Dr. Mary O’Kane AC,
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Dr Peter Turner,
[redacted]
NSW 2508.
[redacted]

4/6/20

RE: Open letter to Premier as a submission opposing the expansion of the Dendrobium and Russell Vale coal mines

Dear Dr O’Kane,

I write on behalf of the signatories to the attached open letter, which was sent to the Premier on the 18th of May regarding mining the Special Areas. Consistent with the intent and directly relevant concerns of the letter, we would like to request that the open letter is distributed to the IPC’s commissioners and is accepted and registered as a submission opposing the proposed expansions of the Dendrobium and Russell Vale coal mines.

The letter may also be obtained with the following URL: www.special-areas-concerns.org

Many thanks for your assistance in this important matter.

Regards, Peter

Open Letter to the Premier of NSW Regarding Coal Mining in the Schedule 1 Special Areas of the Sydney Drinking Water Catchment

18/5/20

Dear Premier,

We the undersigned write as concerned academic researchers and scientists to urge an ongoing suspension of the approval processes for any further planning applications or post-approval plans (Subsidence Management Plans and Extraction Plans) for mining in the Schedule 1 Special Areas of the Sydney Drinking Water Catchment. A summary of our reasons for seeking a suspension of mining approvals is attached.

The suspension of approvals should include new projects, the next stage of existing projects and project modifications, and should include proposals and plans currently under consideration. The suspension should remain in place until the now long recognised deficiencies and inadequacies in data gathering and reporting, alert triggers, data and information access, modelling, knowledge and understanding are comprehensively addressed. The suspension should remain in place until the cumulative impacts and consequences of mining to date can be reliably assessed and quantified, with a suitably high degree of scientific confidence. The suspension should remain in place until predictive estimates of the compounding effects of new mining proposals can be made with a suitably high degree of scientific confidence.

In part our letter is compelled by the reports of the Independent Expert Panel for Mining in the Catchment (IEPMC). Adding to those provided to the government since at least 2007, the IEPMC reports reaffirm that the long known and ongoing inadequacies are such that it is not possible to reliably estimate the extent and, accordingly, significance of water losses and water contamination caused by mining in and around the Metropolitan and Woronora Special Areas.

The 2008 Southern Coalfield Inquiry report points out that "*The single most important land use in the Southern Coalfield is as water catchment.*" The importance of accordingly protecting the Special Areas, which lie within the Southern Coalfield, has been emphasised by the recent drought, with low reservoir levels and revelations of high metal contamination levels in the deeper waters of the reservoirs. Among other impact and consequence concerns, the attached summary points to a drinking water loss rate of between 8 and 25 million litres a day as a consequence of mining the Special Areas. Unlikely to be lower, the loss rate could be greater than the range suggested by the available information.

We further encourage the Government to undertake planning for the phase-out of mining in the Metropolitan and Woronora Special Areas. We note that while these areas have been degraded by mining, they still contain some of the few areas of pristine bushland left in NSW. With just two mines currently active, phase out with no further approvals would seem timely.

Please note that this letter, its concerns and recommendation, reflect our personal views as scientists with expertise in hydrology, chemistry, geology and Earth science, environmental and ecosystem science, and public health. The letter is not intended to reflect or represent the institutions and organisations for which we work or are otherwise associated.

Sincerely, Sincerely,

Prof. Allan Chivas	Prof. Simon Chapman	Assoc. Prof. Timothy Cohen
Assoc. Prof. Matthew Currell	Assoc. Prof. Mark Diesendorf	Mr. Pete Dupen
Assoc. Prof. Jason Evans	Dr. Nicolas Flament	Prof. Melissa Haswell
Prof. Grant Hose	Prof. Lesley Hughes	Prof. Stuart Khan
Dr. Tanya Mason	Prof. Graciela Metternicht	Assoc. Prof. Scott Mooney
Assoc. Prof. Gavin Mudd	Assoc. Prof. Patrice Rey	Dr. Peter Turner
Dr. Floris Vanogtrop	Prof. David Waite	Dr. Ian Wright

Open Letter to the Premier of NSW Regarding Coal Mining in the Schedule 1 Special Areas of the Sydney Drinking Water Catchment

Summary of concerns regarding continued mining of the Special Areas

(Additional WaterNSW quote and Fig. 20 added 31/5/20.)

The Schedule 1 Special Areas constitute the core of the Sydney Drinking Water Catchment and may reasonably be regarded as the primary public health asset for more than five million people. The reservoirs in the Metropolitan and Woronora Special Areas are of importance in contributing some 20% of the total supply for Greater Sydney and the Illawarra. Wollongong is notably dependent on the Avon Reservoir.

Underground coal mining in the Special Areas diverts and consumes water at its source, and irreversibly damages and degrades that source. Mining currently takes place in the Metropolitan Special Area and the Woronora Special Area, and the extent of mining in these areas is indicated in Figure 1. Some 166 longwall panels have been extracted from beneath the Special Areas since this extraction technique began to replace bord and pillar methods in the 1960s. Of these, 31 have been extracted to date at the Metropolitan Colliery from July 1995, and 14 extracted at the Dendrobium mine from March 2005. Currently these are the only operational mines extracting coal from the Special Areas, with Russell Vale Colliery in care and maintenance since September 2015 and Wongawilli Colliery closed in April 2019 for safety reasons.

The extent of bord and pillar mining with pillar extraction in the Special Areas, which can cause the same levels of subsidence as longwall extraction, is poorly documented. The long term, intergenerational, stability of the remaining pillars is not known. Evidently triggered by subsequent mining in an underlying seam, pillar collapse has occurred at what is now the Russell Vale Colliery, and instability prevented the mapping of old extraction areas at this mine. While the area is not one of strong seismic activity, the level of faults within the Woronora fault zone is relatively high between the reservoirs (see Fig. 2).

While coal mining returns economic and social benefits in the short to medium term, the damaging and destructive catchment impacts and associated consequences will last into the long-term and indefinite future. We note the August 2013 advice of what was then the Sydney Catchment Authority to its then board:

> "*The people of NSW will benefit from the Metropolitan dams in the short, medium and long terms. The benefit from coal mining is short term extending into the medium term*"

There does not appear to have been an independent and comprehensive assessment of benefit and cost. An assessment of cost would include the likely very substantial cost of comprehensively addressing monitoring inadequacies, in a manner recognising the very high importance of the Special Areas. Mining companies do not currently replace, pay or otherwise provide compensation for the water diverted or lost from the storage reservoirs. Doing so would be confounded by the lack of reliable knowledge of water losses and the possibility of water losses that continue in perpetuity.[1] There would seem to be no prospect for compensation for water that continues to be lost into the decommissioned and abandoned mines. Other than very limited watercourse remediation of uncertain effectiveness and durability[1], the mining companies are not required to provide compensation for the damage to the watercourses and aquifers that supply and support the reservoirs supplying water to Greater Sydney and the Illawarra, and supply and support the biota of the Special Areas. Water treatment costs arising from mining the Special Areas are not known, nor is appropriate compensation for the unknown quantities of contaminants accumulating on and near the floors of the reservoirs. The Special Areas contain some of the few remaining areas of pristine bushland in NSW, including swamp communities listed as endangered under State and Commonwealth legislation. Some 83% of the Coastal Upland Swamp are found on the Woronora Plateau[2] and most are located in the Metropolitan and Woronora Special Areas. There are no known effective means of swamp remediation[1], [3] and 'like for like' offsets are difficult if not impossible.[4] The swamps of the Special Areas may accordingly be undervalued.

Impact and consequence concerns include:

- Considerable volumes of water entering some of the mines in the Special Areas, including an unknown quantity of water pooling in decommissioned mines and closed-off sections of mines. Inflows to decommissioned mines or closed-off sections of operational mines are either not known or, where there is monitoring by mine operators, are not reported. Mine inflow monitoring is not audited. Publicly available mining company reports have been used[5] to estimate a daily water inflow volume of 29 to 42 million litres. How much of this would otherwise have entered the storage reservoirs in the Special Areas is not known. A 2018 scoping study[6] undertaken on behalf of WaterNSW has estimated that over the period January 2010 to January 2016, some 43% of the water entering the Dendrobium mine would have otherwise contributed to drinking water supplies. Reflecting connected seam to surface fracturing, inflows to the Dendrobium mine vary with rainfall, with peaks of up to 13 million litres a day. Inflows to the adjoining Wongawilli mine are also rainfall dependent and can be similarly substantial (see below).[7] This may also be the case for some of the closed mines in and around the Special Areas.
- The 2018 scoping study[6] commissioned by WaterNSW suggests the possibility that an average of 25 million litres a day of streamflow may be being diverted and lost from the reservoirs, because of coal mining in the Special areas. Emphasizing the longstanding and long known paucity of monitoring and available records, this estimate of catchment streamflow loss is highly uncertain and, accordingly, unreliable. The study doesn't include uncertain or unknown losses arising from the depletion of groundwater supply to the reservoirs, nor uncertain or unknown reservoir leakage volumes.
- The Independent Expert Panel for Mining in the Catchment (IEPMC) has suggested[1] up to 8 million litres a day (Ml/d) are diverted from the storage reservoirs as a consequence of mining the Special Areas. Among other limitations, the IEPMC estimate does not include water volumes diverted by decommissioned mines, and it would not be unreasonable to regard the IEPMC

estimate as a lower-bound on the real rate of drinking water loss. Referring to the 2018 WaterNSW scoping study and noting uncertain or unknown losses of groundwater supply to the reservoirs and uncertain or unknown leakage rates, the total loss rate could conceivably be greater than 25 Ml/d. That is, drinking water losses could be between 2.5 and 9 billion litres a year, or more.

- A loss of 25 million litres a day would correspond to some 10% of the maximum daily output of the desalination plant and approximately 8% of the average daily volume of water supply taken in total from the Avon, Cataract, Cordeaux and Woronora Reservoirs. Wollongong and other parts of the Illawarra depend on the Avon Reservoir. Losses would continue for many decades after mine closure and, as the IEPMC points out[1], some of these losses may continue in perpetuity.
- The volume of water accumulated to date in the mines in and around the Special Areas is unknown but substantial, possibly comparable or greater than the water volume held in the reservoirs. The mining companies may have data that would clarify the extent and magnitude of underground pooling and draining. Provided on request by Wollongong Coal, Figure 3 depicts pooling at the Wongawilli mine. The printed text on the graphic states: "A*pproximate potential position of underground ponded water. Note: some water levels dynamic - some areas inaccessible so confirmation of levels not possible*". The handwritten note states "*Water as high as 212 RL on ISG plans*"; it's not known which part of the mine is referred to in this comment. The Nebo area was closed in 2019 for safety reasons. The mine's Community Consultative Committee has been told that its anticipated that when the ponding reaches about 205 RL, water will begin to drain from a portal in the escarpment, near Dombarton. Pooling is known to be occurring at the other mines in and around the Special Areas. Reflecting this, Metropolitan Colliery's in-rush hazard management plan assumes the adjacent Coal Cliff Colliery is entirely flooded. That the mining companies may have valuable data and information is highlighted, for example, in the recommendations of the 2007 report[8] (see Appendix A) and recognised in the 2014 review[9] of cumulative impacts by the NSW Chief Scientist.
- The mining company's consultant estimates[10] that the mining proposed for Areas 5 and 6 of the Dendrobium mine would result in a total average mine inflow rate of 22 million litres a day between 2023 and 2049. This could approximately double the volume of surface water diverted daily from the reservoirs, by this mine.
- Not all surface water and near surface groundwater diverted from otherwise reaching the storage reservoirs by mining impacts necessarily drains to the mine. Surface water and near surface groundwater loss may be also the result of subsurface dilation effects and the creation of subsidence fractures that connect to groundwater flows that leave the catchment area (see Fig. 4).[11], [12] [13] There does not appear to be a means of reliably determining such losses.
- In reviewing the then proposed expansion of the Appin and West Cliff mines in 2010[9], the Planning Assessment Commission (PAC; now the Independent Planning Commission or IPC) made the following observations:

"*The Panel is of the view that it is no longer a viable proposition for mining to cause more than negligible damage to pristine or near-pristine waterways in drinking water catchments or where these waterways are elements of significant conservation areas or significant river systems*."

And

"*The Panel finds that the exclusion of first and second order streams from consideration of consequences ignores the vital role that these streams play in the interconnectivity of the system. In particular they are important in protecting the continuity of flow and the quality of water conveyed between the upland swamps and the larger streams*."

Subsequent approvals have impacted pristine, near pristine and previously damaged waterways. There does not appear to be a publicly available map recording the mining damaged lengths of streams, of all orders, in the Special Areas.

- Mining induced surface fracturing (see Figs. 5 and 6) may extend to considerably greater depths than has been suggested by mining company consultants.
- The injection of a curtain of barrier material, such as polyurethane resin (PUR; see Fig. 7), as a means of remediating impacted watercourses may be of limited effectiveness[1], [4], [14], particularly during periods of low flow. A 2013 tracer study of impacts to Waratah Rivulet undertaken by Parsons-Brinckerhoff[12] and commissioned by WaterNSW (then the Sydney Catchment Authority) comments on the failure of injected tracer to return to the surface downstream:

  "*Extensive remediation works involving the injection of PUR into fractures has been undertaken since 2008 in the vicinity of the injection bore, which may have caused some retardation of the tracer. However, it is also hypothesised that the tracer has moved through subsurface fractures not connected to the surface water system, but are possibly connected to the deeper Hawkesbury Sandstone*."

  When subsurface water reaches the barrier, some is deflected to the surface. Some, however, may be deflected away from the watercourse in a manner depending on the nature and extent of the surface fracture network. The PAC report for the Metropolitan Colliery expansion comments that "*Polyurethane injection also penetrates natural sub-surface flow networks and so may not fully restore the natural environment*."[2] That is, the blockage of natural flow paths may divert subsurface flows away from the pre-mining path, with the possibility of loss from the local catchment.

  Barrier injection is only feasible in reasonably accessible and favourable locations. The damning effect of barrier injection does not redress a mining-induced water table reduction and consequential loss of stream baseflow from supporting aquifers. Understanding the influence a barrier has on surface and subsurface waters would require comprehensive pre- and post-mining flow, groundwater pressure data and detailed tracer studies. Such work does not appear to have been undertaken.

- The 2010 PAC review[9] of the then proposed expansion of the Appin and West Cliff mines reports:

  "*Studies have also revealed that upsidence extends some tens of metres beneath valley sides and does not necessarily follow the line of a watercourse. Rather, it can cut across valley headlands and bends in a watercourse.*"

- Subsidence induced dilation and fracturing can increase near surface groundwater flow rates from 50 m/day[12] to 4,800 m/day.[15]
- Where surface water diverted into subsidence cracks does return to the surface further down-stream, it may be with groundwater that would not otherwise have joined surface flows. This may 'mask' net water loss, where losses are assessed using only downstream flow gauges.[1], [13]
- There remains uncertainty with respect to the accuracy, precision and calibration of flow gauges, especially those where a natural rock profile is used. Measuring low flow and differentiating baseflow contributions in the Special Areas in order to discern mining impacts, is challenging. In addition, the number of gauges does not appear to be sufficient to reliably characterise the watercourse responses to mining of the Special Area catchments.
- Water loss becomes increasingly significant during low rainfall periods and such periods are expected to increase as climate change progresses.
- There is accumulating evidence that the drainage zone, the zone of connected fractures that forms over a coal extraction (see Figs. 8 to 10), reaches the surface above parts of the Dendrobium mine (Figs. 11 to 13), or gets close enough to join the surface fracture network. This was predicted in 2012 in a set of pre-mining impact assessment reports[16]–[19] commissioned and then rejected by the mine operator. Following concerns raised with the Minister in July 2015[20], [21], a more detailed review[5] of the publicly available data provided to the Minister and Department of Planning in December 2016, found the data consistent with the 2012 drainage zone height estimates. This is affirmed in the mine's most recent extraction impact assessment report.[22] Where the drainage zone reaches the surface, rainfall and other surface water drain relatively rapidly to the mine below. Mining induced depletion of the aquifer that provides groundwater to the reservoirs, watercourses and swamps is maximised. The greater the height of the drainage zone, the greater the rate and spread of aquifer depletion; horizontal depletion occurs between 10 and 1,000 times more rapidly than vertical depletion. The drainage zones over each longwall extraction at the Dendrobium mine are 305 metres wide, on average some two kilometres long, and appear likely to either reach the surface or approach the surface. Adjacent drainage zones will partially merge to form an extended zone over the mining area that draws water towards and into the mine. Aquifer depletion continues to spread outwards from the mine area for as long as water is

pumped from the mine, until pumping stops and the mine is sealed and then fills. As the IEPMC points out, water removal at Dendrobium may need to be continued indefinitely (see below).[1] This may also be the case for the Wongawilli mine (see below).

- Large voids created by total pillar extraction in some of the old mines in and around the Special Areas may also have resulted in the drainage zone approaching or reaching the catchment surface. This may, at least in part, be the reason for the rainfall dependence of inflows at the Wongawilli mine, which vary between 4.3 and 10.4 million litres a day.[7]
- The 2010 groundwater impact assessment for the 2010 longwall mining proposal for the Nebo area of the Wongawilli mine reports:

  > "*bord and pillar as well as pillar extraction and longwall mining has been conducted in the adjacent Wongawilli, Elouera and Dendrobium Area 2 workings, and that vertical hydraulic connection has been observed at some locations between surface streams and the underlying workings*".[23]

  The assessment report further comments that a significant but unquantified component of the water entering the Elouera mine comes "*from surface water seeping through subsidence cracks following extraction of Elouera Longwalls 6 and 7 under Wongawilli Creek*" (see Fig. 5).[23] That is, the longwall mining evidently resulted in a direct hydraulic connection from mine to the watercourse. What was the Elouera Colliery is now part of the Wongawilli mine. As mentioned above, the mine is expected to drain from the escarpment.
- Pillar collapse, as appears to have occurred[24] at what is now the Russell Vale mine, might also result in seam to surface connected fracturing.
- Above the Metropolitan Colliery's longwall extractions, notably low pre-expansion project groundwater pressure in the aquifer that supplies groundwater to Woronora Reservoir is attributed[25], at least in part, to the mine's old extraction area to the east and to closed mines to the south. Full pillar extraction was employed in these mining areas. The extraction details are not publicly available, however it would be reasonable to assume on the basis of the groundwater decline, that this mining will have resulted in large voids and correspondingly substantial drainage zones. There may be connected seam to surface fractures. The Metropolitan mine's longwall expansion project commenced in 2010 and appears to have significantly exacerbated the prior aquifer depletion.[26]
- Reflecting a lack of monitoring installations, there is no knowledge of the extent of the drainage zone formed over multi-seam extractions. Multi-seam extractions have taken place at the Russell Vale and Wongawilli mines. The drainage zone may have reached the surface over some of these extractions.
- As indicated above, estimates of the height of the drainage zone emerged as an issue of significance in 2015.[21] Pre-mining centreline bores are not essential in seeking to determine the relationship between mining geometry and the height of the drainage zone. That is building on the

current limited database of mining geometries and drainage zone heights would not require new mining. As recommended to the Minister and Department in 2015 and 2016[5], [20], a program of post-mining centreline bores above past approval extractions, including multi-seam extractions, would be sufficient. For example, in 2012 Tahmoor Mine commissioned a drilling and investigation program above the centre of Longwall 10A, which had been mined approximately two decades earlier.[27] Centreline bores sunk in areas of high horizontal stress may give anomalous results.[28]

- Mining within the vicinity of the storage reservoirs can cause stored water loss into shear planes that may either facilitate diversion to the mine or take water away from the catchment (see appended Figs. 8 and 18). Shear plane leakage is known to have occurred at the Cataract[29] and Avon reservoirs[30], and appears to have occurred at Cordeaux reservoir.[31] Evidence of shear plane transport has been found 540 metres from Cataract Reservoir.[32] The available data suggest that leakage from Avon reservoir may exceed the tolerable loss limit of the Dams Safety Committee.[33] There is insufficient monitoring to determine whether or not this might also be the case for the other reservoirs. A 2017 recommendation by consultants PSM to follow-up leakage evidence at Cordeaux Reservoir does not appear to have been acted upon.[1], [5], [31]
- A 2014 paper[29] by the Dams Safety Committee reports evidence of shear plane leakage from Cataract Reservoir, following mining below and near the reservoir (see Fig. 14). Presumably a consequence of mining below the reservoir and having implications for mining below Woronora Reservoir, the study also found that subsidence movements continued, with reactivation, for 25 years after completion of the mining. This is much longer than found elsewhere in the Special Areas and may be a consequence of mining below the reservoir. The impacts and consequences of the subsidence continue indefinitely.
- The mining at Cataract Reservoir resulted in the dam wall moving some 3 centimetres, as a consequence of shear plane movements.[9], [14] The ‘en masse’ nature of the land movement did not result in damage, but that movement of this kind can occur gives cause for concern. The mining was some 800 metres from the dam wall.
- Valley bulging can create leakage pathways around and below reservoirs and watercourses, as reported in the 2017 Dendrobium study[31] by consultancy PSM. Though considerably more conservative in character than the mining at Dendrobium, the recently approved mining below Woronora Reservoir (see Fig.15) may result in valley bulging, shear plane activation, geological anomalies and subsidence fractures formed at the base of the reservoir and water being lost from the reservoir and, bypassing the mine, the local area catchment (see Fig. 16).[1] Mining below Woronora Reservoir has been approved without a robust means of reliably estimating consequential water losses, other than monitoring inflow to the mine.
- Currently it is not possible to develop reservoir water balance models (see Fig. 17) for any of the reservoirs, with sufficient accuracy and precision to be able to reliably gauge the magnitude and

significance of water losses caused by mining. There is then the possibility that more than negligible losses may occur without detection.

- Watercourses can change from being groundwater gaining to being water losing, as a consequence of mining induced groundwater drainage and loss (see Fig. 18). This appears to have happened to watercourses over and near the mining in both the Metropolitan and Woronora Special Areas. This includes sections of Waratah Rivulet[11], [12], Wongawilli Creek tributary WC21[22], [34], Wongawilli Creek[22], [34], and possibly sections of WC15 and Eastern Tributary.
- There is ongoing and increasing depletion across the Special Areas of groundwater in the aquifer that provides inflow to the storage reservoirs. Groundwater inflow to the reservoirs has heightened importance during dry and drought periods. The Dendrobium mine (Fig. 11) appears likely to have added considerably to the significant and extensive aquifer depletion between the Avon and Cordeaux Reservoirs, caused by past mining beneath and around the Metropolitan Special Area. The Department of Planning was advised in December 2016[5] that the available data from the Dendrobium mine suggested the possibility of significant depletion of the aquifer providing groundwater to the Avon and Cordeaux reservoirs. Significant depressurisation is reflected, for example, in alert trigger exceedances at a set of four reference bores (TARP sites). The PSM report[31] of March 2017 similarly finds extensive depressurisation, from a different perspective. Approval conditions for the Dendrobium mine require no more than a negligible reduction in groundwater flow to the Avon and Cordeaux. The limited available data point to the possibility that the mine may have caused a more negligible reduction in groundwater support for the Avon and Cordeaux reservoirs. There would appear to be insufficient monitoring sites, however, to be able to unequivocally determine whether or not this is the case.
- The available monitoring data[35] suggest that mining, both before and since the 2010 commencement of the current Metropolitan mine expansion project, has caused a considerable depletion of groundwater in the aquifer that supports Woronora Reservoir.[26] Approval conditions for the Metropolitan mine require no more than a negligible reduction water resources, which would include groundwater, reaching the Woronora Reservoir. The limited available data raise concern that mining will, if not already, cause a more than a negligible reduction in groundwater support for the reservoir. There would appear to be insufficient monitoring sites to be able to unequivocally determine whether or not this is the case.
- Unequivocally establishing a more than negligible change to groundwater flow to the reservoirs, to the satisfaction of all, would require a network of piezometer bores placed some 300 to 400 metres apart around the flanks of the reservoirs nearest the mining. A similar network would be required along watercourses, to establish groundwater support changes. Such bores would need to be sunk at least two years in advance of new mining.

- The appended 2007 McNally and Evans report recommends baseline data for new or proposed mining areas up to 20 years ahead of mining. Areas 5 and 6 of the Dendrobium mine are examples of proposed new mining areas.
- The ongoing depletion of groundwater risks a ‘tipping point’, where a reservoir changes from being groundwater gaining to losing water into the groundwater system, this would compound any leakage pathways that might be created through direct subsidence impacts when a reservoir is undermined. While that point might not be reached during periods of good rainfall and ‘recharge’, it might be passed during extended dry or drought conditions.
- A groundwater system depleted by mining would generally be expected to recover, after many decades, following mine closure and sealing. This will not be the case where the drainage zone reaches the surface, as at Dendrobium, and pumping is continued indefinitely to prevent contaminated water being discharged at the catchment surface (also see below).[1], [5] Ongoing pumping will increase and spread aquifer depletion. In some cases it may not be possible to seal adits or other leakage points, in which case mine drainage could continue indefinitely.[1]
- Allowing the drainage zone to reach the aquifer supplying water to the reservoirs and to further allow it to reach the surface, is inconsistent with the intent of the Special Areas. Highlighting this perspective, in seeking to protect the catchment used for Central Coast Water Supply, the approval conditions set by the Planning Assessment Commission (now the IPC) for the Wallarah-2 project, required “*No connective cracking between the surface, or the base of the alluvium, and the underground workings*". That is, that the drainage zone should not approach or reach the catchment surface. The Wallarah-2 project presents potentially adverse consequences for the Central Coast drinking water catchment. WaterNSW unsuccessfully sought the same protection for the Special Areas in comments submitted to the Department of Planning in February 2018, on the then proposed mining plan for Longwall 16 at the Dendrobium mine. Longwall 16, 17 and 21 have, however, been approved with the drainage zone of each approaching or reaching the catchment surface.
- Dendrobium Area 3B Longwalls 9 to 13 were approved in a controversial manner[21] in February 2013, with total extraction widths of 305 metres and heights of up to 3.9 metres for Longwall 9 and up to 4.6 metres for Longwalls 10 to 13. The mining company sought approval for extraction heights of 4.6 metres for Longwalls 14 to 18 in July 2015. Longwalls 14 and 15 were approved in December 2016, with extraction heights of up to 3.9 metres. The Department characterises its approval of Longwalls 14 and 15 as “*precautionary*” and 3.9 metres as “*substantially less”* than 4.6 metres. As Figure 11 below indicates, the 15% height reduction is actually relatively small. Figure 12 indicates that the height reduction is of limited consequence, with the drainage zone nonetheless either reaching the surface or getting sufficiently close to join the surface fracture network. From this perspective, it is difficult to regard the approval as precautionary. Suggesting mining as the leading consideration, the approval notes the following:

> "*the width of panels would need to be narrowed by more than 40% to significantly reduce the environmental impacts to key surface features. This is not considered economically feasible*"

Longwalls 16 and 17 have subsequently likewise been approved with total widths of 305 metres extraction heights of up to 3.9 metres. A reduction of 40% would correspond to a width of 122 metres, which is similar to the width of Wollongong Coal's Nebo panels at the neighbouring Wongawilli coal mine. At up to 3.6 metres, the extraction height at Wongawilli is less than at the Dendrobium mine. Wollongong coal ceased operations in the Nebo area in 2019 because of concerns.

- Consultants GeoTerra indirectly advise[36], [37] that the drainage zone doesn't need to reach the surface to exert an adverse influence:

  > "*A minimum thickness of unfractured overburden is required to maintain hydraulic separation between a mine and saturated aquifers, with the critical value depending on lithology, structure and topography. The minimum separation has been established through observation and research in NSW mines as ranging from less than 90m up to 150m*."

  This observation would also suggest that drainage zones should not reach an elevation greater than 90 to 150 metres below the elevation of a nearby reservoir.

- Unexpectedly severe impacts to swamps and watercourses have been found above the Dendrobium mine, notably at Wongawilli Creek tributaries WC21 and WC15. WaterNSW has expressed concern that the impacts to Wongawilli Creek have exceeded mining approval conditions. In part at least, the catchment damage reflects the notably aggressive nature of the mining at Dendrobium. As the IEPMC observes[1], establishing a breach of approval conditions is very difficult, if not impossible, because of the nature of those conditions. In its December 2019 comments[38] on the then proposed mining plan (SMP) for Longwall 21 in Area 3C, subsequently approved in March, in Area 3C of the mine, the IEPMC observes as follows:

  > "*The SMP states "The rate of impacts along Wongawilli Creek due to the previous mining [at Area 3B and Area 3A] is considered to be very low".*[6] *As raised in the Panel's Part 2 Report, this is not a generally accepted position. In particular, WaterNSW has questioned whether the performance measure relating to minor impacts to Wongawilli Creek has already been breached. This is a fundamental problem of the suitability of the performance measures, as discussed in the Part 2 Report, and not easily resolved within the current approval consent.*[7]"

  Compounding this difficultly, monitoring is inadequate relative to the scale of the mining. In this highly unsatisfactory context, the agencies and/or community would need to establish beyond reasonable doubt, to the satisfaction of all stakeholders, that an approval condition for mining the Special Areas has been breached. As the IEPMC comments imply, this is difficult, if not impossible.

- In its May 2018 comments[39] on the then proposed Longwall 16 mining plan, approved later that month by the Department of Planning, WaterNSW accepts that there is a lack of unequivocal evidence that the approval conditions for the mining had been breached, but points out the following:

> "*There is however significant circumstantial evidence (e.g. the anomalous piezometric response next to Cordeaux Reservoir, the rapid and sustained drying of a discrete stretch of Wongawilli Ck adjacent to an unexpectedly drained zone of Hawkesbury Sandstone aquifer and other anomalies recorded for Wongawilli Ck flows and water quality, and the sustained drying of streams SC10C, Donalds Castle Ck and WC21) that suggests that they might have and/or that they will in the near future.*"

The approval of Longwall 16, and subsequently Longwalls 17 and 21, reinforces concerns of the benefit of doubt being given to mining in the absence of adequate monitoring, data, knowledge and understanding.

Groundwater monitoring sites at Dendrobium mine report large drawdowns[5] in the aquifer that supports the Avon and Cordeaux reservoirs, suggesting the possibility of a more than negligible reduction in groundwater support for the reservoirs. In the absence of sufficient monitoring installations, it is not possible to unequivocally determine whether or not it is likely that there has been a more than negligible reduction in groundwater supply to the reservoirs.

- The 2008 Southern Coalfield Inquiry recommended a '*reverse onus of proof*' whereby a mining company would be required to demonstrate that natural features identified as being of high significance would not be unacceptably impacted. In 2009 the NSW Planning Assessment Commission stepped back[6][11] from that recommendation, expressing the view that requiring a reverse onus of proof would be unreasonable and likely impossible for companies to provide, given the lack of data and inadequate understanding: "*Given the knowledge gaps in the relationships between subsidence impacts and consequences for natural features, and the poor databases for many key features in the region, this would effectively put the Proponent in the position of trying to prove the unprovable.*" A mining project proponent is instead required to demonstrate the reasonableness (or overall merit) of its proposal in relation to the significant natural features that may be exposed to subsidence impacts. The uncertainty and benefit of doubt inherent in accordingly approving projects in a context of significant data, knowledge and understanding gaps, is manifested in the unexpected impacts and consequences at the Dendrobium and Metropolitan mines.

  Mining may be approved and its performance assessed on a basis of argument from ignorance. The absence of strong evidence does not, however, necessarily mean that significant consequences do not exist or will not occur, particularly in a context of inadequate monitoring, and limited data and information availability. Given the importance of the Special Areas, where limited data point to the possibility of a significant impact consequence, it would seem reasonable to assume that this has occurred or will occur, until reliably established otherwise with scientific confidence.

- Other than circumstances where the evidence is immediate and overwhelming, the onus of unequivocally establishing a likelihood of unacceptable impact and consequence occurring, or having occurred, rests with the agencies, NGOs and the community, in the same context of inadequate data, knowledge, modelling and understanding recognised by the Planning Assessment Commission in stepping back from requiring a reverse onus of proof. These limitations are compounded by lack of access to data, reports and other information held by mining companies. The Dendrobium mine revelations that triggered the sequence of investigations[31], [42] that culminated in the formation of the IEPMC, came from the community in a context of inadequate and refused access to information.[21], [42]
- Compounding the problem of monitoring systems and networks remaining inadequate relative to the scale and complexity of mining impacts and consequences in the Special Areas, failed groundwater instruments are typically not replaced. Where instruments are replaced, the replacement may not be equivalent. As a consequence, for example, it's not possible to reliably determine the height of the drainage zones over Longwalls 302 and 22B at the Metropolitan Colliery.[26] There is insufficient data to be able to quantify mining impacts and consequences with high scientific confidence.
- There is limited ability to model and predict rainfall infiltration and sub-surface recharge, runoff diversion, valley closure and valley bulging effects, shear plane effects, local geology interactions and the effects of geological anomalies/discontinuities (faults, dykes, intrusions).
- Subsidence and groundwater and surface water responses can be significantly underestimated in the vicinity of lineaments. Comparatively modest mining at the Metropolitan Colliery has nonetheless resulted in unexpectedly severe impacts to Waratah Rivulet and Eastern Tributary. Impacts to Eastern Tributary exceeded the approval conditions for the mining. Anomalous geological interactions may also be contributing to the notable depletion of groundwater suggested by the (limited) monitoring[35] in the aquifer supplying groundwater to Woronora Reservoir. There is no means of reliably predicting the outcome of mining in unusual or inadequately understood geological settings.
- In its March 2019 submission[40] to the IEPMC, WaterNSW provided the following recommendation:

  > "*Given the uncertainty associated with predictions of environmental consequences, WaterNSW considers a precautionary approach to the assessment and determination of mining proposals within the Special Areas is warranted. There must be a high degree of confidence that any proposed mining does not exceed key predictions or performance measures in development consents, Subsidence Management Plans (SMPs) and Extraction Plans. On that basis, no further approvals should be given for mining that would permit the level of environmental impacts and consequences that have occurred in Wongawilli Creek, WC21, and Swamps 1a, 1b and 5 at Dendrobium, and Waratah Rivulet and Eastern Tributary at Metropolitan.*"

Notwithstanding modest mining practices, Waratah Rivulet and Eastern Tributary have suffered unexpectedly severe impacts above Metropolitan Colliery. There is currently no means of predicting such impacts.

- Surface water and near-surface groundwater contamination by mining induced ‘iron springs’ (see Fig. 19). Water flowing over subsidence induced fractures dissolves minerals to contaminate both surface water inflows to the reservoirs and groundwater inflows from the aquifer that supplies groundwater to the reservoirs. Groundwater may also be contaminated by shear plane activation and iron spring activity may be triggered some distance from the mine area.[14] As highlighted in the media in December 2019[43], the ongoing accumulation of tonnes of metal containing contaminants on the floors of the reservoirs, becomes evident as reservoir levels fall during drought. The SCA (now WaterNSW) estimated that between February 2002 and August 2009 some 15 tonnes of iron and 4 tonnes of manganese were added into Woronora Reservoir from the mining impacted Waratah Rivulet.[44] The agency’s estimate February 2002 to June 2011 is 19 and 5 tonnes respectively.[45] These estimates would not include the additional loading from contaminated groundwater inflow to the reservoirs. Iron springs remain active for decades. The total iron spring derived contaminant loading on and near the floors of the reservoirs is not known; an assessment program that includes core samples from the reservoir floors would seem to be required. Mining under Woronora Reservoir may cause further loading via subsidence cracking of the reservoir floor.
- The Department of Planning Director General’s June 2009 environmental assessment report[115] for the then proposed expansion of the Metropolitan Colliery describes iron spring activity along the Waratah Rivulet, initiated as a result of the mine’s first longwall mining project:

  > “*Large areas of rocky substrate in the Waratah Rivulet and other watercourses have been observed to be covered by orange-red iron staining for many hundreds of metres downstream of mine subsidence fractures. If the iron concentration is sufficiently high, and the aquatic environment is suitable, then orange, bacterially-based iron flocs may also form in ponds. Potential ecological effects of such flocs are reported to include smothering of benthic habitat and biota and reduced light available for aquatic plants. Bacterially-catalysed oxidation of iron also consumes dissolved oxygen from the water column*.”

  The expansion project was subsequently approved.
- The 2010 PAC review[9] of the then proposed expansion of the Appin and West Cliff mines, has the following observations:

  > “*the consequences of iron staining, opacity, bacterial mats and deterioration of water quality has potentially significant consequences for hydrologic values (water quality), ecological values, environmental quality and amenity value*”.

- Anecdotal reports suggest that the mine workings in the Special Areas can be located from the air by the distribution of stream discolouration caused by iron springs above and around the mines below. The report for a 2013 workshop organised by the SCA[46] comments:

  "*One participant noted that when flying over the Southern Coalfield, the mining impacts on streams were clearly visible, and water discoloration due to iron precipitates in water travelling through new subsurface flow paths and re-entering streams could be used to map the extent of underground workings*"

- The 2010[14] review by the Planning Assessment Commission of the then proposed expansion of the Appin and West Cliff mines has the following observation: *"Isolated stain occurrences located in the upper reaches of O'Hare's Creek and Woronora River are remote from existing mining, but may still be associated with far field movements of the rock strata*". The use of Woronora River as a control for mining induced iron spring contamination of Waratah Rivulet is likewise questionable.[47]

- Allowing catchment water to be degraded on the basis of subsequent treatment contradicts best practice public health risk management and the intent of the Special Areas. Treatment adds to the environmental and economic costs of water supply.

- Where the drainage zone reaches the surface, there will be contaminated water discharges onto the catchment when closed mines fill with water (see Fig. 20).[5], [48] As pointed out by the IEPMC[1], and noted above, avoiding this problem will require the ongoing removal of water from the mine, in perpetuity. The Department of Planning subsequently approved the extraction of Longwall 21, which may again result in the drainage zone joining the surface fracture network, if not reaching the surface.

- Ongoing degradation and loss of the upland swamps (see Fig. 21) through bedrock cracking with linkage to drainage pathways. Reduced bushfire resistance and catchment resilience to drought is eroded through the loss of runoff filtering and moderation capacity. There are no known effective means of swamp remediation.[1], [3] These concerns are compounded by inapropriate swamp loss offsets. Commenting on offsets for damage to swamps over the Dendrobium mine, WaterNSW points out the following[4]:

  "*The proposed biodiversity offsets for swamps are not within WaterNSW's Special Areas or the Sydney drinking water catchment and therefore would not result in any compensatory effect in the water quality, water quantity, aquatic ecosystem or ecological integrity of these resources*."

- Biota and biodiversity loss, including threatened species.

- Methane migration towards and emission from the land and water over the mines. Methane is a much more potent greenhouse gas than is carbon dioxide; it breaks down to form carbon dioxide in the upper atmosphere.

- Notwithstanding the concerns and recommendations of past reports to government (see below), the ongoing lack of transparency and access to data, reports and other information held by mining companies continues to hinder or prevent independent assessment of the impacts and consequences of mining the Special Areas. For example, in their 2017 report on impacts over the Dendrobium mine, consultants PSM note limited data access, with some not being provided notwithstanding repeated requests.[31], [49] Government agency approval of the release of mining company provided reports and information on impacts to the Special Areas, may be nonetheless be opposed by the relevant mining company. The 2014 Chief Scientist's report on cumulative impacts notes the problem of the agencies having limited access to data and information held by the mining companies:

  > "*The problems that the Sydney Catchment Authority has accessing data from companies using the Special Areas was noted, as was the nature of the data that may be held by the companies as well as by government agencies and universities. A contrast was drawn to Alberta, Canada, where any information on public assets must be made publicly available. It was noted that there are no international examples of longwall mining operating in publicly owned drinking water catchments but there are examples of it occurring under streams and aquifers connected to privately owned wells in the Appalachians of the U.S.A.*"

  It would appear that commercial interests continue to be placed ahead of the public interest in the Schedule 1 Special Areas. Further illustrating this, and counter to the practice of science, impact assessment reports commissioned by mining companies often refer to reports withheld by the mining companies. This practice also hinders accountability.

- The calibre of the detailed and informative work[16]–[19] that predicted and modelled the drainage zones at the Dendrobium mine reaching the catchment surface is captured in the comments of WaterNSW (then the SCA) at that time, characterising the work as "*sound and well researched and provides an important step in the development of a rigorous regional groundwater model. The study provides details on estimated groundwater recharge, discusses a new concept of ground deformation and its impact on groundwater hydrology, and applies more constrained ,calibration approach using hydraulic heads, baseflow to rivers, inflows to Dendrobium and other mines) and probabilistic analysis*." As the quote notes, a significant and still distinguishing[38] aspect of this work was its simultaneous calibration with respect to what would appear to be, in the context of limited monitoring and assessment installations, comprehensive sets of groundwater pressure data, hydraulic conductivity data and regional mine inflow volumes. The calibre of this now dated but nonetheless notably informative work remains outstanding. Commercial in confidence privileges are such that it would not be possible to independently update this pioneering work.

- Compounding the problem of lack of access to data and information, is a dependence on assessment reports prepared by consultants selected and funded by mining companies. Such reports cannot be regarded as independent and nor are reviews of these reports undertaken by consultants dependent on subsequent engagement by mining companies. The consequences of incorrect and misleading information provided by consultants and accepted by authorities in a context of scientific uncertainty, have been highlighted in a recent publication addressing the Carmichael Mine and potential impacts to Doongmabulla Springs.[50], [51] Trading under different names, a consultancy referred to in that publication appears to have provided inadequate, flawed or misleading advice on behalf of a number of mining proposals and projects in NSW, including in the Special Areas.[4], [5], [14], [38], [50]–[53] Following initial concerns raised in July 2015[20] and April 2016[4], the Department of Planning was advised[5] in some detail in December 2016 that the groundwater pressure data from the Dendrobium mine appear to have been misinterpreted or misrepresented over a number of years by this consultancy. This was, in effect, affirmed in the PSM report[31] of March 2017. The same consultancy has contributed to impact assessments for the Metropolitan Colliery, including that for Longwalls 305-307.[25] In reviewing the then proposed expansion of the Appin and West Cliff mines in 2010[14], the Planning Assessment Commission made the following recommendation with respect to peer reviews:

> "*15.3.4. Recommendation*
>
> *The Panel recommends that the Department look at this issue with a view to determining whether independent selection and briefing of reviewers should be the norm, even if the cost were borne by the Proponent. As it currently stands the system appears to have little credibility.*"

Directly applicable also to consultants undertaking assessments on behalf of mining companies, the recommendation has not been taken-up. A means to decouple consultant engagement from the proponent is suggested by the funding mechanism for the Mine Subsidence Board, together with random selection from a pool of accredited consultants. While bias would not be eliminated, it should be lessened. De-coupling would also provide an opportunity to remove the commercial in confidence obstacle to data and information access.

- WaterNSW may be insufficiently resourced relative to the scale and complexity of the impacts and consequences arising from mining the Special Areas. This may also be the case for the Department of Planning.

The IEPMC reviews[1], [54] follow, among others, the 2017 PSM[31] review of impacts at the Dendrobium mine and the Galvin[55] and Mackie[56] reviews of that work[57], the 2016 Audit of the Sydney Drinking Water Catchment[58] and prior triennial audits, the 2014 report[9] from the NSW Chief Scientist on cumulative impacts in the Sydney catchment, the 2014 Davey et. al.[3] and Tammetta[59] swamp impact reviews, the 2012 OEH review[60] of impacts at the Dendrobium mine, the 2010 PAC review[14] of the then proposed expansion of the Appin and West Cliff mines, the 2009 PAC review[41] of the Metropolitan Coal Project, the 2008 Southern Coalfield Inquiry[61], the 2007

Krogh review[62] and the 2007 McNally and Evans Southern Coalfield impacts report[8] prepared for the then NSW Department of the Environment and Climate Change.

These reports and references therein document the nature and possible extent of the damage caused by mining beneath the Special Areas and, repeatedly, point to the data, modelling, transparency, balance, knowledge and understanding inadequacies and uncertainties under which mining has been approved and allowed to proceed. The inadequacies and uncertainties are such that it is still not possible to reliably gauge the magnitude, extent and significance of the impact and consequences of mining in the Schedule 1 Special Areas. There continues to be no timetable nor direction to funding to address these longstanding problems.

The ongoing level of ignorance with which mining is approved and undertaken, highlighted by unexpected impacts and consequences at the Dendrobium and Metropolitan mines, urges the suspension of the approvals process for coal mining in the Schedule 1 Special Areas. The suspension should remain in place until deficiencies in data gathering and reporting, data and information access, modelling, knowledge and understanding are comprehensively addressed, such that cumulative impacts to date can be reliably and openly assessed, and quantitative predictions of the compounding effects of new mining proposals can be made with a high degree of scientific confidence. Assessments and predictions should be capable of reliably determining whether or not proposed mining will have a neutral or an adverse effect on the Special Areas, from commencement and into the intergenerational future. As the 2008 report of the Southern Coalfield Inquiry points out, “*The single most important land use in the Southern Coalfield is as water catchment*.”[61]

Appendix A. Recommendations of the 2007 McNally and Evans Southern Coalfield impacts report[8]

1. As a first step towards developing an improved water monitoring system for the Southern Coalfield, the existing fragmented one should be carefully examined. This would involve collation and analysis of information presently held by the Department of Primary Industry, the Sydney Catchment Authority, the Dams Safety Committee and the mining companies themselves, especially BHP Billiton. The aim would be present a regional view of surface and groundwater distribution, flow and quality throughout the coalfield.
2. Plan and implement an upgraded network of observation bores, water sampling points and gauging stations. Such a network would primarily be directed towards:
   - Investigating surface-groundwater interaction, flow and water quality in shallow sandstone aquifers, stream beds and upland swamps.
   - Providing baseline data for new or proposed mining areas up to 20 years ahead of mining.
   - Providing post-mining assessments of water in and around closed mines, the extent of natural remediation and potential groundwater hazards.
   - Devising consistent and cost-effective monitoring and sampling techniques for both groundwater and surface water.
   - Performing numerical modelling of surface and groundwater as required.

Appendix B. Recommendations of the 2014 NSW Chief Scientists cumulative impacts report[9]

Recommendation 1: *That Government create a whole-of-Catchment data repository.*

Recommendation 2: *That Government develop a whole-of-Catchment environmental monitoring system.*

Recommendation 3: *That Government commission computational models which can be used to assess the impacts on quantity and quality of surface water and groundwater.*

Recommendation 4: *That Government encourage the use of data visualisation tools for examining 3D representations of the Catchment.*

Recommendation 5: *That Government establish an expert group to provide ongoing advice on cumulative impacts in the Catchment.*

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Figures

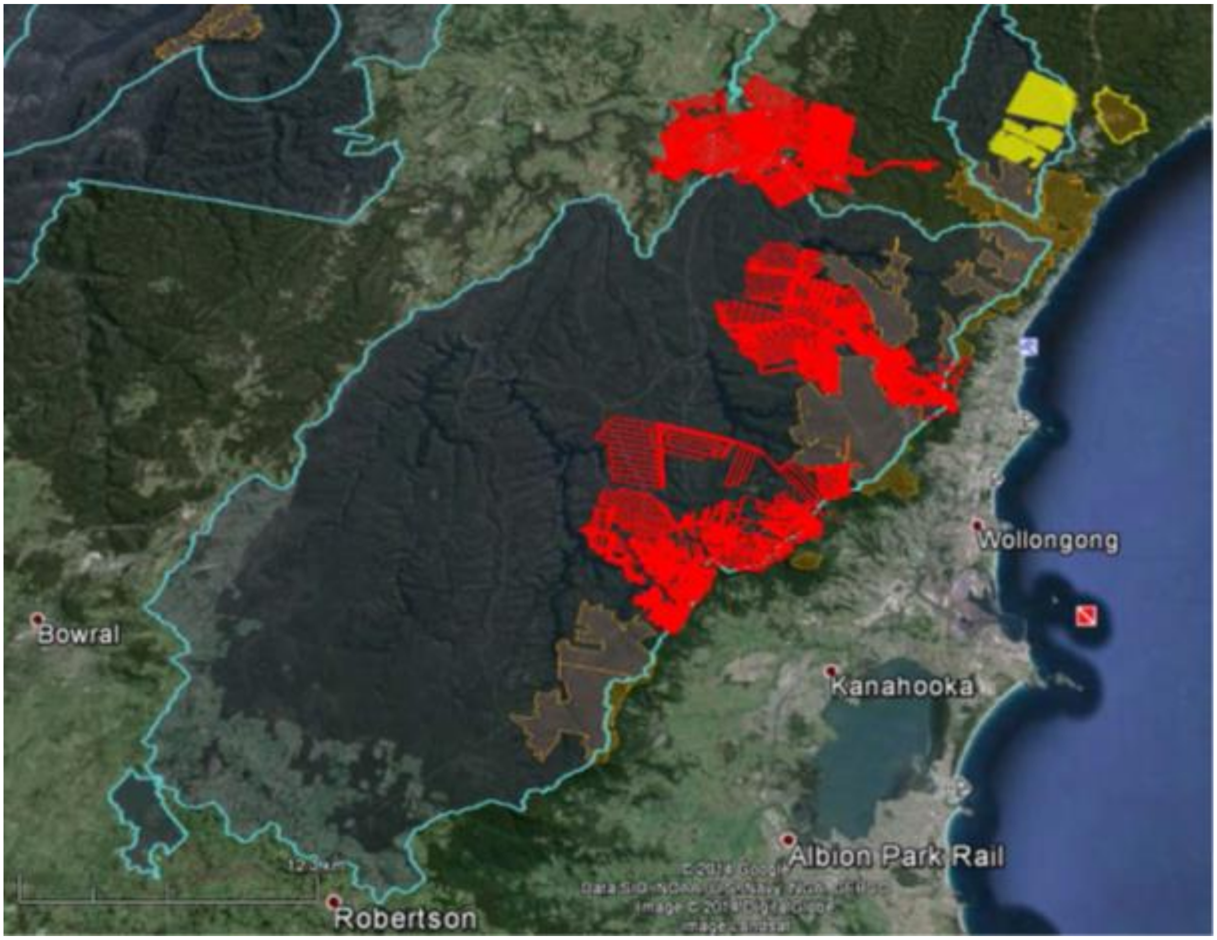


Figure 1. Google Earth depiction of coal extractions (with current approvals) within and adjacent to the Metropolitan and Woronora Schedule 1 Special Areas.

The Special Areas are depicted with pale-blue boundaries. The Metropolitan Special Area is centred in the image while the Woronora Special Area is the smaller region in the top right of the image. Part of the Schedule 1 Warragamba Special Area is shown at the top left. The red and yellow areas represent longwall mines, while the ‘amorphous’ shaded regions, represent older bord and pillar mine areas. The extent of pillar removal from the bord and pillar mine areas is uncertain.

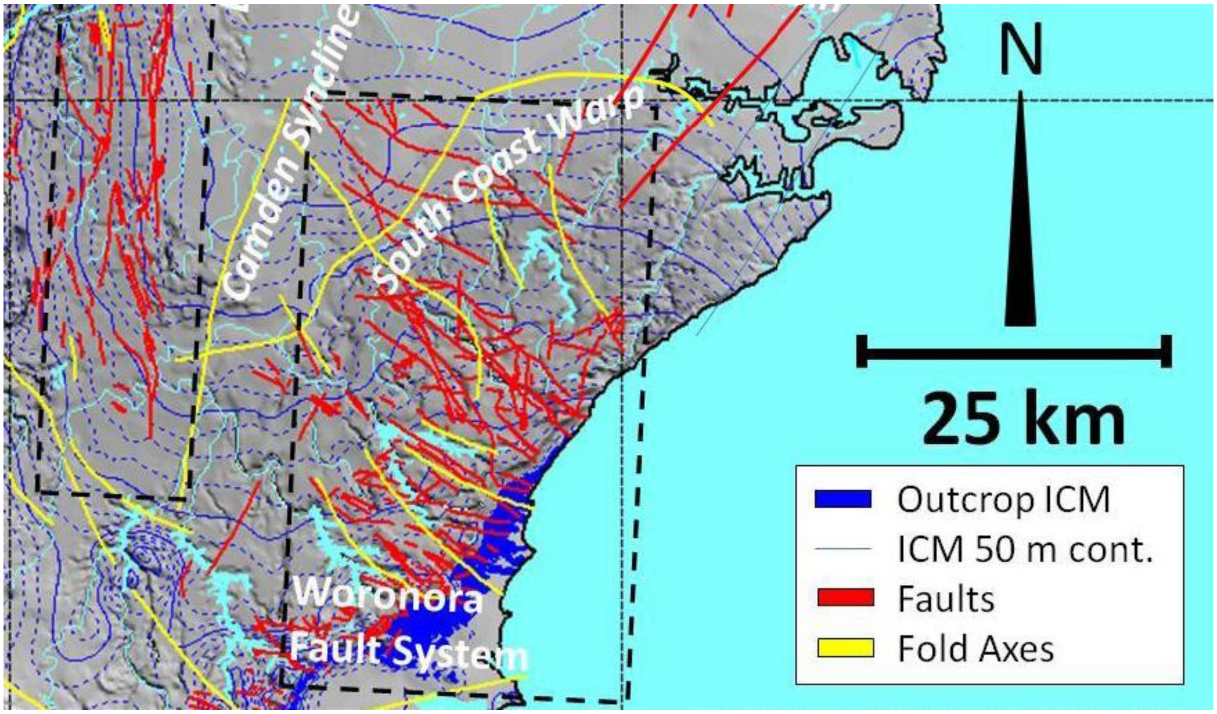


Figure 2. Depiction of faults and folds in the Illawarra region of the Sydney Basin**[63]**, showing a concentration of faults between the storage reservoirs.

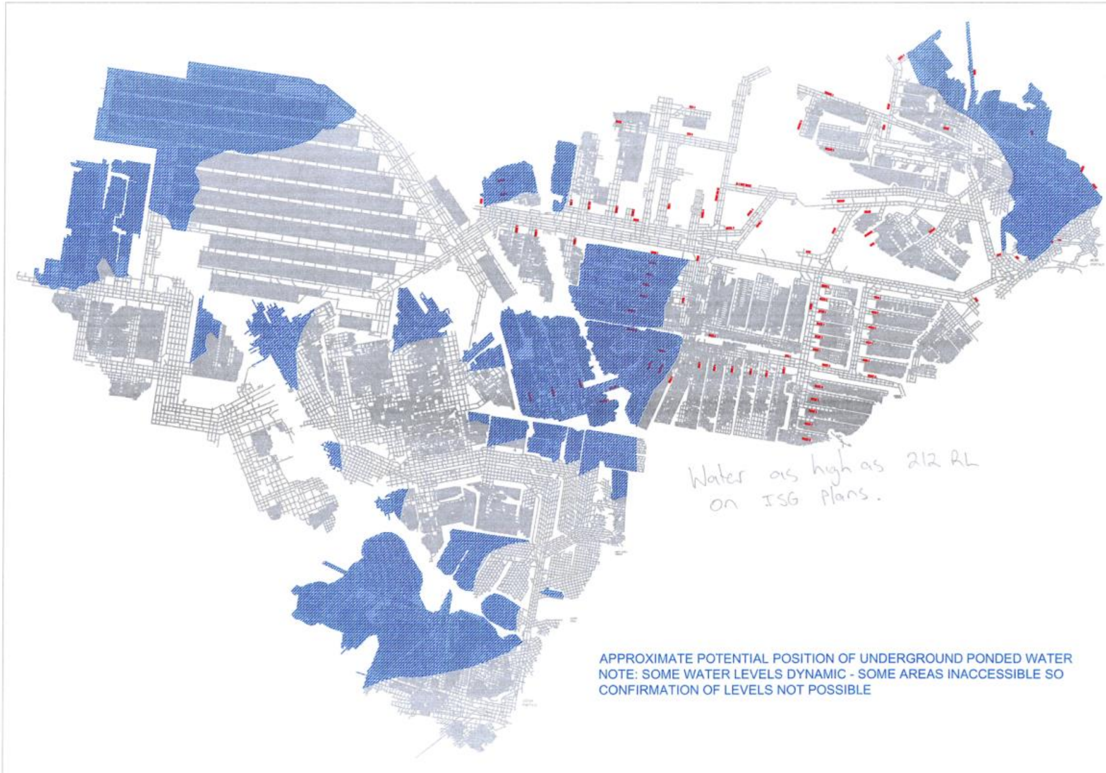


Figure 3. Water lodgement in Wongawilli coal seam extraction areas at the Wongawilli mine.

Provided on request by Wollongong Coal, the date of the above water lodgement map is not known. The printed text states: "A*pproximate potential position of underground ponded water. Note: some water levels dynamic - some areas inaccessible so confirmation of levels not possible*". The handwritten note states "*Water as high as 212 RL on ISG plans*"; it's not known which part of the mine is referred to in this comment. Wollongong coal had been extracting remnant in the Nebo section when operations ceased in 2019 because of safety concerns. The area has been sealed and the Community Consultative Committee has been told that its anticipated that when the ponding reaches about 205 RL, water will drain from a portal in the escarpment, near Dombarton.

The Bulli seam above has also been mined and may hold water. Ponding and draining is known to be occurring at the other mines in and around the Special Areas.

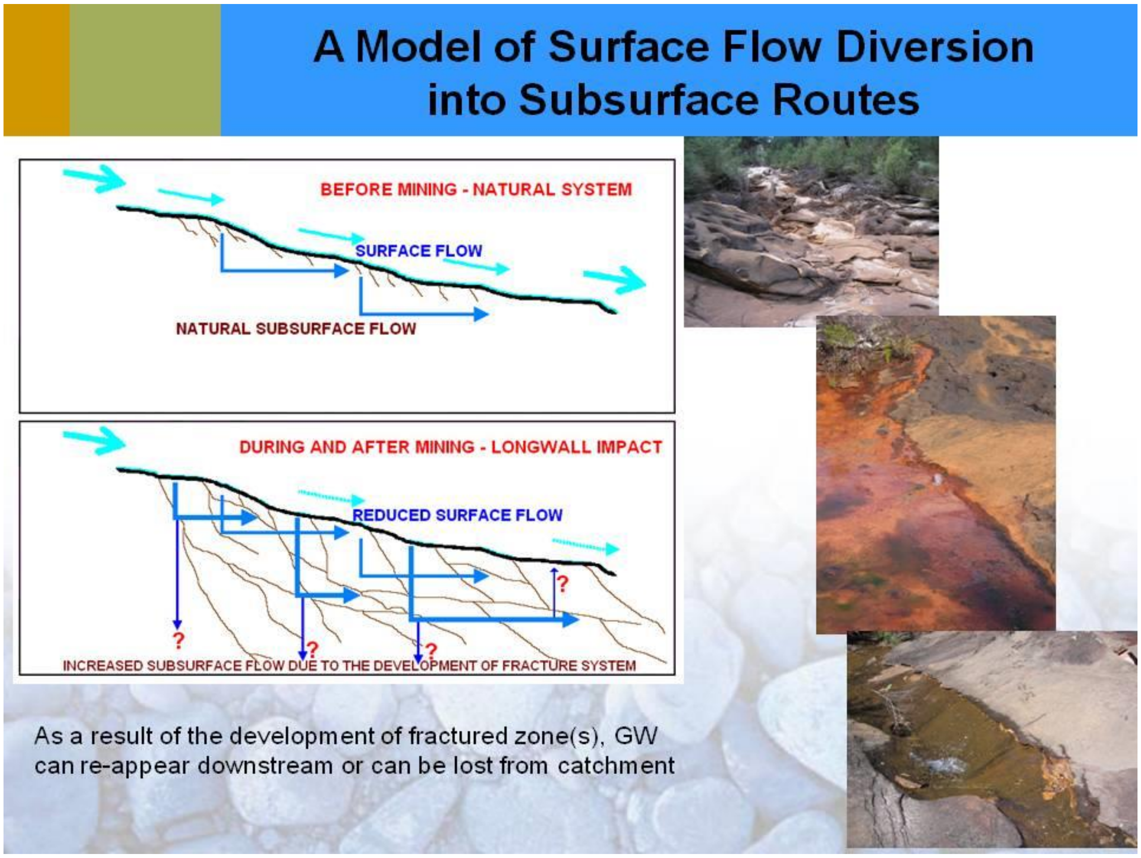


Figure 4. Sydney Catchment Authority (now WaterNSW) depiction**[64]** of surface water diversion and fracture network water flow.

Figure 5. Damage and drainage on Wongawilli Creek resulting from subsidence at Elouera Colliery.[65], [66]

Adjoining the Dendrobium mine, the Elouera Colliery is now part of the Wongawilli mine.

The 2010 groundwater impact assessment for the 2010 longwall mining proposal for the Nebo area of the Wongawilli mine reports:

> "*bord and pillar as well as pillar extraction and longwall mining has been conducted in the adjacent Wongawilli, Elouera and Dendrobium Area 2 workings, and that vertical hydraulic connection has been observed at some locations between surface streams and the underlying workings*".[23]

The assessment report further comments that a significant but unquantified component of the water entering the Elouera mine comes "*from surface water seeping through subsidence cracks following extraction of Elouera Longwalls 6 and 7 under Wongawilli Creek*"

(a) **(b)**

Figure 6. Watercourse damage examples

(a) Water draining in low-flow conditions into a crack in the floor of Waratah Rivulet. Damage of this kind has occurred over and around all of the mining in the Metropolitan and Woronora Special Areas. Of note, Waratah Rivulet provides more water to Woronora Reservoir than does Woronora River. **(b)** Watercourse cracking over a drainage zone that reaches the surface is likely to be the reason sections of Wongawilli Creek tributary WC21, over the Dendrobium mine, have been drained. Such impacts have also drained swamps over the Dendrobium mine.

(a) **(b)**

Figure 7. (a) Fragment of polyurethane resin (PUR) from Waratah Rivulet (b) Aging PUR curtain in Waratah Rivulet bedrock.

The effectiveness of a polyurethane resin (PUR) barrier may be limited, particularly during low flow periods. The ability of the quite brittle material to resist further subsidence movements would seem likely to be limited and its medium to long term durability is also questionable. The watercourse functionality and groundwater impact of injected flow barriers has not been adequately studied.

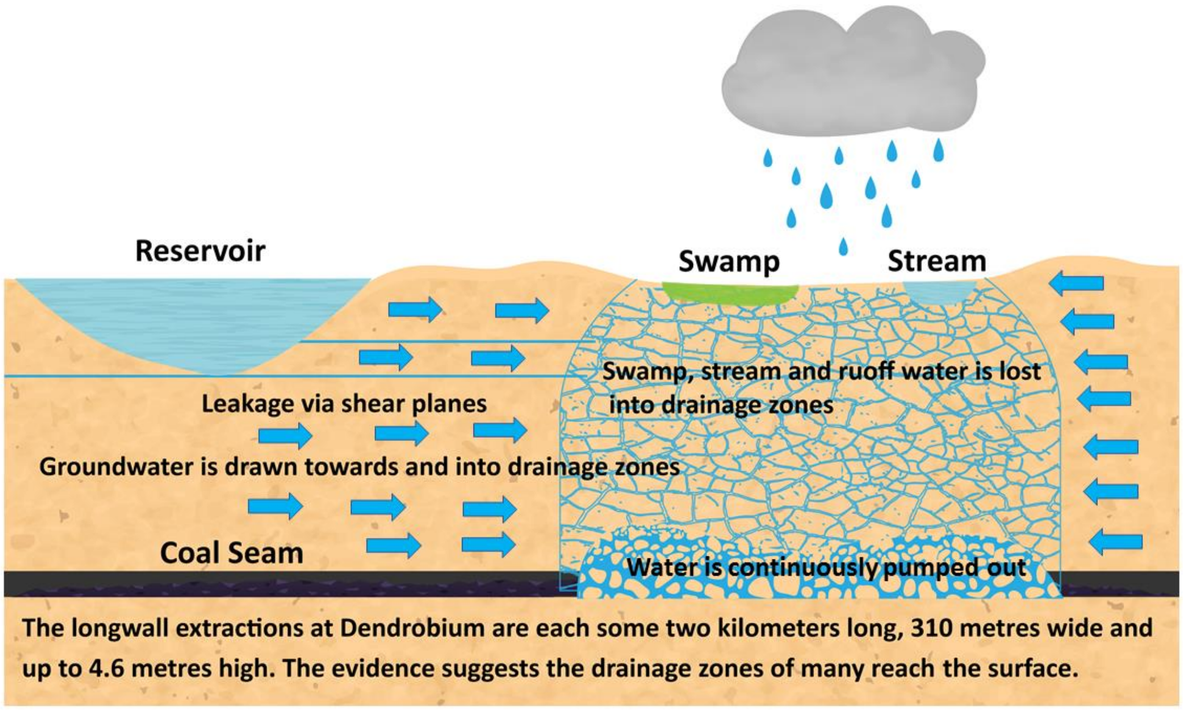


Figure 8. Depiction of the drainage zone reaching the surface beneath a swamp and watercourse, and near a reservoir.

The drainage zone, or zone of complete drainage, is a zone of highly connected fractures that forms over a coal extraction. Surface and groundwater is drawn into this zone, where it then drains relatively rapidly to the mine. The height of the drainage zone depends primarily on the extraction width, height (thickness) and depth below the surface.[67] The mining parameters at the Dendrobium mine are such that the drainage zone may reach the surface over parts the mine. At least in part reflecting this outcome, the inflow of water to the mine is rainfall dependent and has reached peaks of up to 13 million litres a day.

Like reservoirs, watercourses not over a drainage zone may lose water via shear planes.

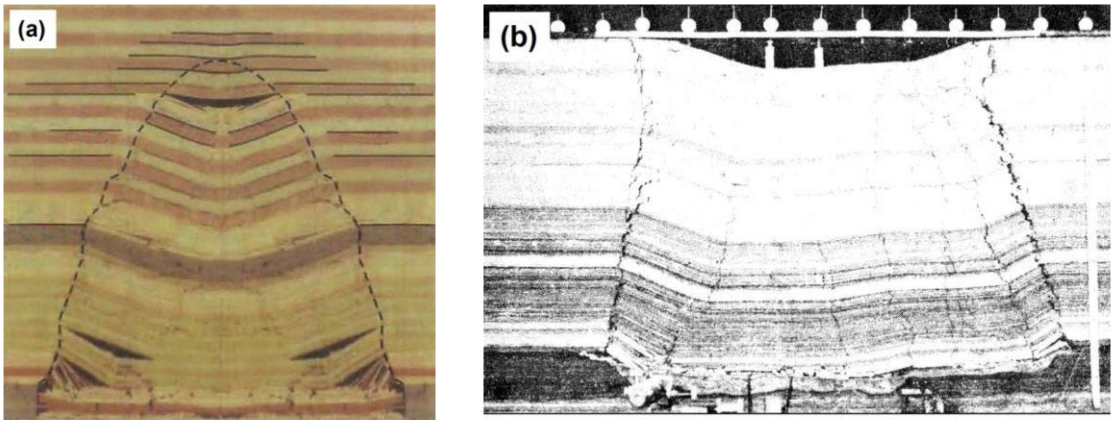
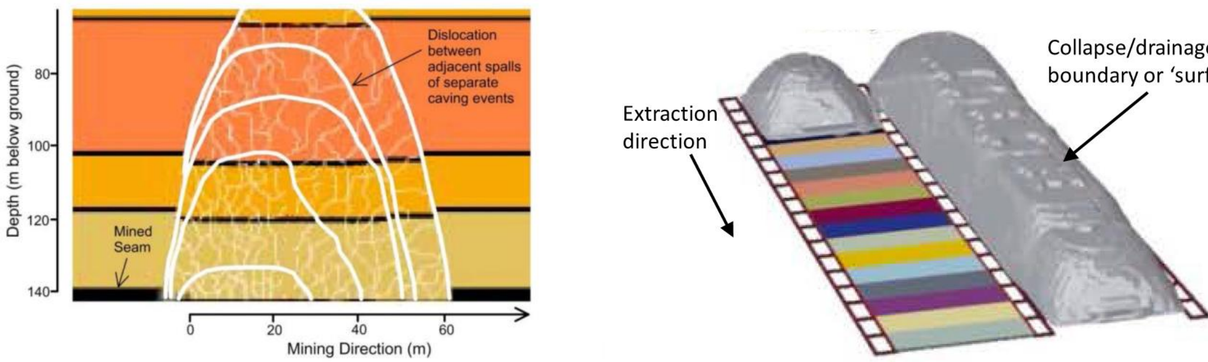


Figure 9. Physical models of the collapsed zone over a coal extraction

(a) Physical model of the collapse of strata downwards and into the void created by coal extraction.[68] Evidence and calculations suggest that the drainage zone formed with this collapse reaches the surface over parts of the Dendrobium mine. It may also have occurred where pillar extraction has taken place.
(b) Physical model of the complete collapse that occurs when the extraction width has passed the point beyond which the rock strata above the extraction is unable to 'bridge' the extraction void.[68] Known as ‘supercritical’, this is thought to have occurred over some of the coal extractions at Dendrobium. While further extraction beyond the critical width doesn’t result in any further surface subsidence, the lateral extent of mine to surface fracturing continues to increase.



(a) **(b)**

Figure 10. Evolution of the drainage zone

(a) Evolution of the collapse zone in the early stages of a longwall extraction, based on data from a Queensland mine.[68] Also known as the zone of complete drainage or drainage zone, this is a zone of connected fractures where water drains relatively rapidly towards the void created by a coal extraction. Evidence and estimates of the height of the drainage zone suggest it has reached the surface over parts of the Dendrobium mine. **(b)** Three dimensional simulation[68] of the boundary of the collapse/drainage zone over a completed longwall extraction and over the early stage of a second extraction, in which the rock surrounding the drainage zone boundary is not shown.

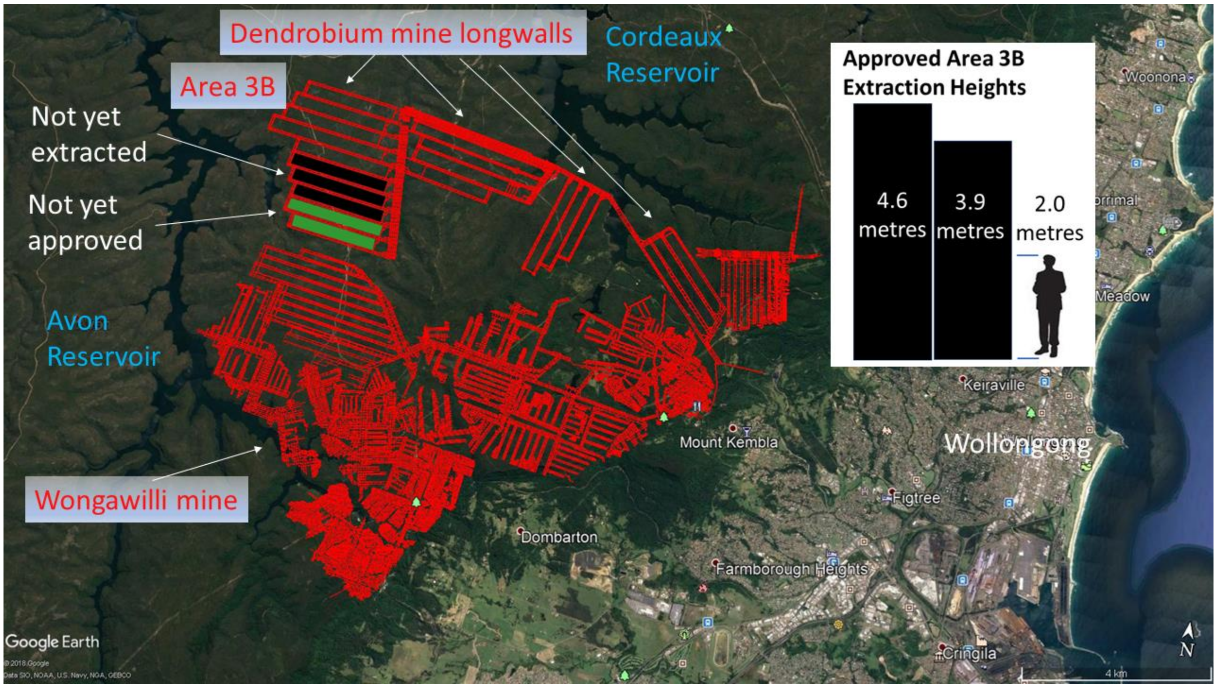


Figure 11. Extent of underground coal mining between the Avon and Cordeaux Reservoirs.

Since this graphic was created, Longwall 14 has been completed and Longwall 17 has been approved. With approved longwall extractions in Area 1, 2, 3A, 3B and 3C, the Dendrobium coal mine is located between the Avon and Cordeaux Reservoirs. The Department of Planning approved extraction dimensions in Area 3B are unusually large with each longwall 'panel' having a width of 305 metres and a height (or thickness) of between 3.9 and 4.6 metres. The first extraction in Area 3C, Longwall 21, was recently approved by the Department of Planning with dimensions that may result in the drainage zone joining the surface fracture network, if not reaching the surface.

extraction height at Wongawilli is also less than at the Dendrobium mine. The Nebo area was closed in 2019 for safety reasons.

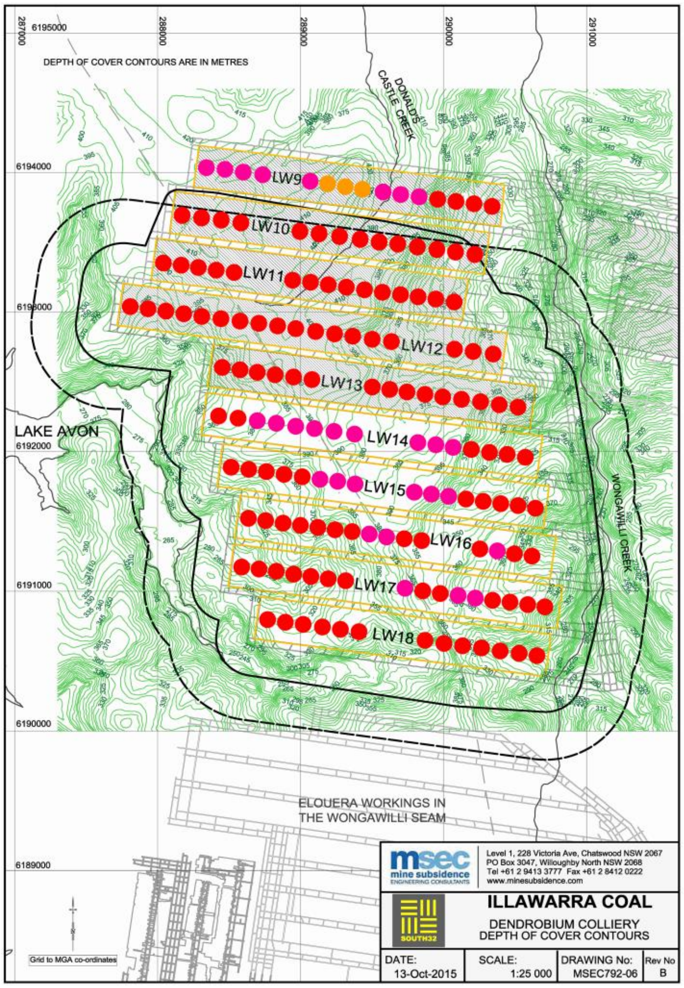


Figure 12. Depiction of estimated drainage zones peaks with respect to the surface above Dendrobium Area 3B.

This augmented MSEC map[69] shows the layout of the longwalls of Area 3B of the Dendrobium mine, together with depth of cover contours. Longwalls 9 to 13 were approved in February 2013, 14 and 15 were approved in December 2016, 16 was approved in May 2018 and 17 in July 2019. The shaded longwalls are those that had been extracted at the time the map created. Longwall 14 commenced in May 2018 and was completed in February 2019. Longwall 15 is being extracted at the time of writing. Coloured circles have been added to the MSEC map to indicate the Tammetta equation[67] estimates of the height of the drainage zone that will form above the 3.9 high extractions (LWs 9 and 14 to 18) and 4.6 metre high extractions (LWs 10 to 13) approved to date by the Department of Planning. A pink indicates that the drainage zone at that point reached between 25 metres from the surface and the surface, while red indicates intersection with the surface. Reducing the extraction height from 4.6 metres to 3.9 metres (see Fig. 11) does not significantly reduce the impact of the mining.

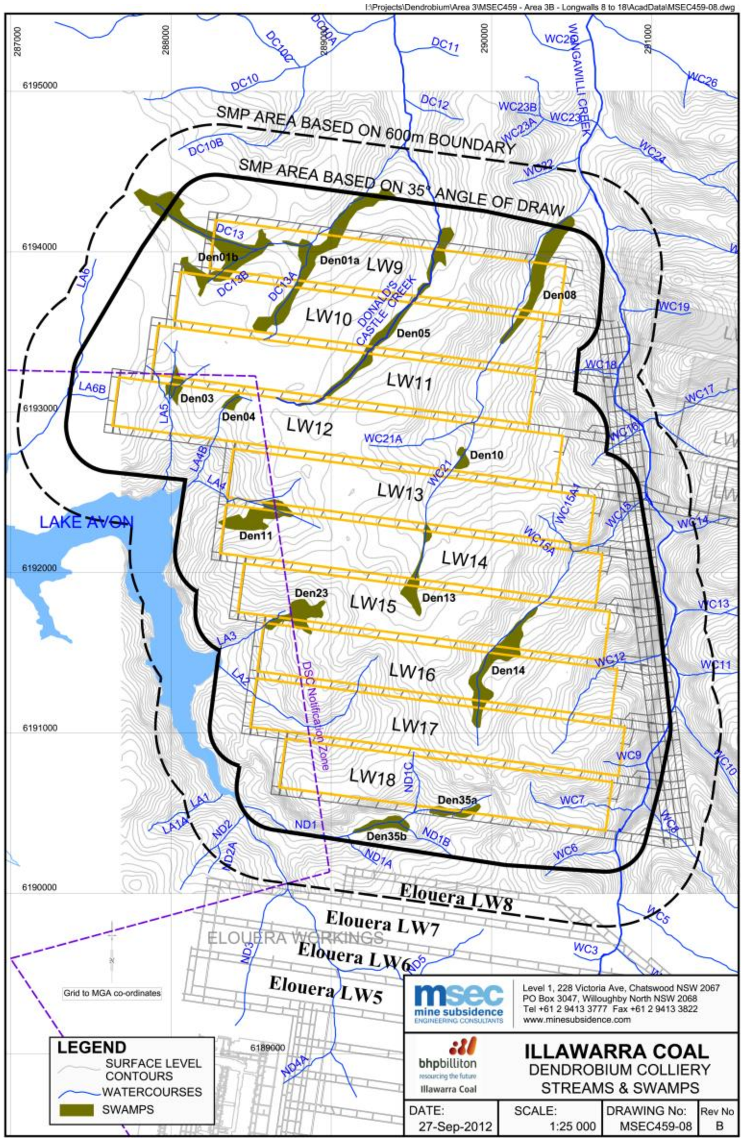


Figure 13. The swamps and watercourses over Area 3B of the Dendrobium mine

Swamps 1a, 1b, 5 and 8 extend over Longwalls 9, 10 and 11 of the Dendrobium mine and are amongst the largest and most complex swamps on the Woronora Plateau. They would merit recognition as being of special significance.[70] They were the first to be impacted by the mining in Area 3B of the Dendrobium mine. Numbers for the longwalls in the Elouera domain of the adjoining Wongawilli mine have been added to this 2012 MSEC map of then planned mining for Area 3B.[71]

Figure 14. Map of mining below and near Cataract Reservoir.**[72]**

Mining took place beneath the reservoir between 1993 and 2000. A 2014 paper[29] by the Dams Safety Committee reports evidence of shear plane leakage and the study also found that subsidence movements continued, with reactivation, for 25 years after completion of the mining; much longer than found elsewhere in the Special Areas.

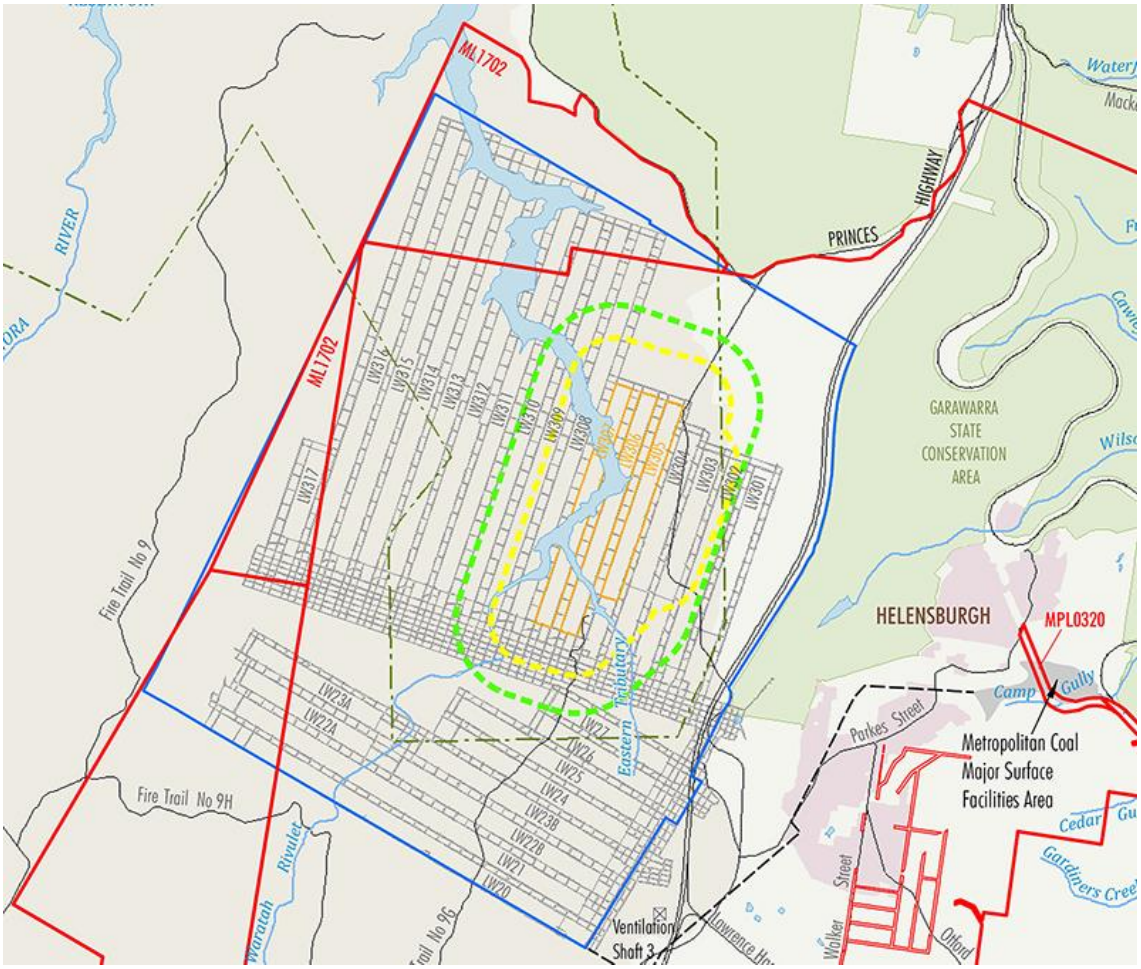


Figure 15. Map of mining below Woronora Reservoir.**[25]**

Longwalls 305 to 307, the first longwalls to pass below Woronora Reservoir, are highlighted. These extractions were approved by the Department of Planning in March 2020.

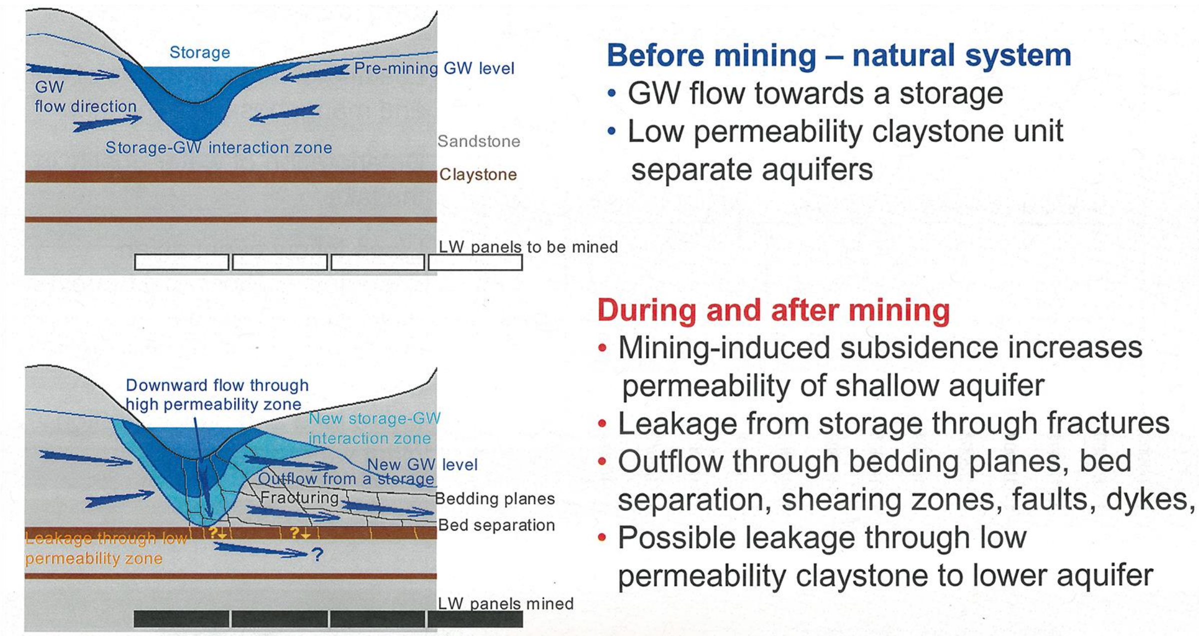


Figure 16. Sydney Catchment Authority (now WaterNSW) depiction of risks of mining below a reservoir

The above depiction[73] doesn't explicitly include shear plane activation. Leakage through these impacts would not result in water entering the mine. Data, knowledge and modelling limitations are such that currently it is not possible to reliably estimate losses of this kind. In particular it is not possible to establish a sufficiently accurate and precise reservoir water balance model (see Fig. 17).

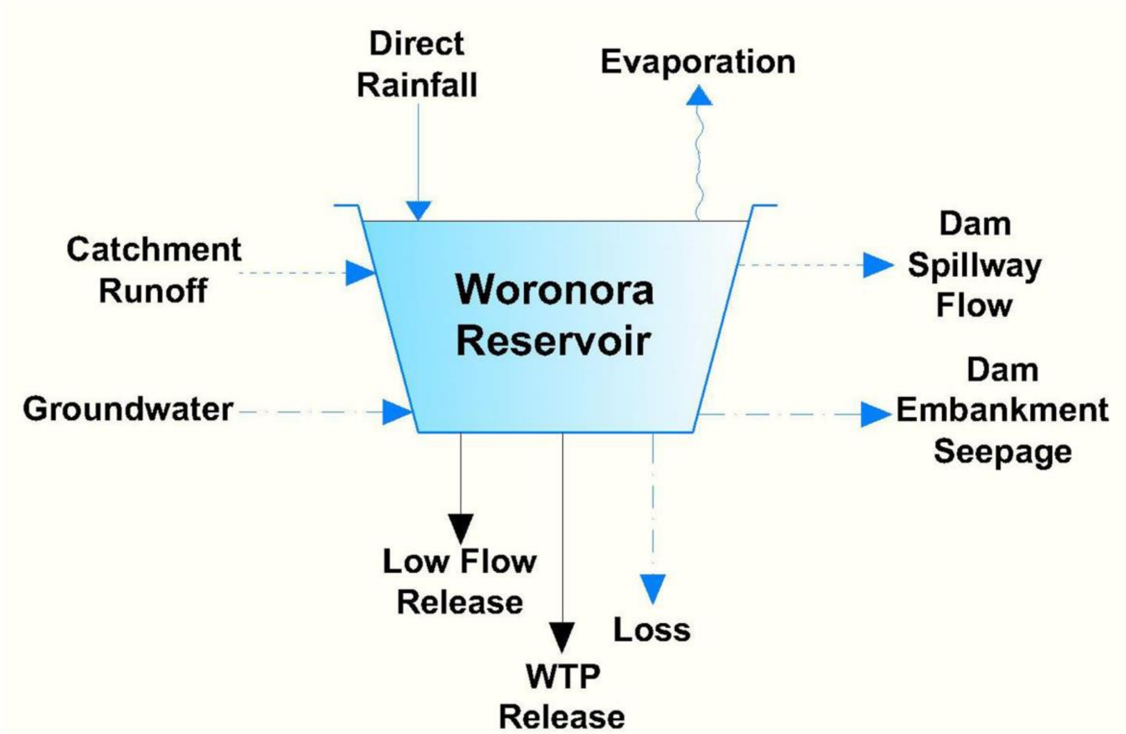


Figure 17. Water balance depiction for Woronora Reservoir.**[74]**

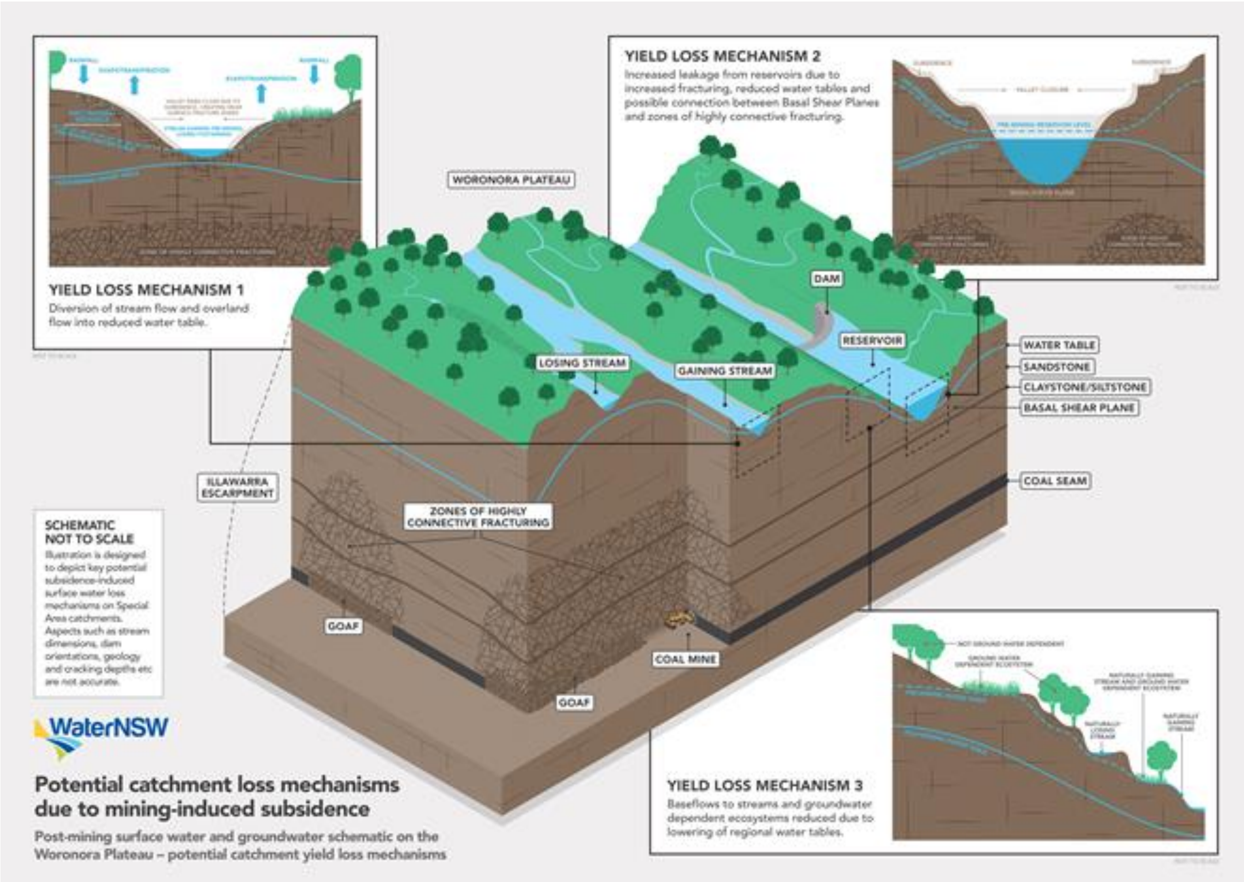


Figure 18. WaterNSW depiction of mechanisms by which water is lost from the catchment.

(a) Mechanism 1: Diversion of stream flow and runoff into fracture networks that join groundwater inflows to the mine or join groundwater flows that take water away from the local catchment. **(b) Mechanism 2**: reservoir leakage into mining induced fractures formed through processes such as 'valley bulging', leakage into 'shear' planes connected to fracture networks, and groundwater 'base flow' decline and loss. **(c) Mechanism 3**: Groundwater decline resulting in a loss of runoff and groundwater base flow to streams, such that they change from being 'gaining' to 'losing' watercourses.

These impacts are found above all of the mining in the Illawarra Special Areas; the amount of water being lost from the storage areas is not reliably known.

The depiction is for comparatively modest mining and, accordingly, the highly connected fracture zone, the drainage zone,

(a)

(b)

Figure 19. Iron spring degradation of Waratah Rivulet

(a) Iron spring discharge via a subsidence crack into Pool H on Waratah Rivulet. **(b)** Iron staining a short distance downstream from Pool H. Iron springs are formed when water passing through fresh rock fractures dissolves minerals from the rock. Iron springs are common over the mines and, reflecting this, the location of the mines can be determined from the air[46], when flying over the Special Areas. Groundwater inflows to reservoirs are similarly contaminated by mining impacts.

Figure 20. Mine water discharge damage to Lizard Creek Swamp

A 2010 Sydney Catchment Authority (now WaterNSW) photograph[75] of a 2004 discharge of alkaline mine water from Russell Vale Colliery onto Lizard Creek Swamp in the Metropolitan Special Area. A visit in 2013 found limited partial recovery.

As the IEPMC points out, discharges of this kind will occur above mines that have caused mine to surface connected cracking, if pumping stops and the mine is closed and sealed. Connected mine to surface cracking has occurred at the Dendrobium mine and the adjoining Wongawilli mine.

(a)

(b)

Figure 21. Swamp loss at the Dendrobium mine

(a) Dehydrating vegetation in Swamp 1b over Area 3B of the Dendrobium mine in early September 2016. Even though there had been significant rainfall in the previous three months, there was no water discharge from the swamp and the stream it would otherwise supply was dry. **(b)** The swamp sediment was firm and dry, whereas it should be soft, wet and dark brown or black in colour with decayed organic matter. In this condition the sediment would readily burn in the event of a fire. There was some sediment moisture in the centre of the swamp.