YS5a and YS5. The lower reaches are located within the Banks Wall Sandstone where, as with the northern tributary discussed above, the gradient steepens due to the change in geological regime. The majority of the swamp relies hydrologically on valley wall seepage from the YS6, YS5a and YS5 aquitards together with direct in-gully input from the lower two plies.

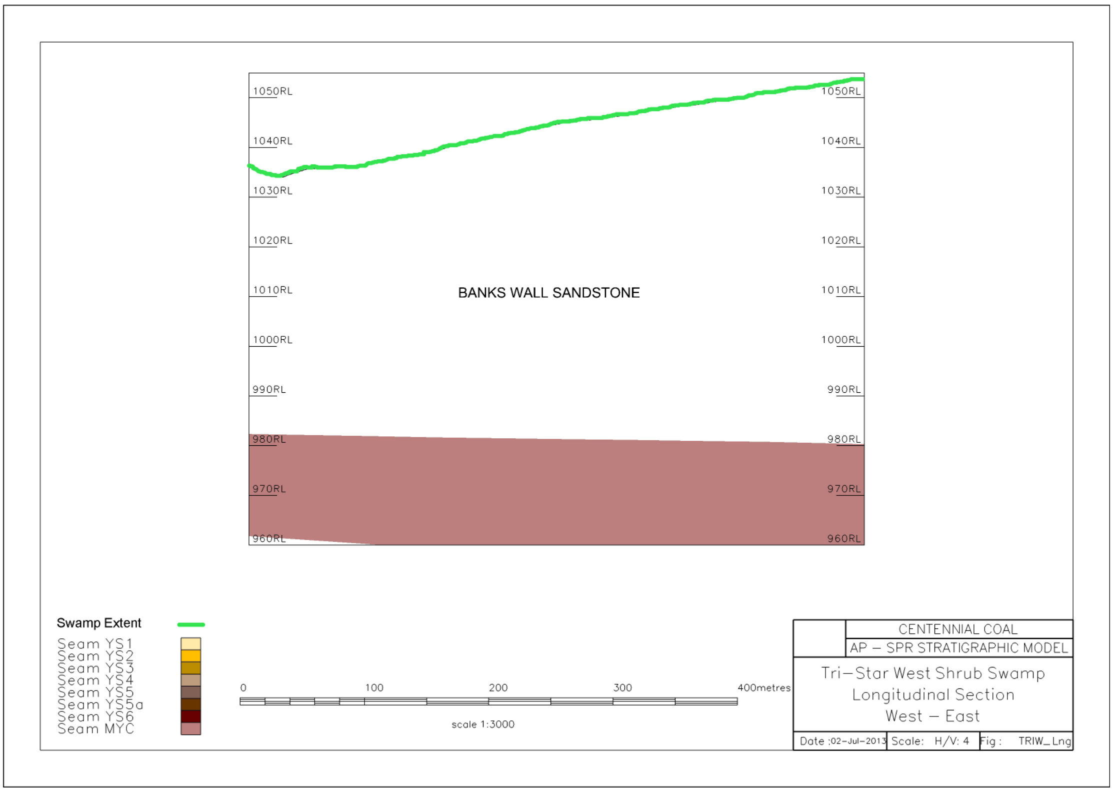

Figure 39 Longitudinal Stratigraphic Section of Tri-Star Shrub Swamp (West-East segment)

The main drainage line of Tri-Star shrub swamp (Figure 39) is stratigraphically located within the Banks Wall Formation. Shrub swamp formation relies on suitable topographic conditions, downstream flow from the upper tributaries and valley wall seepage from the YS6/YS5a/YS5 sequence of aquitards, particularly from the steeper northern flank of the gully at this location.

Figure 40 Pre-mining slumping at Tri-Star Shrub Swamp in the lower reaches of the south-eastern tributary

Pre-mining slumping has been observed in the area by Lembit (pers. com.). The above photo was taken at 237347E / 6306973N GDA, which is situated at the extreme lower reaches of the south-eastern tributary of Tri-Star Shrub Swamp. Lembit (2010) also noted the presence of "dieback and death of swamp plants" and that this location was "close to a drop point along the drainage line". Slumping and die-back, as shown in Figure 40 above, can be natural phenomena which occur as a result of rainfall variation and associated erosional factors.

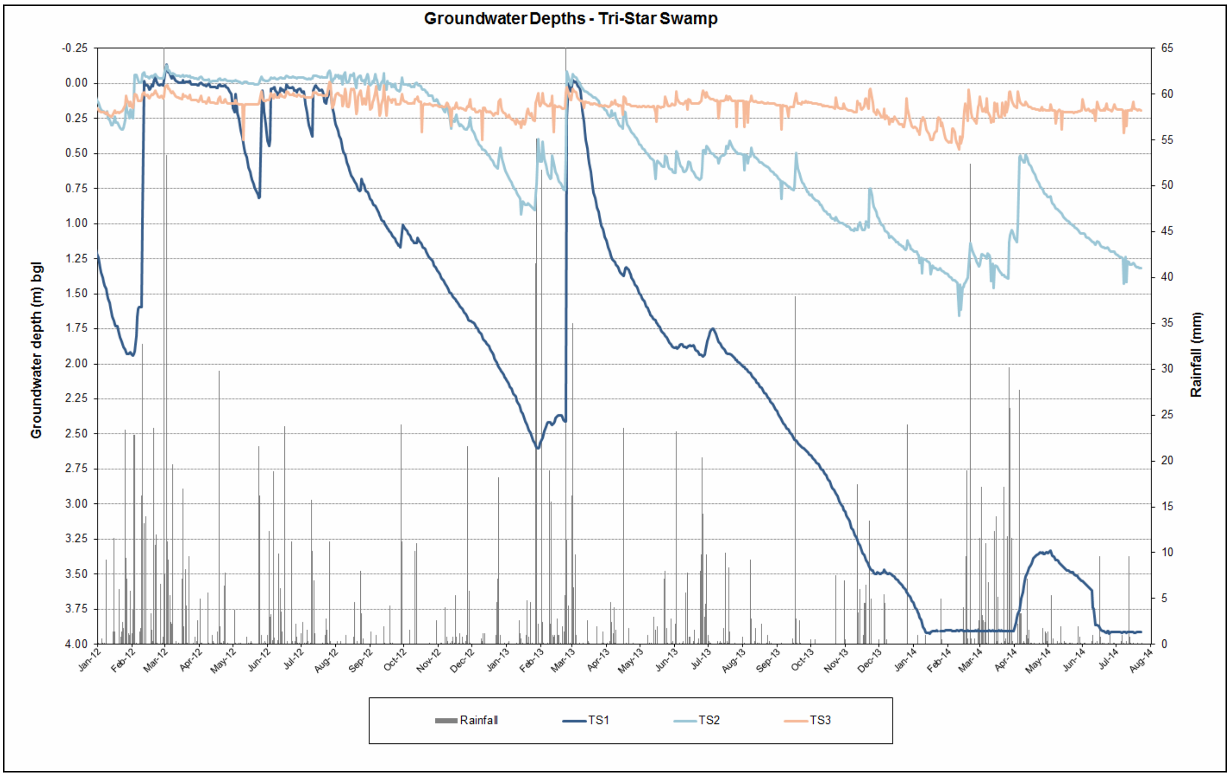

Figure 41 Hydrograph of Tri-Star Shrub Swamp

Figure 41 shows piezometric data from January 2012 to early August 2014 for all three swamps which form part of the Tri-Star complex. Piezometer TS3 (pink), which is located in the lower western reaches of the swamp and is situated within the Banks Wall Sandstone, displays a permanently waterlogged profile with minimal rainfall influence. Negative spikes in the profile represent regular groundwater sampling times.

Piezometer TS2 (light blue) is located in the south-eastern tributary of Tri-Star gully at the northern (lower) end of the upper extension of this swamp (Figure 35). Stratigraphically, it is situated within the Burralow Formation between plies YS5a and YS6. The hydrological pattern displayed at TS2 is essentially groundwater dependent, where groundwater stands at an average of 0.5 metres below ground surface, with a minimum reading of 1.5 metres below ground surface during February 2014. However, there exists slight to moderate increases in groundwater levels in response to rainfall.

Piezometer TS1 (dark blue) is located in the upper reaches of the north-eastern tributary of Tri-Star gully and is stratigraphically located within the Burralow Formation between plies YS5a and YS5 (Figure 35). This piezometer suggests a typical "periodically waterlogged" profile at this location with low rainfall periods corresponding to lower groundwater levels, particularly in the period April 2013 to early August 2014. Moderate rainfall in late February to late April 2014 resulted in slight increases in recorded levels which have subsequently levelled off to the lowest recording of groundwater levels from this site.

The differences in groundwater levels at TS1, TS2 and TS3 are lithologically and topographically controlled. As noted, TS3 in the lower reaches receives groundwater input from two upstream tributaries as well as valley wall seepage from proximal Burralow Formation aquitards. This monitoring station is also located approximately 25 metres above the standing watertable as determined by the proximity of the Wolgan River 400 metres to the west and as such would be expected to experience relatively high standing water levels.

Both TS1 and TS2 register lower groundwater levels than TS3 even though they are situated within the Burralow Formation. This is due to their higher elevation and the effect of the Banks Wall Sandstone substrate which comprises the lower reaches of both tributaries. Like similar "mixed-type" shrub swamps discussed in the Springvale area, these two tributaries consequently have restricted morphologies and varying degrees of groundwater influence.

The positioning of TS1 at the extreme upper reaches of the north-eastern swamp ensures that the groundwater levels are relatively low, hence conditions necessary for peat growth and thus swamp formation cease at this point. By contrast, TS2 is located relatively further downstream of the hydrologically-similar south-eastern arm and thus records higher groundwater levels as shown in Figure 41.

The Tri-Star shrub and hanging swamp complex as a whole is one of the most hydrologically interesting areas within the Angus Place/Springvale leases. This is particularly the case for the hanging swamps in this vicinity which are topographically exposed to high levels of evaporation and have a relatively restricted recharge area. These hanging swamps also have minimal groundwater support, with the higher elevation hanging swamps only supported hydrologically by the YS1 and YS2 aquitards.

Despite these factors, the presence of several hanging swamps in this locale is suggestive of relatively high groundwater levels within the strata. However, due to susceptibility to dry-out, it is recommended that additional piezometers be located within Tri-Star shrub swamp at locations XTS4, XTS5 and XTS6. These proposed piezometers would monitor groundwater levels prior and subsequent to mining and supply useful data to verify any changes which may occur in the associated hanging swamps as detailed above. The locations of these proposed monitoring locations are shown in Figure 35.

IV. *Crocodile Shrub Swamp*

Crocodile Shrub Swamp trends southwest – northeast and the host gully is an upper tributary of Carne Creek (Figure 42). It is approximately 500 metres long and 50 metres wide (not including the fringing hanging swamps on the north-western flank of the gully). The fall is approximately 44 metres. The upper reaches of the swamp are situated marginal to the angle of draw for proposed longwall LW1003 but is distal from any known structure zones (Section 4, Figure 4).

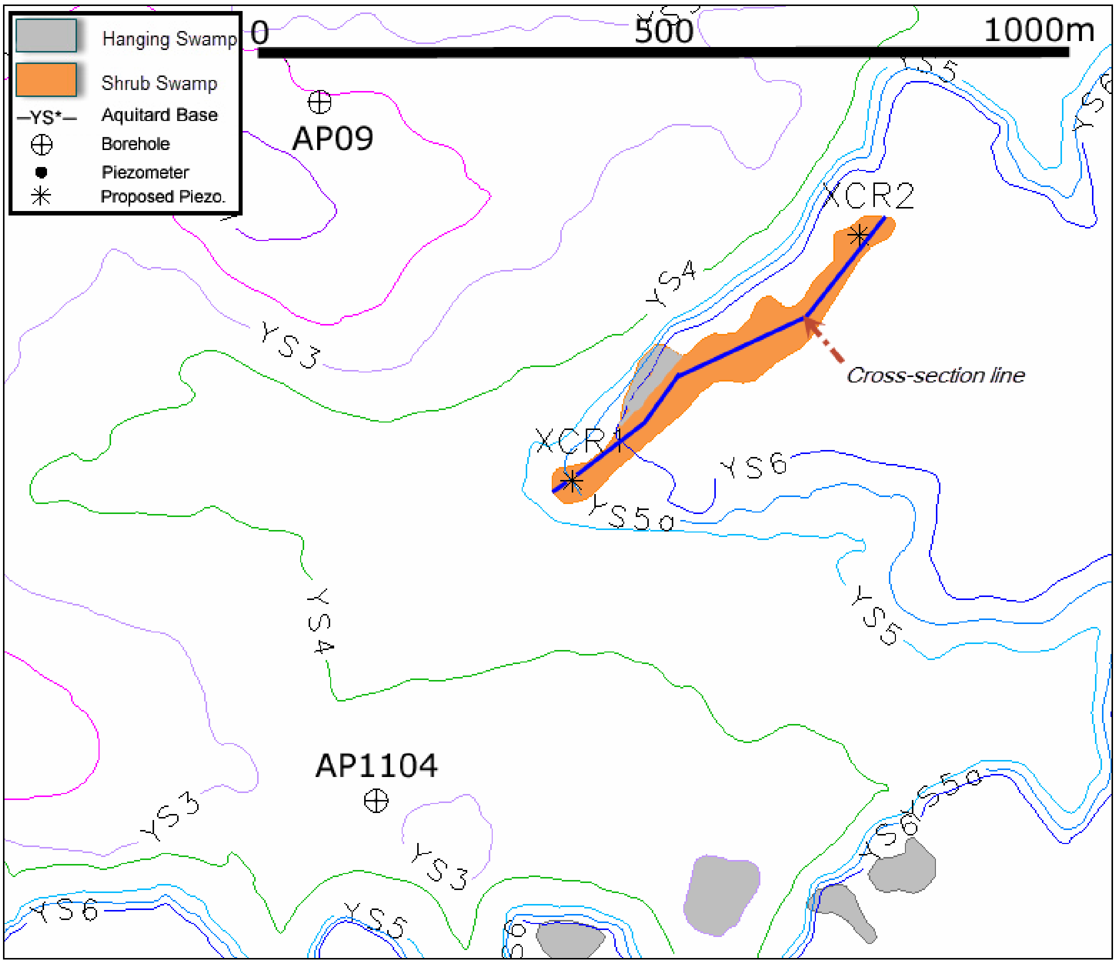

Figure 42 Plan of Crocodile Shrub Swamp

Crocodile Shrub Swamp is a "mixed-type" swamp with its upper reaches supported hydrologically by the YS6, YS5a and YS5 aquitards. For the bulk of its length, the swamp relies on valley wall seepage from the above plies plus the YS4 aquitard, all of which crop out along the steep northern flank of this shrub swamp.

Lembit (2010) confirmed the presence of suspected hanging swamps along the northern flank of this shrub swamp and thus this swamp deviates from its previous DEC (2005) classification and Figure 42 represents the updated configuration. The associated hanging swamps are dominated by Coral Fern (*Gleichenia dicarpa*). The presence of hanging swamps illustrates the relatively high groundwater levels at this location due to the virtual coalescence of aquitard plies YS4, YS5, YS5a and YS6 along the northern flank. However, the dominant Banks Wall Sandstone substrate ensures that this swamp is relatively short in length compared to Burralow-type swamps with their associated multiple in-gully aquitard groundwater input.

Figure 43 Crocodile Shrub Swamp flanked by hanging swamp vegetation

Figure 43 shows a view of Crocodile Shrub Swamp from the upper reaches looking northwards towards the hanging swamp on the relatively steep northern flank. The photo was taken from 239734E 6306563N GDA. This is the widest portion of the swamp due to the added width of the hanging swamp at this location.

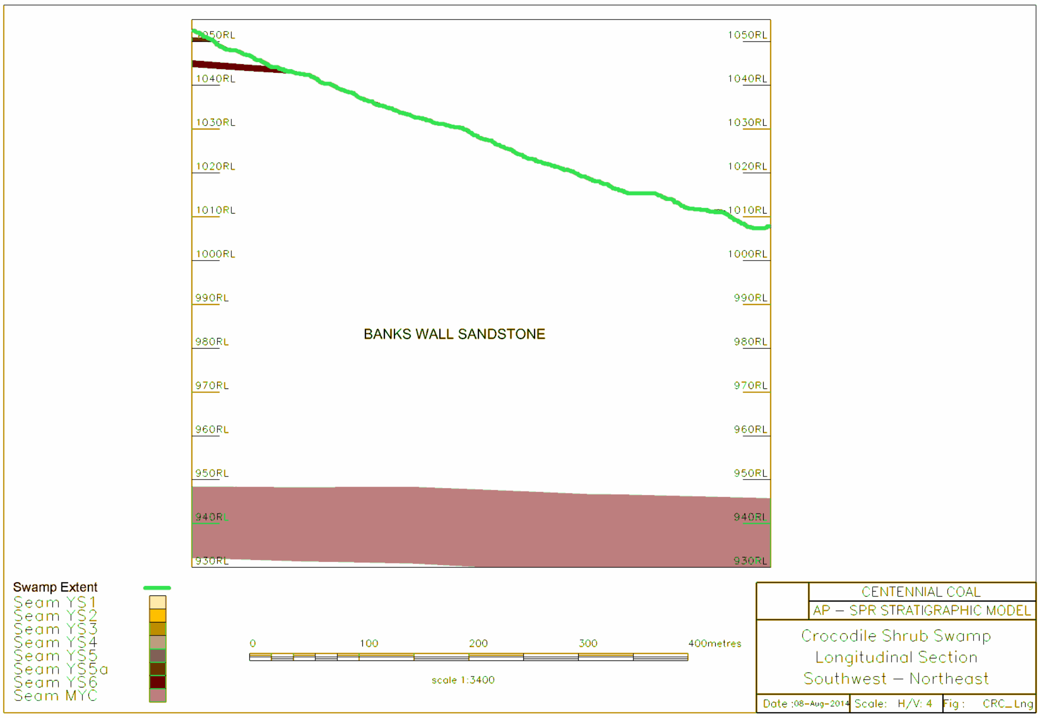

Figure 44 Longitudinal Stratigraphic Section of Crocodile Shrub Swamp

Figure 44 shows a longitudinal stratigraphic section of Crocodile Shrub Swamp. The extreme upper reaches are underpinned by the YS5a aquitard with both the YS5a and YS6 plies supplying direct in-gully groundwater to the upper reaches. The bulk of the swamp consists of a Banks Wall Sandstone substrate, which influences the relatively steep gradient and the limited length of the swamp as compared to those swamps underpinned solely buy the Burralow Formation.

There is no piezometer data for Crocodile Swamp to date and this situation should be addressed prior to mining. Two swamp piezometer monitoring sites have been suggested for this swamp and are labelled XCR1 and XCR2 in Figure 42 above. The former site has been selected to provide upstream groundwater data that will monitor groundwater response to mining. The downstream site was chosen to have pre-mining data reflecting the groundwater regime at this location and to act as a control groundwater monitoring site.

V. Rattlesnake Gorge Hanging Swamp Complex

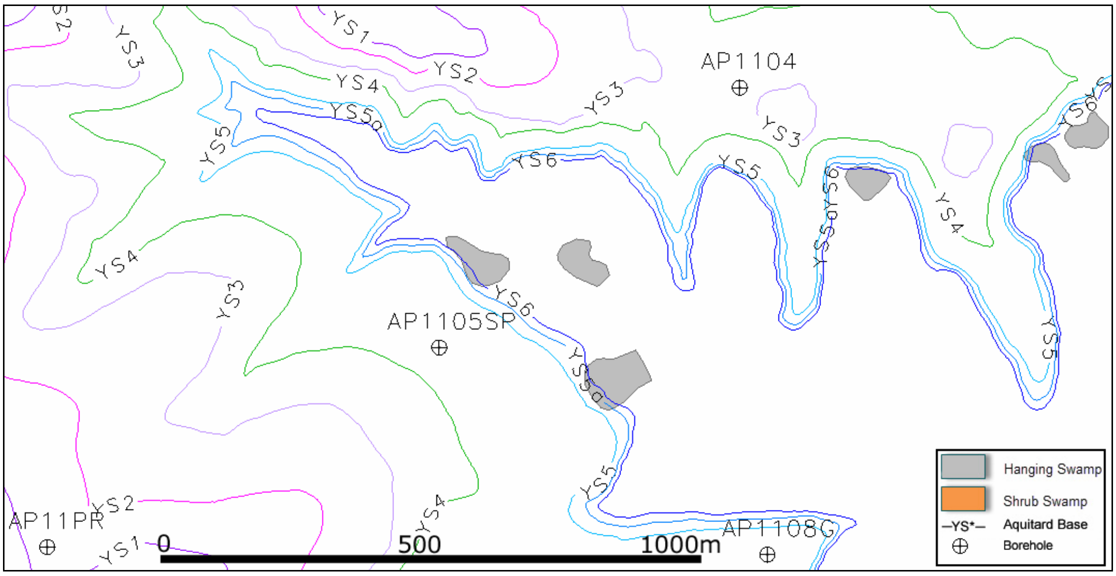

Figure 45 Hanging Swamp Complex at Rattlesnake Gorge

The Rattlesnake Gorge Hanging Swamp complex has been included in the current report due to the proximity of the three westerly swamps near AP1105SP (Figure 45) to longwall mining. The hanging swamp to the north-east of AP1105SP will be undermined by proposed longwall LW1002. The western half of the hanging swamp due east also falls within the angle of draw for LW1002. The hanging swamp to the east-south-east of AP1105SP is outside of the predicted angle of draw (P.Corbett pers. comm.). It is recommended that the two former swamps be monitored for changes in vegetation status before and after longwall extraction.

All five of the upper hanging swamps at this location are hydrologically supported by the YS5, YS5a and YS6 aquitards (Figure 45). The kidney-shaped “hanging swamp” north-east of AP1105SP has been observed only from the northern escarpment and has not been formally ground-truthed due to access difficulties (Lembit, 2014).

It can be noted from Figure 42 that the Rattlesnake Gorge suite of swamps is hydrologically contiguous with the hanging swamp system adjoining Crocodile shrub swamp.

VI. Smithston Hanging Swamp Complex

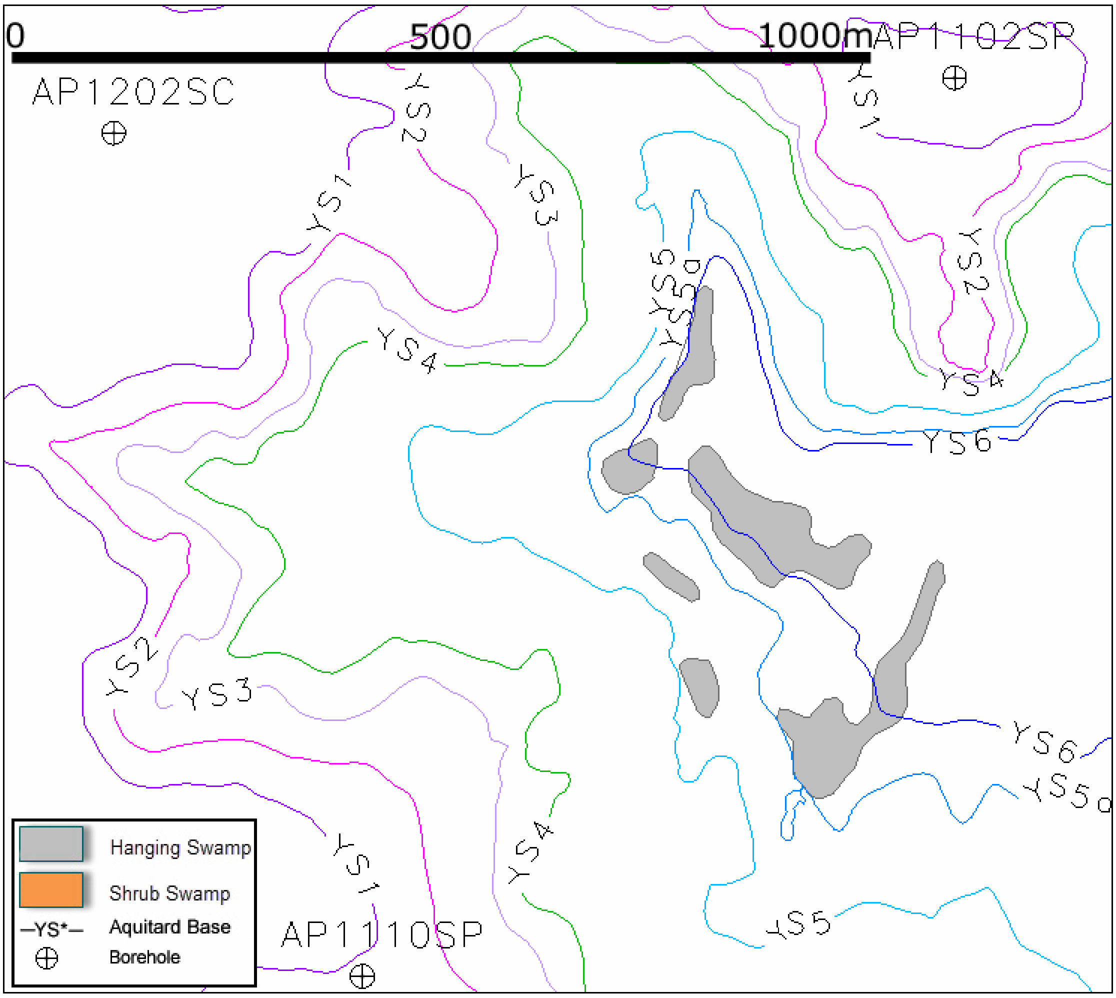

Figure 46 Smithston Hanging Swamp Complex

The Smithston Hanging Swamp Complex covers an area of appropriately 18 hectares and is included in the present study of Angus Place East due to its proximity to longwall LW1008. The most northerly hanging swamp overlies the tailgate of LW1009, while the three small western swamps lie within the angle of draw of LW1008 (P.Corbett pers.com). This suite of swamps is hydrologically supported by the YS5, YS5a and YS6 aquitards. The larger swamps drape between 100 and 300 metres down the slopes of this western tributary of Carne Creek.

Figure 47 Hanging Swamp in Smithston Hanging Swamp Complex

Figure 47 shows the view from the northern side of the large central hanging swamp in this complex looking in a westerly direction up the gully wall. This particular swamp has a total drop of 100 metres at its widest point and is supported hydrologically by the YS5a and YS6 aquitards.

SRK (2012) identified a Type 2 structure zone trending east-north-east to the immediate west of this hanging swamp complex (Figure 4). This, together with the more dominant Type 1 NNW-oriented basement to surface structural trend, may account for the composite topographic patterning at this locality and its immediate vicinity.

The hanging swamps of the Newnes Plateau, including their hydrological significance, will be discussed in detail in a subsequent report

13. Selected Newnes Plateau Shrub Swamp Descriptions within Springvale South Extension

Springvale South extension consists of longwall panels 424 to 432 and is overlain by those shrub swamps with headwaters surrounding the more elevated areas of Springvale Ridge.

As shown in Figure 48 below, the shrub swamps associated with the Springvale South Extension and its immediate surroundings include Nine Mile Swamp, Pine and Upper Pine Swamp, Paddy's Creek Swamp, Paddy's Creek East Swamp and Marrangaroo Swamp.

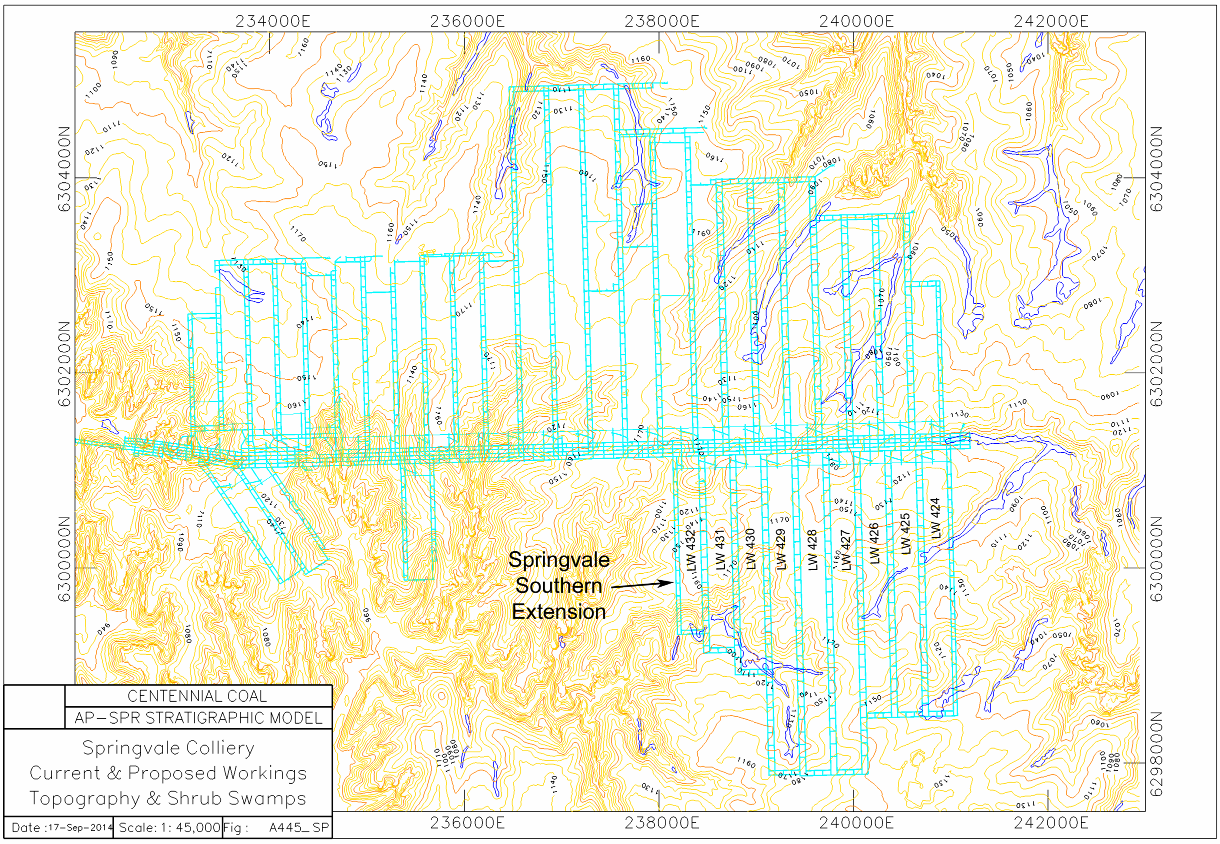

Figure 48 Springvale and Springvale South Extension Areas showing shrub swamp locations, mine layout and topography

Figure 49 below shows the location of the shrub swamps within the Springvale South extension area together with a key for swamp abbreviations used throughout the Angus Place and Springvale leases. The Springvale South extension swamps are discussed separately below.

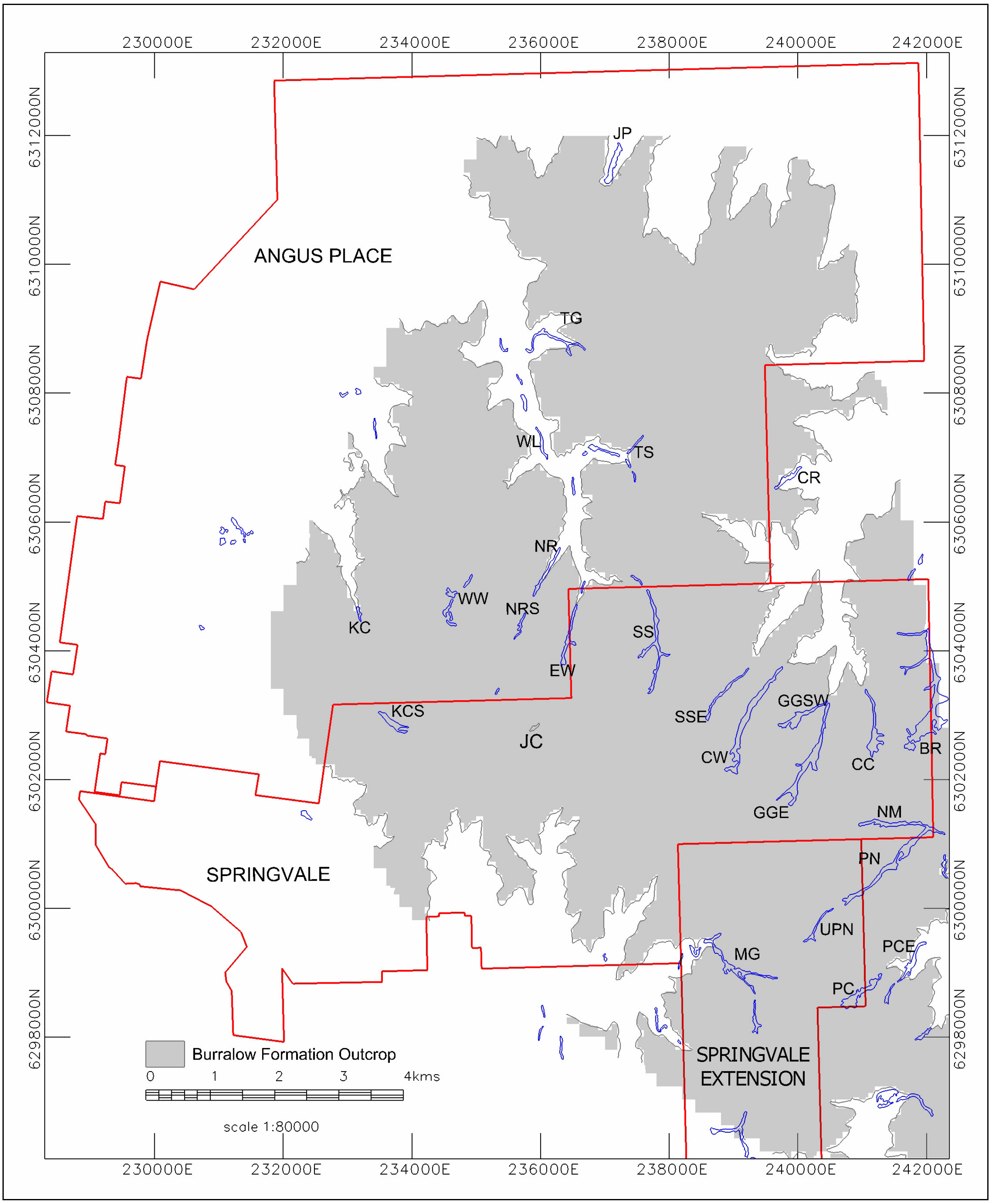

Figure 49 Shrub Swamp Localities in Angus Place, Springvale and Springvale South Extension

Key to swamp abbreviations:
JP: Japan (Trail 6), TG: Twin Gully, WL: Wolgan, TS: Tri-star, 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, BA: Barrier, NM: Nine Mile, PN: Pine, UPN: Pine Upper, PCE: Paddy's Creek East Swamp, PC: Paddy's Creek Swamp, MG: Marrangaroo

I. Nine Mile Shrub Swamp

Nine Mile Shrub Swamp trends west-east, with a length of slightly over 1300 metres and a maximum width of 80 metres (Figure 50). It has a fall of 35 metres and is contained wholly within the Burralow Formation. Pine Creek is a tributary of Nine Mile Creek as shown below. Nine Mile Shrub Swamp lies outside the proposed Springvale South extension area, however the upper reaches of this swamp will be affected by proposed development headings although not subject to longwall extraction.

Nile Mile Swamp, in conjunction with Pine Shrub Swamp and Upper Pine Shrub Swamp discussed in subsequent sections, are also collectively known as Bungleboori Swamp.

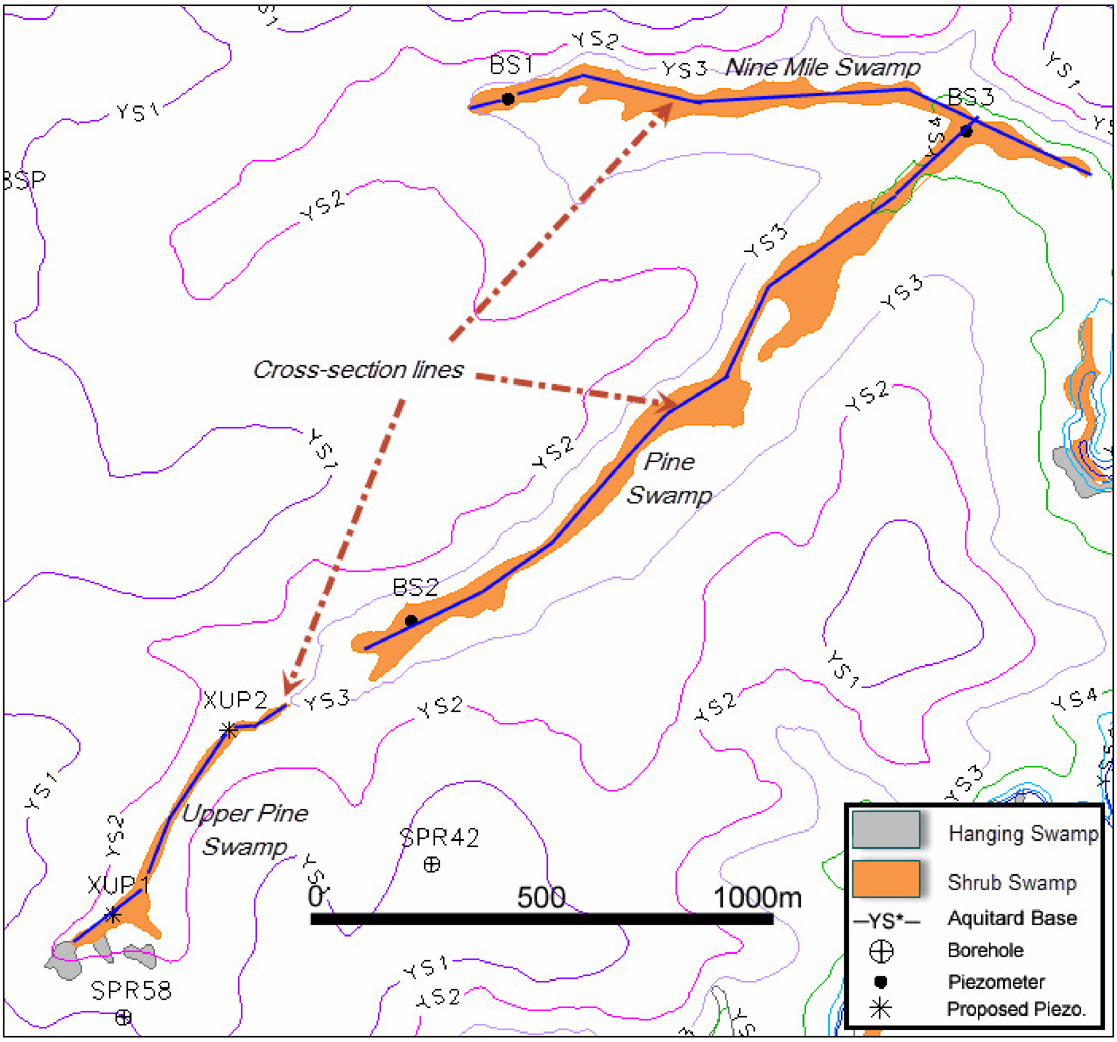

Figure 50 Plan of Nine Mile, Pine and Upper Pine Shrub Swamps

Figure 51 shows a west-to-east longitudinal cross section of Nine Mile Shrub Swamp. The upper two-thirds of the swamp is situated between plies YS3 and YS4, while the lower reaches of the swamp lie between the YS4 and YS5 horizons.

The majority of the swamp relies on valley wall seepage from plies YS2 and YS3, with minor input from YS1 and YS4 in the lower reaches along the northerly aspect of this swamp. Although YS4 and YS3 both intersect the gully floor, they are not particularly thick horizons at this location, and YS3 only influences the extreme upper reaches.

The west-east trend of this swamp mimics the topography present. Geological modelling indicates that the upper aquitards present in the vicinity of Nine Mile Swamp are relatively thin, as illustrated in Figure 51 below. These two factors impact on the morphology of Nine Mile Swamp in terms of average width, and contrasts with that of other Burralow-type shrub swamps such as Carne West.

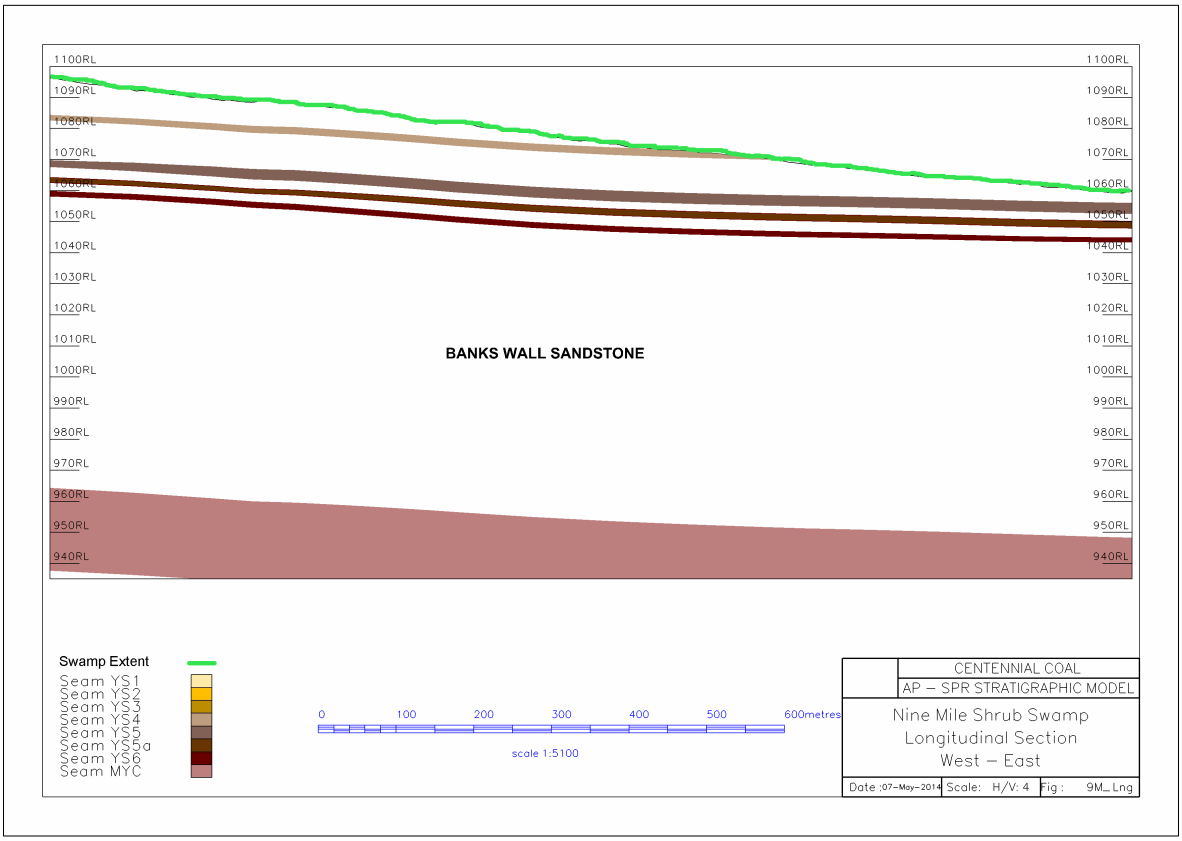

Figure 51 Longitudinal Stratigraphic Section of Nine Mile Shrub Swamp

The above longitudinal section of Nine Mile swamp illustrates that the upper half of the swamp lies stratigraphically between the YS4 and YS3 plies while the remainder of the swamp in the lower reaches is hydrologically supported by the YS5 aquitard.

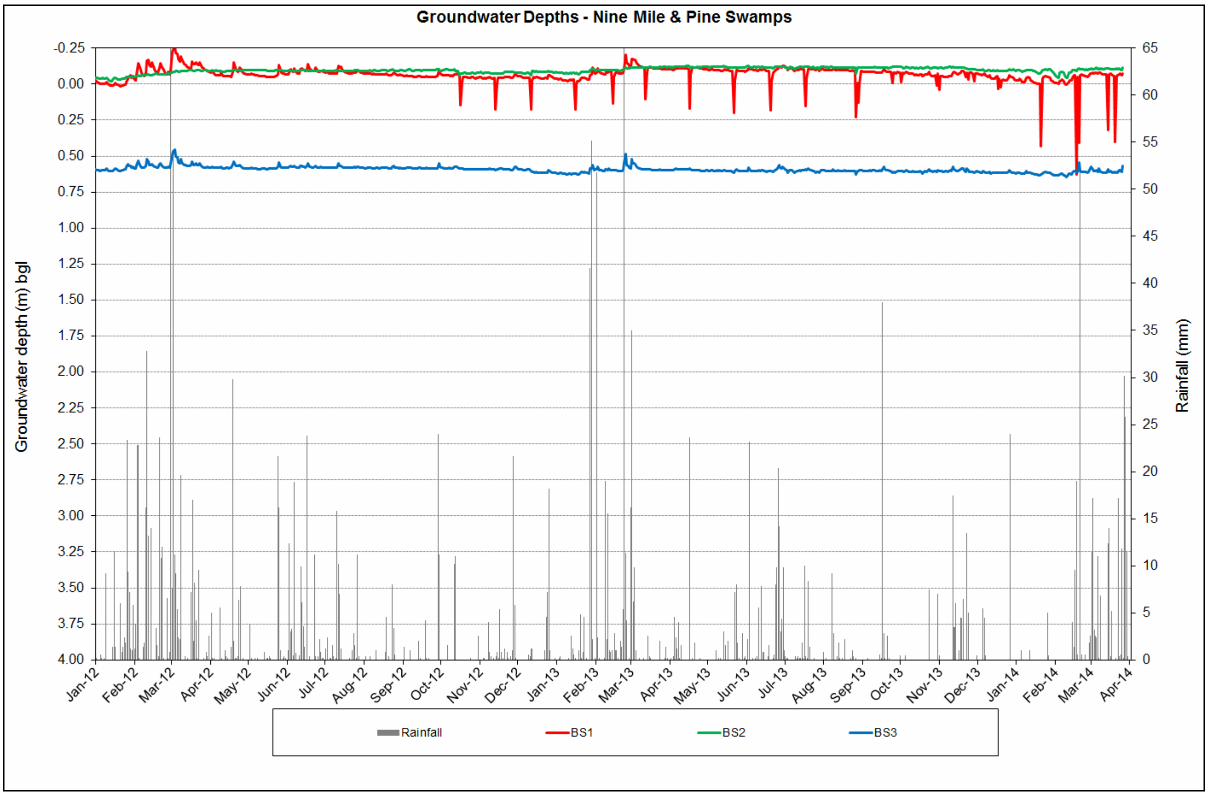

Figure 52 Hydrograph of the Nine Mile, Pine and Upper Pine Swamp Complex

Figure 52 shows piezometric data from January 2012 to April 2014 for the Bungleboori group of swamps which are discussed separately for clarity. Piezometer BS1 (red) is situated in the upper reaches of Nine Mile swamp and overlies the development headings for Springvale and Springvale South (Figure 48). It displays a consistent surface groundwater level and is permanently saturated. At times throughout the monitoring period, groundwater is recorded above ground level, within the casing. The negative spikes from October 2012 onwards represent regular water sampling. Hence the upper reaches of Nine Mile Swamp display typical groundwater-dependent shrub swamp characteristics.

II. Pine Shrub Swamp

Pine Shrub Swamp trends SW-NE with a length of approximately 1750 metres and a maximum width of 140 metres near the lower third of its length (Figure 50). It has a fall of approximately 85 metres and is contained wholly within the Burralow Formation. Pine Creek is a tributary of Nine Mile Creek also shown in Figure 50 above. The upper reaches of Pine Shrub Swamp overlie proposed longwall 424.

Pine Shrub Swamp is stratigraphically situated within the unconfined aquifer above the YS4 horizon. However, for the majority of the length of the swamp, additional groundwater is supplied by valley wall seepage from the YS3 ply (Figure 50). Towards the lower reaches of this swamp, the YS4 horizon influences the morphology of the swamp, as shown in Figure 50, where the YS4 subcrop coincides with a widening of the swamp to a maximum width of 150m.

As with other Burralow-type shrub swamps, the occurrence of valley wall seepage as a source of consistent groundwater is supplemented by the intersection of aquitard horizons as the gully floor erodes downstream, supplying a direct input of groundwater to the above swamps at specific locations. These locations as per geological modelling commonly coincide with wider sections of individual swamps. However, it should be noted that boreholes used for the correlation of Burralow Formation plies are sparse in the vicinity of Pine Shrub Swamp (Figure 50) and the model at this location is largely determined by interpolated data from surrounding deep boreholes.

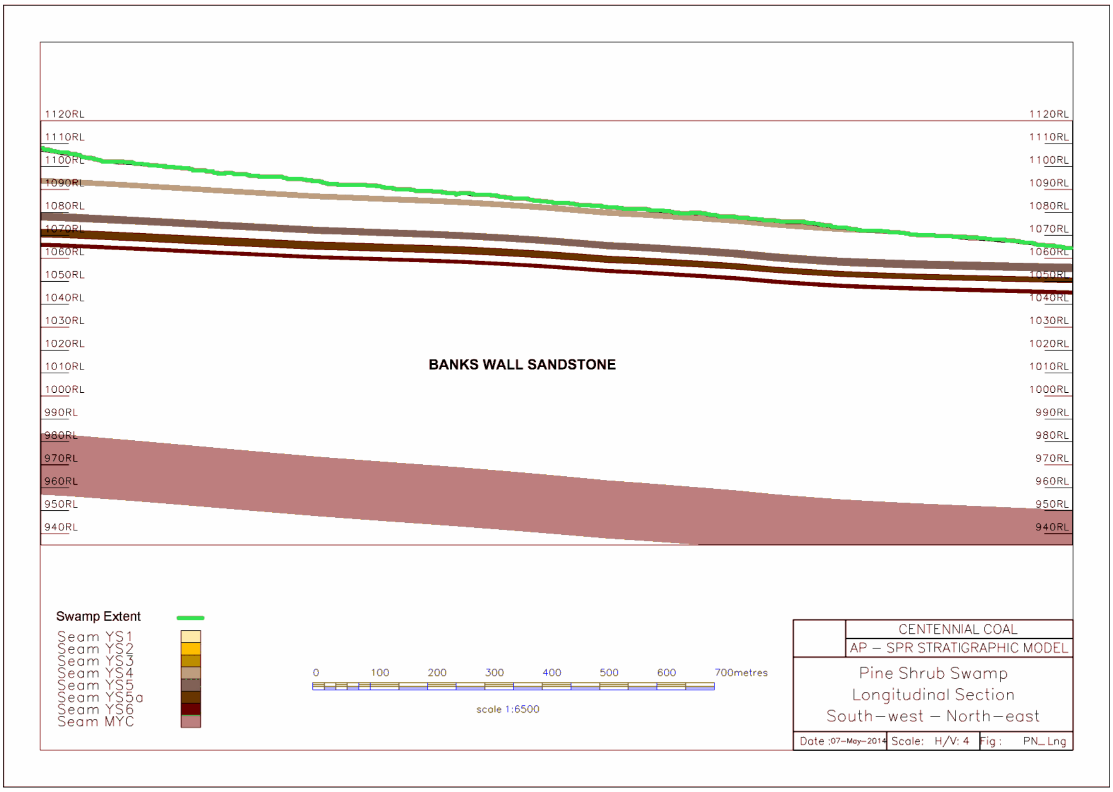

Figure 53 Longitudinal Stratigraphic Section of Pine Shrub Swamp

Figure 53 illustrates the stratigraphic profile along the gully floor of Pine Shrub Swamp. The majority of the swamp is hydrologically supported by the YS4 aquitard with additional supplementation from the YS5 aquitard in the lower reaches of the swamp.

Figure 52 above shows the hydrological status for piezometer BS2 (green) which is situated in the upper reaches of Pine Shrub Swamp (Figure 50). As with monitoring station BS1 in Nine Mile swamp, the groundwater level has been consistently high since installation despite significant variations in rainfall, and displays a consistent pattern typical of groundwater-dependency for the upper reaches of this shrub swamp.

III. Upper Pine Shrub Swamp

Upper Pine Shrub Swamp also trends SW-NE and occupies the same watercourse as its downstream equivalent. Upper Pine has a length of approximately 700 metres and a maximum width of 100 metres near its upper extremity (Figure 50). It has a fall of 18 metres and is contained wholly within the Burralow Formation. Upper Pine Creek is essentially a tributary of Nine Mile Creek as shown in Figure 50. Upper Pine Shrub Swamp overlies proposed longwalls 425 and 426.

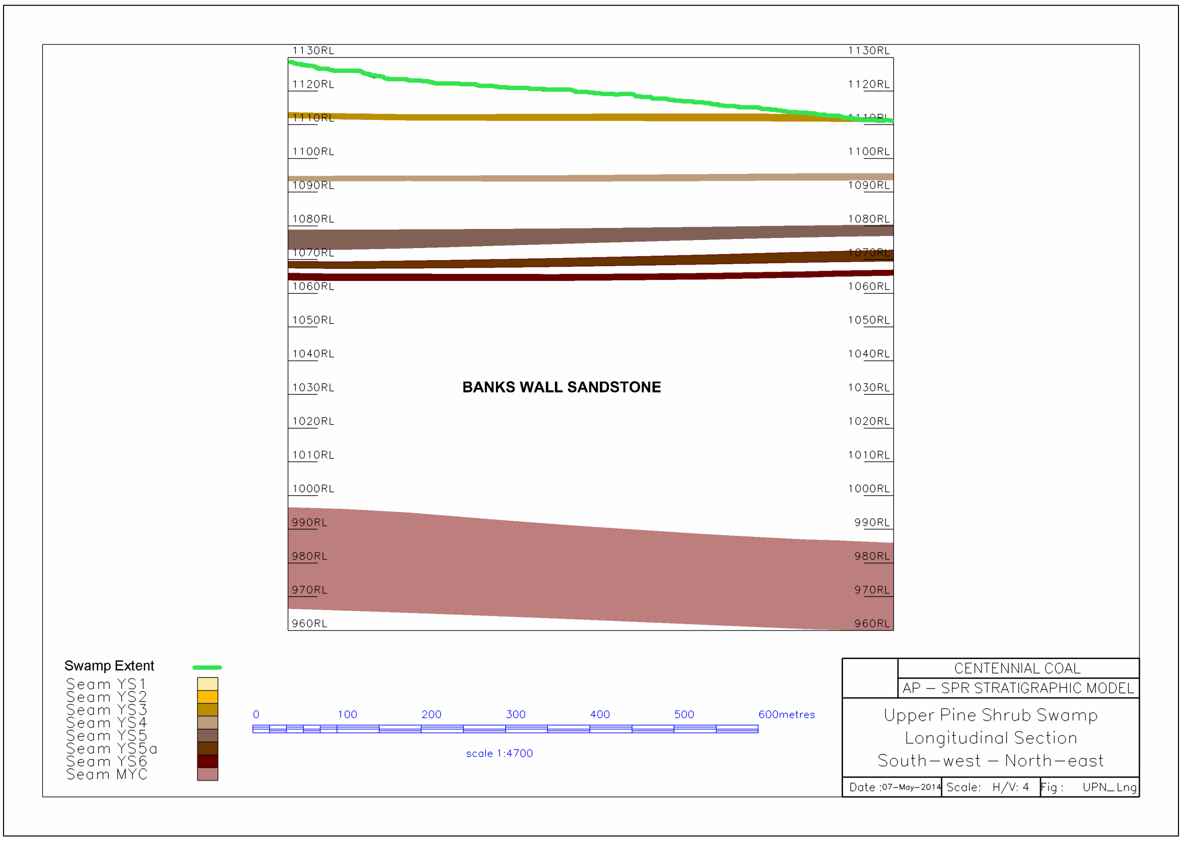

Figure 54 Longitudinal Stratigraphic Section of Upper Pine Shrub Swamp

Figure 54 shows a longitudinal section of Upper Pine Shrub Swamp. The entire length of the swamp is stratigraphically located within the unconfined aquifer above YS3. There are no gully-aquitard intersections present within Upper Pine and hence this swamp is reliant on valley seepage flow from aquitards YS2 and YS1 in addition to the groundwater confined by the YS3 aquitard which is located beneath the entire length of the host gully.

However a cluster of hanging swamps is present at the extreme upper reaches of this shrub swamp which are supported by the presence of the YS2 aquitard. The presence of these groundwater-supplied hanging swamps confirms the theory of groundwater-dependence of shrub swamps which will be discussed in a subsequent report. In addition, the accuracy of the stratigraphic model at this location can be observed by the positioning of the YS2 aquitard and its relationship to the three hanging swamps which the latter ply supports.

A break of approximately 200 metres exists between Upper Pine Shrub Swamp and Pine Shrub Swamp to the north-east. As this area forms part of the proposed Springvale southern extension, it is recommended that this zone be assessed pre-mining for pre-existing surface or subsurface anomalies, including pre-mining slumping.

There is no piezometer data for Upper Pine Shrub Swamp to date and this situation should also be addressed prior to mining. Two swamp piezometer monitoring sites have been suggested for this swamp and are labeled XUP1 and XUP2 in Figure 50. The latter site has been selected to provide downstream groundwater data which may indicate the presence of a periodically waterlogged groundwater regime at this location.

Piezometer BS3 (Figure 52 in blue) is located at the junction of Nine Mile and Pine Creeks and is outside of the proposed Springvale southern extension mining area. Very muted responses to rainfall input are evident, however groundwater is consistently high, with near-surface groundwater levels and minimal groundwater level variation. Hence the hydrograph pattern is typical of that of a permanently saturated groundwater-dependent swamp.

IV. Paddy's Creek East Shrub Swamp

Paddy's Creek East Shrub Swamp trends roughly SW-NE, with an approximate length of 1200 metres and a maximum width in its middle reaches of 100m (Figure 55). It has a fall of 73 metres. This swamp is outside of the Springvale South Extension area but falls within the Clarence Colliery lease.

As shown in Figure 55, this shrub swamp is divided into two sections separated by a break in continuity of approximately 50 metres. The larger northern segment of this swamp is located within the Banks Wall Sandstone with the exception of the southernmost 60 metres which is located within the Burralow Formation. Hence the swamp in its entirety is a "mixed-type" shrub swamp.

However, it is important to note that, as with Pine Shrub Swamp, boreholes used for the correlation of Burralow Formation plies are comparatively sparser in the vicinity of Paddy's Creek East Swamp and the model at this location is largely determined by interpolated data from surrounding deep boreholes. The nearest borehole to the east of the downstream section of Paddy's Creek East swamp which contains correlatable data of Burralow Formation plies is CLRP05 at a distance of 1.5km to the southeast.

Hence the delineation between the outcrop of the Banks Wall Formation and the overlying Burralow Formation is expected to differ slightly from Figure 55, particularly in the lower reaches of Paddy's Creek East swamp, as further borehole data became available within the Clarence lease.

However, large volumes of groundwater are present in the strata surrounding the lower Paddy's East complex as evidenced by the size and number of hanging swamps in the immediate vicinity. It is predicted from the study of shrub swamps in both

Angus Place and Springvale that, given the location of hanging swamps in this location, including the hanging swamp to the east of the lower reaches of Paddy's East swamp, that the subcrop of the Burralow Formation may actually include all hanging swamps and possibly lower Paddy's East swamp in its entirety. The proposed piezometer XPCE2 (Figure 55) at Clarence Colliery would assist in determining groundwater levels at this site in the absence of appropriate drilling data, however without the latter the classification of this swamp remains undetermined.

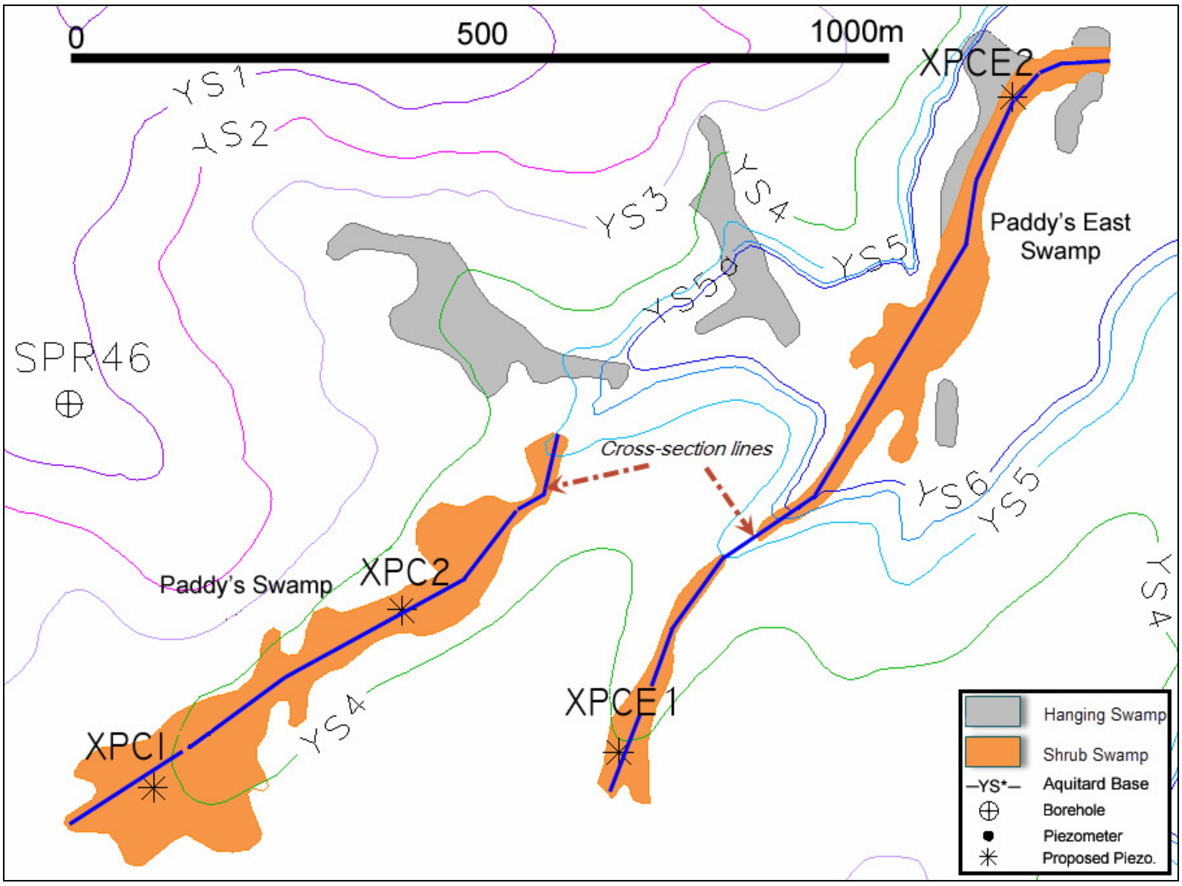

Figure 55 Plan of Paddy's Creek and Paddy's Creek East Shrub Swamps

Figure 55 also shows the southernmost section of Paddy's Creek East Shrub Swamp. The upper reaches of this section are underpinned by the YS4 aquitard, with the majority of the upper swamp situated stratigraphically between the YS4 and the YS5 plies. Just upstream of the break between the upper and lower Paddy's East swamp sections, the swamp is located stratigraphically between the YS5 and YS5a horizons. The presence of the YS4 aquitard has a significant effect on the morphology of the upper reaches of Paddy's East Swamp, and reinforces the importance of in-gully groundwater input on the hydrology of Newnes Plateau shrub swamps.

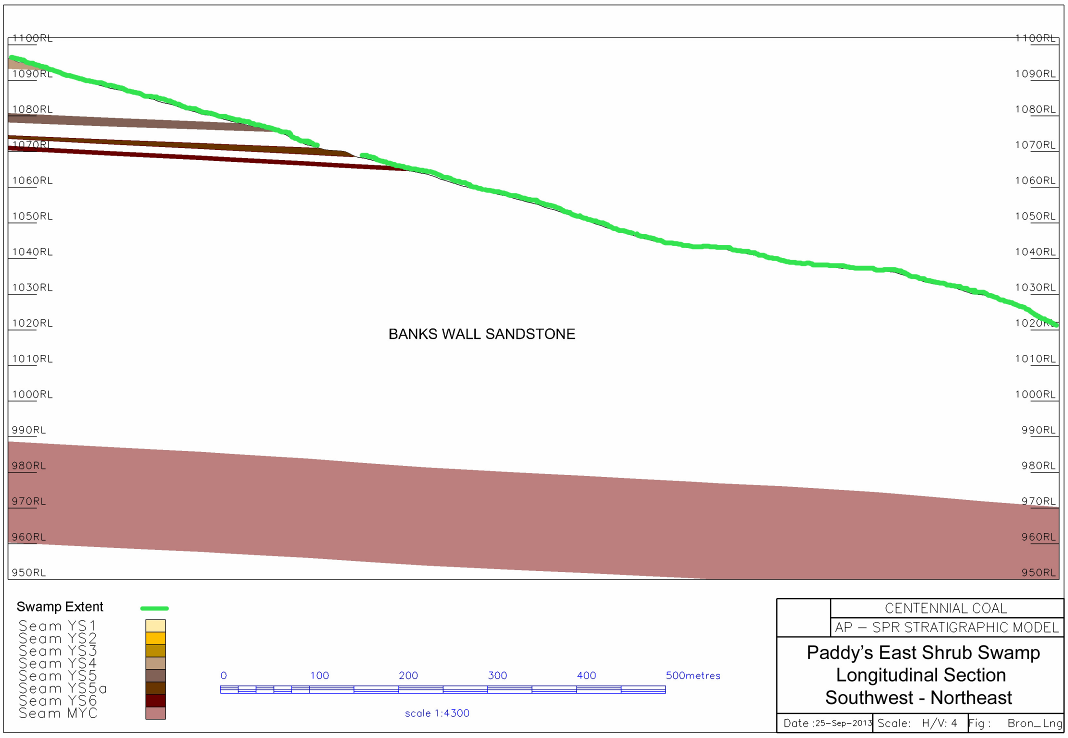

Figure 56 Longitudinal Stratigraphic Section of Paddy's East Shrub Swamp

Figure 56 is a longitudinal section of Paddy's Creek East Shrub Swamp. The break between the upper and lower swamps is shown by the break in the swamp extent, marked in green, the model indicating the YS5a crops out at this point. This diagram clearly illustrates the stratigraphic positioning of this swamp from the Burralow Formation and into the Banks Wall Sandstone below. From limited current data and interpolation as noted above, the upper reaches of Paddy's East Swamp represent a Burralow-type swamp, while the lower two-thirds appear to lie stratigraphically within the Banks Wall Sandstone. Extensive hanging swamps (Figure 55) are present within the lower reaches of this shrub swamp and are associated with the YS6, YS5a, YS4 and YS3 plies.

As Paddy's Creek East Shrub Swamp overlies Clarence Colliery, it is recommended that this area be assessed pre-mining for pre-existing surface or subsurface anomalies. There is no piezometer data for this swamp to date and this situation should also be addressed prior to mining. To that effect, two piezometric monitoring sites, XPCE1 and XPCE2 have been selected as indicated in Figure 55. XPCE1 has been chosen to determine groundwater levels in the upper reaches of this swamp and to observe the effects on groundwater levels of the YS4 aquitard. By contrast, XPCE2 has been selected to observe the effects of a possible Banks Wall Sandstone substrate combined with the confounding influence of the groundwater input from the extensive hanging swamp complexes at the northern extent of this shrub swamp.

V. Paddy's Creek Shrub Swamp

Paddy's Creek Shrub Swamp trends approximately SW-NE with an approximate length of 800 metres and a maximum width in its upper reaches of 200 metres. This swamp overlies longwall 424 of the Springvale South Extension area, has a fall of 35 metres and is wholly contained within the Burralow Formation.

Figure 57 is a plan of Paddy's Creek Shrub Swamp showing subcrops of the aquitards in the vicinity. The extreme upper reaches are located in the unconfined aquifer above the YS4, and the broad southern expanse of the swamp is underpinned by the subcrop of the YS4 ply and demonstrates the importance of direct in-gully groundwater input to the morphology of shrub swamps. The YS4 ply also provides a source of indirect groundwater via valley wall seepage for most of the length of the swamp. The YS3 and YS4 aquitards also hydrologically support the two hanging swamps to the immediate north of this shrub swamp. The majority of Paddy's Creek Shrub Swamp lies stratigraphically between the YS4 and the YS5 aquitards. The extreme northern extremity is hydrologically supported by the YS5a aquitard.

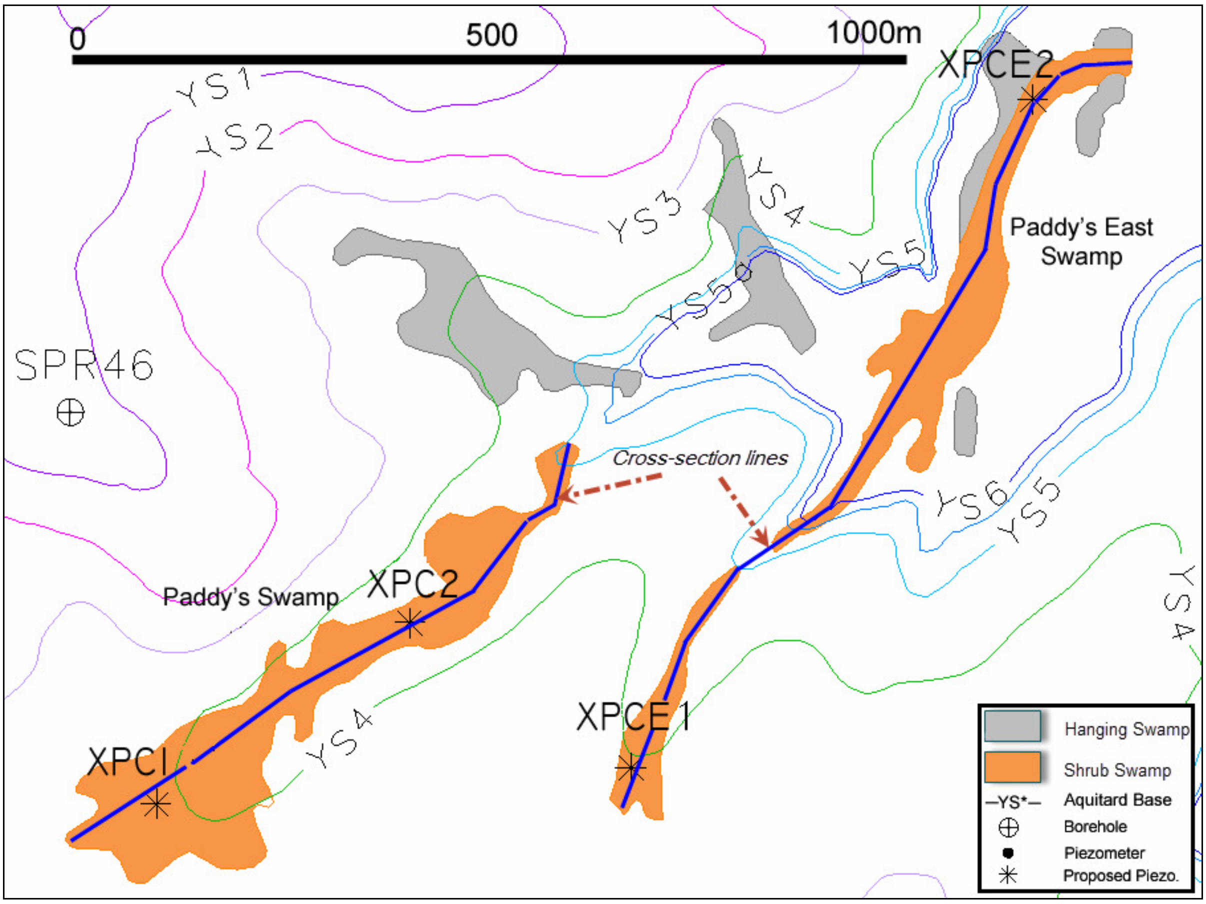

Figure 57 Plan of Paddy's Creek Shrub Swamp

Figure 58 shows a longitudinal stratigraphic section of Paddy's Creek swamp and highlights the role of the YS4 in the upper reaches, the presence of the YS5 aquitard as the principal retainer of groundwater and the relatively steep gradient at the northern end of the swamp where the aquifer between the YS5 and the YS5a crops out.

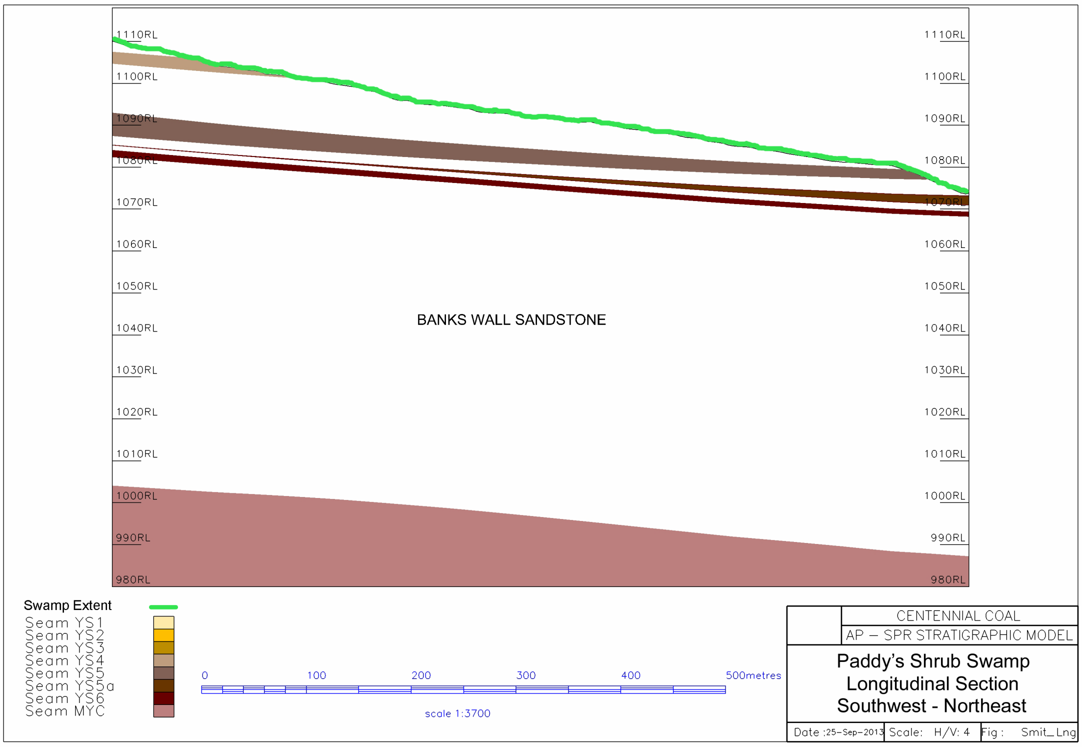

Figure 58 Longitudinal Stratigraphic Section of Paddy's Shrub Swamp

As Paddy's Creek swamp forms part of the Springvale South extension lease, it is recommended that this area be assessed pre-mining for pre-existing surface or subsurface anomalies. There is no piezometer data for this swamp to date and this situation should also be addressed prior to mining.

To that effect, two piezometric monitoring sites, XPC1 and XPC2, have been selected as indicated in Figure 57. XPC1 has been chosen to determine groundwater levels in the upper reaches of this swamp and to observe the effects on groundwater levels of the YS4 aquitard. XPC2 has been selected to capture groundwater levels in a comparatively drier area of the swamp but still within the angle of draw of the current proposed mine plan.

VI. Marrangaroo Shrub Swamp

Marrangaroo Shrub Swamp trends approximately SW-NE, with an approximate length of over 1700 metres and a maximum width of 150 metres. It has a fall of 67 metres and is mostly contained within the Burralow Formation, with the exception of the extreme lower reaches where it is underpinned by the Banks Wall Sandstone. Hence this swamp which drains into the Cox's River and thence into the Warragamba

Dam catchment area is a "mixed-type" swamp. It currently overlies longwalls 428, 429, 430 and 431 of the Springvale South extension area and has a gradient of 3.8%.

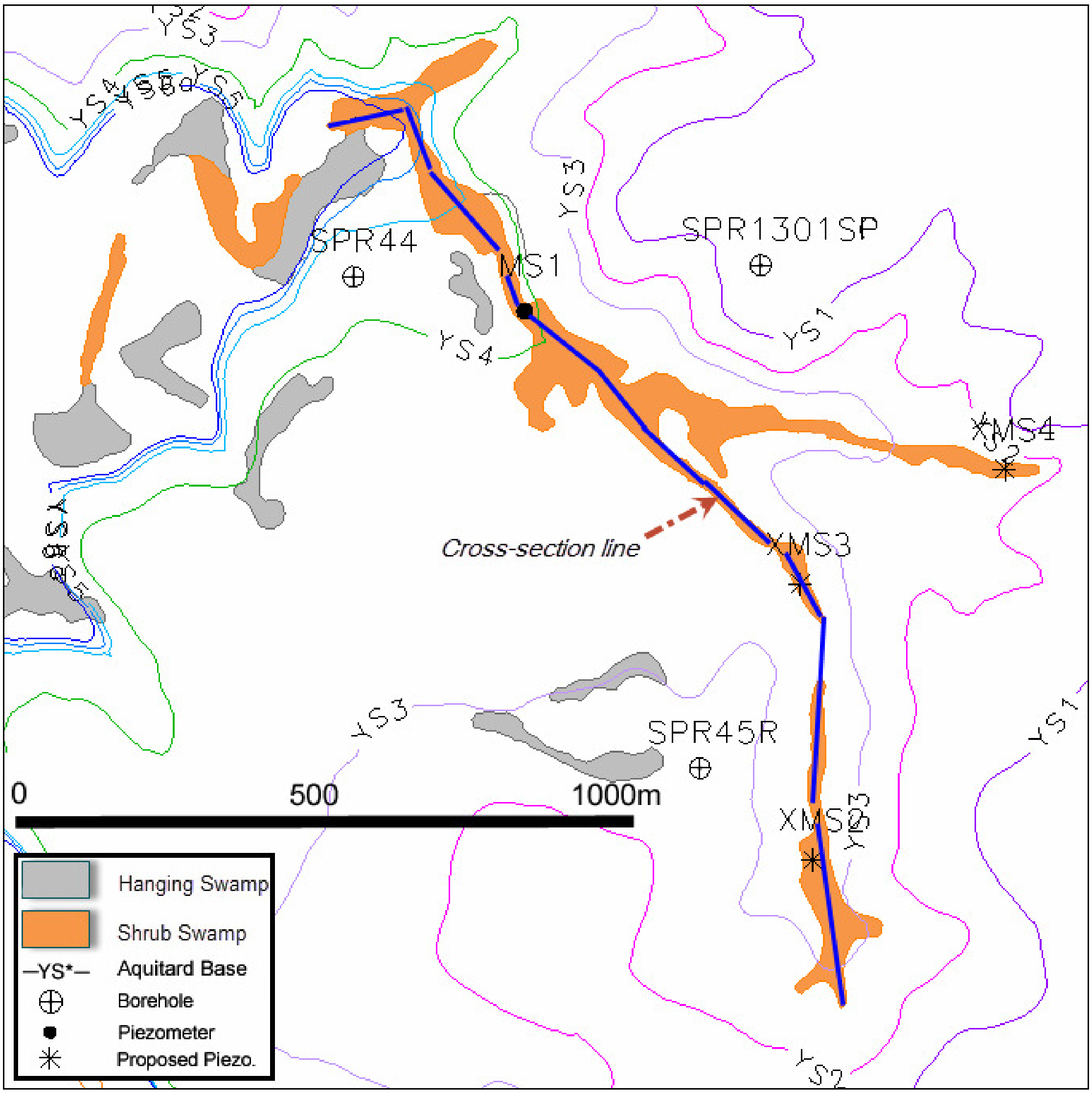

Figure 59 Plan of Marrangaroo Shrub Swamp

Figure 59 is a plan of the Marrangaroo Shrub Swamp and associated Marrangaroo Hanging Swamp complexes. The extreme upper reaches of the southern extension of the Marrangaroo Shrub Swamp is intersected by the YS3 aquitard, providing an in-gully groundwater source to this relatively wider section of the southern arm of the Marrangaroo swamp system. The YS3 ply also provides valley seepage along the length of the southern course of the host creek. The eastern upper reaches also receive valley wall seepage and direct in-gully input from the YS3 ply, in addition to minor valley seepage from the YS2 aquitard.

Hanging swamps in the general area of Marrangaroo shrub swamp are supported by the YS2 and YS3 aquitards to the south, and the YS4, YS5, YS5a and YS6 aquitards adjacent to the lower reaches of the shrub swamp, where the Burralow Formation conformably overlies the Banks Wall Sandstone. The hydrogeology of the hanging swamps throughout the Angus Place, Springvale and Clarence leases is discussed in the subsequent report, *The Geology and Hydrogeology of the Hanging Swamps of the Newnes Plateau.*

Near the confluence of the southern and the eastern reaches of Marrangaroo Creek, the base of the YS4 aquitard intersects the gully floor and it is at this location that the creek widens to its maximum width as a result of both direct and indirect input of groundwater, in additional to topographic influences.

The YS5 and YS6 plies are relatively thick in the vicinity of this shrub swamp and supply additional in-gully and valley wall seepage to the lower reaches of this creek, which accounts for the widening of Marrangaroo Swamp at this location, as well as the presence of its north-eastern tributary in the extreme lower reaches (Figure 59). Here the stream bed and accompanying shrub swamp progress lithologically from the Burralow Formation into the Banks Wall Sandstone due to erosion.

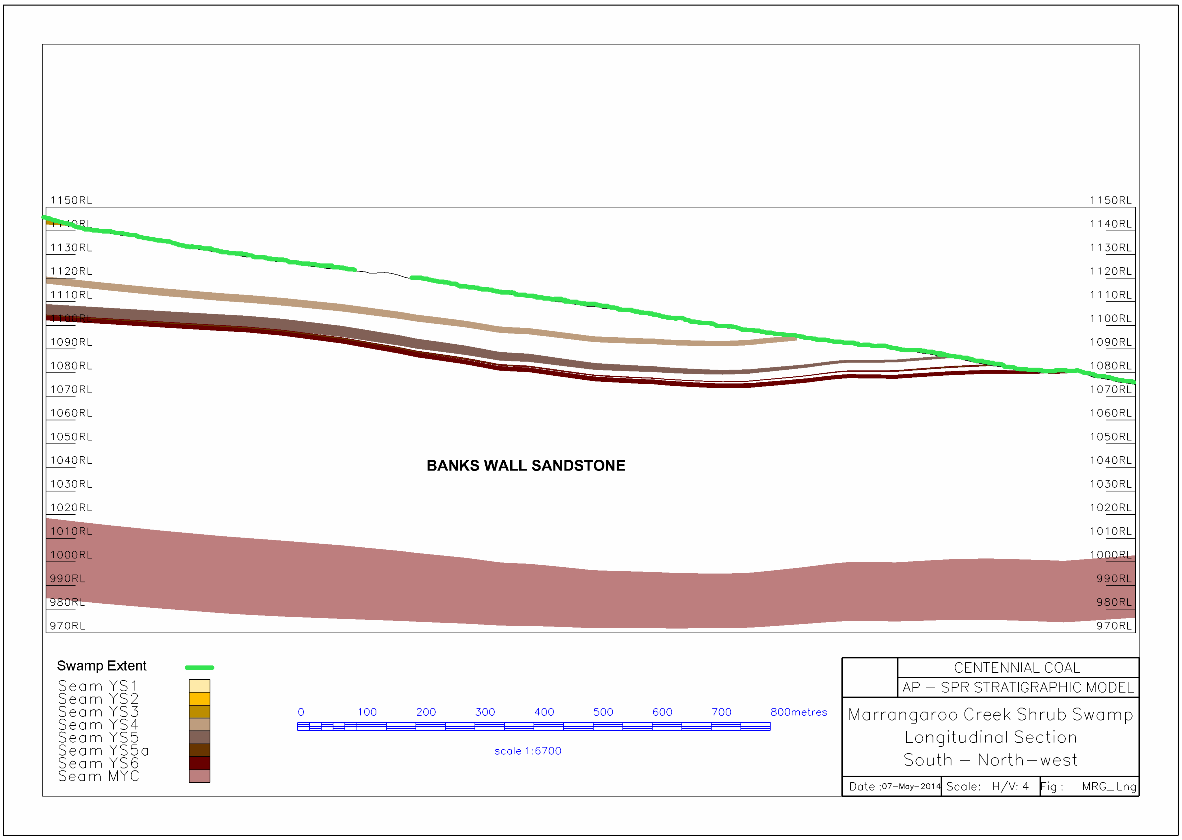

Figure 60 Longitudinal Stratigraphic Section of Marrangaroo Shrub Swamp

Figure 60 shows a longitudinal section of Marrangaroo Shrub Swamp from the southern tributary to the north-eastern extent of the swamp. YS3 underpins the extreme upper extent of this swamp, with YS4 intersecting the gully floor approximately 1300 metres downstream.

Figure 60 also displays the breach in continuity between the main body of this shrub swamp and its southernmost extremity. It is recommended that this area be ground-truthed for pre-mining slumping or other surface anomalies prior to longwalling. As this figure demonstrates, the swamp is underlain by the aquifer between YS4 and

YS3, followed sequentially in the lower reaches by the aquifer between the YS4 and the YS5, and ultimately the aquifer between the YS5 and YS6. The YS5a is essentially non-existent at this location and forms part of the YS5 ply and subcrops only in the extreme lower reaches of this swamp.

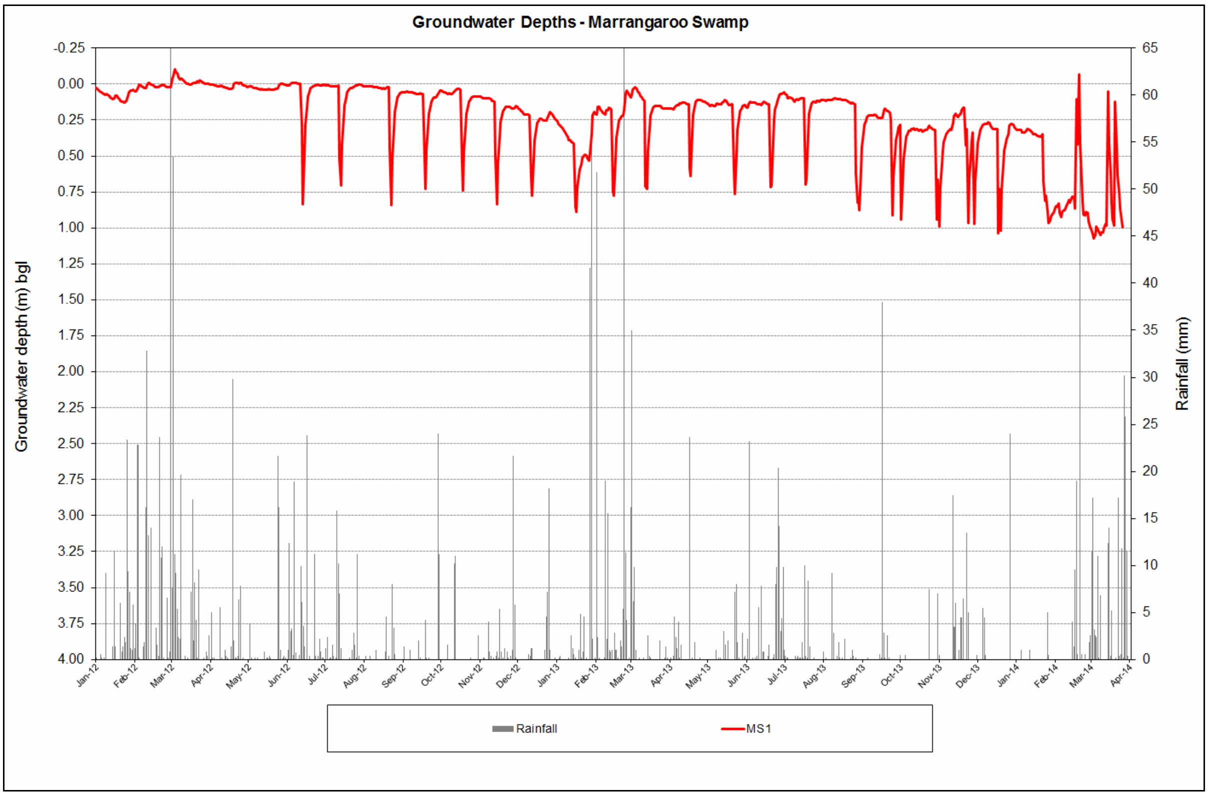

Figure 61 Hydrograph of Marrangaroo Shrub Swamp

Figure 61 shows recorded groundwater levels for piezometer MS1. Piezometer MS1 is located above the projected subcrop of the YS5 ply (Figure 59). This piezometer was installed in November 2011 and the above graph shows data from January 2012 to mid-April 2014. Although piezometer MS1 in general displays a pattern of a permanently waterlogged swamp at this location, there is a significant and consistent lowering of groundwater levels from November 2012 through to January 2013, although only between 0.12 to 0.5 mbgl. High rainfall in February – March 2013 has increased groundwater levels briefly for that time period, and groundwater levels remain consistently high (approximately 0.12mbgl) until mid-October 2013 when the swamp was burned out.

The hydrograph above indicates that the October 2013 fire and the accompanying changes to vegetation and peat conditions in this swamp have had an effect on the consistently high groundwater levels at this location within Marrangaroo swamp, with an apparent change to an atypical periodically-saturated profile. It is expected that the typical groundwater-saturated pattern will prevail in time as peat formation and shrub swamp vegetation reestablish. Installation of additional piezometers at the locations suggested below would add significant value to understanding the groundwater regime in this “mixed-type” shrub swamp.

Marrangaroo Shrub Swamp is hydrologically a "mixed-type" swamp, that is, it contains both a Burralow and a Banks Wall substrate. However, at the location of piezometer MS1, this shrub swamp displays an essentially groundwater dependent profile, unlike the mixed-type swamps described previously, such as Twin Gully and the upper tributaries of Tri-Star shrub swamps. This is due to the Burralow/Banks Wall substrate ratio along the fall of the gully floor and the lack of additional piezometers in the upper (potentially drier) reaches of this extensive shrub swamp.

As discussed previously, the presence of a Banks Wall substrate within a Burralow-type shrub swamp creates a different lithological regime for groundwater movement whereby the Banks Wall Sandstone acts as an efficient vertical conduit for relocating water from the swamp system. This is in comparison to a Burralow-type lithological profile, where a sequence of major and minor aquitards within the Burralow Formation serves to maintain high groundwater levels within the upper sequences.

While the majority of Marrangaroo Swamp is located within the Burralow Formation, the extreme lower reaches are situated in the Banks Wall Sandstone. The intersection of aquitards YS2, YS3, YS4, YS5, YS5a and YS6 with the gully floor indicates the importance of direct in-gully input in maintaining the relatively high water levels in this swamp, together with its extensive length.

Marrangaroo Shrub Swamp is one of the longer shrub swamps in the Angus Place/ Springvale area and it is proposed that its length is related to the number of aquitards the gully encounters, either directly or indirectly, as is passes down through the lithological sequence. However, the presence of the Banks Wall Sandstone at the lower reaches, as determined by the stratigraphic model, also likely contributes to the differing morphology of this swamp as compared to Carne West swamp, for example. This concept will be further discussed in *Geological and Hydrogeological Influences on Shrub Swamp Types.*

As Marrangaroo Shrub Swamp forms part of the proposed Springvale southern extension, it is recommended that this zone be assessed pre-mining for pre-existing surface or subsurface anomalies. It is strongly suggested that swamp piezometers be installed at XMS2 and XMS3 (Figure 59) to capture the hydrological response in the southern section of this shrub swamp. In addition, a piezometer at XMS4 would determine groundwater levels at eastern extent of this shrub swamp.

14. Conclusions

Newnes Plateau Shrub Swamps (NPSS), Newnes Plateau Hanging Swamps (NPHS), and Newnes Plateau Rush Sedge Snow Gum Hollow Wooded Heath Grassy Woodlands (NPRSSG) are present within the Angus Place/Springvale lease areas. The present study focuses primarily on the Newnes Plateau Shrub Swamps. Not all shrub swamps in the Angus Place/Springvale lease have been included in the current study.

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 strata 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 predominantly sandstone-based lithology, results in steeper-sided 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.

Finally, the presence of the Newnes Plateau Shrub Swamps is 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.

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Appendix A

Core Photographs of SPR1211SP