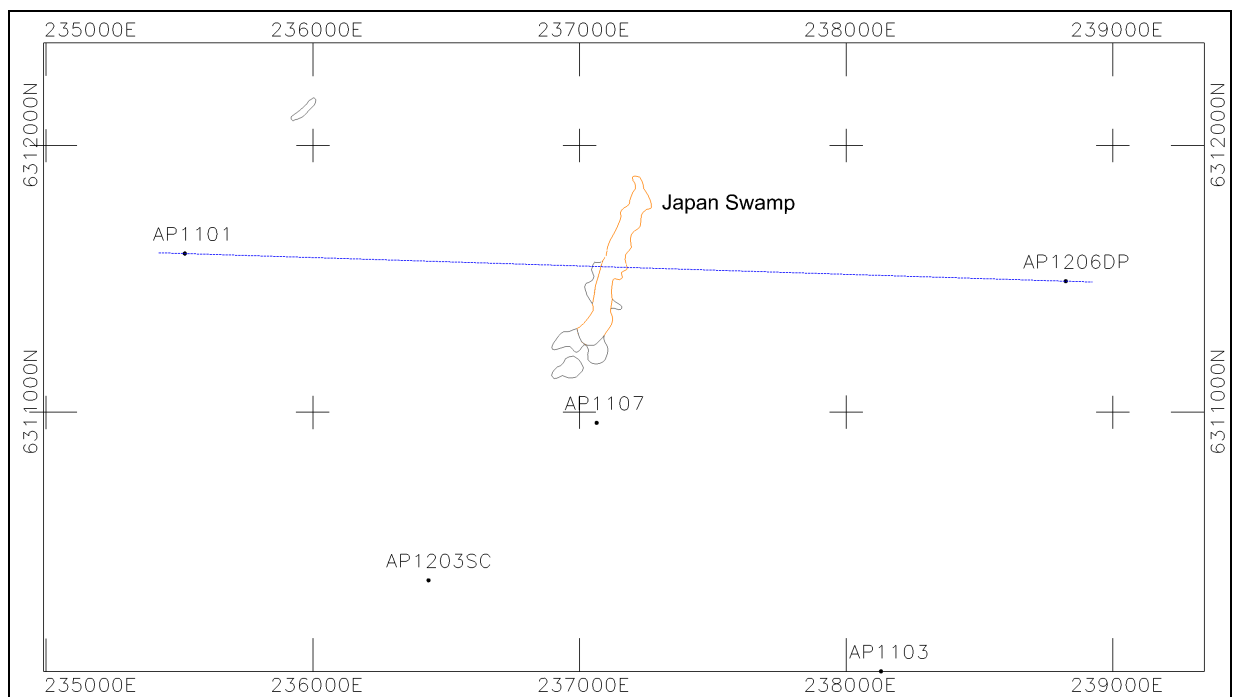


**Figure 15 Sunnyside - Sunnyside East - Carne West Shrub Swamps Cross Section**

As shown in Figure 15, swamp profiles in the eastern Burralow-type shrub swamps are generally asymmetrically concave with the lowest depression to the west of centre, often adjacent to the steeper side of the pertinent gully. This asymmetric profile can be seen in the above figure in the case of Sunnyside East and Carne West Shrub Swamps, as well as Sunnyside Shrub swamp which reflects an opposing concavity due to the general topography of this area. This shallow, spoon-shaped swamp morphology contrasts with that of the Banks Wall-type shrub swamps of which Japan Shrub Swamp (Figure 16 below) is a typical example. Banks Wall-type shrub swamps in general have much steeper-sided valley walls and a narrower width as compared to Burralow-type swamps, as previously illustrated in Figure 9.

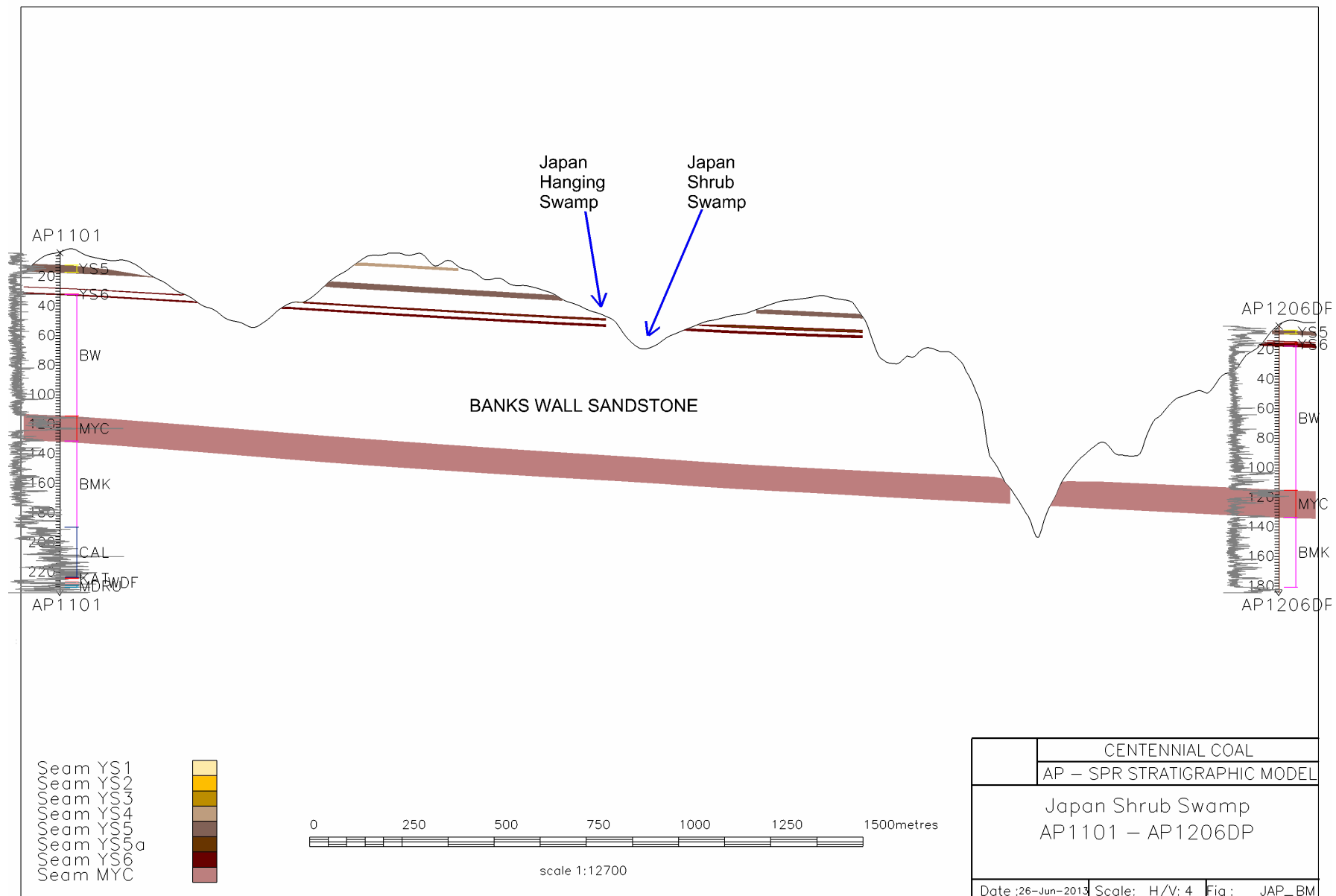
Figure 15 (above) also illustrates the difference in geophysical response between the Banks Wall Sandstone and the overlying Burralow Formation. This west-east cross section, encompassing boreholes SPR 33, SPR 62, SPR 36 and SPR60, clearly shows the generally muted gamma response of the Banks Wall Sandstone compared to the Burralow Formation. The latter displays increased gamma response associated with clay-rich aquitard horizons. The gamma response of the Mt York Claystone which lies stratigraphically below the Banks Wall Sandstone also reflects the high clay content of this formation. Hence, in geophysical terms, the Banks Wall Sandstone is referred to in this study as the “muted zone”, as noted in Section 5 above.



**Figure 16 Plan of Japan Shrub Swamp**

Figure 16 shows a plan diagram of the two boreholes used to create the cross section (Figure 17) below and includes the hanging swamp on the western flank of the host gully. Shrub swamps are in orange and hanging swamps are in grey.

# Geology of the Shrub Swamps within Angus Place, Springvale & Springvale Extension Areas



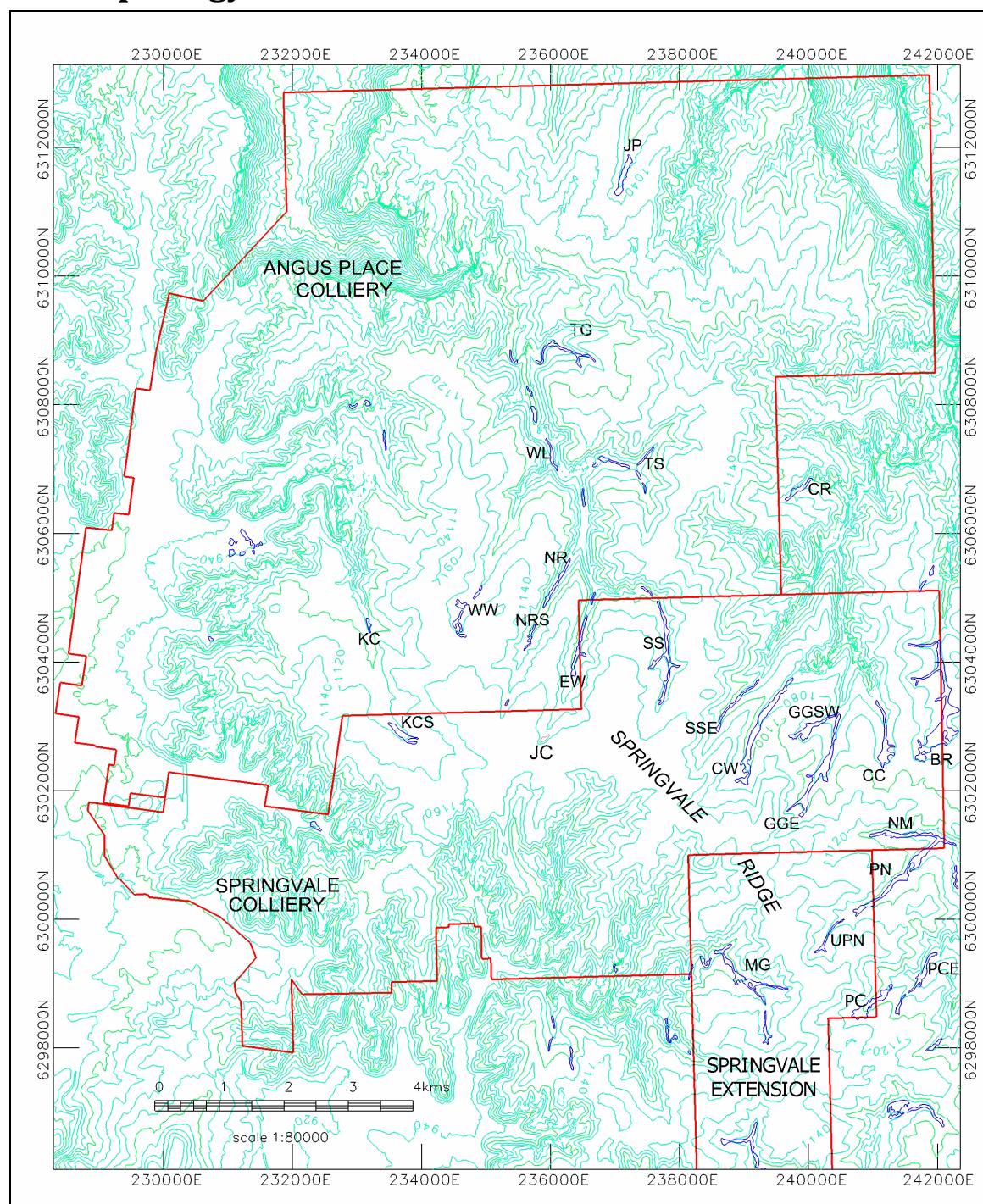
**Figure 17 Japan Shrub Swamp Cross Section**

Figure 17 shows a cross section of Japan Shrub Swamp and associated hanging swamps. With the same vertical exaggeration as the Burralow-type shrub swamp diagram (Figure 15), Japan Shrub Swamp appears as areally smaller with comparatively narrower gully sides. Additional gully profiles within this cross-section, particularly to the east of Japan Shrub Swamp also reflect this trend, displaying the steep-sided erosional gullies which are characteristic of watercourses located solely within the Banks Wall Sandstone.

Benson and Baird (2012) stated that monitoring of swamps in the western part of the Newnes Plateau revealed that these swamps are drier than those in the east. This finding further emphasizes the role of the Burralow Formation, and in particular, the important role of Burralow Formation thickness and therefore access to multiple aquitards to retain moisture content within this stratigraphic unit.

Benson and Baird also found that the eastern swamps were all associated with *Epodisma minus*, *Grevillea acanthifolia*, and *Epacris paludosa* which were virtually absent from the western swamps. This again reflects the influence of Burralow Formation thickness on both swamp morphology and swamp vegetation, due to its ability to retain water via the presence of numerous semi-permeable layers. Hence the Burralow Formation influences not only swamp morphology, including valley wall profiles and soil type, but ultimately swamp floristics.

## 10. Topography, Burralow Formation and Shrub Swamp Morphology

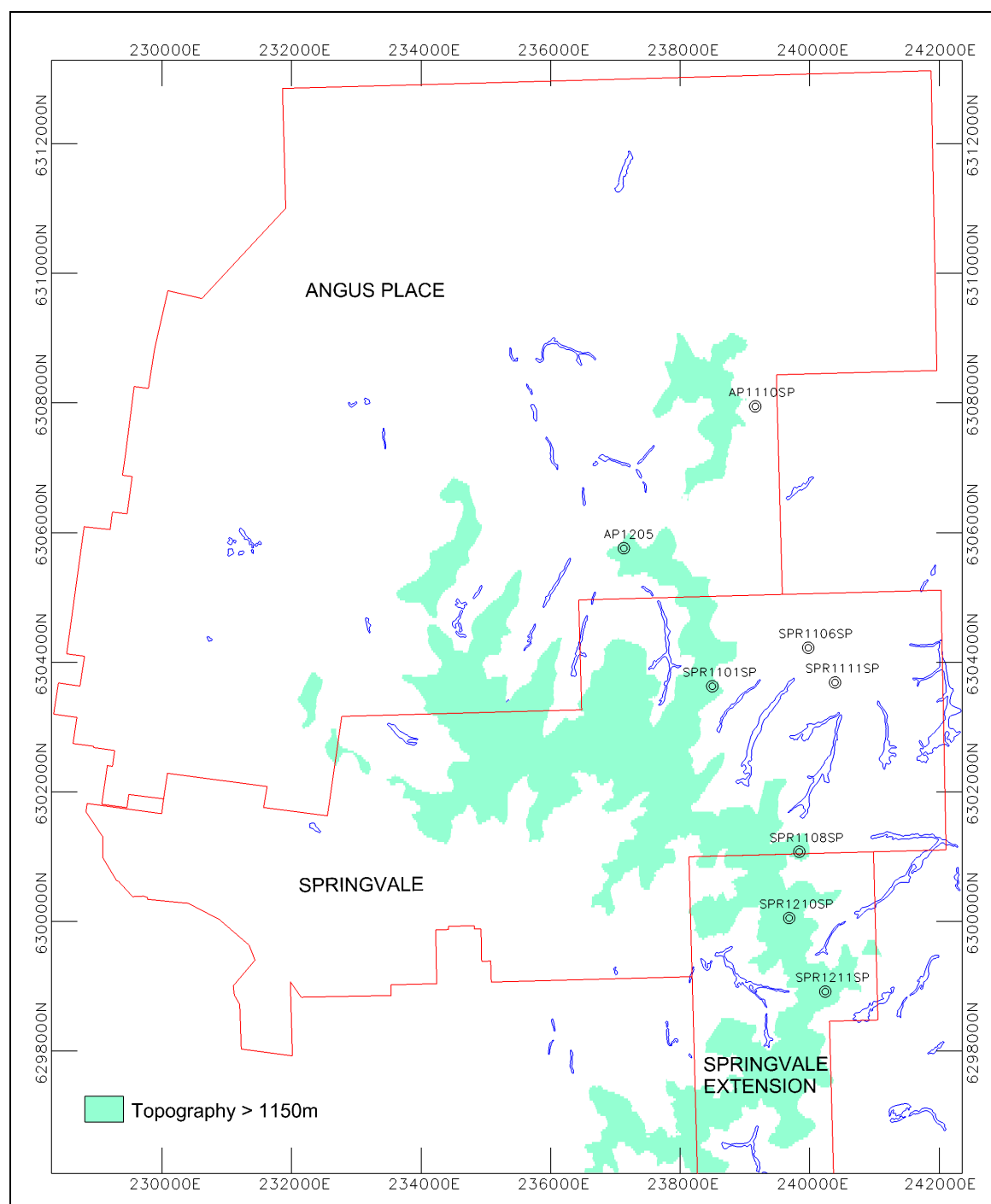


**Figure 18 Topography and Shrub Swamp Locations in Angus Place/Springvale**

**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

Figure 18 shows topography and shrub swamp locations for the Angus Place and Springvale leases. As shown, the length, breadth and frequency of shrub swamps in the study area generally increases to the south-east, principally in the Springvale Colliery lease. This is due in part to the topography present but is also dependent upon the thickness of the Buralow Formation and the hydrological influence of its associated aquitards. Hence, there is a persistent pattern of increasing shrub width and length towards the south and east of the study area.



**Figure 19 Topography in Study Area above 1150 metres**

The highest point on the Newnes Plateau in the study area is 1180 metres but an arbitrary topographic height of 1150 metres has been selected to highlight the dominant ridge systems in the area (Figure 19).

As illustrated above, in Angus Place the highest elevation is 1150 to 1160 metres and is located west of AP1110SP. This short piezometer hole is located topographically lower than the arbitrary 1150-metre cut off, but still contains the full YS6 to YS1 sequence. Geophysically logged holes in the most elevated areas of Angus Place also indicate that the full aquitard sequence from YS6 to YS1 is present.

The maximum thickness of the Burralow Formation in Angus Place is 100 – 110 metres and coincides with the highest catchment area as described above. Hence, there is a positive correlation between Burralow Formation thickness and topographic elevation.

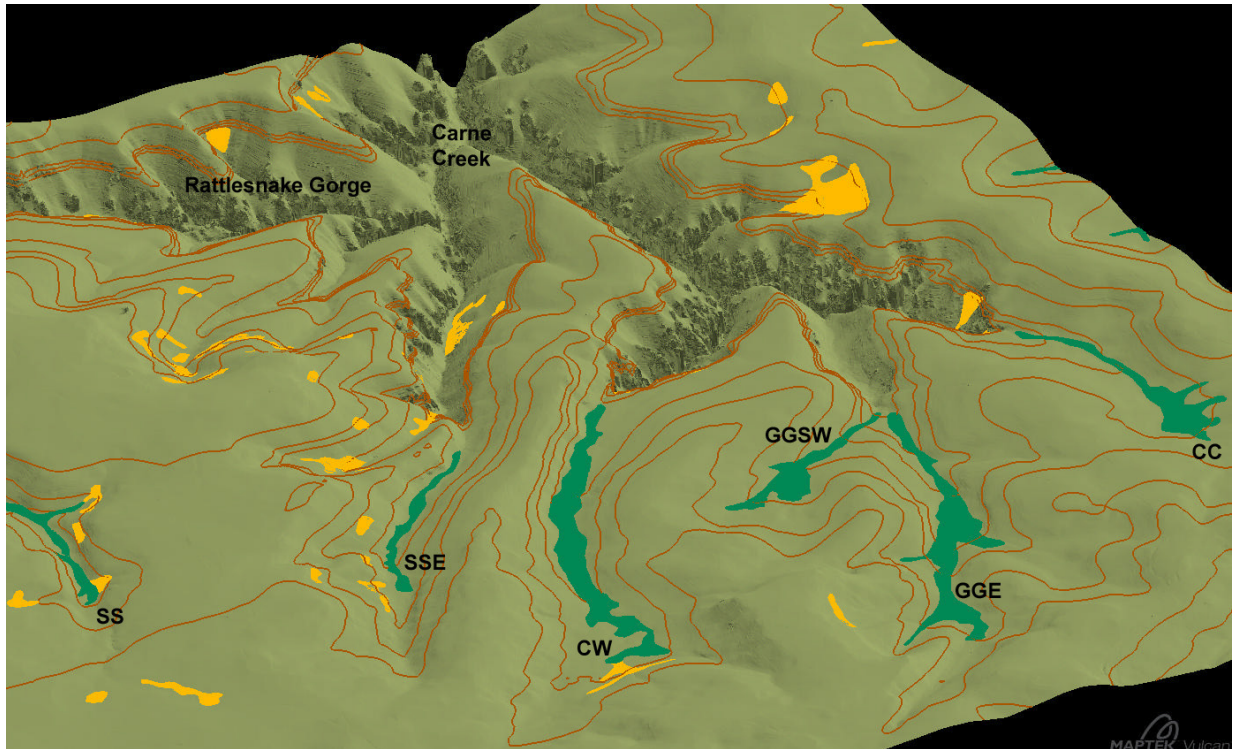
A second, more extensive ridge system (> 1150m -1180m) is present in the Springvale area and represents the most elevated region of the study area. This ridge system, Springvale Ridge (Figure 18), extends from south of the West Wolgan Shrub Swamp to south of the Narrow, East Wolgan, Sunnyside, Sunnyside East, Carne West, Gang Gang, Pine and Marrangaroo Creek Shrub Swamps, thus creating an extensive watershed for the formation of the creeks which support the above watercourses. Further, this topographic feature, like the elevated plateau in Angus Place described above, is underlain by the maximum thickness of the Burralow Formation and contains the full sequence of YS aquitards. Again there exists a positive correlation between topography and Burralow Formation thickness at this location.

An outlier of elevated topography occurs to the north-west of West Wolgan Shrub Swamp which serves to supplement groundwater seepage to this swamp complex via the series of aquitards present in the Burralow Formation at this location.

These elevated ridges, particularly the elongated twelve kilometre system in the Springvale area, are important recharge areas for both the hanging and shrub swamps. In Angus Place, the 1150+ metre zone is more areally restricted and few major waterways are associated with this feature. The nearest shrub swamps are Tri-Star and Twin Gully Shrub Swamps to the west at a distance of between one to two kilometres, and Crocodile Shrub Swamp, over one kilometre to the east (Figure 6).

The Springvale Ridge system provides not only an extensive recharge area for the associated creeks and shrub swamps, but the maximum thickness of the Burralow Formation is an important component in the hydrological cycle that drives the formation of both shrub and hanging swamps in the region.

The full YS aquitard sequence (YS6 to YS1) is present in all cored holes within the designated 1150+ metre shaded area, that is, AP1110SP, AP1205, SPR1108SP, SPR1210SP and SPR1211SP. Borehole SPR1101SP, located between Sunnyside and Sunnyside East Shrub Swamps, does not contain the YS6 ply as the borehole was terminated above this horizon.



**Figure 20 Schematic View of Carne Creek Shrub Swamp Systems**

Figure 20 shows a view looking north-west from the direction of the Springvale Ridge system. Aquitard horizons which support the shrub and hanging swamps are shown in brown. Shrub swamps are marked in green and hanging swamps in yellow.

Carne West Shrub Swamp (CW) in teal green, with its associated Newnes Plateau Hanging Swamp (in yellow) can be seen in the middle foreground. To the east is the Gang Gang Shrub Swamp complex (GGSW and GGE), while Carne Central Shrub Swamp (CC) is to the extreme right of the figure.

To the west of Carne West swamp lies Sunnyside East Shrub Swamp (SSE) together with an array of hanging swamps (in yellow) associated with several aquitards cropping out west of this swamp. The lower tip of Sunnyside Shrub Swamp (SS) can be observed in the left foreground on the opposing side of Sunnyside Ridge which forms part of the extensive recharge areas discussed above. Several hanging swamps are also associated with this shrub swamp.

This figure illustrates the extensive subcrops of aquitards present in this area of the Angus Place/ Springvale lease. As the regional dip is less than one degree, the aquitard horizons generally follow topography. Hence there is a relative lack of aquitard outcrops in the flatter, elevated ridge areas, whereas the gully sides form frequent outcrop points. As was noted in Section 9, aquitard horizons crop out along the sides of valley walls, as well as within gully floors, thus supplying a constant source of groundwater moisture for both the shrub swamps in the gullies and the hanging swamps that occur along cliffs and the steeper upper sections of valley sides.

The presence of hanging swamps throughout the lease area is an important indicator of the amount of groundwater contained within the aquitard/aquifer system operating

throughout the vertical extent of the Burralow Formation. As noted above and shown in Figure 20, there exists an extensive suite of hanging swamps to the immediate west of Sunnyside East Shrub Swamp. Sunnyside Shrub Swamp also has associated hanging swamps, the southern examples of which can be seen in the above figure. Other hanging swamps are present in Figure 18, including those in Rattlesnake Gorge, the western tributary of Carne Creek in the upper left of this figure. The latter demonstrate the typical outcrop pattern for hanging swamps.

Hanging swamps occur in both high and low relief areas, while shrub swamps are restricted to areas of low relief. The formation of a hanging swamp is dependent on the presence of a suitably thick aquitard (generally > 1 metre) and an appropriate topographic setting. The hanging swamps of the Newnes Plateau are discussed in a separate report, however their presence and morphology are indicative of considerable reserves of water held within aquifer units of the Burralow Formation, which is also of crucial importance to the development of shrub swamps.

As can be observed in Figure 20, by virtue of the regional dip, the aquitard horizons are often present along the sides of ridges and thus follow the gully sides of the host creek below. The presence of aquitards at these locations leads to the occurrence of valley wall seepage which is an important source of moisture for the shrub swamps in the upper reaches of both Carne Creek and the Wolgan River.

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

The presence of swamps in catchment headwaters cannot be fully explained by rainfall alone and require an additional continuous source of hydration though periods of restricted rainfall. As noted in Section 9, the presence of the Burralow Formation is essential to the formation of both hanging and shrub swamps. Piezometer readings, both in-stream and on ridge locations, record only part of the full hydrological picture for any given swamp system. Valley wall seepage, which occurs however minutely at some locations along aquitards outcrops, still permits continuity of hydration during periods of drought. More importantly, in regard to Burralow-type swamps, direct in-gully groundwater input forms a crucial contributor to swamp hydration and morphology.

Figure 20 illustrates the relative abundance of aquitards in the Burralow Formation providing continual groundwater supplies to both shrub and hanging swamps along valley sides. Aquitards also crop out within the host gully of a shrub swamp, for example, in Carne West and Gang Gang Shrub Swamps, and hence provide additional input of groundwater to the valley wall seepage. The latter phenomenon accounts for the relatively extensive morphologies of these two shrub swamps. This concept will be further discussed in a subsequent report.

## **11. Major recharge areas within the Angus Place/Springvale Leases**

The Springvale Ridge system as noted previously provides a major recharge zone for the shrub swamps to the north and south of this feature. The western half of the ridge system contains numerous boreholes which were geophysically logged (eg. SPR24, SPR 31, SPR 25R, SPR 44, SPR52, SPR35 and SPR 51) in which the full YS1 to YS6 sequence is present. Several short piezometer holes were also cored in the eastern extent of this elevated zone, with results as follows:

- In AP1110SP, the closest cored borehole to the Angus Place 1150+ m zone, the strata from approximately 6m to 36m consists largely of slightly weathered to unweathered fine- to medium-grained sandstone interspersed with thin zones of more highly weathered material. It is this resistant sandstone cap which likely forms the Angus Place elevated zone to the immediate west.
- AP1205 is similar to AP1110SP, with the resistant/competent sandstone extending to approximately 30m.
- SPR1108SP consists of slightly weathered fine-to-medium sandstone from 6m to 13m. From 13m to 42m, the strata consist of slightly weathered to unweathered fine- to medium-grained sandstone interspersed with zones of more highly weathered material. Figure 21 shows core photographs from 6 to 13.5 metres within this hole and illustrates the competent nature of this near-surface material.
- SPR1210SP contains a slightly weathered sandstone/siltstone cap from 6 to 8 metres, but this is underlain by more highly weathered material than shown in the previously discussed boreholes.
- SPR1211SP contains slightly weathered fine siltstone from 6 to 8 metres, but below this depth, there is a higher proportion of moderately to highly weathered material than slightly weathered, competent material.

The common feature from each of these bores is the presence of relatively unweathered, competent strata at very shallow depth.

By comparison, boreholes SPR1106SP and SPR1111SP which are located near the confluence of the Sunnyside East, Carne West and Gang Gang Creeks show quite different lithological patterns. Although both located in the Buralow Formation, these bores contain non-competent, heavily weathered and iron-stained material near the surface and hence, at this RL, no ridge system exists. Figure 22 shows the material present in the upper 12.3 metres of SPR1111SP which clearly demonstrates the extreme weathering at this site.

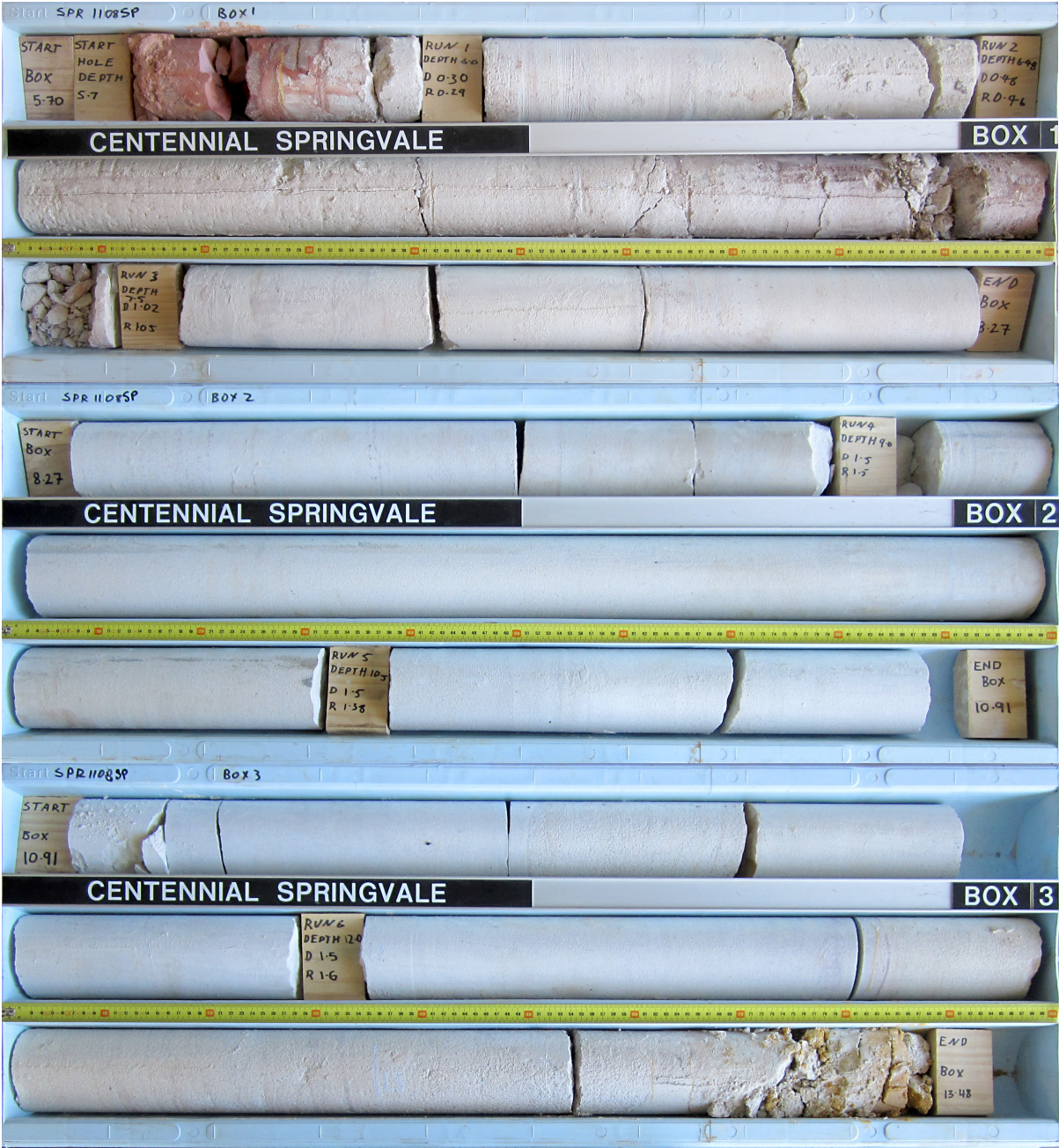


Figure 21 Core Photos of SPR 1108SP (6-13.5 m)

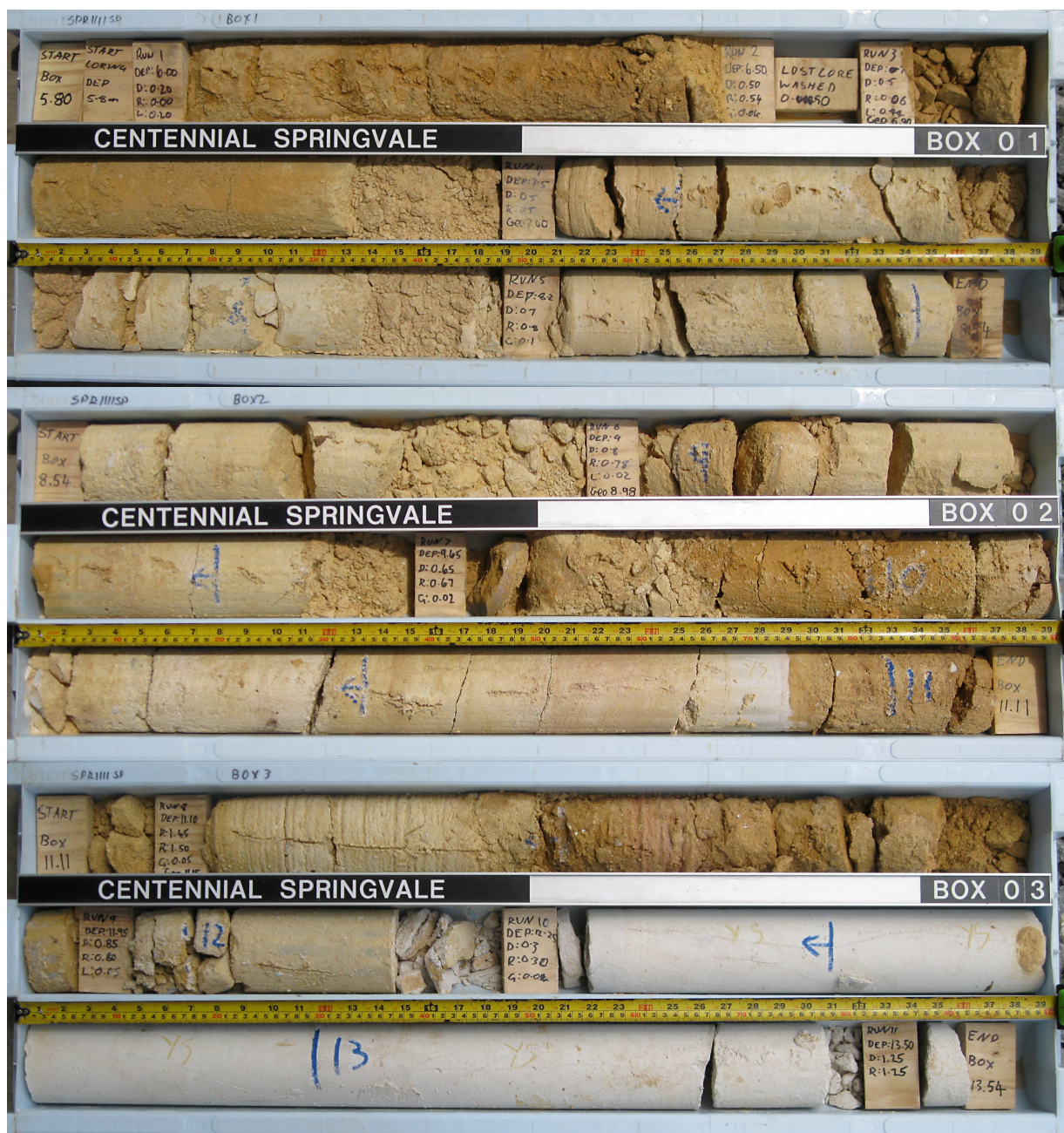


Figure 22 Core Photos of SPR1111SP (6-12.3m)

## **12. Selected Newnes Plateau Shrub Swamp Descriptions within Angus Place East**

A selection of shrub swamps in both the Angus Place and Springvale South area are described in Sections 12 and 13 below in order to present an overall understanding of the varying morphologies between differing lithologically controlled shrub swamp types. As described in Section 10, the underlying lithology plays an important part in the morphology of the resultant shrub swamp.

Angus Place East consists of proposed longwall panels 1001 to 1017 east of the Wolgan River (Figure 23) and is overlain by three shrub swamps: Japan, Twin Gully and Tri-Star. An additional shrub swamp, Crocodile, is situated within the Angus Place lease area approximately 100m to the east of LW1003. All four swamps are discussed in this report and are shown in Figure 24 below. In addition, the Rattlesnake Gorge Hanging Swamp Complex and the Smithston Hanging Swamp Complex are briefly discussed due to their proximity to the proposed mining area. These swamps will be considered in detail in a subsequent report *The Hanging Swamps of the Newnes Plateau*.