WALLARAH 2 - PAC ASSESSMENT AND NSW PLANNING & ENVIRONMENT
RESIDUAL MATTERS REPORT OF SEPTEMBER 2017

Philip Pells was briefed by EDO NSW, on behalf of the Australian Coal Alliance, to provide expert advice in relation to the Wallarah 2 Project. This report provides that advice.

1. A FUNDAMENTAL CONSIDERATION

An important fact known by specialist groundwater engineers since the early 1930s, but poorly or not at all understood by most persons, is that there are two independent physical entities when considering groundwater systems. These are:

1. Flow quantity (or flux); and

2. Pressure, or more correct, Potential Head.

Everybody understands flow quantity but few understand the impacts of the pattern of Potential Head (technically called equipotential lines) on the levels of water in bores, or loadings against retaining walls, or base flows to creeks.

It is a fact that without any change to the groundwater table one can achieve a totally different set of pressure impacts (bore levels, base flows, etc.) by simply changing the pattern of equipotentials, and thereby the direction of groundwater seepage.

It is unfortunate that the work that has been done by the Department of Planning & Environment (DPE) in relation to Wallarah 2 has focused primarily on groundwater flows. In my opinion there has been poor understanding of the impacts of changes in seepage flow directions, and this has led to several incorrect, or insufficient, findings and recommendations.

In decades of lecturing on this topic at Sydney University and the University of NSW, and in making public presentations, I have found it very difficult to get across the key distinctions between flow quantities and pressure distributions. The best original work in this regard is by Terzaghi (1934) and Skempton (1968) which I have...
summarised in a two part paper in the Australian Geomechanics Journal, an extract of which is in Appendix C of this report.

In this report I seek to show the importance of separating the impact of seepage quantities from the critically important changes in flow directions, and I seek to show where such distinctions have not been properly considered in previous assessments of groundwater impacts of the Wallarah 2 project.

2. SCOPE AND BACKGROUND

2.1 Previous work by Dr Pells

This report by Dr Philip Pells addresses matters related to groundwater and surface water impacts of the proposed Wallarah 2 underground coal mine. It does not deal with subsidence impacts on the natural and built surface environment.

My first work in relation to the Wallarah 2 project was on behalf of the then Wyong Council in 2010. A copy of my PowerPoint presentation to the PAC public meeting is given in Appendix A. My reason for including this presentation is that it is now 7 years later but no additional technical work of substance, relating to groundwater and associated surface water impacts, has been presented by the Proponent since that first PAC presentation. A good summary of the assessment process since 2012 is given in Section 1 of DPE’s Addendum report of February 2013 and need not be repeated herein.

I consider it very important to record again that I have done no independent groundwater modelling and have relied entirely of the modelling done by the Proponent.

In my reports and presentations to PAC1 and PAC2, I showed what that modelling actually meant in respect to likely impacts on bores, stream base-flow from groundwater, and aquatic ecosystems. In my report presented to PAC2 I stated:

"In this Section 4 we simply take what is given by calculations presented in the EIS without critical assessment of the validity of the calculations."

I showed that the Proponents analyses demonstrated significant impacts on yields from existing bores, and any future bores, in the area, and beyond the perimeter, of the mine, and base-flows to streams by virtue of the changes to flow directions.

It was therefore with some surprise that I found in the PAC report of June 2014:

"The Commission met with Professor Pells on 28 April 2014 and with the Proponent’s expert, Dr Mackie, on 29 April 2014, in order to explore these opposing views concerning movement of water from the surface to the zone of depressurisation."

My findings were from mathematical interpretation of the changes in the equipotential lines analyses given by the Mackie analyses. As per the discussion in Section 1, above, these changes have nothing to do with quantity of flow into the workings. My comments in respect to flow quantities were based on the fact that the permeability values used by Mackie for the undisturbed strata (nothing to do with the cracking) are on the low side of actual measurements. Therefore, I concluded that the Mackie

Pells Consulting

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31 October 2017
computed mine inflows (see Figure 1) may be less than reality. I retain this opinion because no new data or facts or analyses have been presented to cause me to recompute.

![Predicted mine water influx - all models](image)

**Figure 1:** Mackie predicted mine inflows (Mackie Figure E19, February 2013)

I do not understand how the above computed mine inflows relate to the conclusions by Mackie regarding water losses and compensatory measures. The Mackie (Feb 2013) report states:

Groundwaters are not part of the water resources that are defined within the Water Sharing Plans applicable to the area. However it is possible that subsidence in the alluvial lands may induce temporary leakage from surface drainage systems to subsided panels as the groundwater table re-equilibrates. This scenario is most likely in alluvial areas adjacent to Jilliby Jilliby Creek or its tributaries while in areas more distant from the creek(s), groundwater movement and rainfall runoff infiltration is likely to provide the greatest contribution. The highest groundwater storage increase is associated with LW9N9 where it is estimated that 181 ML may accrue before the adjacent panel LW10N acts to mitigate the increase.

It is also possible that subsidence associated LW6SW in the Wyong River catchment may initiate a localised increase of approximately 8ML in groundwater storage.

Given a measure of uncertainty in respect of permeability and effective porosity of the alluvium at a local scale, a conservative approach is considered to be appropriate. Accordingly, 300ML per annum could be redirected from runoff and baseflow contributions to temporary storage within the alluvial lands. With respect to the current Water Sharing Plans and future accounting (licencing), this volume of water could be distributed as 270 ML in relation to the Jilliby Jilliby Creek Water Source and 30 ML in relation to the Central Coast Unregulated Water Sources.

I cannot determine from the Mackie report the basis of the 270ML per annum from Jilliby Jilliby Creek. What is clear is that from year 10 to year 30, about 730ML to 880ML per year will be entering the mine from the groundwater system. The figure could be many times higher if actual rock mass permeability values are higher than those adopted by Mackie.

In my opinion, it is highly probable that losses from the surface water system will be much greater than the stated 270ML per year.
In addition, if the water entering the mine is considered to be disconnected from the upper rock, alluvium and surface water regimes, as per the Proponent’s view, it is not possible to know if a 270ML compensatory scheme is sufficient.

2.2 Groundwater Studies by the Proponent

The key, and to my knowledge, only publicly available study of computed groundwater impacts, is that by Mackie Environmental Research (Mackie). This was first published prior to October 2010 and was addressed by the Planning Assessment Commission (PAC) in a report dated November 2010.

The first Mackie report was updated in September 2012, for a further EIS submission as Appendix H.

This second EIS submission is called PAC1 by DPE\(^1\). I provided a response to this EIS in a report presented to PAC2, dated 10 June 2013. A copy of my report is given in Appendix B.

Following delay caused by dispute in relation to crossing Darkinjung Land, the project was resubmitted with amendments to rail access, conveyor system and sewer connections. The resubmitted project was subject to another report by the PAC, which DPE call PAC2.

I note that at the time of preparing this present report, an updated version of the EIS is available on the DPE website. The updated EIS is different from that I examined in 2013. This later version includes the Mackie report as Appendix I, with a changed name\(^2\) and it is dated February 2013.

I have examined the two versions of the Mackie report and note the following:

1. According to document analysis software, there are 2,282 changes between the September 2012 and February 2013 versions of the Mackie report.
2. However, there are no additional data on hydrogeological properties or existing piezometer pressures in the February 2013 version.
3. And there are no additional groundwater modelling analyses in the February 2013 version.

Therefore, the modelling analyses upon which I based my findings in my report of 10 June 2013 are still the only existing predictive analyses for the project.

My examination of the changes between the September 2012 and February 2013 Mackie reports reveals many surprising changes of interpretation, despite there being no additional data or analyses. Two relevant examples of these changes are given below.

\(^{1}\) I don’t understand why the original submission, rejected by the then Labour Government, has been forgotten; “On the final day of the Keneally Government (the day before the issue of the wnts), Minister Tony Kelly announced that the Government had made a decision that the proposal would not go ahead".

\(^{2}\) It was originally titled Groundwater Management Studies; in Feb 2013 it was changed to Groundwater Impact Assessment.
First Example

In relation to 'Loss of groundwater yield at existing bore locations' (Section 6.4 of both Mackie reports), the September 2012 document states:

- Loss of pressure induced by mining within the deep hard rock strata is not predicted to affect yield of any existing boreholes due to the very low leakage fluxes that are estimated by numerical modelling of the groundwater systems.

The February 2013 document states:

- There are 12 boreholes located within the area of subsidence that may exhibit some loss of yield.

Second Example

In relation to 'Change in groundwater quality' the September 2012 document states:

- It is unlikely that any measurable change in groundwater quality will be observed in deep hard rock strata as pore pressures decline.

This sentence does not appear in the February 2013 document but rather it states:

- It is unlikely that any measurable change in water quality will be observed in the shallow unconsolidated alluvial groundwater system post mining.....

In respect to the hard rock, the February document states:

- It is likely that subsidence induced surface cracking of hard rock strata will initiate re-direction of surface flows into some related cracks at some locations thereby promoting new water-rock hydro chemical interactions....

I raise these two particular matters up-front in this report because the revised interpretations given in February 2013 report agree with interpretations I presented to PAC in 2010, and PAC1, but which then were rejected by the Proponent on both occasions as being wrong, because the views given in the September 2012 Mackie report were stated as being correct, and my understanding was therefore wrong. Clearly this was not true.
2.3 Post 2013 documentation

Following the PAC1 deliberations, the PAC issued a report:

Since that time, there has been a proliferation of documentation including:
- Planning & Environment February 2017, *Addendum Report, State Significant Development Wallarah 2 Coal Project (SSD 4974).*
- Planning & Environment, September 2017, *Residual Matters Report, Wallarah 2 Coal Project (SSD 4974).*

2.4 Scope of this report

In this document I seek to address, with as few words as possible, the situation viz a viz possible groundwater and associated surface water impacts.

I use the word ‘possible’ quite deliberately because, as groundwater engineers, the best we can do is give a likely range of impacts. There is such substantial uncertainty in respect to stratigraphy, faulting, dyke intrusions, and the key parameters of permeability’s and Coefficients of Consolidation, that all that can reasonably be done by numerical modelling is to produce a spectrum, or range, of impacts.

How the precautionary principle is applied to this information is a matter for wise persons to decide. But it is important to note that if actual impacts fall in the upper range, an unacceptable part of the predicted spectrum, there is nothing which can be done to alleviate the impacts. Adaptive Management is, in this context, a meaningless panacea.

3. REQUIREMENTS OF PAC1

The PAC Review Report of June 2014 stated that:

- "the principal findings and recommendations of this review can be summarised as follows:

  (i) Whilst there is inevitable uncertainty concerning the subsidence predictions, they provide a basis for assessment of the potential subsidence-related impacts of the project. There is ample scope to revise the predictions based on site-specific experience and a rigorous adaptive management regime can be imposed to ensure impacts and consequences remain within the performance criteria in any consent.

The Commission has recommended two formal reviews be undertaken: one after the first 5 longwalls and another after the next 4. This will cover the major environmental issues likely to be encountered during this project. The Commission has also recommended that each Extraction Plan be based on subsidence predictions that have been revised utilising site-specific experience and that these revised subsidence predictions are consistent with achieving the performance criteria in the consent during mining of the longwall in question."
As presented, the project predicts risk of reduced availability of water for the Central Coast Water Supply (CCWS) in some years if the subsidence impacts on the catchment coincide with adverse climatic conditions. The maximum predicted impact on catchment yield is 300 ML/y.

The Commission has recommended that there be no net impact on potential catchment yield from the mining operation and that the maximum predicted impact should be offset by return of suitably treated water to the catchment side of the CCWS system for the period during which subsidence may impact on the Project Area catchments.

The project presents an array of water supply risks to landowners in the Project Area. The Commission has recommended a number of conditions to ensure that potential impacts are properly investigated and that landowners receive prompt compensatory supply in the event of problems.

The project will have impacts on the morphology of streams within the Project Area. These impacts are predicted to be no greater than ‘minor consequences’, unless a flood event happens to coincide with a period of particular vulnerability for a section of stream undergoing subsidence changes.

The Commission considers that, as the impacts are likely to lie within expectations for normal variation for the Project Area streams, the performance criteria should be set at ‘minor consequences’, with a requirement to return impacted streams to an equivalent or better condition than their pre-subsidence condition.

The project will have some impact on flood levels and behaviour. With one exception these are considered to be manageable with standard approaches. The exception is increased delays for emergency access to some properties in major floods.

The Commission has recommended that individual emergency access and evacuation plans be prepared in consultation with the owners for each of these at-risk properties as well as Wyong Shire Council.

The project will undermine or potentially cause subsidence impacts to a substantial number of residences (some 245) and an array of other public and private infrastructure. For most of these structures the subsidence impacts are predicted to be small, the strategies for managing the subsidence impacts are well developed and, within the statutory concept of the Mine Subsidence Districts and statutory compensation scheme, are well understood.

The Commission has recommended some improvements to the performance criteria for built infrastructure and that some other types of infrastructure need to be included in the relevant provisions.

Impacts from the surface facilities on noise and air quality are expected to be both minor and manageable. Where necessary, recommendations have been included to address the residual impacts.

Potential biodiversity and aquatic ecology impacts have been reduced by removal of the eleven western longwalls under the steeper terrain in the Jilby SCA that were included in the previous version of this project. The Commission is satisfied that the draft consent conditions attached to the Department’s PAR deal adequately with impacts on biodiversity and aquatic ecology.”
DPE provides an overview of the PAC1 findings in Part 2 of their Addendum report, February 2017. Unfortunately, this overview by DPE considers only Section 5 (Recommendations) of the PAC1 report. That Section 5 does not fully express the findings of PAC1, not even those expressed in the Executive Summary reproduced above. I discuss relevant parts of the DPE Addendum Part 2 documentation in Section 4.3 below.

In a process which I do not fully understand and which appears illogical, but must flow from the DPE Residual Matters Report of September 2017, the PAC1 recommendations appear to have been reduced to four considerations summarised in a letter from DPE dated 30 June 2017. In that letter, DPE requested a response to four items in relation to PAC2. These four items are:

- Compensatory water supply system;
- Noise impacts;
- Nikko Road; and
- Economic data.

Logically this means that items (ii), (iii), (iv), (v) and (viii) of the PAC1 Executive Summary, set out above, have all been reduced to the package called "Compensatory water supply system". Subsequent to this, "Compensatory water supply system" was reduced to an agreement "that repatriated water would only be for CCWS purposes and that water should be returned as close as possible to the CCWS's water supply off take in Wyong River". This decision meant that no compensatory water would be supplied within the catchment of Jilliby Jilliby Creek (see Figure 1).

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3 The reason why I say illogical is that there are no changes to the groundwater and surface water impacts between the submissions addressed by PAC1 and PAC, so all the PAC1 findings in regard to water must remain valid.
6 Central Coast Water Supply.
Figure 1: Location of "Compensatory water supply system".

It is simply a matter of fact that this proposed compensatory system addresses only item (ii) of PAC1. No consideration is given to:

- The array of water supply risks to landowners in the Project Area (item (iii))
- Impacts on the morphology of streams (item (iv))
- Impacts on flood levels and behaviour (item (v)); and
- Impacts on aquatic ecology and biodiversity upstream of the Wyong River return site (item (viii)).
4. PROBABLE IMPACTS ON THE GROUNDWATER AND STREAM BASE-FLOW SYSTEMS

4.1 Impact on groundwater extraction by bores

I sought to explain the mechanism whereby bore extraction would be affected in Section 4.3 of my report to PAC2 (P012.R1, reproduced here as Appendix B). As explained in Section 2.2, above, nothing has changed since that time, so I need make no changes to my analyses.

In respect to water supply risks to landowners, I note that the Mackie report of September 2012 listed 37 registered bores and wells within 2km of the proposed mine plan footprint7. I have extracted from that listing bores which produce water from the "hard rock" (as opposed to alluvial soils) and which produce good quality water with yields of up to 5L/s. As shown in Figure 2, seven of these bores are directly above the mining area and yields will be substantially reduced, and one is so close to the eastern edge that it will certainly be affected.

Obviously any future bores which land owners may wish to drill in the valley of Jilliby Jilliby Creek would probably be useless.

The point is that the existing bores represent a resource which to date may only have been tapped at a few locations. But it is a resource of value which could be tapped at many more locations. From my understanding of words of the NSW Aquifer Interference Guidelines, such destruction of a groundwater resource for more than 50 years should be unacceptable.

Figure 2: Existing bores producing groundwater from hard rock (from Mackie 2012).

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7 The September 2012 and February 2013 reports state there are 12 NOW registered bores "within the area of subsidence".
The above data and analyses, and the conclusions in the revised Mackie report of February 2013, lead me to think that the following findings of PAC1 are not valid:

However, the argument put by both the Proponent and NOW is that the current registered bores and wells do not intercept aquifers that would be subject to these drawdown pressures and that there is no impact beyond level one in the NSW Aquifer Interference Policy.
The Commission considers that the weight of evidence in this case favours the view that drawdown will be limited.

4.2 Stream base-flows

The changes to flow directions given by the Proponent’s analyses (see Figures 2 and 3 taken from my report of June 2013) constitute significant changes to the groundwater regime. These pressure drops within the rock must reflect in pressure decreases within the shallow alluvium within the Dooralong Valley, and these decreases, in turn, cause decreases to base-flows to Jilliby Jilliby Creek.

Computed mine inflows reach about 1.5ML/day in Year 6 and are up to 2.5ML/day for 20 years after Year 18. The EIS notes that these calculations do not include flows from fracture zone that could increase inflows by about 0.5ML/day.

The EIS is silent as to where this water comes from. It implies that it would largely come from water stored in the ground, but this avoids the fact that water stored in the ground comes from somewhere, and is in equilibrium with natural recharge.

While no groundwater engineer can define precisely what portions of what rivers will be affected, it is, by virtue of Figure 1, reasonable to conclude that Jilliby Jilliby Creek will be the dominantly affected river system. I cannot say, with confidence, how many years it will take for the impact of underground extraction to reflect in surface flows.

However, it is not a question of whether there will be any impact on base-flows, it is only a question of how long will it take for the impacts to become significant and be noticed. It is likely to be less than the operational life of the mine - let alone the post-mining recovery period.

It is valid to compare expected mine inflow with the flow records of Jilliby Jilliby Creek (see Appendix B). It is readily seen that 2.5ML/day of mine inflow is more than half the average flow of Jilliby Jilliby Creek and is greater than the flows recorded for 40% of the time since 1972. Therefore, periods of low flow in the creek will be of greater duration in future, assuming climatic conditions similar to those experienced since 1972.

I would expect that reduction in groundwater pressures, redirection of groundwater flows downwards towards the mine, and reduction in stream base-flows would have an impact on aquatic ecosystems, but I acknowledge that this is a scientific area outside my expertise.
4.3 Some comments on DPE overview of PAC1 requirement in respect to groundwater and surface water

4.3.1 The report

As introduced in Section 3, above, the DPE Addendum Report, Part 2, of February 2017 gives the Departments "Overview of Commission’s First Review" (June 2014). In Table 14 DPE gives the "Department's Consideration and Action" in respect to the PAC1 Recommendations.

4.3.2 Base-flow losses

In regard to potential losses of base-flow from impacts on groundwater, DPE states:

"As requested by the Commission revised estimates of baseflow losses were provided in WACJV's response to the Commissions review report (see Appendix F) and subsequently reviewed by DPI Water."

The cited WACJV document gives the following table:

<table>
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<th>Project Year</th>
<th>Vertical leakage (ML)</th>
<th>Loss to crack storage (ML)</th>
<th>Shallow alluvial transfers (ML)</th>
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<td>0</td>
</tr>
<tr>
<td>3 - Construction</td>
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</tr>
<tr>
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Comparing this table with the calculations given in the Mackie report at Figure E19 suggests to me that the units in the 1st and 2nd columns of the table are incorrect, because in Year 20, for example, the Mackie plot show mine inflow in the range of 2.2 to 2.4ML/day, whereas Table 1 shows vertical leakage of 0.0148 ML per day.

Try as I may I cannot understand Table 1 reproduced above, and I consider that it is an inadequate response to the requirement of PAC1.

Furthermore, the WACJV document continues to state: Vertical leakage, additional crack storage and alluvial transfers resulting from the Project are predicted to have only negligible effect on baseflow.

In my understanding this statement contradicts fundamentals of groundwater physics as encapsulated in the Mackie 3D modelling and in simple 2D modeling I did for my submission to PAC in 2010 (see Appendix A). Furthermore, it contradicts the following statement in Mackie (February 2013):

Given a measure of uncertainty in respect of permeability and effective porosity of the alluvium at a local scale, a conservative approach is considered to be appropriate. Accordingly, 300ML per annum could be redirected from runoff and baseflow contributions to temporary storage within the alluvial lands.

If water is redirected from baseflow contributions this must represent a significant reduction in baseflow.

4.3.3 Bore impacts

In regard to the PAC1 recommendations regarding impacts on privately owned bores and burden of proof, the DPE response is:

The Department has recommended new conditions for a comprehensive water monitoring program which would include monitoring of groundwater and specifically requires the program to monitor and report on mine-induced changes in groundwater yield/quality against background, in particular, on groundwater bore users in the vicinity of the site.

In my opinion, any reasonable understanding of the physics of groundwater impacts will lead to the conclusion that the above statement is of no value in respect of landowners who lose their bore water yields. Once the water is gone it will not come back in 50 to 100 years. This is not a theoretical viewpoint, it is what is documented to have happened to at least 5 production bores in the area above Tahmoor Colliery near Picton, NSW.8

8 Pells Consulting Report M032. R1, April 2017. Report on the Water Levels of Thirlmere Lakes. This report is in the public domain having been made available at a public meeting in Picton, and having been made available to NSW Department of Planning & Environment.
This same philosophy of implementing monitoring systems, as if those will solve a
real impact, is repeated by DPE in respect to Impacts on Stream Morphology, Water
Quality and Porter’s Creek Wetland. In my opinion, this is not reasonable where there
is no way to mitigate such impacts, as is the situation here.

If the wise persons of our Society deem it appropriate for the Wallarah 2 project to
proceed then there should be open, and brutally honest, statements as to the likely
impacts so that the community is fully informed.

5. CONCLUDING COMMENTS

i. No additional factual data of substance, in respect to the hydrogeology of the
Wallarah 2 project site, have been made available since the first submission to
the PAC in 2010.

ii. No additional groundwater modelling has been undertaken since that given in
Appendix H of the EIS in 2013.

iii. Groundwater modelling in the Proponents report (Mackie) of September 2012
is the same as in the report of February 2013. Yet despite the absence of any
additional data, or any additional 3D modelling analyses, there are substantial
differences in the interpretations given in these two reports.

iv. The groundwater modelling provided by the Proponent shows changes in
seepage directions, and associated equipotential pattern, which demonstrate
that there will be substantial impacts on the groundwater systems, particularly
the ‘hard rock’ system, and that these changes will cause significant decreases
in, or total loss of, yields from existing bores above the footprint of the mine
and extending beyond the perimeter. This is acknowledged explicitly in the
Mackie report of February 2013.

v. The changes set out in Item (iv) above mean that there will be negative
impacts on base-flows to the creek systems, particularly Jilliby Jilliby Creek.

vi. I cannot determine from the Mackie report the basis of the 270ML per annum
from Jilliby Jilliby Creek. What is clear is that from year 10 to year 30, about
730ML to 880 ML per year will be entering the mine from the groundwater
system. The figure could be many times higher if actual rock mass
permeability values are higher than those adopted by Mackie.

vii. In my opinion, it is highly probable that losses from the surface water system
will be much greater than the stated 270ML per year.

viii. If the water entering the mine is considered to be disconnected from the upper
rock, alluvium and surface water regimes, as per the Proponent’s view, then,
logically, it will be impossible to know if a 270ML compensatory scheme is
sufficient. This is because the losses from surface and near surface water
regimes are not measurable; only the ‘disconnected’ quantities entering the
mine are measurable.

ix. In my opinion the Proponents view set out in Item (viii) is scientifically
inappropriate for the extended time period of the life of the mine and the slow
groundwater level recovery after mining is completed.
My study of the documentation since the PAC1 Review Report of June 2014 is that the PAC questions and recommendations have not been properly addressed by the Proponent and DPE. It appears that many of the matters raised by PAC1 have been lost, forgotten or ignored.

The proposed compensatory system addresses only item (ii) of PAC1 Executive Summary. It provides no compensation for:

- The array of water supply risks to landowners in the Project Area (item (iii));
- Impacts on the morphology of streams (item (iv));
- Impacts on flood levels and behaviour (item (v)); and
- Impacts on aquatic ecology and biodiversity upstream of the Wyong River return site (item (viii)).

Yours faithfully

PHILIP PELLS
FTSE BSc(Eng) MSc DSc(Eng) FIEAust MASCE
APPENDIX A

PELLS POWERPOINT PRESENTATION OF OCTOBER 2010
WALLARAH 2
PAC Presentation

Assessment of Groundwater Impacts
28 October 2010
Flow through uniformly permeable material
Uniform flow through permeable material overlying impermeable strata

Perched water table over impermeable strata. Separated from main water table

Stratigraphy

TERRIGAL FORMATION (250m)

MATONIA CLAYSTONE (60-110m)

TUGGERAH FORMATION (200m)

MUHOMAR CONGLOMERATE (70-90m)

DOORALONG SHALE (50-70m)

Australasian Northern Coal (Up to 8m)
Groundwater Investigations – Emergency Town Water Supply
Gosford-Wyong Councils Water Authority
Joint Water Supply Scheme
(paper by L Cook, August 2009)

"Exploration in the Terrigal Formation has resulted in the
development of 4 borefields of which 3 are operational and
have provided up to 10% to 15% of the LGA's daily water
requirements during emergency dry periods".

"The interpreted presence of extensive and pervasive structural
discontinuities, the occurrence of laterally extensive
transmissive sandstone units, and groundwater recovery
characteristics noted from aquifer testing suggests large areas
of influence of these borefields".

BASIS OF GROUNDWATER ASSESSMENT

Assessment of the potential impacts of the
proposed Wallarah 2 longwalls on the
groundwater regime is based primarily on a
report by Mackie Environmental Research
(Mackie) dated October 2009.
KEY ASSUMPTIONS IN MACKIE MODEL (1)

There are, in effect, no joints, faults or bedding defects within most of the rock strata above the coal seam, and therefore no pathways for water flow, other than directly through the pore space within the sandstones, siltstones and claystones.
KEY ASSUMPTIONS IN MACKIE MODEL (2)

The permeability values for most of the strata above the extracted longwalls, and within the Confined Zone, are equal to the pore space permeabilities of the rock.

Hence, Mackie have adopted permeability values between 10 times and 100 times lower than those measured in the Cooranbong study and in the Wyong groundwater study.

PERMEABILITY VALUES

<table>
<thead>
<tr>
<th>UNIT</th>
<th>MACKIE ADOPTED</th>
<th>LAB MEASURED</th>
<th>COFFEY FIELD</th>
<th>PACIFIC POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HORIZONTAL</td>
<td>(Mackie)</td>
<td>MEASURED</td>
<td>(Forster 1997)</td>
</tr>
<tr>
<td></td>
<td>m/sec</td>
<td>m/sec</td>
<td>[Log Mean]</td>
<td>m/sec</td>
</tr>
<tr>
<td>Alluvium</td>
<td>5.8 x 10^{-5}</td>
<td>580</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Terrigal Formation</td>
<td>2.4 x 10^{-6}</td>
<td>0.0024</td>
<td>3.8 x 10^{-4}</td>
<td>4.3 to 6.3 x 10^{-6}</td>
</tr>
<tr>
<td>Patonga Claystone</td>
<td>2.1 x 10^{-6}</td>
<td>0.0021</td>
<td>1.7 x 10^{-4}</td>
<td>3.3 x 10^{-4}</td>
</tr>
<tr>
<td>Tuggerah Formation</td>
<td>3.6 x 10^{-6}</td>
<td>0.0036</td>
<td>3.8 x 10^{-6}</td>
<td>4.3 to 6.3 x 10^{-6}</td>
</tr>
<tr>
<td>Musmorah Conglomerate</td>
<td>3.9 x 10^{-6}</td>
<td>0.0039</td>
<td>4.8 x 10^{-11}</td>
<td>4.3 to 6.3 x 10^{-8}</td>
</tr>
<tr>
<td>Dooralong Slate</td>
<td>2.3 x 10^{-6}</td>
<td>0.0023</td>
<td>1.2 x 10^{-4}</td>
<td>3.3 x 10^{-3}</td>
</tr>
<tr>
<td>Coal Seam</td>
<td>5.8 x 10^{-9}</td>
<td>0.059</td>
<td>2.8 x 10^{-8}</td>
<td>1.5 x 10^{-9} to 1.9 x 10^{-11}</td>
</tr>
<tr>
<td>Below Coal</td>
<td>1.2 x 10^{-10}</td>
<td>0.0012</td>
<td>0.5</td>
<td>4.7 x 10^{-6} to 2.2 x 10^{-3}</td>
</tr>
</tbody>
</table>
KEY ASSUMPTIONS IN MACKIE MODEL (3)

The findings are almost completely dictated by two sets of input parameters, namely:

- the assumed permeabilities for the natural strata prior to mine extraction, and in the Confined Zone that is deemed not affected by mining, and
- the thickness of two zones whose permeabilities are increased by mining, namely, the zone directly above extraction (220m assumed by Mackie) and the Surface Zone where there is increased vertical permeability.
SCT PREDICTIONS

ROCK FAILURE MODES

- None
- Shear fracture and reactivation
- Bedding shear and reactivation
- Tension fractures reactivated in shear
- Tension reactivation of shear fractures
- Tension fracture
- Tensile failure of bedding and reactivation in tension
- Pre-existing joint or cleat shear reactivation
- Pre-existing joint or cleat tensile reactivation
Figure 2.35 Overburden Vertical Permeability Profile for the Valley case
MACKIES ADOPTED RECHARGE VALUES

- Rock near the surface 0.15mm/year
- Alluvium 50mm/year
- Coastal Sands 90mm/year
MACKIE CONCLUSIONS

- There will be no impact on the alluvial groundwater systems anywhere above the mine (Jilliby Jilliby Creek, Little Jilliby Jilliby Creek and Wyong River).
- There will be minor changes in the shallow rock aquifer system with no impact in the Yarramalong Valley, and small impacts in the Dooralong and Hue Hue Valleys.

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- There will be minor changes in the shallow rock aquifer system with no impact in the Yarramalong Valley, and small impacts in the Dooralong and Hue Hue Valleys.
Farmer Brown’s 100m Deep Borehole

MINING COMPANY’S PREDICTION

After Mining
200 years to recover
STC Predictions of Impact on Groundwater Pressures

Figure 25  Pore pressure distribution during mining.
2D Model gives same result as Mackie 3D model for the same parameters
**IN SUMMARY**

- The conclusions of negligible impact are primarily the result of the input parameters adopted for the numerical modelling.
- The input permeability values are substantially lower than given by the available data, and hence the recharge assumption is far too low.
- Even with these mine-friendly assumptions the modelling predicts substantial impact on the groundwater pressures and flow directions.

Because of the major flaws in the modelling, it is not known what will be the impacts of Wallarah 2 on groundwater resources, and on groundwater that feeds into the streams of the Dooralong and Yarramalong Valleys.

However, all indications are that there will be substantial impacts on bores, and on groundwater feeding into the streams. This will reduce stream flows during low rainfall periods.

The present modelling does not allow a proper assessment to be made of the likelihood of draining normal runoff water from the creeks and streams.
APPENDIX B

PELLS CONSULTING REPORT OF 2013
1. INTRODUCTION

This report deals with potential impacts on groundwater and surface water resources arising from the proposed Wallarah 2 longwall coal mine. The report is based substantially on material presented in Appendices H and I of the Wallarah 2 Environmental Impact Statement (EIS), these being:

- H: Groundwater Management Studies
- I: Surface Water Impact Assessment

2. THE CRITICAL IMPORTANCE OF EXTREME EVENTS IN RELATION TO WATER RESOURCES

The assessments in the Wallarah 2 EIS in relation to groundwater impacts are made in relation to average rainfall conditions, and the same is true for some of the critical assessments in relation to surface waters. Such assessment in terms of averages warrants careful consideration.

In Australia, cities, towns and farms have typically developed in sympathy with water resources dictated by average climate conditions, i.e. average rainfall and average temperatures.

The people of Brisbane, Sydney, Adelaide, Perth, and Mt Isa, Bourke, Orange and Esperance, do not become concerned about water supplies in times of average rainfall. Neither do the farmers of the Darling Downs, Liverpool Plains, or the WA wheat belt.

However, in times of drought everything changes. Pictures of dead cattle and sheep, and even rabbits, fill our newspapers. Householders are reduced to using buckets to keep their gardens alive. Panic sets in, such that following the Millennium Drought, more than $12 billion dollars was spent on desalination plants in Sydney, Melbourne, Adelaide, Perth and the Gold Coast. As of 2012, when rainfall had returned to about average, many of these plants were mothballed.

The potential impacts of projects, such as Wallarah 2, on water resources should not be evaluated in relation to average climatic conditions. This is a class of problem defined by Nassim Taleb\(^9\),\(^{10}\) where “the average – the first order effect – does not matter”. He goes on to state “The notion of average is of no significance when one is fragile to variations”. In this regard Taleb reproduces a very old saying:

"Do not cross a river if it is on average four feet deep."

\(^{10}\) Nassim Nicholas Taleb (2013), *Antifragile*, Allen Lane.
3. THE MINE AND JILLIBY JILLIBY CREEK CATCHMENT

Figure 1 shows the catchment of Jilliby Jilliby Creek in relation to the mine footprint. It clearly shows that this catchment is the one most vulnerable to mine impacts.

Figure 1: Jilliby Jilliby catchment complete.
Photograph 1 shows the nature of Jilliby Jilliby Creek near the Public School, while Photographs 2 and 3 show the typical alluvial plain of the Jilliby Jilliby (Dooralong) Valley that is used for horse studs and general farming... The locations of Photographs 1 to 3 are shown in Figure 2

**Photograph 1:** Little Jilliby Jilliby Creek near the Public School; the river bed is incised about 3m below the flood plain.

**Photograph 2:** View to the SE of Photograph 1
**Photograph 3:** View to the north of Photograph 1. Jilliby Jilliby Creek is behind the trees in the distance.

**Figure 2:** Typical floodplain of Little Jilliby Jilliby Creek and Jilliby Jilliby Creek, showing locations of Photographs 1 to 3.

One of the important facets of this catchment is that just downstream of where it joins the Wyong River is the main pump station from which water is pumped to either Mardi Dam or Mangrove Creek Dam (see Figure 3B). Pumping rates over the past few years are shown in Figure 3A.
Figure 3A: Pumping rates from Wyong River since 2010

Figure 3B: Location of pumping station on Wyong River just downstream of confluence of Jilliby Jilliby Creek.
It stated in the EIS that it will take almost 40 years to complete all the planned longwalls. It must be realised that the workings will remain depressurised until the last longwall is completed.

Figure 4 gives the statistical analyses of the flows in Jilliby Jilliby Creek, upstream of the Wyong River, from records since 1972.

Figure 4: Statistics of flows in Jilliby Jilliby Creek, 1972 – 2013.

The median flow rate is 4.5 Megalitres per day (ML/day). However, the flow is less than 1ML/day for 24% of the time of record, and less than 0.1 ML/day for 10% of time.

These percentage values might not mean as much, to the lay reader, as the data in Figure 5 which shows the consecutive days, since 1972, when flows were less than 1 ML/day and 2 ML/day. It can be seen that for 190 days, flows were less than 2ML/day (less than half the average), and again for different periods of 180, 168, 166 and 135 days.
Figure 5: Consecutive days for which flow in Jilliby Jilliby Creek was less than either 1ML per day or 2ML per day.

The particular periods that are plotted in Figure 5 are summarised in Table 1 below.

### TABLE 1

**CONSECUTIVE DAYS OF LOW FLOW**

<table>
<thead>
<tr>
<th>Rank</th>
<th>Flow Condition (ML/d)</th>
<th>Days</th>
<th>Start Date</th>
<th>End Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt;2</td>
<td>190</td>
<td>31/07/1980</td>
<td>5/02/1981</td>
</tr>
<tr>
<td>2</td>
<td>&lt;2</td>
<td>179</td>
<td>10/03/2006</td>
<td>4/09/2006</td>
</tr>
<tr>
<td></td>
<td>&lt;1</td>
<td>164</td>
<td>19/10/1997</td>
<td>31/03/1998</td>
</tr>
<tr>
<td>3</td>
<td>&lt;2</td>
<td>168</td>
<td>17/04/2004</td>
<td>1/10/2004</td>
</tr>
<tr>
<td></td>
<td>&lt;1</td>
<td>146</td>
<td>8/08/1980</td>
<td>31/12/1980</td>
</tr>
<tr>
<td>4</td>
<td>&lt;2</td>
<td>167</td>
<td>17/10/1997</td>
<td>1/04/1998</td>
</tr>
<tr>
<td></td>
<td>&lt;1</td>
<td>129</td>
<td>30/01/1991</td>
<td>7/06/1991</td>
</tr>
<tr>
<td>5</td>
<td>&lt;2</td>
<td>135</td>
<td>25/01/1991</td>
<td>8/06/1991</td>
</tr>
<tr>
<td></td>
<td>&lt;1</td>
<td>112</td>
<td>25/11/1982</td>
<td>16/03/1983</td>
</tr>
</tbody>
</table>

While the flow records for Jilliby Jilliby Creek capture the Millennium Drought, they do not capture the more intense droughts of World War 2 (WW2), and the time of Federation. Figure 6, taken from Appendix H of the EIS, clearly shows how much more severe was the drought of WW2. This means that Figure 5, in all likelihood, does not capture the largest periods for which low flows occurred in the creek.
Figure A1: Rainfall residual mass plot for Wyee Gauge 061082 from 1900

Figure 6: Droughts in Wyong are shown by 113 years of rainfall records at Wyee. Downward slopes are periods of below average rain; the steeper the slope the more intense the drought; the longer the downward sloping period the longer the drought.

4. COMPUTED IMPACTS IN THE EIS ON GROUNDWATER AND SURFACE WATER

4.1 What the EIS states

In this Section 4 we simply take what is given by calculations presented in the EIS without critical assessment of the validity of the calculations. Critical assessment is given in Section 5, below. However, it is worth noting at this point that the computations in the EIS are probably, inadvertently, biased in favour of the mine. This is normal human behaviour and is not intended as a criticism of those who prepared the EIS.

4.2 Surface Water Impacts

Based on the 3D groundwater model, the EIS predicts mine inflows as given in Figure 6.
Figure 6: Computed mine inflows as given in the EIS.

It can be seen that computed inflows reach about 1.5ML/day in Year 6 and are up to 2.5ML/day for 20 years after Year 18. The EIS also notes that these calculations do not include flows from fracture zone that could increase inflows by about 0.5ML/day.

The EIS is silent as to where this water comes from. It implies that it would largely come from water stored in the ground, but this avoids the fact that water stored in the ground comes from somewhere, and is in equilibrium with natural recharge. A valid way to consider this matter is encapsulated in the following quotation from Dr Rick Evans, principal hydrogeologist of Sinclair Knight Merz, viz:

"There is no free lunch here. It's very simple — every litre of water your pump out of the ground reduces river flow by the same amount".

Australian Financial Review,
24 May 2007

While we cannot define precisely what portions of what rivers will be affected, it is, by virtue of Figure 1, reasonable to conclude that Jiliby Jiliby Creek will be the dominantly affected river system. We also cannot say, with confidence, how many years it will take for the impact of underground extraction to reflect in surface flows. However, it is not a question of if it will occur, it is only a question of how long will it take for the impact to occur. And as discussed in Section 5.2.2, below, the available evidence is that the impact will be far sooner than indicated in the EIS.

It is valid to compare the data in Figure 6 with the flow records of Jiliby Jiliby Creek. It is readily seen that 2.5ML/day of mine inflow is more than half the average flow of Jiliby Jiliby Creek and is greater than the flows recorded for 40% of the time since 1972. It is reasonable to assume that the periods of low flow in the creek (see Figure 4) will be longer in future under climatic conditions similar to those experienced since 1972.
This matter of overall water balance is incorrectly addressed in the EIS. On page 86 of Appendix I is the misleading statement that:

"It is possible that undermining of Jilliby Jilliby Creek may generate some additional groundwater storage which would be sourced from regional rainfall recharge, as well as surface runoff. The diverted water volume would represent less than 1% of the total licensed extraction volume for the area".

The inference from this statement is that the flow loss in Jilliby Jilliby Creek is of no consequence. But page (iii) of the same Appendix states that the flow loss may be 0.74 ML/day\textsuperscript{11}.

For 20% of the time since 1972, the flows in Jilliby Jilliby Creek have been less than 0.74ML/day and the truth is that a loss of 0.74ML/day will substantially change the low flow characteristics of Jilliby Jilliby Creek. As discussed below, this will be associated with a substantial change to the groundwater system in Dooralong Valley.

4.3 Groundwater Impacts

Figure E17 of Appendix H of the EIS gives calculations of the groundwater pressure regime around the mine under natural conditions, at the end of mining (Year 38). The plots are very difficult for non-specialists to understand, so the writer has set out to interpret them in practical terms.

Figure 7 is an annotated version of part of the EIS plot of natural groundwater conditions above the mining area. To interpret the plot the writer has added what are termed 'equipotential lines'. The easiest way for non-technical persons to think of an equipotential line is to understand that water will rise to the same level in any borehole, open only at the bottom, whose bottom is placed on that equipotential line. To turn this into more practical terms the writer has chosen three imaginary bores as shown on Figure 7, called Bores A, B and C. The water level in the bores is shown by the blue column for each bore. It can be seen that the two bores (B and C) on the 20m equipotential line rise to the same level, namely RL20m.

\textsuperscript{11} The document states 270ML per year, which is 0.74ML/day.
Figure 7: Pre-mining groundwater regime from Figure E17 of Appendix H of the EIS.

Figure 8 is the prediction in the EIS of the groundwater regime at completion of mining. Again, the writer has added selected equipotential and has included the same three bores (A, B and C) given in Figure 7. The water levels in these bores predicted at the end of mining are again shown by the blue columns. The drop in level for each bore is shown by the red column and as written on the figure. It can be seen that:

- the water level in Bore A drops 40m;
- the water level in Bore C drops 100m; and
- the water level in the relatively shallow, 70m deep, Bore B drops 12m.

Figure 8: Prediction in the EIS of the groundwater regime at completion of mining.
It is obvious that the above water level drops in bores are substantial and indicate significant changes to the groundwater regime. These pressure drops within the rock must reflect in pressure decreases within the shallow alluvium within the Dooralong Valley, and these decreases, in turn, cause the decrease in base flows to Jililby Jililby Creek that are discussed in Section 4.2, above.

It is therefore very clear from the modelling results presented in the EIS that there will be very substantial changes to the groundwater regime above the area of the proposed Wallarah 2 coal mine. Any other conclusion is simply dishonest to the computations given in the EIS.

5. COMMENTS ON THE GROUNDWATER MODELLING IN THE EIS

5.1 The Accuracy of Groundwater Models

The validity of any hydrogeological model, notwithstanding its extent, sophistication and cost, depends entirely on:

1. the accuracy of the permeability and storativity parameters for the ground strata,

2. the boundary conditions, including recharge from the surface and around the perimeter of the model, and

3. whether the model properly simulates three dimensional behaviour.

Numerical models always contain a significant degree of uncertainty because of uncertainties in respect of items 1 and 2 listed above, and inherent limitations of the methods of analysis within item 3 above.

In the case of the model run by Mackie for the Wallarah 2 project, the findings are almost completely dictated by two input parameters, namely:

(a) the assumed permeabilities for the natural strata prior to mine extraction, and in the Confined Zone that is deemed not affected by mining, and

(b) the thickness of the two zones whose permeabilities are increased by mining, namely, the zone directly above extraction (220m assumed by Mackie) and the Surface Zone (Forster 1995 Figure 1) where there is increased vertical permeability. \(^{12}\)

These facets are discussed in further detail below. However, the fundamental point that the writer makes is that the groundwater model for Wallarah 2 should have been run for a range of assumptions for the assumed permeabilities (point (a) above) and extent of fracturing above the longwalls, thereby giving ranges of:

- mine inflows,
- change of flow directions above the area of mining.

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\(^{12}\) This zone has been studied in some detail in the Southern Coalfields and was the cause for loss of water in the Cataract River and the Woronora Rivulet.
- downward loss of water from the alluvium of Dooralong Valley,
- probable drops in bore levels within Dooralong Valley, and
- decrease in base flow to Jilliby Jilliby Creek.

The reality is only one set of figures covering the above facets has been given in the EIS and this is misleading in respect to the probabilities of the mine impacts on groundwater and stream flows.

5.2 Specific matters in respect to the groundwater model

When the Wallarah 2 project was presented to the Planning Assessment Commission (PAC) in 2010, the writer provided a critique of the groundwater model that was provided by Mackie Environmental Research. There have not been substantial changes to the assumptions that were adopted by Mackie in 2010, compared with those presented in Appendix H of the EIS (September 2012). This is confirmed by a statement in paragraph E4 of Appendix H, namely,

"The 2012 model is identified as model W3. This model is very similar to the previously reported model W1 (MER, 2010)."

The only significant change in respect to assumed permeability values (hydraulic conductivity) is a change for "the Terrigal Formation in hilly terrain".

The following issues represent the uncertainties in the parameters adopted in the model. There are always such uncertainties and it is for this reason that a range of assumptions should have been presented in the EIS to allow proper evaluation of the risks to groundwater and surface waters.

5.2.1 Permeability (hydraulic conductivity) assumptions

The Mackie assessment of permeability values is based on the assumption that there are no significant fractures (joints, faults, dykes etc) in the Narrabeen Formation below the weathered near surface environment.

Leaving aside increases in permeability above extraction areas, there is a fundamental issue in respect to the use by Mackie of the permeability of intact core samples, as being a realistic measure of rock mass permeability.

The concept that groundwater flow through rock masses is normally dominated by fracture flow, and not substance (core) flow, is so well established in the civil engineering, tunnelling and mining professions that it does not warrant that this writer spring to its defence. All field permeability testing that has been done for dams, tunnels and coal mines in the Sydney Basin over the past 80 years was unnecessary if core permeability was the relevant measure.
All science and every experience in groundwater flow, down to depths of at least 500m, demonstrates that it is fracture permeability that matters and not core permeability. There are many references to support this contention with many being cited in the following recent publication:


The Mackie assumption as to the absence of fractures within the bulk of the Narrabeen sequence is also in contradiction to findings of a paper by Cook (2009) which are as follows:

"The bores intersected Terrigal Formation with a preserved thickness of up to 145m in the LGA. Extensive geological and geophysical bore logging delineated aquifers and enabled stratigraphic correlation within and between borefields................. Aggregate yields greater than 15 L/s were recorded from multi-layered aquifers in several bores.

Networks of nested multi-level hardrock and alluvial monitoring bores installed in the borefields revealed direct and indirect hydraulic connection between multi-layered hardrock aquifers with varying degrees of artificially induced vertical leakage from the overlying valley-fill systems during pumping."

The permeability values adopted for the Wallarah 2 model are given in Table 2 (taken from Appendix G of the EIS).

### TABLE 2
NARRABEEN FORMATION (PRE-MINING) PERMEABILITY (HYDRAULIC CONDUCTIVITY) VALUES ADOPTED BY MACKIE FOR THE WALLARAH 2 MODFLOW MODEL

<table>
<thead>
<tr>
<th>UNIT</th>
<th>HORIZONTAL</th>
<th>VERTICAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>m/day</td>
<td>m/sec</td>
</tr>
<tr>
<td>Terrigal Formation</td>
<td>$2.1 \times 10^{-5}$</td>
<td>$2.4 \times 10^{-10}$</td>
</tr>
<tr>
<td>Patonga Claystone</td>
<td>$1.8 \times 10^{-5}$</td>
<td>$2.0 \times 10^{-10}$</td>
</tr>
<tr>
<td>Tuggerah Formation</td>
<td>$3.1 \times 10^{-6}$</td>
<td>$3.5 \times 10^{-10}$</td>
</tr>
<tr>
<td>Munmorah Conglomerate</td>
<td>$3.4 \times 10^{-5}$</td>
<td>$3.9 \times 10^{-10}$</td>
</tr>
<tr>
<td>Dooralong Shale</td>
<td>$2.0 \times 10^{-5}$</td>
<td>$2.3 \times 10^{-10}$</td>
</tr>
<tr>
<td>LOG MEAN</td>
<td>$2.7 \times 10^{-10}$</td>
<td>$3.0 \times 10^{-11}$</td>
</tr>
</tbody>
</table>
Analysis of the field measurements from Coffey Partners International\textsuperscript{13} (Wyong), Pacific Power (Dooralong) and Mackie Environmental Research (Ulan) give the following log mean values for the Narrabeen Formation.

\begin{align*}
\text{Wyong and Dooralong} & \quad 3.37 \times 10^{-9} \\
\text{Ulan} & \quad 4.69 \times 10^{-7}
\end{align*}

It can be seen from the above data that the vertical permeability values adopted by Mackie for the Wallarah 2 model are between 100 and 1000 times lower than values suggested by the field testing.

These values apply to ground that has not been disturbed by subsidence effects and are used by Mackie in the so-called Constrained Zone that is considered to exist from 220m above the extraction level to the weathered portion of the Narrabeen Formation. Therefore, in essence, Mackie assumes that there will remain a 150m to 300m thick layer with a very low vertical permeability even after mining is completed. This assumption dictates the findings of the model. This assumption that there will be a Constrained Zone of unaffected permeability more than 220m above the level of extraction cannot be justified on the basis of data from the Southern Coalfields and at Ulan.

5.2.2 Major contradictions within the EIS

The assumptions regarding permeability in the Mackie 3D model are contradicted by calculations given in the MSEC/SCT report in Appendix F to the EIS. The calculations show some disruption of the strata throughout the 350m profile above the level of extraction.

Furthermore, Figures 2.28, 2.34 and 2.48 of Appendix F give the post-mining vertical permeability profiles for:
\begin{itemize}
    \item the Hue Hue 4 mining thickness case,
    \item the 'valley' case, and
    \item the 'forest' case.
\end{itemize}

These permeability profiles are very different from those adopted in the Mackie model, upon which groundwater impacts are assessed.

To demonstrate the very large differences between what the EIS states as being appropriate permeability ranges, and what has actually been used in the EIS to assess impacts on the groundwater regime, we have plotted, in Figure 9, the parameters used by Mackie (3D model) against the 'valley' case permeability ranges given in Appendix F.

We actually had to extend to the left of the plot given in Figure 2.35 of Appendix F in order to show the Mackie values.

\textsuperscript{13} The writer has ignored all the Coffey results that are presented simply as $<43.2 \times 10^{-5}$ m/day.
Figure 9 Permeability values from Appendix F of the EIS versus values used in groundwater impact assessment in Appendix G

The information summarised above indicates that the hydraulic conductivity values adopted in the Wallarah 2 model are substantially on the low side of reality. Therefore, the computed mine inflows, and the rate at which depressurisation progresses through the strata are substantially on the low side of reality.

Figure 10 summarises the progression of depressurisation through the strata from the Mackie model, a process still continuing after 38 years. If Mackie had adopted the parameters recommended in the previous chapter in same EIS then depressurisation would have been calculated as occurring much faster and to a much greater extent.
Figure 10 Depressurisation curves extracted from the plots of the Mackie 3D groundwater model given in Appendix G of the EIS

Therefore, the flow quantities and extents of depressurisation discussed in Section 4, above, must be viewed in the context that they are non-conservative in respect to impacts on groundwater and surface waters. Therefore, the significant impacts actually shown by the Mackie model, as outlined in Section 4, above, will in all probability be much more adverse.

5.2.3 Absence of critical parameters for the Mackie 3D groundwater model

There is a matter that will be well beyond the lay-persons understanding that must be documented in respect to the Mackie 3D model.

Mackie has properly used the version of MODFLOW that addresses the impact of desaturation in the strata on reducing permeability values. This reduction in permeability has a very important impact on the computed mine inflows and the rate of depressurisation.

There is no information in the EIS, and in particular in Appendix G, that sets out what assumptions have been made in the model in respect to permeability reduction in the desaturated zone in the goaf. Therefore, it is impossible for a measured review to be made of the model results.

In addition to presenting the material parameter assumptions, it would have been proper for the assumptions to be validated against field data from Mandelong Colliery, where there has been substantial depressurisation above the extracted longwalls, viz:

- Mining of the longwall panels has however resulted in depressurization of the deeper overburden.
- Whereas at some depths this may be a temporary depressurization due to bedding parting, at deeper levels the bedrock has probably been permanently...
depressurized/dewatered when mining intersected a fault and/or goafing provided hydraulic connection with the mine. The alluvium and shallow overburden has however not been impacted with the exception of site BH22, as stated.

The data also indicates that the Great Northern Seam to the south of the Mandalong Mine may have been depressurized as a result of mining in the area, but that the deeper Fassifern Seam has not been impacted.

6. ADAPTIVE MANAGEMENT AND MONITORING

In recent years a trend has developed for adopting, so-called, Adaptive Management to deal with uncertainties in respect to future impacts on groundwater and surface water systems from mining operations. This developed to the point that adaptive management involved changing the targets that were established in environmental impact statements in response to what actually occurred in the field. This was done in conjunction with the establishment of groundwater monitoring systems and the visual and flow monitoring in creeks and rivers.\(^1\)

The fallacy of this approach was determined by the Land and Environment Court in the recent case (2013) in regard to the proposed expansion of Berrima Colliery. The judges found as follows in respect to Adaptive Management:

Adaptive management regime

The intention of the Water Management Plan is to provide an adaptive management regime, under which management actions would be modified in response to the results of the monitoring program. Preston CJ held that,

\[
\text{"in adaptive management, the goal to be achieved is set, so there is no uncertainty as to the outcome and conditions requiring adaptive management do not lack certainty, but rather they establish a regime which would permit changes, within defined parameters, to the way the outcome is achieved."}
\]

It follows that it is necessary for there to be precise limits imposed on the cumulative operations of the colliery.

They went on to quote Judge Preston in a previous case in relation to the need for implementation of the precautionary principle when there is uncertainty in respect to future environmental impacts. They stated:

Preston CJ held in Telstra at [150], the following, in regard to the precautionary principle and the shifting of the evidentiary burden of proof:

\[
\text{"If each of the two conditions precedent or thresholds are satisfied – that is, there is a threat of serious or irreversible environmental damage and there is the requisite degree of scientific uncertainty – the precautionary principle will}
\]

\(^{1}\) For example: responses to cracking of Cataract Creek and Waratah Rivulet in the Southern Coalfields; draining of swamps at Springvale Colliery in the Lithgow area, complete depressurisation of the groundwater systems at Berrima Colliery and Ulan Colliery, and major cliff collapse at Dumbarton Colliery, Nattai North Colliery, Katoomba, Newnes and Baal Bone Colliery

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be activated. At this point, there is a shifting of an evidentiary burden of proof. A decision-maker must assume that the threat of serious or irreversible environmental damage is no longer uncertain but is a reality. The burden of showing that this threat does not in fact exist or is negligible effectively reverts to the proponent of the economic or other development plan, programme or project:

We are satisfied that the precautionary principle is activated as the risk of significant environmental harm currently remains uncertain.

The judges determined that the proposed expansion of Berrima Colliery should not proceed on the basis of Adaptive Management as was proposed by the colliery owners.

The writer considers that the legal findings summarised above should be taken into account in respect to the proposed Wallarah 2 project, because future impacts on groundwater and surface waters are likely to be substantial to both town water supplies in drought periods, and to agriculture under even average climatic conditions. Furthermore, there are substantial uncertainties in respect to these impacts, making it probable that the impacts will be greater than assessed in the EIS.

Yours faithfully

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APPENDIX C

EXTRACT FROM PART 1 OF TWO PART PAPER ON GROUNDWATER FLOWS AND PRESSURES
3.4 USE OF THE PRINCIPAL OF EFFECTIVE STRESS FOR STABILIZATION OF NATURAL SLIPS

The importance of the effective stress principle was shown elegantly by Skempton in a variation to his infinite slope teachings. He pointed out a matter that seems nowadays easily forgotten, namely that a change in flow direction may be all that is needed to increase effective stresses, and hence stability. His example, as per Figure 15, is drainage for stabilization of shallow semi-planar slides, typical of many natural landslides.

![Diagram of Shallow Landslide and Downslope Trench]

**Figure 15:** Stabilization of shallow landslide typical of natural hillsides (as per Skempton 1967).

By means of a version of Figure 16, Skempton made the point that downslope trenches are substantially effective even if the phreatic surface (water table) is not lowered, simply because of changes in flow directions, and associated changes in the shapes of the equipotentials.

That this key point is often missed in current geomechanics is shown by recent book “Guidelines for Evaluating Water in Pit Slope Stability” (Beale and Read, 2013). In the 82 page chapter on implementation of slope depressurisation systems, there is not one illustration showing equipotentials, and no discussion of the relevance of changes to equipotentials. This chapter confuses flow quantities, dewatering, draw-down, and depressurisation. When considering slope stabilization the quantity of water extracted from an open pit, or a discrete part of a slope is irrelevant, and focus on drawdown of the phreatic surface is simplistic and secondary. All that matters is reduction in pore and joint water pressures.
Figure 16: Flow lines and equipotentials with no drawdown of phreatic surface; sliding surface 4m below initial water table; drain spacing 20m.

This understanding is taken further in Part 2 of this paper where consideration is given to depressurisation for stabilization of landslides and open pit slopes.