8. SUBSIDENCE PREDICTIONS AND IMPACTS ON NATURAL FEATURES

8.1. THE NEPEAN RIVER

8.1.1. Predictions along the Nepean River

The predicted profiles of incremental and cumulative subsidence, upsidence and closure along the Nepean River, after the extraction of each proposed longwall, are shown in **Appendix A**. A summary of the maximum predicted values of cumulative subsidence, upsidence and closure anywhere along the Nepean River within the SMP Area, after the extraction of each proposed longwall, is provided in **Table 8.**1. A summary of the maximum predicted values of cumulative subsidence plus upsidence anywhere along the Nepean River within the SMP Area, after the extraction of each proposed longwall, is provided in **Table 8.2**.

Table 8.1 - Maximum Predicted Cumulative Subsidence, Upsidence and Closure at the Nepean River Resulting from the Extraction of Longwalls 705 to 710

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Upsidence (mm)	Maximum Predicted Cumulative Closure (mm)
After LW705	60	315	535
After LW706	60	320	545
After LW707	60	320	545
After LW708	60	320	545
After LW709	60	340	545
After LW710	60	380	545

Table 8.2 - Maximum Predicted Cumulative Net Vertical Movements Resulting from the Extraction of Longwalls 705 to 710

Longwall	Maximum Predicted Cumulative Subsidence plus Upsidence (mm)	
	Net Subsidence	Net Uplift
After LW705	< 20	255
After LW706	< 20	265
After LW707	< 20	265
After LW708	< 20	265
After LW709	< 20	305
After LW710	< 20	345

The maximum predicted systematic tilt along the alignment of the river, at any time during or after the extraction of the proposed longwalls, is 0.3 mm/m (i.e. < 0.1%), or a change in grade of 1 in 3335. The maximum predicted systematic strains along the alignment of the river, at any time during or after the extraction of the proposed longwalls, are less than 0.1 mm/m and the associated minimum radii of curvature are is greater than 150 kilometres.

Compressive strains across the alignment of the Nepean River are likely to result from the valley related movements. The compressive strains resulting from valley related movements are more difficult to predict than systematic strains, especially where rivers and creeks are located above solid coal, i.e. outside the areas located directly above extracted longwalls, such as the case for the Nepean River.

Compressive strains due to valley related movements greater than 2 mm/m are expected to occur along the Nepean River at the predicted magnitudes of the upsidence and closure movements. The maximum compressive strains in the base of the Nepean River, resulting from the extraction of the proposed longwalls, is expected to be similar to that observed where Appin Longwalls 301 and 302 mined adjacent to the Cataract River, where a maximum measured compressive strain of 15 mm/m was observed. Because the Nepean River is a flooded valley, the maximum strain in the floor of the valley was not able to be monitored after Longwall 17 was extracted under the Nepean River at Tower Colliery.

Whilst compressive strains in excess of 2 mm/m may cause localised surface fracturing in the sandstone base of incised valleys, given the flooded nature of the Nepean River valley it is very unlikely that any such fracturing will lead to water loss within the flooded river system.

8.1.2. Impact Assessments for the Nepean River

The section of the Nepean River within the SMP Area is different to most other rivers in the Southern Coalfield. The Nepean River within the SMP Area is a flooded system, where the river water level is predominantly controlled by the Menangle Weir, as opposed to other local creeks and rivers where the pool water levels are controlled by natural rockbars.

The impacts observed during the mining of these previous longwalls provide a good indication of the likely impacts that might occur as a result of mining the proposed Longwalls 705 to 710. The following sections provide detailed assessments of the likelihood of each of the potential impacts on the Nepean River.

The Potential for Changes to Water Levels

Menangle Weir is located approximately 2.5 kilometres north of the proposed Longwalls 705 to 710 and, therefore, the predicted systematic subsidence and valley related movements at the weir are negligible. It is possible that the weir could experience very small far-field horizontal movements, however, these movements are expected to be bodily movements with no significant associated ground strains. It is expected that the survey monitoring would reveal no noticeable movements and it is unlikely, therefore, that the extraction of the proposed longwalls would result in any significant impacts on Menangle Weir.

Since Menangle Weir controls the water level along the Nepean River within the SMP Area and since no significant movements are expected at the weir, it is unlikely, therefore, that there would be any significant change in the water level along the Nepean River within the SMP Area resulting from the extraction of the proposed longwalls.

The Potential for Loss or Diversion of Surface Waters

There has been no reported or observed loss of surface water as a result of previous mining directly beneath or near the Nepean River by Tower Longwalls 15 to 20 and Appin Longwall 701. This includes observations at a monitoring site that was located directly above Tower Longwall 17, which directly mined beneath the river for a length of approximately 800 metres.

The potential for diversion of surface water in the Nepean River is very low as the river bed is flooded and the gradient of the river is very flat. Any rockbars present along the river bed are completely submerged. Any fractures in the bedrock that develop as a result of mining are likely to be immediately filled by water or sediment. The volume of water that fills these fractures is likely to be an extremely small proportion of the total volume of water that is retained by the weir.

The potential for infiltration of water into the groundwater system is very low as the Nepean River represents the regional low point in the water table. Further detailed discussions on the potential for this form of flow diversion are provided in **Appendices B** and **H**.

It is therefore assessed that the potential for surface water flow diversion to occur as a result of the extraction of the proposed longwalls is very low.

The Potential for Ground Water Inflows

There are no natural springs along the Nepean River within the SMP Area, although it is possible that some seepage occurs into the river. Although the proposed longwalls do not mine directly beneath the Nepean River, it is possible that mining-induced springs may develop following the extraction of the proposed longwalls. The chemical characteristics of mining-induced springs near previously mined longwalls in the Southern Coalfield suggest that the water passes through upland Wianamatta Shale areas and permeates through natural or mining-induced fractures into the Hawkesbury Sandstone before emerging in the valley (EcoEngineers, 2008).

Vertical dilation between Wianamatta Shale and Hawkesbury Sandstone is possible along the tributaries to the Nepean River, particularly if the thickness of the Shale is less than 10 to 15 metres, since field studies suggest that vertical dilation in creeks and rivers extend, as a maximum, to this depth (Mills and Huuskes, 2004). The confluence of the tributaries which flow into the Nepean River is not directly mined beneath and, in these locations, the vertical dilation is expected to be small. The upper reaches of these tributaries, however, are directly mined beneath by the proposed longwalls.

Further discussion on the likely occurrence and impacts of springs is provided in **Appendix B**.

The Potential for Gas Emissions

It is likely that some mining-induced gas emissions in the Nepean River will be observed during the extraction of the proposed Longwalls 705 to 710. It is known that mining results in fracturing or dilation of the strata above the extracted area and this may result in the liberation of methane and other gases. Gas emissions have typically occurred within deep river valleys, although some gas emissions have also been observed in creeks and water bores. Emissions are most noticeable in the form of bubbles in water.

Gas emissions typically occur in river valleys and gorges. However, some gas emissions have also occurred in upland areas that have been mined beneath. Gas emissions have previously been observed in the Nepean River during the mining of Tower Longwalls 17 to 20 and Appin Longwall 701.

Recent estimates of gas emissions in the Nepean River during the mining of Longwall 701 indicate gas emissions of about 3 L/sec. It is possible, if substantial gas emissions occur at the surface, that these could result in localised vegetation dieback. In the past these impacts have been limited to small areas of vegetation and local to the points of emission. The gas emissions have declined and the affected areas have successfully recovered. Such vegetation dieback is rare and has only been recorded in one location in the Southern Coalfield. Vegetation dieback has not been observed in areas that have not been directly mined beneath.

Further discussions on the potential impacts of gas emissions on water quality are provided in **Appendix B**. Further discussions on the potential impacts of gas emissions on flora and fauna are provided in **Appendix D**.

The Potential for Water Quality Change

It is possible that the emission of strata gas emission into the Nepean River may give rise to a reduction in dissolved oxygen in the river at very low flows due to the microbiological consumption of methane. However, further monitoring and analysis of the possible influence of gas emissions in the river at low flow conditions is necessary to validate this possibility and quantify any subsequent dissolved oxygen reduction and aquatic ecology impacts. Additional monitoring has been proposed to investigate this issue.

Minor iron flocs are expected to occur in the Nepean River in association with gas release sites. No detectable change in water quality is predicted to occur from such iron staining, however minor aesthetic impacts may occur. The pre-existing total alkalinity in the river is adequate to fully neutralize any sulfuric acid produced from any increase in the dissolution of pyritic minerals in the underlying sandstone formation caused by mining.

The inducement of ferruginous springs due to mining has been occasionally observed in Bulli Seam mining areas, especially when they are in proximity to areas of Wianamatta Shale. However, mining to date in Appin area 7 has not led to the creation of any ferruginous spring, and it might be inferred that the catchments further to the north proposed to be mined under by Longwalls 705 to 710 are at a low probability of risk from this phenomenon. Such springs generally do not contain sufficient dissolved iron and manganese to cause a significant depression of river pHs through the oxidation and precipitation of hydrous iron and manganese oxides because the river water contains significant bicarbonate/carbonate alkalinity. Due to the low likelihood of ferruginous springs being induced and the inherent alkalinity of the river, any ecological consequence of ferruginous springs is predicted to be minor. However, the consequences of such a spring on aesthetics of the river could be minor to major.

The Potential for Surface Fracturing

Longwall mining can result in the development of surface fractures in stream beds. Surface fractures have been observed in most large streams that have been directly mined beneath by longwalls. The majority of mining-induced fractures are observed where rivers are located directly above extracted longwalls.

In this case, the proposed Longwalls 705 to 710 do not mine directly beneath the Nepean River. Observations indicate that only minor fracturing may occur in the bed of the Nepean River as a result of the extraction of the proposed longwalls (Kay et al, 2006). The furthest distance of an observed fracture from a goaf edge is approximately 415 m from Longwall 401 at the base of Broughtons Pass Weir. Longwalls 705 to 710 are at least 180 m away from the Nepean River. Any fracturing that may occur is expected to be minor in nature. Fractures may be visible within the base of the river valley in exposed areas such as river banks and alluvial flats, or be inferred from the emission of gas bubbles in the river.

The likelihood of fracturing is very low for bedrock that is located beyond the predicted limit of subsidence, although some minor fracturing may occur up to approximately 400 m from the proposed longwalls. Mining-induced fracturing at these remote distances is unlikely to result in surface flow diversions or reduction in water quality.

The Potential Changes to the Levels of River Bed and Banks

Whilst the Nepean River water levels are not expected to change as the result of the extraction of the proposed longwalls, it is expected that the river bed could uplift by up to a maximum of 345 mm, as the result of the extraction of the proposed longwalls. This is because the maximum predicted upsidence of 380 mm exceeds the maximum predicted subsidence of 60 mm along the river, however, it should be noted that these predictions are based on the conservative empirical predictions of upsidence and subsidence. As seen by the experience of Longwall 701, it is likely that the actual movements along the river could be significantly less than those predicted.

Measurable changes in river bed levels have been observed at survey pegs TK17 and TK18, which were located at RLs 60 and 62 m AHD, (i.e. on the opposite banks of the river), as a result of mining Tower Longwall 17. Based on these measured observations, these river banks rose (uplifted), by up to 150 mm, as the longwall was extracted and, on completion of mining, the banks of the river rose by 50 mm. The subsidence, upsidence and uplift movements observed during the mining of Tower Longwall 17 were less than the movements that were predicted before the mining of Tower Longwalls 16 and 17 and are substantially greater than those observed during the mining of Longwall 701 and those predicted for the proposed longwalls.

The water levels in the Nepean River fluctuate in response to changes in water flow rates. It is apparent from relative water level surveys that the water level in the river generally rises and falls within a range of 150 mm, except at times of significant flooding. For example, the maximum rise in water level that has been recorded at Menangle Weir since August 1990 is 10.1 metres on 11 June 1991. During these extreme flow events, significant changes occur to the bed and banks of the river.

In the sections of the Nepean River where the upsidence exceeds the subsidence, it is expected that small areas of these sections would experience a reduction in the frequency of water inundation. Field investigations of the banks of the Nepean River have been conducted by GeoTerra and further discussion on the riparian zone and the potential impacts of the predicted uplift on this zone are included in the report by GeoTerra (2008). Refer **Appendix H**.

8.1.3. Impacts due to Increased Subsidence Predictions

Assessments of the likelihoods of changes in water levels along the Nepean River are based upon predictions of net vertical movement, being the addition of subsidence and upsidence. If the predictions were increased by factors of up to five times, this could lead to a large array of possible permutations for the changes in water level for each section of the river. It is noted that predictions of upsidence are generally more conservative than predictions of subsidence and it is possible, therefore, that the magnitude of the net uplift will be less than predicted. This has recently been observed, for example, in the Nepean River during the mining of Longwall 701.

It is possible that observed movements could deviate significantly from the predicted net vertical movements due to the combination of uncertainties in the addition of predicted subsidence and upsidence. The greatest potential source of deviation lies in the prediction of upsidence, which is an upperbound prediction. Given that this method is conservatively based, it is more likely that the actual uplift will be less than the predicted uplift. This allows for the impact assessment to be conservative. As discussed in the above sections, the banks of the Nepean River are relatively steep, and the estimation of the extent of desiccation would not alter substantially if the predicted uplift was increased.

While the predicted ground movements are an important parameter when assessing potential impacts on the river, it is important to note that the impact assessments have also been heavily based upon empirical observations of previous impacts of mining on rivers.
The assessment of the likelihood of surface fracturing and gas emissions in the river has been largely based upon observations from past mining rather than on the magnitude of the predicted mining-related movements. However, if the predicted ground movements were increased, the incidence and size of fracturing would be expected to increase.

It is recommended that flora and fauna studies investigate the potential impact of flooding and desiccation within a zone of 500 mm below the current baseline water level, which represents an increase in the predictions of maximum net vertical movement of approximately 50% for net uplift. It is also recommended that the impact assessment consider the effects of minor flooding of less than 100 mm.

8.2. CREEKS

The locations of the creeks within the SMP Area are shown in **Figure 6.1**. The predictions and impact assessments for the major drainage lines are provided in the following sections.

8.2.1 Predictions for Foot Onslow Creek

The predicted profiles of incremental and cumulative subsidence, upsidence and closure along Foot Onslow Creek, after the extraction of each proposed longwall, are shown in **Appendix A**. The predicted changes in surface level along the alignment of the creek are also illustrated by the predicted net vertical movement profile shown in this figure, which has been determined by the addition of the predicted subsidence and upsidence movements.

A summary of the maximum predicted values of cumulative subsidence, upsidence, net vertical movement and closure anywhere along the creek within the SMP Area, after the extraction of each proposed longwall, is provided in **Table 8.3**.

Table 8.3 - Maximum Predicted Cumulative Subsidence, Upsidence, Net Vertical Movement and Closure along Foot Onslow Creek Resulting from the Extraction of Longwalls 702 to 710

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Upsidence (mm)	Maximum Predicted Cumulative Subsidence plus Upsidence (mm)		Maximum Predicted Cumulative Closure (mm)
			Net Subsidence	Net Uplift	
After LW705	75	40	45	< 20	55
After LW706	965	150	865	20	125
After LW707	1360	255	1190	20	185
After LW708	1445	290	1245	25	215
After LW709	1490	325	1245	30	245
After LW710	1495	350	1240	30	270

The predicted subsidence provided in the above table are the maximum values which occur along the creek within the general SMP Area, including the predicted movements resulting from the extraction of Longwalls 702 to 704. The predicted upsidence and closure movements in the above table are the maximum values which occur along the creek within the predicted limits of 20 mm additional upsidence and 20 mm additional closure, due to the extraction of Longwalls 705 to 710, but also include the predicted movements resulting from the extraction of Longwalls 702 to 704.

A summary of the maximum predicted changes in gradient, due to the predicted systematic tilts, and the maximum predicted systematic strains along the alignment of Foot Onslow Creek, after the extraction of each proposed longwall, is provided in **Table 8.4**.

Table 8.4 - Maximum Predicted Cumulative Changes in Gradient and Systematic Strains along the Alignment of Foot Onslow Creek Resulting from the Extraction of Longwalls 702 to 710

Longwall	Maximum Predicted Cumulative Systematic Tilt (mm/m)		Maximum Predicted Cumulative Systematic Strain (mm/m)	
	Increase in Gradient	Decrease in Gradient	Tensile Strain	Comp. Strain
After LW705	0.2	0.4	0.1	0.1
After LW706	0.5	4.9	0.6	1.1
After LW707	1.3	6.5	0.8	1.3
After LW708	2.0	5.6	1.1	1.3
After LW709	2.1	5.6	1.2	1.3
After LW710	2.2	6.2	1.3	1.3

The maximum predicted systematic tilts and strains provided in the above table are the maximum values which occur within the general SMP Area, including the predicted movements resulting from the extraction of Longwalls 702 to 704.

Foot Onslow Creek will also be subjected to travelling tilts and strains across its alignment as the extraction faces of the proposed longwalls pass beneath it. A summary of the maximum predicted travelling tilts and strains at the creek, during the extraction of each proposed longwall, is provided in **Table 8.5**.

Table 8.5 - Maximum Predicted Travelling Tilts and Strains at Foot Onslow Creek during the Extraction of Longwalls 705 to 710

Longwall	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
During LW705	0.2	< 0.1	< 0.1
During LW706	3.0	0.4	0.3
During LW707	3.4	0.5	0.3
During LW708	3.2	0.4	0.3
During LW709	3.0	0.4	0.3
During LW710	3.0	0.4	0.3

8.2.2 Predictions for Harris Creek

The predicted profiles of incremental and cumulative subsidence, upsidence and closure along Harris Creek, after the extraction of each proposed longwall, are shown in **Appendix A**. The predicted changes in surface level along the alignment of the creek are also illustrated by the predicted net vertical movement profile shown in this figure, which has been determined by the addition of the predicted subsidence and upsidence movements.

A summary of the maximum predicted values of cumulative subsidence, upsidence, net vertical movement and closure anywhere along the creek within the SMP Area, after the extraction of each proposed longwall, is provided in **Table 8.6**.

Table 8.6 - Maximum Predicted Cumulative Subsidence, Upsidence, Net Vertical Movement and Closure along Harris Creek Resulting from the Extraction of Longwalls 702 to 710

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Upsidence (mm)	Maximum Predicted Cumulative Subsidence plus Upsidence (mm)		Maximum Predicted Cumulative Closure (mm)
			Net Subsidence	Net Uplift	
After LW705	35	60	< 20	30	40
After LW706	130	125	45	40	80
After LW707	1010	215	805	60	185
After LW708	1325	295	1040	75	255
After LW709	1405	330	1085	80	290
After LW710	1410	345	1075	80	310

The predicted subsidence provided in the above table are the maximum values which occur along the creek within the general SMP Area, including the predicted movements resulting from the extraction of Longwalls 702 to 704. The predicted upsidence and closure movements in the above table are the maximum values which occur along the creek within the predicted limits of 20 mm additional upsidence and 20 mm additional closure, due to the extraction of Longwalls 705 to 710, but also include the predicted movements resulting from the extraction of Longwalls 702 to 704.

A summary of the maximum predicted changes in gradient, due to the predicted systematic tilts, and the maximum predicted systematic strains along the alignment of Harris Creek, after the extraction of each proposed longwall, is provided in **Table 8.7.**

Table 8.7 - Maximum Predicted Cumulative Changes in Gradient and Systematic Strains along the Alignment of Harris Creek Resulting from the Extraction of Longwalls 702 to 710

Longwall	Maximum Predicted Cumulative Systematic Tilt (mm/m)		Maximum Predicted Cumulative Systematic Strain (mm/m)	
	Increase in Gradient	Decrease in Gradient	Tensile Strain	Comp. Strain
After LW705	0.3	0.2	0.1	0.1
After LW706	1.0	0.9	0.3	0.4
After LW707	1.1	2.8	0.7	0.5
After LW708	1.1	3.4	0.8	0.5
After LW709	1.1	3.6	0.8	0.5
After LW710	1.1	3.7	0.8	0.5

The maximum predicted systematic tilts and strains provided in the above table are the maximum values which occur within the general SMP Area, including the predicted movements resulting from the extraction of Longwalls 702 to 704.

For further details on predictions for the creeks refer **Appendix A**.

8.2.3 Impact Assessments for the Creeks

The maximum predicted systematic tilts along the alignments of Foot Onslow and Harris Creeks are 6.5 mm/m (i.e. 0.7%) and 3.7 mm/m (i.e. 0.4%), respectively, or a changes in grade of 1 in 155 and 1 in 270, respectively. The maximum predicted systematic tilt along the alignments of the other drainage lines within the SMP Area is 8.0 mm/m (i.e. 0.8%), or a change in grade of 1 in 125.

The natural grade along the alignment of Foot Onslow Creek within the general SMP Area varies between a minimum of 10 mm/m and a maximum of 100 mm/m, with an average natural grade of approximately 20 mm/m. The natural grade along the alignment of Harris Creek within the general SMP Area varies between a minimum of 5 mm/m and a maximum of 250 mm/m, with an average grade of approximately 25 mm/m.

The predicted systematic tilts along the alignments of the drainage lines are small when compared to the existing natural grades and are unlikely, therefore, to result in any significant increases in the levels of ponding, flooding or scouring. The predicted changes in the surface level along the alignments of Foot Onslow and Harris Creeks, resulting from the extraction of Longwalls 702 to 710, are illustrated in **Figure 8.1** and **Figure 8.2**, respectively.

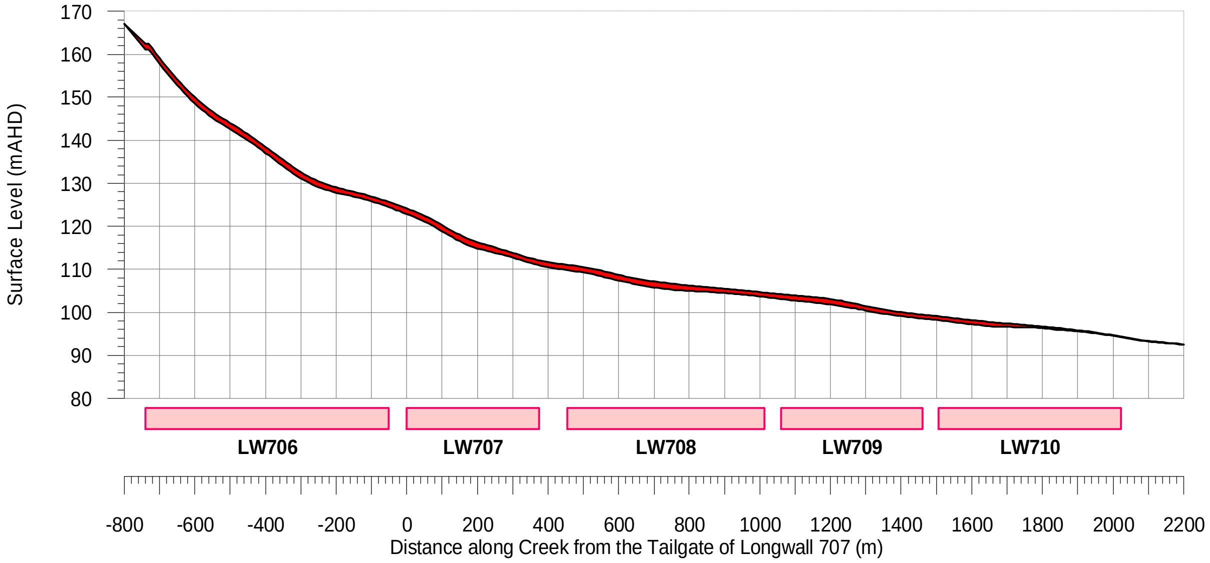

Figure 8.1 - Initial and Final Surface Levels along the Alignment of Foot Onslow Creek

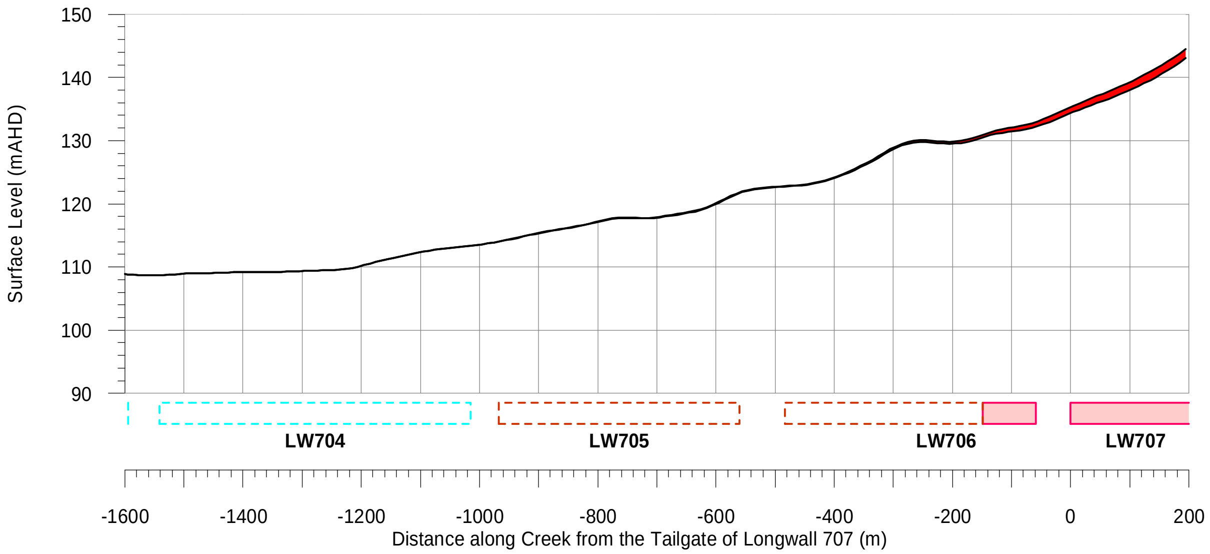

Figure 8.2 - Initial and Final Surface Levels along the Alignment of Harris Creek

It is possible that there could be very localised areas along the drainage lines which could experience a small increase in the levels of ponding and flooding, where the predicted maximum tilts occur in the locations where the natural gradients are low. As the predicted maximum systematic tilts are less than 1%, however, any localised changes in ponding or flooding are expected to be minor and not result in a significant impact on the drainage lines.

Fracturing of the uppermost bedrock has been observed in the past, as a result of longwall mining, where the systematic tensile strains have been greater than 0.5 mm/m or where the systematic compressive strains have been greater than 2 mm/m. It is likely, therefore, that some fracturing would occur in the uppermost bedrock based on the predicted maximum systematic strains.

For further detail on the impact assessments for the creeks refer **Appendix A**.

8.2.4 Impact Assessments for the Creeks Based on Increased Predictions

If the predicted systematic tilts along the alignments of the drainage lines were increased by factors of up to 2 times, the predicted maximum changes in gradient would be in the order of 1 to 2%, which would still be small when compared to the existing natural gradients. It is possible that there could be localised areas along the drainage lines which could experience small increases in the levels of ponding and flooding, however, any changes are expected to be minor and not result in any significant impacts on the drainage lines.

If the predicted systematic strains at the drainage lines were increased by factors of up to 2 times, the likelihood and extent of fracturing and dilation in the bedrock would increase accordingly directly above the proposed longwalls.

If the predicted valley related movements at the drainage lines were increased by factors of up to 2 times, the likelihood and extent of fracturing and dilation of the uppermost bedrock would increase accordingly directly above and adjacent to the proposed longwalls. It should be noted, however, that the method used to predict the valley related movements adopts very conservative prediction curves and it is unlikely, therefore, that the maximum predicted movements would be exceeded by any more than 15%.

8.3. CLIFFS

8.3.1 Predictions for the Cliffs

The locations of the cliffs within the SMP Area are shown in **Figure 6.3**. The predictions and impact assessments for the cliffs are provided in the following sections.

A summary of the maximum predicted values of systematic subsidence, tilt and strain at the cliffs within the SMP Area, at any time during or after the extraction of the proposed longwalls, is provided in **Table 8.8**.

Table 8.8 - Maximum Predicted Systematic Subsidence, Tilt and Strain at the Cliffs within the SMP Area Resulting from the Extraction of Longwalls 705 to 710

Cliff	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
A7_078 to A7_087	135	0.9	0.1	< 0.1
A7_090 to A7_095	60	0.5	0.1	< 0.1
A7_096 to A7_100	85	0.8	0.1	< 0.1
A7_101 to A7_113	75	1.0	0.1	< 0.1
A7_128	< 20	0.1	< 0.1	< 0.1
A7_129	< 20	0.2	< 0.1	< 0.1
A7_130	75	0.5	0.1	< 0.1
A7_131	< 20	< 0.1	< 0.1	< 0.1

The values provided in the above table are the maximum predicted parameters which occur within a distance of 20 metre from the identified extents of the cliffs. The predicted tilts and strains are the maximum values which occur anytime during or after the extraction of the proposed longwalls.

8.3.2 Impact Assessments for the Cliffs

The proposed Longwalls 705 to 710 do not directly mine beneath the cliffs within the SMP Area. As can be seen from **Table 6.3** previously, the cliffs are located at distances varying between 80 and 400 metres from the proposed longwalls. It is expected, therefore, that the potential impacts on the cliffs within the SMP Area would be similar to that experienced as a result of Appin Longwalls 301 and 302. Refer **Appendix A** for further details on case studies.

It is possible, therefore, that minor isolated rock falls could occur as a result of the extraction of the Longwalls 705 to 710. It is not expected, however, that any large cliff instabilities would occur as a result of the extraction of the proposed longwalls. Any impacts on the cliffs within the SMP Area, resulting from the extraction of the proposed longwalls, are expected to represent in the order of 1 % to 3 % of the total length of cliffs within the SMP Area.

One of the most significant consequences associated with rock falls or cliff instabilities is the potential to cause injury to people or death. The cliffs along the Nepean River are located on private land, however, access to the banks below is generally only by boat.

It is recommended, therefore, that persons who enter the area in the vicinity of the cliffs are made aware of the potential for rockfalls resulting from the extraction of the proposed longwalls. The conditions of the cliffs should be monitored throughout the mining period until such time that the mine subsidence movements have ceased, as may be required.

The aesthetics of the landscape could be temporarily altered by isolated rock falls, which would typically result in the exposure of a fresh face of rock and debris scattered around the base of the cliff or slope. As with naturally occurring instabilities, the exposed fresh rockface weathers and erodes over time to a point where it blends in with the remainder of the cliff face and vegetation below the cliff regenerates to cover the talus slope. If cliff instability were to occur, however, the appearance of the landscape could be restored, if necessary, by the remediation of the rockface and vegetation below the cliff.

Rock falls or cliff instabilities could have a minor impact on water quality if debris were to fall into the Nepean River, or if water runoff over the debris were to reach the river. Refer **Section 9.1** for potential impacts on surface water quality.

8.3.3 Impacts due to Increased Subsidence Predictions

If the predicted systematic tilts were increased by factors of up to 2 times, the likelihood and extent of cliff instabilities would not significantly increase, as the changes in grade would still be small when compared to the existing slopes of the cliff faces.

If the predicted systematic strains were increased by factors of up to 2 times, the potential for cliff instabilities would not increase significantly, as the maximum predicted systematic strain would be in the order of 0.1 mm/m.

If the predicted valley related movements were increased by factors up to 2 times, the potential for rock falls or cliff instabilities would increase accordingly, primarily along the cliffs closest to the proposed longwalls, or on the bends in the Nepean River valley. The total length of affected cliffline, resulting from the extraction of the proposed longwalls, would still be expected to be in the order of 1 % to 3 % of the total length of cliffs within the SMP Area.

8.4. STEEP SLOPES

The locations of the steep slopes within the SMP Area are shown in **Figure 6.3**. The predictions and impact assessments for the steep slopes are provided in the following sections.

8.4.1. Predictions for the Steep Slopes

The steep slopes within the SMP Area are generally located within the valleys of the Nepean River and its associated tributaries. There are also isolated steep slopes located along the hills above the western ends of the proposed longwalls. A summary of the maximum predicted values of systematic subsidence, tilt and strain at the steep slopes, at any time during or after the extraction of the proposed longwalls, is provided in **Table 8.9**.

Table 8.9 - Maximum Predicted Systematic Subsidence, Tilt and Strain at the Steep Slopes Resulting from the Extraction of Longwalls 705 to 710

Location	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
Nepean River Valley and Associated Tributaries	1070	6.2	1.3	0.6
Hills above the Western Ends of the Proposed LW's	1480	6.6	1.1	1.7

The values provided in the above table are the maximum predicted parameters anywhere along the steep slopes, including the predicted movements resulting from the extraction of Longwalls 702 to 704. The predicted tilts and strains are the maximum values which occur anytime during or after the extraction of the proposed longwalls.

8.4.2. Impact Assessments for the Steep Slopes

Tensile strains greater than 0.5 mm/m or compressive strains greater than 2 mm/m may be of sufficient magnitude to result in the fracturing or buckling of the uppermost bedrock. The maximum predicted systematic strains at the steep slopes are likely, therefore, to be of sufficient magnitude to result in fracturing of the uppermost bedrock, which could result in surface cracking where the depths to bedrock are shallow.

Surface cracking in soils as the result of systematic subsidence movements is not commonly seen at depths of cover greater than 500 metres, such as in Appin Area 7, and any cracking that has been observed has generally been isolated and of a minor nature. It would be expected, therefore, that any surface cracking that occurs along the steep slopes, as a result of the extraction of the proposed longwalls, would be of a minor nature due to the relatively small magnitudes of predicted systematic strains and due to the relatively high depths of cover. Surface tensile cracking is generally limited to the top few metres of the surface soils. Minor surface cracking tends to fill naturally, especially during rain events. If any significant cracking were to be left untreated, however, erosion channels could develop along the steep slopes. In this case, it is recommended that appropriate mitigation measures should be undertaken, including infilling of surface cracks with soil or other suitable materials, or by locally regrading and recompacting the surface. With these remediation measures in place, it is unlikely that there would be a significant impact on the environment.

The steep slopes within the SMP Area have natural gradients typically less than 1 in 2 and the depths of cover greater than 500 metres. It is unlikely, therefore, that the predicted systematic strains would be of sufficient magnitudes to result in the slippage of soils down the steep slopes or the development of any significant tensile cracks at the tops of the slopes.

If movement of the surface soils were to occur during the extraction of the proposed longwalls, minor tension cracks at the tops of slopes and minor compression ridges at the bottoms of slopes may form. In some cases these cracks could lead to increased erosion of the surface and minor mitigation measures would be required, including infilling of the surface cracks with soil or other suitable materials and local regrading and recompacting of compression bumps. With these remediation measures in place, it is unlikely that there would be a significant impact on the environment.

Refer **Appendix A** for further detail on impact assessments for steep slopes.

8.4.3. Impact Assessments for the Steep Slopes Based on Increased Predictions

If the predicted systematic tilts were increased by factors of up to 2 times, the potential impacts on the steep slopes would not significantly increase, as the predicted tilts would still be much less than the natural surface gradients of the steep slopes within the SMP Area.

If the predicted systematic strains were increased by factors of up to 2 times, the extent of potential surface cracking would increase accordingly at the steep slopes located directly above the proposed longwalls. It is expected, however, that any surface cracking could still be remediated by infilling with soil or other suitable materials, or by locally regrading and compacting the surface. With these remediation measures in place, it is unlikely that there would be a significant impact on the environment.