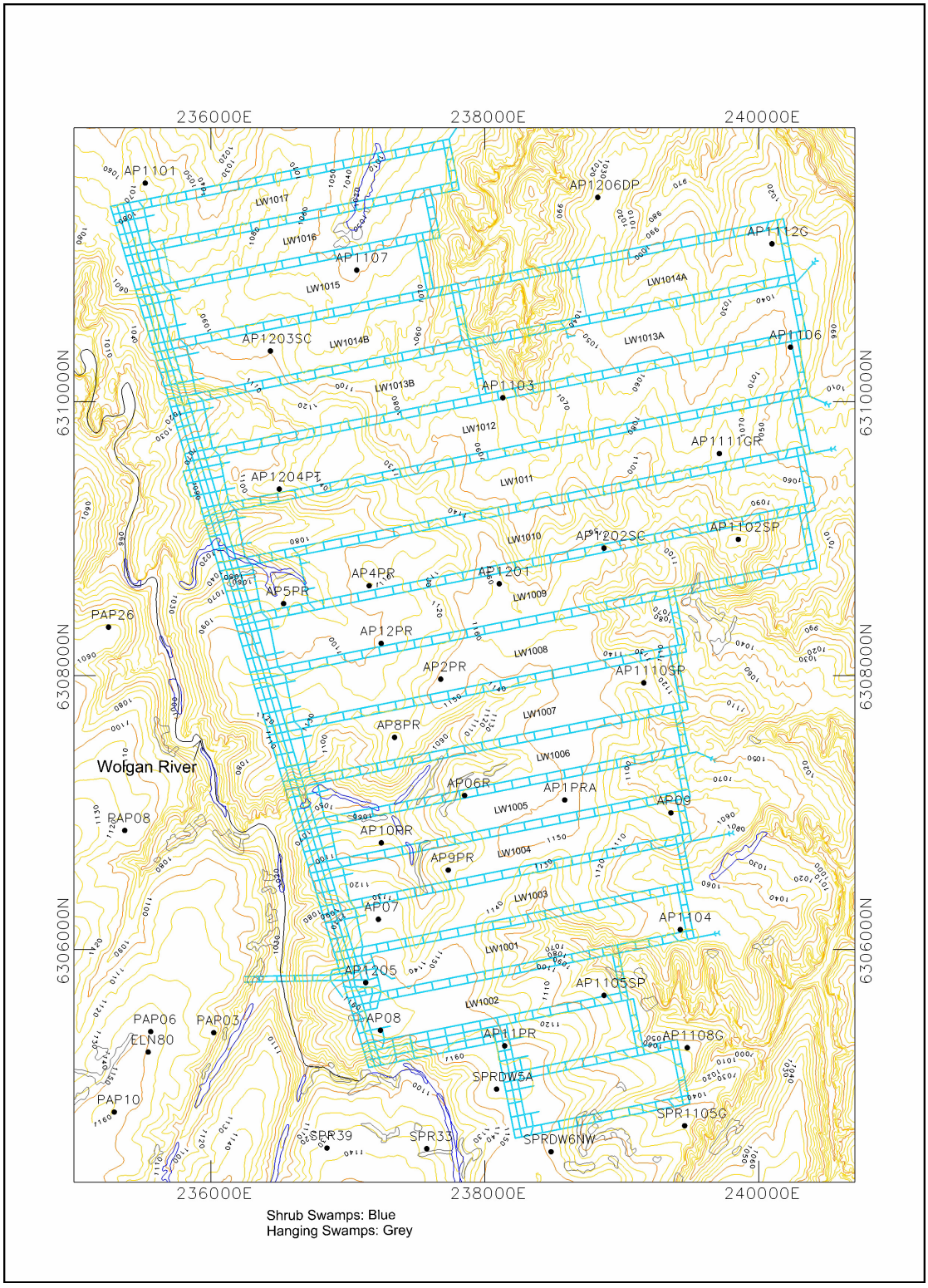

Figure 23 Angus Place East showing shrub swamp locations, mine layout and topography

Similar to shrub swamps located in the Springvale and Springvale South areas, Japan, Twin Gully, Tri-Star and Crocodile shrub swamps are located such that their headwaters are proximal to the more elevated regions of the Angus Place East lease.

However, unlike the Burralow-type swamps in the south-eastern parts of the Springvale lease, stratigraphic conditions differ to the north such that none of the Angus Place shrub swamps are “Burralow-type” swamps (Section 9).

All shrub swamps in the Angus Place East area comprise either “mixed-type” swamps or are contained wholly within the Banks Wall Sandstone. The result of this change in geological regime is that the size and morphology of the Angus Place East shrub swamps differ significantly from many of their shrub swamp equivalents in the Springvale area. The “Banks Wall” and “mixed-type” swamps of Angus Place are generally smaller and narrower than the “Burralow-type” swamps which dominate the Springvale lease. This is illustrated when comparing a shrub swamp such as Crocodile with the Pine and Upper Pine complex in the south-east of Springvale, for example.

Shrub swamps which are either wholly or partially situated stratigraphically within the Banks Wall Sandstone are also present in the Clarence Colliery lease area and are similarly restricted in morphology compared with Burralow-type swamps in the same vicinity. This phenomenon will be discussed in subsequent sections.

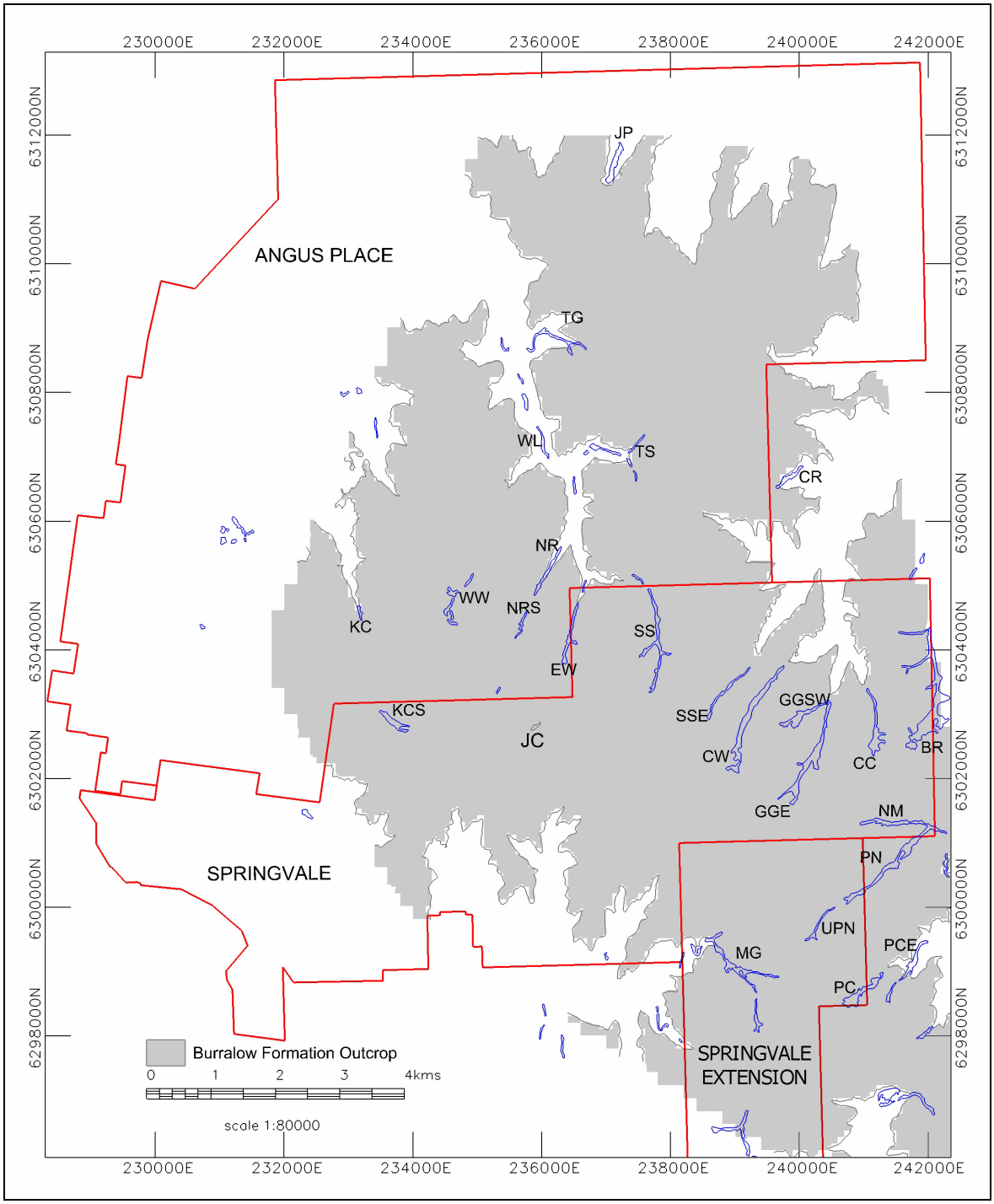

Figure 24 Shrub Swamp Localities in Angus Place, Angus Place East, Springvale and Springvale South Extension and Burralow Formation Outcrop

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, BR: Barrier, NM: Nine Mile, PN: Pine, UPN: Pine Upper, PCE: Paddy's Creek East, PC: Paddy's Creek, MG: Marrangaroo

As shown in Figure 24, Japan shrub swamp lies to the north of the Angus Place lease and is situated stratigraphically within the Banks Wall Sandstone. Almost due south is Twin Gully shrub swamp, which is a "mixed-type" swamp, with its upper reaches located stratigraphically within the Burralow Formation while the majority of the swamp is situated within the Banks Wall Sandstone. Similarly, Tri-Star shrub swamp also displays mixed-type characteristics, as the host gully moves stratigraphically from the Burralow Formation in the upper reaches down into the Banks Wall Sandstone in the main section of the swamp.

Approximately due east of Tri-Star (Figure 24), Crocodile Shrub Swamp is also a "mixed-type" swamp with its extreme upper reaches located within the Burralow Formation and the majority of the swamp situated stratigraphically within the Banks Wall Sandstone.

"Burralow-type" shrub swamps are absent from the Angus Place East lease, with all swamps displaying "mixed-type" or "Banks Wall-type" shrub swamp characteristics. This is due to topographic influences whereby the Wolgan River and Carne Creek watercourses have progressively eroded the plateau in this area to expose the Banks Wall Sandstone as the principal outcropping lithology within the four host gullies of the shrub swamps discussed above. This phenomenon demonstrates the effects of the partial or complete absence of the Burralow Formation on the relative morphologies of all four of the Angus Place East shrub swamps.

Figure 24 clearly demonstrates differences in shrub swamp characteristics between the northerly Angus Place lease and the general Springvale area, the latter consisting of thicker Burralow sequences, a consequent increase of aquitard horizons and decreased exposure of the Banks Wall Sandstone, all of which leads to an increase in length and width of the shrub swamps of the general Springvale area. Hence differences in gully substrates, in conjunction with topography, result in differences in shrub swamp morphology.

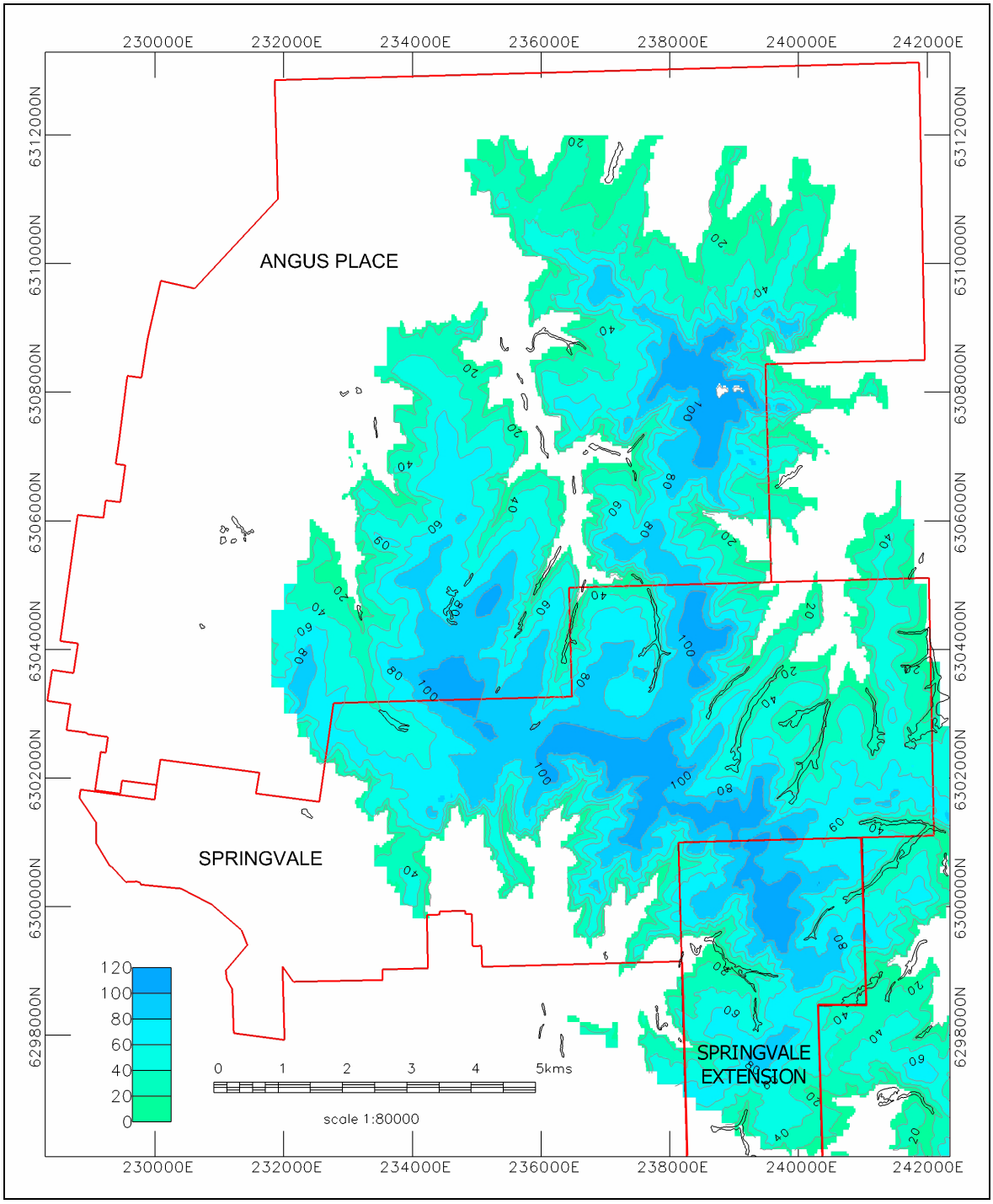

Figure 25 Burralow Formation Isopach for Angus Place and Springvale leases (Note: shrub swamps shown in black outline)

The importance of gully substrate lithology is shown in Figure 25 which illustrates the relative thickness and extent of the Burralow Formation in the Angus Place East and Springvale areas. There exists no equivalent of the extensive Springvale Ridge in the Angus Place East area and discussed in Section 10, hence the recharge area is comparatively smaller. This, in conjunction with the more heavily incised plateau which exposes larger sections of the Banks Wall Sandstone, means that the swamps in

the Angus Place area are relatively shorter and narrower compared with those in Springvale and Springvale South due to the differing geological regimes present.

I. Japan Shrub Swamp

Japan Shrub Swamp (also known as Trail 6 Swamp) trends approximately north-south, with a length of 750 metres and a maximum width of 75 metres (Figure 26). It has a fall of 32 metres, is wholly contained within the Banks Wall Sandstone and is distal from any known structure zones (Figure 4). The gully in which Japan shrub swamp lies forms part of the extreme upper reaches of a tributary of the Wolgan River and overlies longwalls LW1016 and LW1017.

Originally identified by DEC (2005) as a Newnes Plateau Hanging Swamp (NPHS) on the basis of aerial photograph interpretation, it was evident from geological and topographic data that this interpretation was incorrect and that the majority of the gully appeared to express characteristics of a Newnes Plateau Shrub Swamp (NPSS).

This swamp was subsequently ground truthed by R. Lembit (2010) and vegetation patterns were found to concur with geological findings, with Lembit reporting the presence of hanging swamps in the upper reaches of the host gully, and along side valleys as indicated in Figure 26.

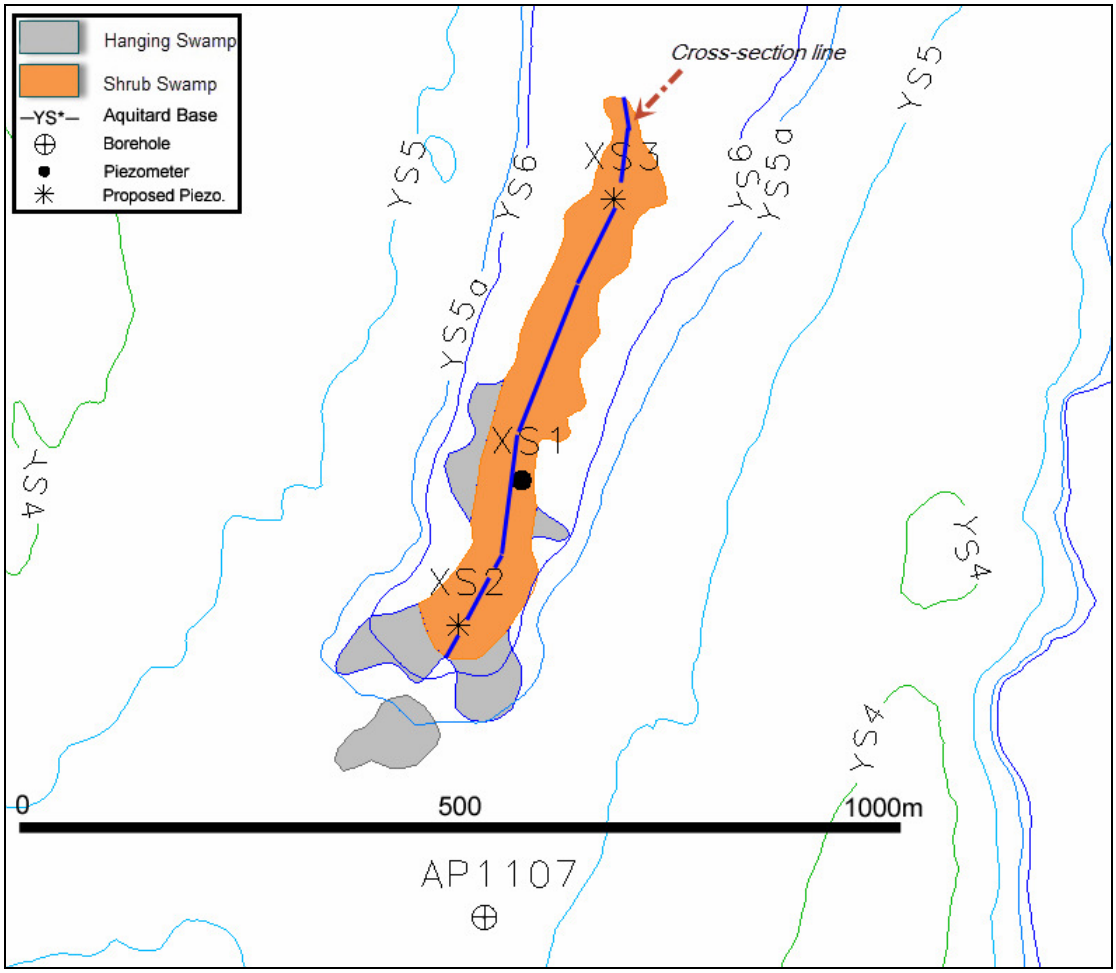

Figure 26 Plan of Japan (Trail 6) Shrub Swamp

Japan Shrub swamp is the largest shrub swamp in the Angus Place lease and its relatively expansive width as compared to Twin Gully, Tri-Star and Crocodile is due to its topographic positioning and presence of three aquitards along the length of the host valley. This swamp lies in a narrow, steep gully due to the characteristics of the Banks Wall Sandstone substrate which displays a different erosional pattern to gullies with Burralow substrates. Hence the narrow nature of the Japan gully results in the close proximity of aquitards YS6, YS5a and YS5 which supply valley wall seepage along the length of the gully such that a shrub swamp can be formed and sustained within the aquitard-poor Banks Wall Sandstone.

Aquitards YS6 and YS5a are sufficiently developed in thickness to permit a change in hydrological gradient to form the hanging swamps at the headwaters of Japan Shrub Swamp as well as along the down-dip western side of the gully (Figure 26).

Figure 27 View of Japan Swamp (Trail 6)

Figure 27 was taken in the middle of the drainage line of the swamp, oriented in a northerly (downstream) aspect approximately one-third of the way from the upper reaches of the host gully. This photo gives an indication of the relative narrowness of this swamp compared to Burralow-type shrub swamps described previously. This swamp is wholly underlain by the Banks Wall Sandstone and thus the morphology differs significantly from shrub swamps with Burralow Formation substrates.

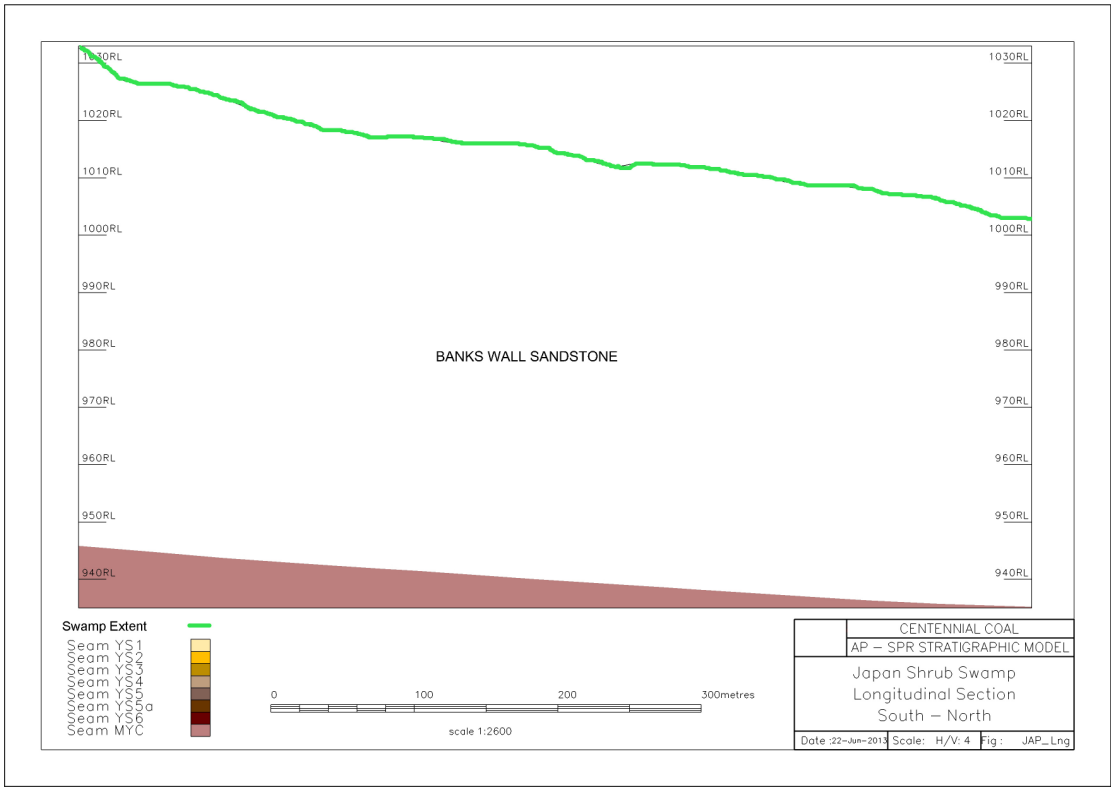

Figure 28 Longitudinal Stratigraphic Section of Japan Shrub Swamp

Figure 28 shows a south-to-north longitudinal stratigraphic cross section of Japan Shrub Swamp. Note the absence of Burralow Formation lithologies and the consequent continuous Banks Wall Sandstone substrate. The latter contributes to the relatively attenuated length of this swamp compared to Burralow-type swamps due to the absence of direct in-gully aquitards.

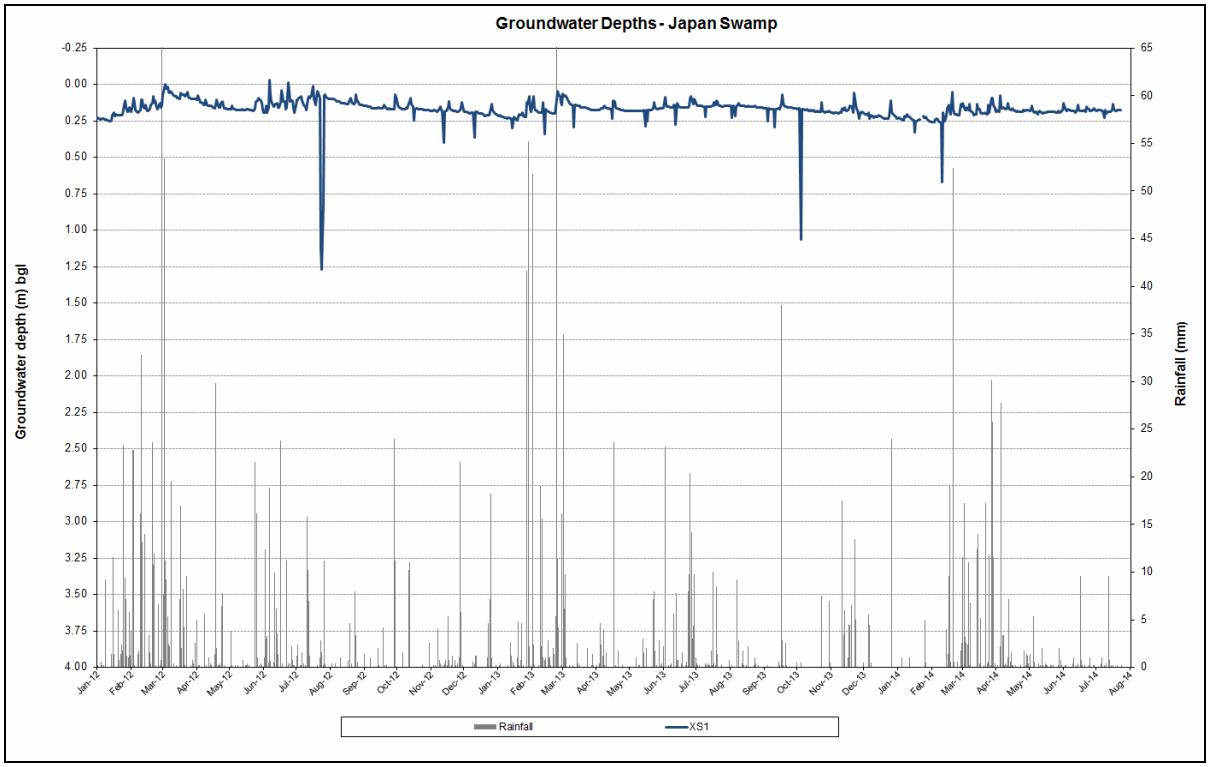

Figure 29 Hydrograph of Japan Shrub Swamp

Figure 29 shows piezometric data from January 2012 to late July 2014. Piezometer XS1 is situated roughly in the middle reaches of this swamp and overlies the pillar between longwalls LW1016 and 1017. Piezometer readings display consistently high groundwater levels over above period. The negative spikes represent regular groundwater sampling. The pronounced dips in August 2012 and November 2013 are due to data sampling problems (D. Hilyard pers.com). The negative spike on February 10, 2014 is due to purging and sampling of hole (J.Carr pers.com.). Overall, Japan Shrub Swamp at this locality displays typical groundwater-dependent shrub swamp characteristics. In order to capture the overall hydrological characteristics of the upper and lower reaches of this swamp, additional piezometers are suggested at XS2 and XS3 as shown in Figure 26.

II. Twin Gully Shrub Swamp

This swamp trends roughly west-east, with the lower reaches of the host gully emptying into the Wolgan River to the west, and is distal from any known structure zones (Section 4, Figure 4). Twin Gully Shrub Swamp forks in its upper reaches (Figure 30) and has a maximum length in its longer tributary of just under 1200 metres. The average maximum width is 40 metres with a fall of 65 metres. The upper half of this shrub swamp lies above proposed longwall LW1010.

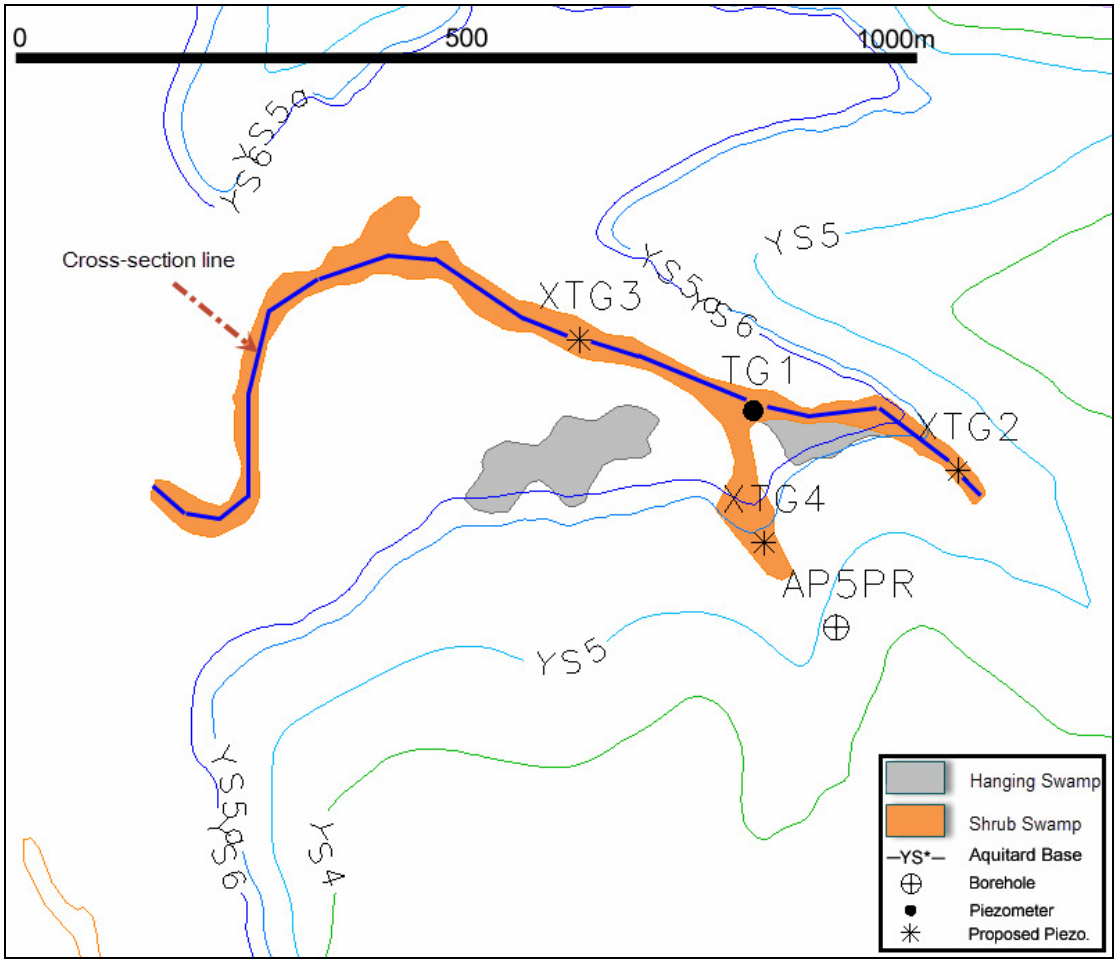

Figure 30 Plan of Twin Gully Shrub Swamp

As with the majority of the shrub swamps in the Angus Place area, Twin Gully is a "mixed-type" swamp, with its extreme upper reaches located stratigraphically within the Burralow Formation, topographically above the point where the host gully bifurcates. At this location, the swamp is supported by groundwater from the YS6 and YS5a aquitards. These plies provide direct in-gully seepage at this location thus widening the shrub swamp where the aquitard transects the gully floor (Figure 30).

Relatively high groundwater availability in the general vicinity is indicated by the presence of two hanging swamps (Figure 30) which are both hydrologically supported by the YS6 and YS5a aquitards. The importance of hanging swamps in the regional hydrological regime will be discussed in *The Hanging Swamps of the Newnes Plateau.*

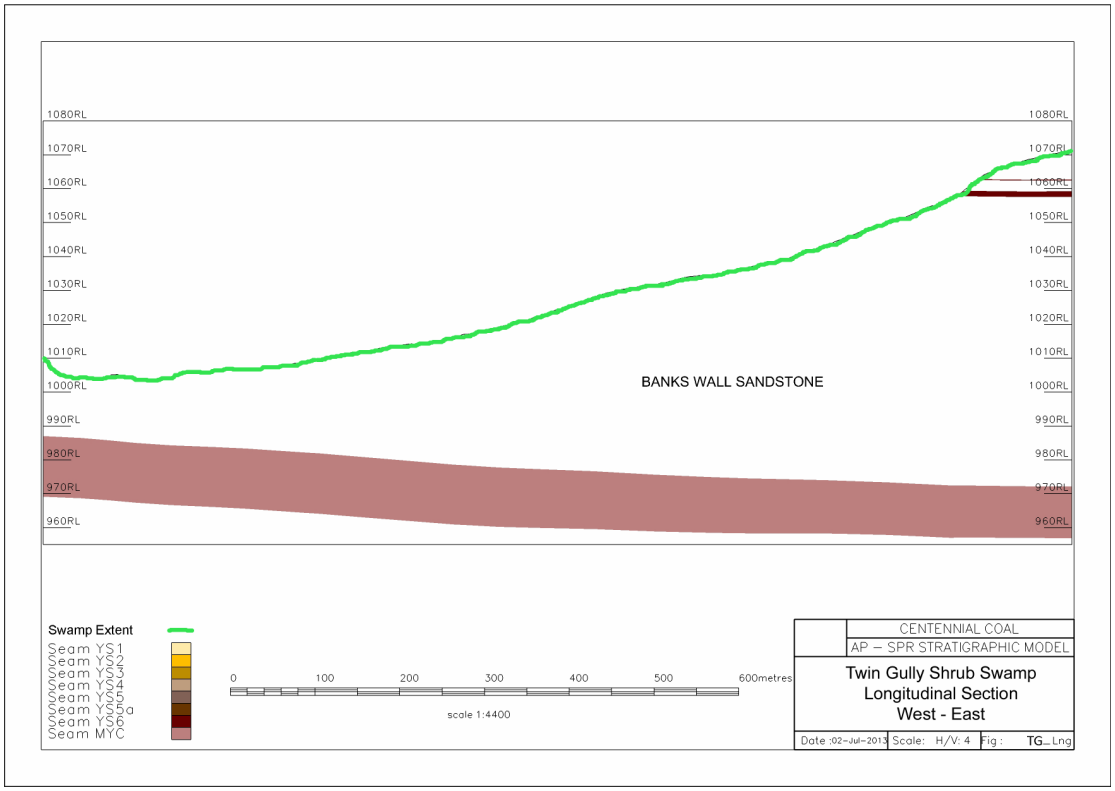

Figure 31 Longitudinal Stratigraphic Section of Twin Gully Shrub Swamp

The above longitudinal section of Twin Gully Swamp shows the eastern extremity as being underpinned by the Burralow Formation, with the majority of the swamp underlain by the Banks Wall Sandstone. The lithological characteristics of the Banks Wall Sandstone ensure that the morphology of the swamp is both relatively short and narrow as compared to Burralow-type shrub swamps within the Springvale lease.

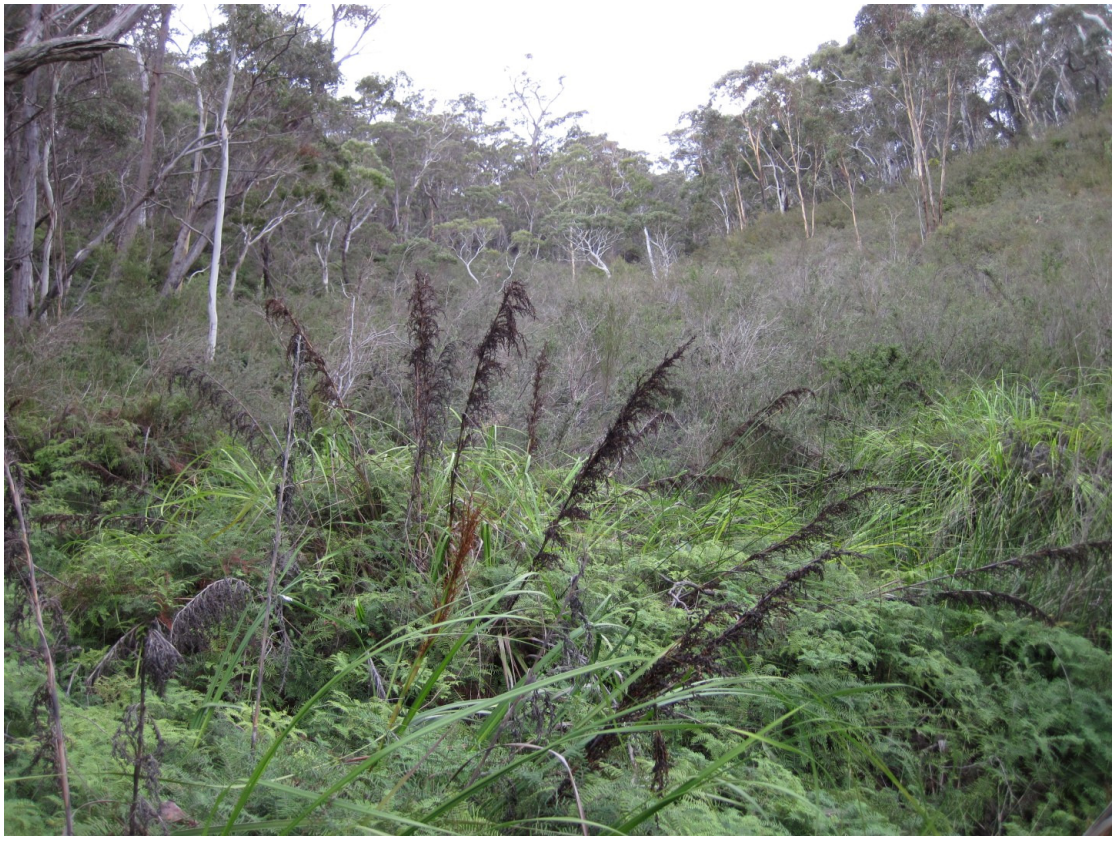

Figure 32 View along eastern extent of Twin Gully Shrub Swamp

Figure 32 was taken from 236 523E/ 6 308 783N GDA which is located almost half way along the eastern fork of Twin Gully swamp and close to the modelled boundary between the Banks Wall Sandstone and the Burralow Formation (Figure 30). This photo illustrates the relatively narrow morphology of the main drainage line of Twin Gully as compared to the more open expanses of the Burralow-type swamps in the Springvale area. While vegetation types are similar in both swamp types (Lembit, 2013), the Banks Wall Sandstone substrate at this location results in a more confined swamp width.

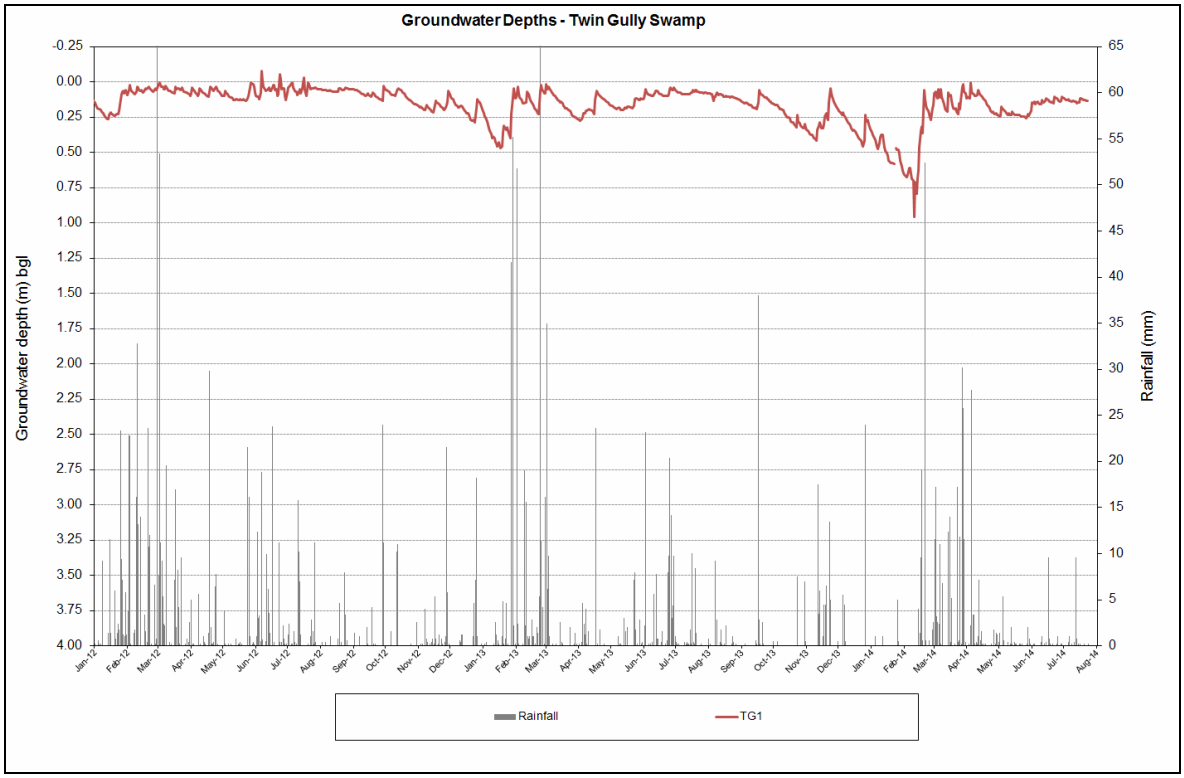

Figure 33 Hydrograph of Twin Gully Shrub Swamp

Twin Gully Swamp presently contains one piezometer monitoring station (TG1) which is located at the junction of the two upper tributaries (Figure 30). TG1 overlies proposed longwall LW1010 in a section that currently is not earmarked for extraction. Figure 33 shows that at location TG1 the groundwater level is generally high with minor fluctuations due to input from rainfall. Aurecon (2013) have identified this swamp as a permanently saturated groundwater-dependent entity with near-surface groundwater levels and minimal groundwater fluctuation.

However, it is suggested that three additional swamp piezometers be installed at locations XTG2, XTG3 and XTG4 (Figure 30). Proposed swamp piezometers XTG4 and XTG2 are located above proposed longwall LW1010 and will provide excellent indicators of groundwater levels within the upper reaches of Twin Gully both prior to and after longwall mining of LW1009. Combined data from the above three localities will assist in providing valuable data that may be used to determine feasibility of mining beneath Twin Gully Shrub Swamp.

Additional proposed swamp piezometer XTG3 has been chosen to provide accurate groundwater monitoring in the potentially drier Banks Wall Sandstone zone of this swamp, at a distance from the influence of the Burralow Formation and its associated aquitards, valley wall seepage and hanging swamps. Regular photo monitoring of the upper reaches of both upper tributaries of Twin Gully is also suggested as no pre-mining data of this nature currently exists.

It is also suggested that ground-truthing of the northern arm of the host gully of Twin Gully swamp be undertaken. DEC (2005) aerial photographic mapping does not delineate this area as a shrub swamp but regular ground photo monitoring of this area

suggests that this northern arm includes vegetation that may be comparable with an MU52 classification. This tributary of Twin Gully trends ENE, overlies proposed longwall LW1101 and enters the southern main gully at the point where the known shrub swamp temporarily widens before taking a southerly course and ultimately emptying into the Wolgan River (Figure 30).

Ground-truthing is required to determine the extent of shrub swamp vegetation along this northern arm. Figure 30 indicates that the majority of this unmapped potential shrub swamp would be underpinned by the Banks Wall Sandstone, with the possibility of upper reaches being hydrologically assisted by the Burralow Formation. If vegetation mapping provides evidence for the presence of a shrub swamp at this location, additional swamp monitoring is advised. The location of any additional piezometers would be determined after vegetation mapping has been undertaken.

III. Tri-Star Shrub Swamp Complex

Figure 34 shows the original DEC (2005) aerial mapping of the shrub and hanging swamps which comprise the Tri-Star complex.

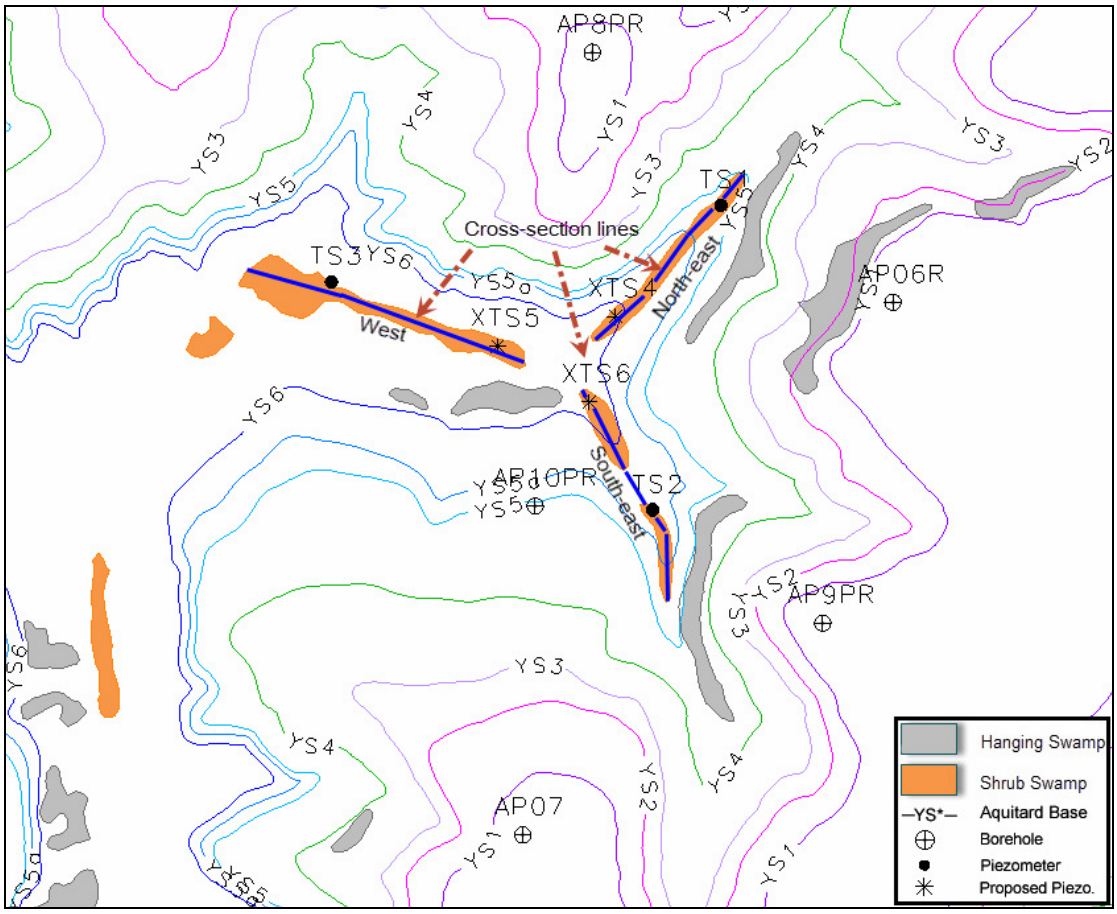

Figure 34 Original DEC (2005) plan of Tri-Star Swamp Complex

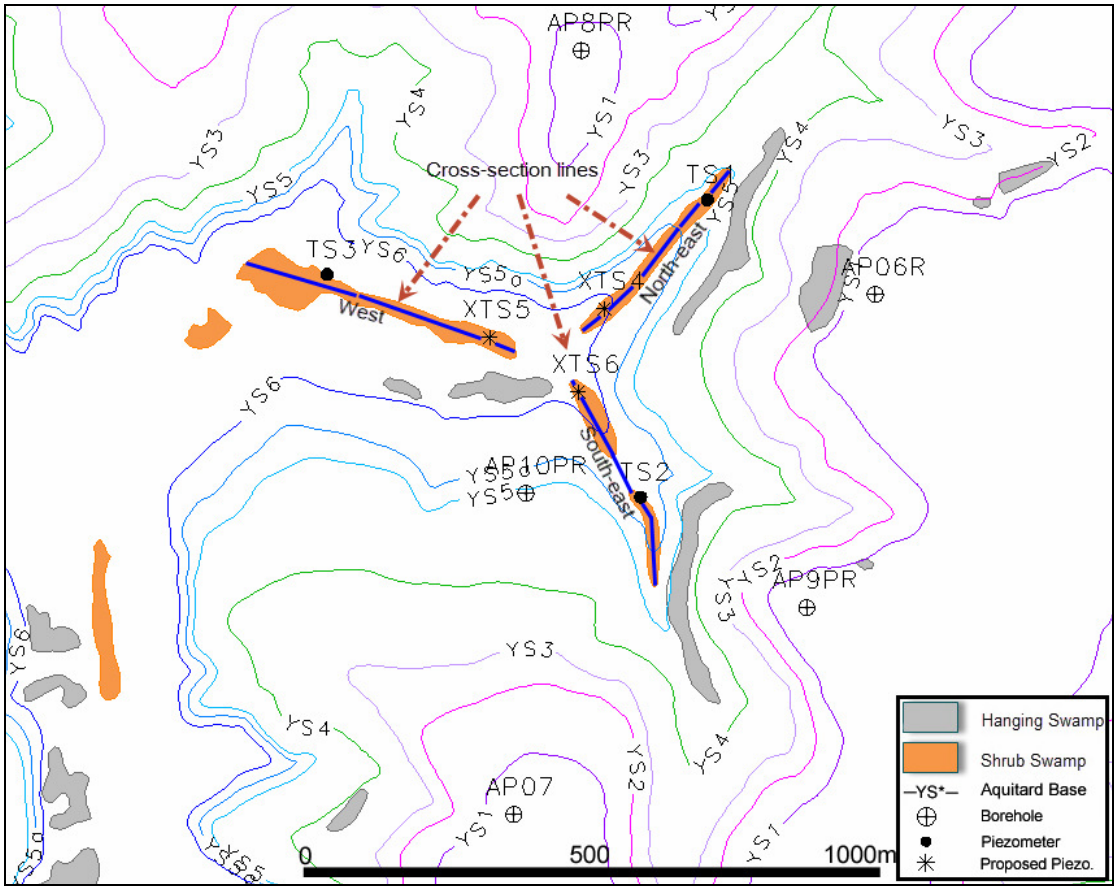

Figure 35 Amended Plan of Tri-Star Shrub and Hanging Swamp Complex

Tri-Star Shrub Swamp comprises a complex of three individual swamps which lie in a bifurcated host gully draining westward into the Wolgan River (Figure 35).

The three shrub swamps overlie longwalls LW1004, LW1005 and LW1006. Associated with these shrub swamps are numerous hanging swamps to the east and south-east. This swamp is not associated with any known structure zones (Section 4, Figure 4).

The principal western gully trends roughly east-west and is approximately 500 metres in length. It averages 35 metres in width with the exception of the extreme lower reaches where topographic influences result in a maximum width of 80 metres. It has a drop of approximately 20 metres. Stratigraphically, this section of the Tri-Star complex lies wholly within the Banks Wall Sandstone but receives drainage flow from the two upper tributaries.

The north-eastern tributary is 375 metres in length with a width of 30 metres. It has a drop of approximately 18 metres. This arm of the Tri-Star swamp complex is a "mixed-type" swamp, with its upper reaches located stratigraphically in the Burralow Formation and its lower reaches in the Banks Wall Sandstone.

The south-eastern tributary is divided into an upper and lower section (Figure 35). The lower section is 150 metres in length with a maximum width of 40 metres. The

upper section is 185 metres in length with a maximum width of 30 metres. Like the north-eastern tributary, this arm of Tri-Star is a "mixed-type" with its upper reaches located stratigraphically in the Burralow Formation and the lower reaches in the Banks Wall Sandstone. The total drop of both segments of the south-east tributary of Tri-Star is 22 metres. In all, the Tri-Star shrub swamp complex has a total drop of approximately 50 metres from the upper reaches of the south-eastern arm to the lower reaches of the western shrub swamp in the principal drainage line.

Lembit (2014) mapped both the shrub and hanging swamps in the Tri-Star area. All three shrub swamps were found by Lembit to coincide with previous DEC (2005) aerial mapping (Figures 34 and 35). However, the hanging swamps associated with the Tri-Star shrub swamp group were found to differ from the original DEC mapping, including the addition of a new, small hanging swamp to the north-east of AP9PR (Figure 35). The latter is hydrologically supported by the YS1 aquitard.

The hanging swamp due west of AP06R is significantly smaller than originally mapped and the easternmost hanging swamp has been redefined by Lembit as being comprised of two, smaller hanging swamps. In addition, the hanging swamp to the north of AP10PR has been slightly modified.

The hanging swamps in this vicinity are hydrologically supported by the YS6 (with additional input from YS5a and YS5), YS4, YS2 and YS1. Hanging swamps dependent upon plies YS2 and YS1 (Figure 35) are susceptible to dry-out due to a relatively restricted catchment and the absence of the full sequence of aquitards to assist in maintaining elevated groundwater levels. Regular vegetation mapping is suggested for the Tri-Star area in general.

Figure 36 View across north-eastern arm of Tri-Star Shrub Swamp

Figure 36 shows a view looking north-west across the north-eastern tributary of Tri-Star swamp taken from 237 284E / 6 307 061N GDA. As with Twin Gully described above, swamp width is restricted due to the dominant Banks Wall Sandstone substrate as compared to Burralow-type shrub swamps. The steep north-western flank of the gully can be clearly seen. This photo location is adjacent to the modelled boundary between the Banks Wall Sandstone and the Burralow Formation.

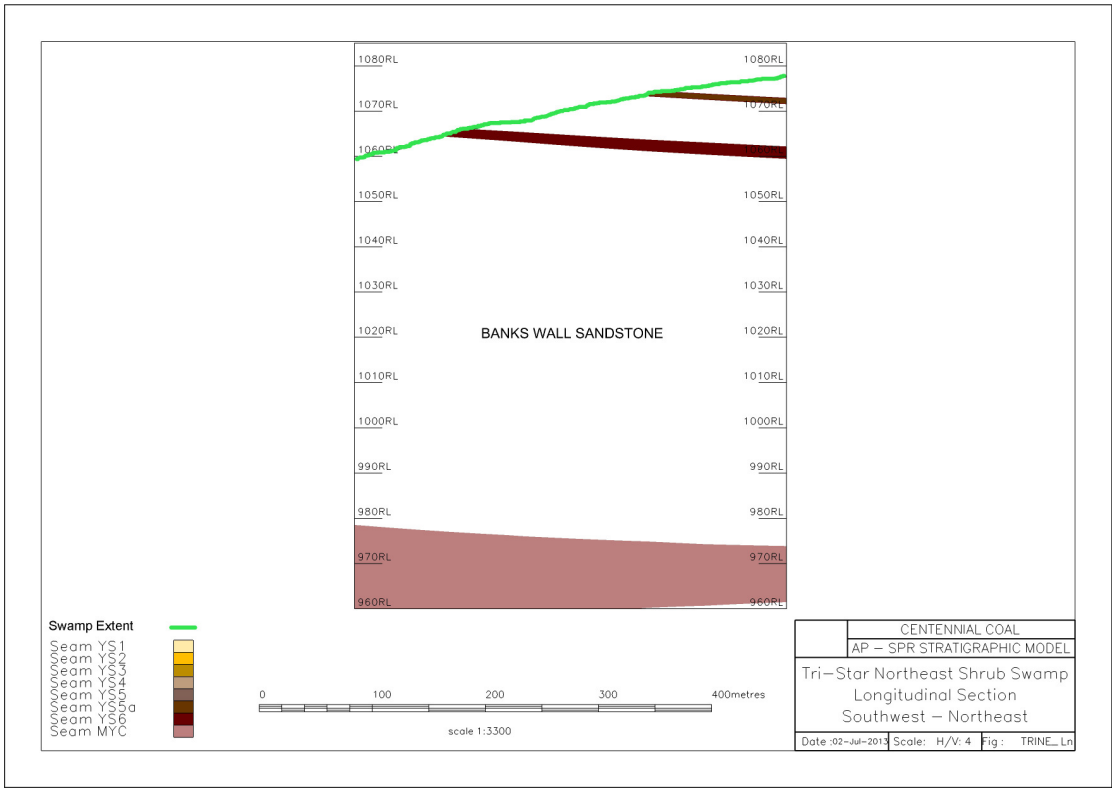

Figure 37 Longitudinal Stratigraphic Section of Tri-Star Shrub Swamp (North-East segment)

Figure 37 shows a south-west to north-east longitudinal cross-section of the north-east tributary of Tri-Star swamp. The upper two-thirds are located within the Burralow Formation and are located stratigraphically between plies YS6 and YS5. The lower reaches are located within the Banks Wall Sandstone, where the gradient steepens due to the change in geological regime. The majority of the swamp relies on valley wall seepage from the YS6 and YS5a aquitard together with direct in-gully input from these latter plies.