Thirlmere Lakes Inquiry – Review of the Final Report of the Independent Committee

NSW Chief Scientist and Engineer

February 2013

NSW GOVERNMENT | Chief Scientist & Engineer

The Hon. Robyn Parker, MP
Minister for the Environment
Minister for Heritage
Level 32 Governor Macquarie Tower
1 Farrer Place
SYDNEY NSW 2000

Dear Minister

Review of the Final Report of the Independent Committee – Thirlmere Lakes Inquiry

In November 2012, you requested that I review the Final Report of the Independent Committee – Thirlmere Lakes Inquiry. The review has now been completed and I am writing to inform you of the outcomes and recommendations of next steps.

We reviewed the Inquiry Report and provide comment on the specific findings and recommendations provided by the Independent Committee. We have assessed whether there was clear evidence within the Inquiry Report for the findings and provide comment on next steps in regards to the Inquiry Report and the Committee Recommendations.

The Independent Committee should be congratulated on its contribution to the body of knowledge regarding the Lakes given the time constraints, limited resources and considerable volume of previous work and data that was analysed. The Committee should also be congratulated on its approach to addressing specific concerns of the community in the Inquiry Report.

The Inquiry highlights the complexity of the Thirlmere Lakes catchment and surrounding region, and presents the difficulties associated with attributing the observed variations in lake levels to specific environmental, geological, and human factors. It is clear from the Inquiry Report and other studies conducted on the Lakes (Pells Consulting, NSW Office of Water and Xstrata Consultants) that there are significant data gaps that need to be filled if we are to understand not only the Lakes system but how various factors, both environmental and human, have impacted the Lakes.

The Committee has produced an important and extensive report that goes a long way to clarify our current knowledge of the area and also the gaps in knowledge. Given this and the high level of interest and tension in the general community around this issue, we recommend that additional editorial work be undertaken to assist in making the report more accessible to community readership.

The community has significant concerns regarding the current status and future of Thirlmere Lakes and there should be an on-going forum where questions can be asked, research commissioned, data contributed and information shared in a manner that encourages openness and transparency. There, for example, could be a formal role for the community on a Plan of Management Consultative Group for the National Park Plan of Management and on a Supervisory Committee to oversee future science and research activities for the Lakes.

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If you have any further questions please don't hesitate to contact Dr Chris Armstrong, Director, Office of the NSW Chief Scientist and Engineer on 9338 6745 or chris.armstrong@chiefscientist.nsw.gov.au.

Yours sincerely

Mary O'Kane
NSW Chief Scientist and Engineer

28/2/13

Executive Summary and Recommendations

In November 2012, the Minister for the Environment, the Hon Robyn Parker MP, requested that the NSW Chief Scientist and Engineer review the Final Report of the Independent Committee, Thirlmere Lakes Inquiry.

This review of the Inquiry Report was conducted by assessing whether there was evidence in the Inquiry Report for the findings made and a clear link between those findings and the recommendations. The Review Report provides a discussion of the Inquiry Report as well as the specific Findings and Recommendations. Recommendations on potential next steps for the Office of Environment and Heritage are provided below.

The Inquiry Report highlights the complexity of the Thirlmere Lakes catchment and surrounding region, and presents the difficulties associated with attributing the observed variations in lake levels to specific environmental, geological, and human factors.

Overarching editorial comments

The extensive and complex nature of the Inquiry Report has led to some inconsistencies, typographical, referencing and grammatical issues many of which could have been overcome with additional editorial resources. These issues can lead to some confusion with regards to the interpretation of some of the conclusions and findings in the Report. Definitive statements are often made in the Inquiry Report, sometimes on topics where there appears to be significant uncertainty in the data and information, or where the background information provided in the Inquiry Report to support the definitive statement is sparse. This editorial issue should be addressed, as it could lead to misinterpretations.

The Inquiry was undertaken in part to address community concerns regarding the impact of mining on the Lakes, given the high level of public interest in the outcomes of this Inquiry, it is important that the findings are communicated in manner designed to maximise community understanding.

Uncertainties

The Inquiry undertook a desktop analysis of the situation in the Lakes including bringing together and analysing previous work (Pells Consulting, NSW Office of Water and Xstrata consultants). The Committee also conducted some field work to generate data for analysis.

These calculations and analyses do not appear to include an assessment of the statistical uncertainties and error. Inclusion of these uncertainty measurments would provide important contextual information to the discussion in the Inquiry Report.

Ongoing community engagement

The inclusion of a community representative in the membership of the Inquiry Committee is welcomed. Consideration should be given to how to engage the community in an ongoing way in the discussion about the technical issues and characteristics of the Lakes and surrounding area as new information emerges. Engaging with the community is particularly important given that the scientific and engineering factors are complex, where the modelling work has produced mixed results to date, and where community stakeholders themselves own infrastructure (e.g. water bores) that can contribute data.

Many different parties have strongly held views regarding the Lakes and their current low levels. Engagement of the community in the process of collaborating with experts, government, and industry on the scientific research questions regarding the Lakes is important to improve understanding and dispelling any misconceptions.

Inquiry Recommendations

The Inquiry Report recommendations include studies in the areas of socioeconomics, geomorphology, geohydrology, hydro-metrology, hydrology and ecology, to be overseen by a Supervisory Committee. The Inquiry Report has also put forward priorities and ordering of the activities.

The Inquiry Report makes it clear that there are data gaps that have limited the Committee's ability to make conclusions regarding the impact of various factors influencing lake levels. The limited data available for Thirlmere Lakes and the surrounds leads to a situation where there is uncertainty around the level of contribution of the factors (e.g. climate, mining, groundwater flow and extraction) implicated in the current low water level of the Lakes. More data will increase the statistical significance of the measurements and analyses, and increase our understanding of the interactions between factors both above and below ground influencing the Lake system.

The Inquiry recommends that a review of the Plan of Management for the Thirlmere Lakes National Park be conducted. The current Plan of Management was developed in 1997 and is due for review in 2014.

Further the Inquiry recommends that a 'water mound' be investigated as a potential for remediation. It is felt that a better understanding of the Lakes and groundwater system would be required to understand whether the proposed remediation, and required infrastructure, would have a net benefit for the Lakes and surrounding region.

CSE Recommendations

CSE Recommendation 1: If editorial changes to the Inquiry Report can be made, that work be undertaken to address:

- review of the language in relation to definitive descriptions and uncertainties;
- typographical errors, referencing, grammatical issues and inconsistencies; and
- that the data and analyses that led to the Findings and Recommendations are clearly identified.

If editorial changes to the Inquiry Report cannot be made, then the key findings should be synthesised into a short concise document that the public can easily access and digest. This summary document would be a companion to the Inquiry Report, setting out the data that led to the findings, conclusions and the recommendations.

CSE Recommendation 2: The sections of the Inquiry Report where the Committee has undertaken measurements and calculations would benefit by an indication of, or discussion of, the uncertainties and statistical significance of the data.

CSE Recommendation 3: Any future coordinated approach to the science, engineering and research requires a recognised role for the community, the mining company and other stakeholders. Whether these formal roles are on a Plan of Management Consultative Group, or on a Supervisory Committee, there should be an on-going forum where questions can be asked, research commissioned, and data contributed, and information shared in manner that encourages openness and transparency.

CSE Recommendation 4: That the Supervisory Committee recommended by the Committee be brought together to refine and coordinate the data collection and research program for Thirlmere Lakes. The Supervisory Committee could include key stakeholders (including residents, National Parks and Wildlife (NPWS) officers, council, and Xstrata) and experts. This should draw on the significant work from the Inquiry (recommendations and realisations) and other studies, to fill data gaps and undertake further modelling of the Lakes once sufficient data is available.

CSE Recommendation 5: Investigating the installation of automated water level monitors and rain gauges should be undertaken to begin collecting data on Thirlmere Lakes as suggested by Gilbert & Associates (2012), a consultant for Xstrata, and the Inquiry Report (Section 9.2.3). These recommend that automated water level monitoring in each lake, rain gauge facilities, and other hydrology meters should be established within the catchment. The monitoring devices should be Internet Protocol-enabled to allow for near to real time data and this data could be made available online through a government website (e.g. Office of Environment and Heritage, NSW Office of Water or NPWS) to provide data to the community, government and researchers.

CSE Recommendation 6: That the review of the Plan of Management for Thirlmere Lakes National Park be brought forward (the review is currently due in 2014). The Plan of Management should integrate any research programs that emerge from the Inquiry or the subsequent Supervisory Committee to improve the management of the Lakes.

CSE Recommendation 7: Remediation options should be investigated, including the 'water mound', after further research is conducted on the Lakes. Investigation of remediation options could form a component of the research program overseen by the Supervisory Committee.

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Thirlmere Lakes Inquiry – Review of the Final Report of the Independent Committee

1. Introduction

In November 2012, the Minister for the Environment, the Hon Robyn Parker MP, requested that the NSW Chief Scientist and Engineer review the Final Report of the Independent Committee, Thirlmere Lakes Inquiry. It was requested that the review cover:

- veracity of the findings of the Committee with specific reference to the extent to which the findings are supported by the data presented within the Report.
- whether the recommendations of the report are an appropriate course of action for Government to consider from a scientific perspective.

2. Background and context

Thirlmere Lakes are a wetland that is believed to be 15 million years old (NSW Office of Enviroment and Heritage 2011). The Lakes are located within the Thirlmere Lakes National Park, part of the Greater Blue Mountains World Heritage Area. Thirlmere Lakes are made up of five lakes: Lake Gandangarra, Lake Werri Berri, Lake Couridjah, Lake Baraba, and Lake Nerrigorang.

Over the last 10 years, the water levels in the Thirlmere Lakes have declined, and there has been concern at their current low water levels (NSW Office of Enviroment and Heritage 2011). The community has expressed concern that the cause of the low water levels is the potential impact of mining activities in nearby Tahmoor.

Given the high level of community interest in the Lakes, and the long history of fluctuating water levels, there have been a number of studies and attempts to model the hydrological nature of the lakes over many years. Due to the recent period of water level decline, there has been particularly high level of interest over recent years.

In December 2010, the NSW Office of Water released the report *Thirlmere Lakes groundwater assessment* (Russell et al. 2010). This work was an assessment of the possible causes of water level decline reported for Thirlmere Lakes in recent times. The report considered evidence from Tahmoor Colliery operations, rainfall records, broader catchment river flow data and regional groundwater levels, although at the time there was no hydrology data specifically for the Lakes to indicate water levels. The report concluded that “there was no evidence to suggest that mine fracturing or subsidence has affected the water levels in Thirlmere Lakes in any substantial way.” The NSW Office of Water Report (Russell et al. 2010) found that “drier than normal weather is impacting on surface water flows as well as groundwater levels, and it is these factors separately, or in combination, that have resulted in the reported decline in lake levels.”

In October 2011, Pells Consulting on its own initiative produced reports with modelling undertaken, and finding that historically water levels in Thirlmere Lakes have been very low at times (Pells Consulting 2011). Their findings, available on their website, also state that the low levels occurred prior to mining and have resulted from climatic processes and water pumping. The report notes that the falls in water levels since 1990 have been accompanied by net deficit in rainfall over the period, and that climatic forces go some way to explaining current low water levels. The groundwater modelling work of Pells Consulting indicated that mining activities may have changed the

groundwater flow pattern (postulating that longwall mining has caused an increase in 'deep recharge' as water is moved downwards to replace that removed in mine dewatering), however they note that there is insufficient data to determine the change in quantity of groundwater flow from the lakes. During the period of the Thirlmere Inquiry (December 2011, May 2012 and June 2012), some of the data from the Pells reports were updated and with updated modelling, this was included as addenda to their report, which are publicly available.

In February 2012, the NSW Office of Water released the *Thirlmere Lakes drilling report* (Russell 2012). The work of the NSW Office for Water aimed to fill the gap identified in the 2010 report (Russell et al. 2010) regarding groundwater information in the vicinity of the Lakes, and drilled a 100m core and took samples of the geology. The work also included construction of 4 piezometers, one to 100m and three between 15 and 30 metres. The NSW Office of Water released the *Thirlmere Lakes monitoring bores survey report* (Gleeson 2012). This report describes the activities in relation to the surveying of the NSW Government monitoring bores within the Thirlmere Lakes National Park.

In 2012, Xstrata commissioned two reports on Thirlmere Lakes to investigate the low water levels; these were by Gilbert & Associates Pty Ltd (2012) and Heritage Computing (2012). The Gilbert & Associates report concluded that there was significant uncertainty in the data regarding Thirlmere Lakes including lake water levels, climatic data, and the effects of fire, evapotranspiration and human activity. This led to significant uncertainty in the hydraulic models developed, demonstrated using sensitivity analyses. They then recommended data collection methodology (including rain gauges and automated water level monitoring) for the Lakes for development of better models. The Heritage Computing (2012) report looked more widely over the area including the mines, discussing groundwater hydrographs and previous modelling, and developed a conceptual model. The Report concluded that "While it is possible that mining could have had a marginal effect on groundwater levels beneath the lakes, there is no definitive evidence that this has occurred. On the other hand, there is clear evidence for the drying of the lakes being coincident with a severe drought." The Inquiry submission by Xstrata indicates that Heritage Computing (Dr Merrick) has been commissioned to develop and maintain the regional groundwater models as new data becomes available.

3. Thirlmere Lakes Inquiry

On October 2011, the NSW Minister for the Environment appointed an Independent Committee of Inquiry to establish the reasons for fluctuation in the level of the Thirlmere Lakes and, if relevant, recommend actions to ameliorate these changes.

The Independent Committee has five members and included:

- Dr Steven Riley (chair)
- Professor Max Finlayson
- Associate Professor Damian Gore
- Dr Wendy McLean
- Mr Kevin Thomas (Community representative)

The terms of reference for the Inquiry and membership of the inquiry independent committee are at **TAB A**. The Committee was supported by the National Parks and Wildlife Service (NPWS). The inquiry process is discussed at length in Section 2 of the Inquiry Report. The Thirlmere Lakes Inquiry Draft Report was released for public exhibition and comment on 28 June 2012.

4. Review of the Thirlmere Lakes Inquiry Final Report

The Independent Committee conducted the Inquiry through an extensive desktop review using available data and reports, as well as observations and measurements made by the Committee during the Inquiry. The Committee has brought together and assessed a number of recent studies and reports published on Thirlmere Lakes including those by Pells Consulting (2011), the NSW

Office of Water (Russell et al. 2010), and Xstrata (Heritage Computing (2012), and Gilbert & Associates Pty Ltd (2012)). These as well as other studies appear to have provided the Committee with a significant (but not comprehensive) body of information to further the understanding of the Thirlmere Lakes system.

The structure of the Inquiry Report included:

- A set of findings and recommendations based on community concerns in Section 0.1
- A set of findings and recommendations at Section 0.4
- At the end of most Sections the report provided a set of conclusions
- Section 9 discusses various findings, and recommendations based on the findings, including prioritisation of recommended research projects.

The approach used in the review is to focus on the findings and recommendations as described in Section 0.4 (as requested by the Minister). This section provides an assessment of the findings and recommendations in Section 0.4.

Overarching editorial comments

The extensive and complex nature of the Inquiry Report has led to some inconsistencies, typographical, referencing and grammatical issues many of which could have been overcome with additional editorial resources. These issues can lead to some confusion with regards to the interpretation of some of the conclusions and findings in the Inquiry Report.

Definitive statements are often made in the Inquiry Report, sometimes on topics where there appears to be significant uncertainty in the data and information, or where the background information provided in the Inquiry Report to support the definitive statement is sparse. This editorial issue should be addressed, as it could lead to interpretations of the Inquiry Report that could be incorrect.

The links made between the data in the chapters and summary findings (at the beginning and end of the Inquiry Report) can be difficult to follow. The Inquiry Report would benefit from editorial work on Chapter 9 to clarify the attributions to other publications as well as locations of the relevant data and recommendations within the report. This problem has also led to difficulties in reviewing the Inquiry Report, and identifying how findings are backed up by evidence, this may have led us to miss links between data and findings.

The Inquiry was undertaken in part to address community concerns regarding the impact of mining on the Lakes, given the high level of public interest in the outcomes of this Inquiry, it is important that the findings are communicated to maximise community understanding.

CSE Recommendation 1:

If editorial changes to the Inquiry Report can be made, that work be undertaken to address:

- review the language in relation to definitive descriptions and uncertainties
- typographical errors, referencing, grammatical issues and inconsistencies
- that the data and analyses that led to the Findings and Recommendations are clearly identified.

If editorial changes to the Inquiry Report cannot be made, then the key findings should be synthesised into a short concise document that the public can easily access and digest. This could draw on Section 9 of the Inquiry Report as well as key data and figures from the main body of the Inquiry Report. This summary document would be a companion to the Inquiry Report, setting out the data that led to the findings, conclusions and the recommendations.

Uncertainties
The Inquiry undertook a desktop analysis of the situation in the Lakes including bringing together and analysing previous work as described above. However the Committee did also undertake some field work to generate data for analysis. This included: calculation of thalwegs; inflow-outflow measurements in Section 5.3.4; and the discussion of groundwater census data.

These calculations and analysis do not appear to include an assessment of the statistical uncertainties and error. Inclusion of these measurements would provide important contextual information to the discussion in the Inquiry Report.

CSE Recommendation 2:
The sections of the Inquiry Report where the Committee has undertaken measurements and calculations would benefit by an indication of, or discussion of, the uncertainties and statistical significance of the data.

Ongoing community engagement
The inclusion of a community representative in the membership of the Inquiry Committee is welcome. Consideration should be given to how to engage the community in an ongoing way in future discussions about the technical issues and characteristics of the Lakes and surrounding area as new information emerges. Engaging with the community is particularly important given the scientific and engineering factors are complex, where the modelling work has produced mixed results to date, and where community stakeholders themselves own infrastructure (e.g. water bores) that can contribute to future assessments and modelling work.

Many different parties have strongly held views regarding the Lakes and their current low levels. Engagement of the community in the process of collaborating with experts, government, and industry on the scientific research questions regarding the Lakes is important to improve understanding and dispelling any misconceptions.

CSE Recommendation 3:
Any future coordinated approach to the science, engineering and research requires a recognised role for the community, the mining company and other stakeholders. Whether these formal roles are on a Plan of Management Consultative Group, or on a Supervisory Committee, there should be an on-going forum where questions can be asked, research commissioned, and data contributed, and information shared in manner that encourages openness and transparency.

Comments on Findings

> ***Finding 1 -*** *The lakes have fluctuated between substantially dry and full conditions within European, Traditional Custodian and Geological time frames and the present low levels are not unprecedented.*

There are historical records of the levels of the Lakes fluctuating significantly in recorded history, with the Lakes being very low and dry during the Federation and WW2 droughts. These records include anecdotal evidence as well as aerial photographs.

The discussion and evidence of lake levels is noted in Sections:
- 5.3.1 – Geologic and geomorphic evidence
- 5.3.3 – Evidence from Traditional Custodians
- 5.3.5 – Anecdotal, historic and terrestrial imagery evidence collected by Pells Consulting
- 5.3.6 - Aerial photographs from 1955 to 2005

From the data and information provided in the report, this finding appears to be supported.

Finding 2 -*The only cause for lake level fluctuations prior to European settlement was climatic (droughts and heavy rains).*

Evidence presented in the report makes it difficult to confirm that climate was the "only cause" for lake level fluctuations prior to European settlement. Section 5.3.1 discusses the work of Black et al. (2006) on sediment cores which demonstrated lake level fluctuations before the Last Glacial Maximum (21000-28000 years before present (BP)), with dry periods between 5200 and 6000 years BP. These cores demonstrate that global climatic issues such as ice ages, not just droughts and heavy rains, may have impacted lake levels in the past. The report cannot find evidence that tectonic events in the past have impacted the Lakes, but these cannot be ruled out (see Section 9.1.1) as well as the potential impacts from factors in the past such as erosion, fire and vegetative changes (including changes in evapotranspiration rates).

Finding 3 - *There is clear evidence from 1974 and 1975 and other times that lake levels declined by more than 2 m in less than one year, and this could only be as a result of evaporation and groundwater drainage as it was prior to coal mining in the area.*

Section 5.3.2 ('Evidence of rapid changes in lake levels') discusses a study by Vorst (1974), on the peat islands in the Lakes, which reported high lake levels in mid-1974. The Committee has compared a terrestrial photograph by Vorst from 1974 with the height of a block concrete wall near Lake Couridjah to estimate the level of the Lake as 306 m AHD (Section 5.3.1). We believe that this was then used as an estimate of the height of Lake Werri Berri as Lakes Werri Berri and Couridjah were connected at the time as reported by Vorst (1974). This level was compared, by the Committee, to estimates of lake levels (Lakes Werri Berri and Nerrigorang) in 1975 from aerial photographs taken by NSW Department of Lands. The difference between the estimated 1974 and 1975 levels is approximately 2-3m. It should be noted that elsewhere in the Inquiry Report, the difficulty of estimating water levels using aerial photographs is discussed (Sections 5.3.5 and 5.3.6).

The Report states that "A drop in water level of 2 to 3 m can only be explained by a considerable groundwater loss", and the Committee estimates that daily groundwater loss from the Lakes would be "approximately 1.3 ML/day".

The Report also mentions other aerial photograph comparisons of Lake Couridjah which indicate rapid declines in 1986, 1990 and 1991.

Section 5.3.2 also discusses pictorial evidence for other major variations in lake levels in the past. The Committee also notes that modelling undertaken by Pells Consulting (2011) and Gilbert & Associates (2012) show rapid changes in lake levels in the order of 2 to 3 m in a short period. Since major changes in the lakes levels in 1974/75 occurred before mining it is reasonable to assume that the most likely major cause of the drop was evaporation, transpiration and groundwater drainage, but it is difficult to determine that these factors are the "only" cause.

The main message of the finding, being that lake levels can drop quickly and significantly, even in the absence of mining, appears to be supported by the work of Vorst, Pells and Gilbert & Associates and comparisons of aerial photographs.

Finding 4 - *While changes in rainfall (natural climate change) were undoubtedly responsible for the majority of the change in lake levels in the last 30 years there may be other factors involved in the present low levels.*

This Finding states rainfall as "undoubtedly responsible for the majority of changes in lake levels" differs slightly from the finding in Section 9.1.1. The conclusion in Section 9.1.1 states "fluctuations in rainfall appear to account for a substantial component of the variation in lake levels, but there is some doubt about changes in the last 40 years, some of which may be related to changes in sub-catchment geometry of Lakes Baraba and Couridjah, possible increases in evapotranspiration

brought about by higher temperatures, possible impacts of fire on the hydrologic regime, and possibly changes in the groundwater losses."

The conclusion in Section 9.1.1 suggests that rainfall "appear to account for a substantial component", which is different from the "undoubtedly responsible for the majority" in Finding 4. The time frames between the conclusion in 9.1.1 and finding 4 differ, being 40 and 30 years respectively. The conclusion in Section 9.1.1 expands on the other possible factors that may have impacted lake levels including higher temperatures, evapotranspiration rates, fire and groundwater losses. It is not stated in Finding 4 what the other potential factors responsible in the change in lake levels in the last "30 years" could be.

Section 5.3.4 may be the source of Finding 4 'majority of change' comment. This section reported the Committee's study and analysis of data captured from piezometers installed at Thirlmere Lakes between January and August 2012. The conclusion to this section includes the statement: "The falls are consistent with evaporation rates from the Lakes, taking account of the small amount of rainfall in the period and the losses to groundwater that would have occurred during the period. There is nothing in the last four months of records of lake levels to suggest that there is any unusual decline in water level beyond what would be expected with evapotranspiration and possibly some groundwater drainage. Community reports of the water being "sucked" into the bed are not evident in the water level data."

Without information on the uncertainties in the measured data, as well as uncertainties in data on rainfall, evaporation and transpiration levels, and a clearer presentation of the calculations used, it is unclear how significant are the findings and observations in Section 5.3.4.

It is important to balance up the relative contributions from different factors in the discussion relating to the decreased level of rainfall since 1992. The negative slope of the graphs in Section 4.2.3 and 4.4.3 over the last 20 year appears to align to similar decreases in rainfall during the Federation and WW2 droughts (periods which also coincide with low lake levels). These graphs also appear to be supported by surface water flow graphs in the report on Thirlmere Lakes by the NSW Office of Water (Russell et al. 2010). The rain graphs do appear to confirm a coincidence of long periods of low rainfall with low lake levels.

It is difficult from reading the Inquiry Report to attribute Finding 4 to specific data and analyses in the Report. As noted in CSE Review Recommendation 1 the Inquiry Report would benefit from clearer and concise explanations of how the data and analyses have led to the findings.

The use of the term "natural climate change" is confusing in the report, especially with short and long term cycles in climate due to seasonality, or the El Niño/La Niña–Southern Oscillation, or drought-flood dominated regimes, as well as the progressive global warming effects from climate change including anthropogenic. The report discusses flood- and drought-dominated regimes in section 4.3, however it appears that there is no discussion of the potential impacts from the El Niño/La Niña – Southern Oscillation on the Lakes. The Inquiry Report would benefit from explanation in regard to the various types of climate change (cyclical and non-cyclical) as well as and their potential impacts on the Lakes.

Finding 5 - *Hydrology models applied to the lakes are based on water level data with significant errors. The models do not represent the dynamic and changing nature of the catchments and their hydrologic regime. The hydrology models have significant variance in optimisation to the water level data and are weakly suggestive of discordance/accordance between rainfall, runoff and lake levels.*

The Committee did note that determining the water levels from aerial and terrestrial photographs is difficult and can lead to significant errors in lake water level estimations (Sections 5.3.5 and 5.3.6).

The various hydrology models used by the Committee, Pells Consulting (2011) and Gilbert & Associates (2012) are discussed and compared in Section 5.4 “Evaluating the Hydrology Models for Thirlmere Lakes”. The modelling approaches of Pells (2011), the Committee and Gilbert & Associates (2012) all show potential contribution to lower water levels from climate, evapotranspiration, groundwater leakage, mining, and other human factors. The difference between the conclusions of the models is really in the relative balance of contribution between these factors. None of the models appear to discount that mining has a potential impact. The models and reports appear to agree that there is not enough data to make a definitive conclusion on the cause of the reduction in lake levels.

A major hurdle in developing robust hydrology and hydrogeology models is access to good data over an acceptable period of time. To date, several data sources from the Lakes are characterised by low levels of accuracy, or with estimates based on local but not site-specific data, or short collection periods, these include:

- analysis of terrestrial and aerial photographs to obtain water level estimates (Inquiry Committee, Pells Consulting (2011), and Gilbert & Associates (2012));
- temporary water level monitors established by the Inquiry Committee;
- rainfall estimates from a series of rain gauges and weather stations located in the vicinity of the Lakes but not in the catchment (the Maidla Station may fall within the very northern perimeter of the catchment), and not generally maintained to Bureau of Meteorology Standards;
- piezometer infrastructure (four bores at three sites) put in place by the NSW Office of Water in 2011;
- SILO data for evaporation;

And local long term high accuracy data such as piezometer data from Xstrata bores to the east of the lakes.

It is clear that to develop appropriate conceptual or numerical hydrology and hydrogeology models; more data that is specific for the Lakes and the surrounding region is required.

Finding 6 - *There is no direct evidence that mining has breached geologic containment structures underneath lakes, including the Bald Hill Claystone bed.*

The language used in the Inquiry Report to describe the evidence of breaching of the claystone below the Lakes is used inconsistently, with the distinction between *no evidence that something has occurred* and *evidence that something has not occurred* needs clarifying. For instance, Section 9.1.2 states “There is no evidence that the Bald Hill Claystone beneath Thirlmere Lakes has been breached or ‘punctured’ in any way.” However, the conclusions to chapter 8, includes the following: “There is evidence that mine subsidence has affected the surface-groundwater link in the area above the mining but the evidence suggests that there has been no impact of mine subsidence on Bedrock to the west of the Loop Line (Section 8.4).”

This Finding 6 appears to be drawn from Section 8.4, wherein there is considerable discussion of subsidence with the Committee presenting a description of how subsidence occurs, and described the propagation of the subsidence outward as the angle of draw.

The Inquiry Report, draws on a NSW Department of Planning study (2008), stating that mine subsidence can result in far-field displacement, which is horizontal surface displacement of tens of millimetres some kilometres from the limits of mining.

The Inquiry Report also indicates that they requested the Mine Subsidence Board to search for claims of subsidence east of Thirlmere Lakes. It is not clear what the basis for these claims are, whether the nature of claims tends to focus on private property holdings or whether claims are made on public property, such as the Thirlmere Lakes National Park, as well. The Inquiry Report states that Mine Subsidence Board did not have any claims with 1 km of the Lakes, but also

indicated that the Mine Subsidence Board "also pointed out that property damage is not a suitable measure to establish geotechnical impacts that may result from coal extraction".

The Inquiry Report states that surveys undertaken by Waddington and Associates (2002) along the Loop Line at Couridjah found some instances of subsidence 20 to 35 mm, with residual subsidence predicted to be 3 to 4 mm.

The Inquiry Report section 9.1.2 states: "There is no evidence that the Bald Hill Claystone beneath Thirlmere Lakes has been breached or "punctured" in any way. The stratigraphic evidence suggests that it is some distance below the supposed maximum depth of the valley of Thirlmere Lakes of 50 m (245-250 m AHD). In addition, the sediment filling the Lakes, to the depth that it has been drilled, to approximately 30 m (270 mA HD), textures as clays, and there may be beds of thick clay throughout the valley fill. Such clayey material would act as aquitards and would be flexible to small distortions in the strata."

The Committee's conclusion that there is a lack of evidence of subsidence at Thirlmere Lakes or breaching of the Bald Hill Claystone appears consistent with what was found in the in the NSW Office of Water Report (Russell et al. 2010):

- "Most of the groundwater impacts have been observed above the mined areas."
- "The lakes are shown to be outside the angle of incidence where most vertical and horizontal movement occurs. Also subsidence has been shown to be exacerbated beneath sites with medium to high topographic relief (Holla and Barclay 2000). This is not the situation at Thirlmere Lakes."
- "As identified from mine plans supplied by Xstrata, the closest proximity of longwall extraction to the lakes was of the order 660m. This is more than double the distance within which mine-induced subsidence would be expected, and further reduces the likelihood that longwall extraction has impacted the lakes."
- "It is accepted that far field fracturing can occur outside of the angle of incidence but there was no evidence of such fracturing found in the field. If any fracturing caused by mining does exist in the sandstone below the Lakes it is expected to be minor in nature and not materially affect the groundwater flow into the Lakes in a measurable way."

The Inquiry Report also makes comment on the postulation by Pells Consulting that the paleovalley beneath Lake Nerrigorang has been eroded and consequent cutting into the bedrock during the geological history of Thirlmere Lakes has resulted in the Bald Hill Claystone being breached in the western section of the Thirlmere valley (Pells Consulting 2011). In Section 0.1 of the Inquiry Report, Finding 23 states "No depressurisation is evident in a bore located near the outlet of Lake Nerrigorang, which raises considerable doubt that breaching of the Bald Hill Claystone has occurred and dewatering in the mine has depressurised the aquifer underneath Lake Nerrigorang and caused the lake to dry out (Section 6.5)." This point is discussed further in Finding 11.

The Committee may have relied on other data and information to confirm the hypotheses or underpin the finding, however this is not apparent.

It is recommended that the language used in this section be carefully reviewed, so that a clear picture of the evidence for and against breaching is made. The data and information that has been considered in coming to the Committee's conclusion should be clearly set out.

Finding 7 - *There is substantive evidence of groundwater leakage from the lakes towards the east and east-northeast within the Hawkesbury Sandstone aquifers.*

There appears to be agreement among reports (Pells Consulting 2011; Russell et al. 2010; Inquiry Report 2012) into the Thirlmere Lakes system, that water does leave the lake system through groundwater pathways, and there also appears to be agreement that the geology of the overall

region slopes from the west to the east. The 2011 Pells Consulting report includes Figure 3.3 demonstrating a West to East slope of the geology, while the NSW Office of Water report (Russell et al. 2010) also demonstrates a slope from West to East in its conceptual regional groundflow system (Fig 22).

Inquiry Report Section 3.1.3 "Regional dip slopes" discusses that the slope of lineaments suggest that groundwater flow will be towards the East, "particularly as the elevation of the land surface also declines towards the East"

Inquiry Report Section 4.1.2 notes "The Hawkesbury Sandstone is not geologically uniform either vertically or spatially, so variations in the hydraulic conductivity of the rock are considerable and the Hawkesbury Sandstone cannot be treated as a uniform aquifer. There is an East to East-Northeast dip in the sandstone and the highest points in the catchment surface are to the West. However, in the West are a number of deep valleys which intercept the Eastward flow of water into the valley containing Thirlmere Lakes."

Also in Section 4.1.2, the Committee notes "To the East the land surface is lower than the lakes. Surrounded by deep valleys and lower topography, Thirlmere Lakes is "perched" in the topography. It is assumed that in an open aquifer groundwater would preferentially drain towards the lower levels. In the West this means that groundwater flows into the valleys. Towards the East the groundwater interfluve will be affected by the Eastwards dip of the sandstone beds, so it will be further to the West than a simple bifurcation based on elevation suggests. The water movement to the East is further complicated by the Thirlmere Monocline, whose throw will add an additional gradient towards the East."

There seems to be agreement and evidence to support Finding 7.

Finding 8 - *There is leakage of groundwater towards the West and down Blue Gum Creek, but it is not possible to determine the relative groundwater flows from the lakes towards the East and West.*

Finding 25 in Section 0.1 notes that "Changes in lake levels can be accounted for by droughts and heavy rains and some groundwater losses down Blue Gum Creek and into the surrounding Hawkesbury Sandstone (see Section 4.4)." Unfortunately Section 4.4 relates to "Droughts and flooding rains in the Picton Area" and does not discuss Blue Gum Creek.

There are various statements made throughout the Report that address water flow into Blue Gum Creek, these include:

- Section 3.2.1 – "While the topography rises West of the lakes the deeply incised streams, such as Blue Gum Creek, are lower than the bed of the lake. Any regional groundwater drainage would be away from the lakes so they are not a regional groundwater sink."
- Section 5.4.2 – "So it is unlikely that all of the groundwater loss through "recharge" is groundwater leakage down Blue Gum Creek. More likely there is recharge of local and deep aquifers on the margin and beneath the lakes as well as loss of water due to groundwater flow down Blue Gum Creek.
- Section 6.2.2 – "Groundwater flow may be either towards the West or East, depending on where the groundwater divide is placed. Based on the Committee's observations of groundwater flow in Blue Gum Creek and at the outlet, it is likely that shallow groundwater flow is towards the West, into Blue Gum Creek, but deeper groundwater flow beneath the lake is another matter."
- Conclusion 4 at the end of Section 6 – "It is not possible to separate and assess the quantities of groundwater flowing East from the lakes and those flowing west and also downstream in Blue Gum Creek (Section 6.2)."

One of the recommendations of the Committee (Groundwater 9.2.4) would seem to have been developed to address the gaps in the knowledge of groundwater under the Lakes.

Finding 9 - *There is substantive evidence of the steepening of the hydraulic groundwater gradient and lowering of the groundwater table in the Hawkesbury Sandstone towards the east of the lakes over the last 30 years, which would have potentially increased the rate of groundwater flow towards the east.*

The Inquiry Report Section 6.8. "Conclusions" states that "There appears to be a lowering and steepening of the groundwater surface towards the east and over the last 40 years, but it is not possible to determine the relative contribution of drought, pumping from groundwater sources, and the extraction of water from the mine (Section 6.2)." This conclusion differs from Finding 9 in that the time periods discussed (30 and 40 years) are different.

The region East of the Lakes are characterised by a significant number of water bores, some of which are owned by private landholders and Xstrata. Various statements and conclusions were made in regards to this data, these include:

- Section 6.5 - "Water level data collected during the hydrocensus confirm a groundwater gradient towards the east. These bores are in the Hawkesbury Sandstone and hence not accessing/monitoring groundwater levels in the underlying strata."
- Section 6.5 - "While the Committee was not able to find the depths to water level at time of construction for all the bores there is nevertheless a most interesting pattern in the West to East trend in the difference in water levels between construction and the time of our census."

The private landowner bore data was collected in a hydrocensus conducted by the Committee, however the data is difficult to interpret as there are only two data points for the bores, once at installation and once at the census (Section 6.5). It must be noted that the installation dates range from 1961 to 2011, making the initial data points difficult to compare. The fact that only two data points are available for each hydrocensus site makes it difficult to determine a trend in water level at each site and the entire area.

Xstrata also provided their groundwater data from bores and piezometers located within the longwall mining region (section 6.4.2). These bores showed declines based on impacts of mining, with some partial or complete recovery after mining.

The Inquiry Report notes that there are clear gaps in the data around the mining and groundwater flow and further work needs to be conducted.

Finding 10 - *There is evidence to suggest that mining has contributed to changes in groundwater tables and hydraulic gradients in the Hawkesbury Sandstone but it is not possible to disentangle groundwater changes due to mining, from those due to private bores, which access the groundwater, natural climate change (droughts), and anthropogenic climate change (primarily increased temperature).*

The entire Inquiry Report attempts to disentangle the different factors that could impact the groundwater in the area, and therefore the Lakes. It is clear from the report that this is a complex task, some data is available but it is incomplete with some bores showing a range of responses when longwall mining passed near or under them (Section 6).

Finding 10, as written here also relates to Finding 22 in Section 0.1 "It is not possible to separate the impact on groundwater levels of private bores accessing groundwater, the reduction in recharge as a result of drought, and longwall mining to the east of the Loop Line (Section 6.2)."

Finding 11 - *There is evidence that the Hawkesbury Sandstone aquifer beneath Lake Nerrigorang has not been depressurised.*

The evidence in the Report that the Hawkesbury Sandstone aquifer beneath Lake Nerrigorang has not been depressurised is most likely from Section 6.5. In Section 0.1, Finding 23 states that "No depressurisation is evident in a bore located near the outlet of Lake Nerrigorang, which raises considerable doubt that breaching of the Bald Hill Claystone has occurred and dewatering in the mine has depressurised the aquifer underneath Lake Nerrigorang and caused the lake to dry out." Section 6.5 is a discussion of the hydrocensus of private bores in the area undertaken by the Committee between March and September 2012. A comparison of water levels was made between the time of well drilling and the time of the Inquiry census survey to see any patterns in the water levels. The analysis of the results discussed one particular bore close to the Lake Nerrigorang, GW0101247, which has only changed by 1.2 m since its installation in 1998 (301.874 AHD 1998; 300.64 AHD 2012).

The report notes that:

- "Of considerable importance are the elevations of the water surface in bore GW0101247 at time of construction and time of the census. They are similar. If there was a significant dewatering of the aquifer in the vicinity of Lake Nerrigorang the difference in water levels would be much greater than shown. GW0101247 is approximately 500 m downstream of the outlet to Lake Nerrigorang and is located within Hawkesbury Sandstone"
- "The hypothesis of a depressurisation of the aquifer below Lake Nerrigorang is not supported by the limited groundwater data available to the Committee."

The Committee may have relied on other data in determining this Finding; however this was not identified in our review. Based on the GW0101247 data alone it is difficult to make a broad conclusion based on two data points from a single well. There needs to be more data before a finding can be made in regards to depressurisation of the aquifer underneath the Hawkesbury Sandstone.

Finding 12 - *It is not possible to say whether the impact of mining on groundwater in the Hawkesbury Sandstone is temporary or long-lasting. There is evidence from local private and Xstrata bores of both possibilities.*

In Section 0.1 of the Report Finding 18 states that "There are recorded instances in the Thirlmere region of private bores in the Hawkesbury Sandstone aquifers experiencing catastrophic decline in groundwater level and going dry or experiencing a reduction in yield when longwall mining passed near or under them. There are also instances of private bores not being affected and of affected wells recovering following mining and of water rising in some wells (Section 6.4)."

In Section 6.4 data from bores from NSW Office of Water, and Xstrata, are discussed. The bores exhibited different water levels during longwall mining activities, with some bore showing drop and others showing minimal or no changes. Section 6.5 about the hydrocensus of private bores shows a variable pattern of bore water levels over time, with no clear consistency. It should be noted that this census presented data that contained only two data points for each bore over various time periods (out of the 16 water bores investigated, only 11 had data from installation and census).

The Xstrata data was provided on water make and water bores (also discussed in commentary on Finding 9) over the long wall panels. The Inquiry Report discusses mine dewatering and found that: "It is not possible to judge exactly where the water discharge from the mine is coming from within the mine and the committee was not made aware of any detailed quantitative record of within-mine water transfers and it is unlikely that they exist."

The information in the Inquiry Report appears to indicate that with the current level of data available, it is not currently possible to determine whether the impact of mining on groundwater is temporary or long-lasting.

Finding 13 - *The Plan of Management for the lakes needs to be reviewed and there are gaps in ecological knowledge.*

The Plan of Management for the Lakes was developed in 1997 and is due for review in 2014; this is discussed in Section 7.2 of the Inquiry Report. The Inquiry Report highlights that the Plan is old and does not address issues related to drying of the Lakes and the proximity to the longwall mine (especially on ecology and biodiversity). This finding directly relates to Recommendation 5 of the Report and is discussed further below.

Recommendations

Data collection and analysis – Further studies

Recommendation 1 - *A socio-economic study of the lakes be commissioned, aimed to assess community values and community opportunities to realise all the potential values of the lakes in whichever hydrologic state they are in.*

Recommendation 2 - *A consortium of suitably qualified researchers are invited to undertake a geomorphic study of the lakes, comprising geophysical investigations, coring, and a suite of studies, including but not limited to, palaeontologic, mineralogical and ecologic investigations.*

Recommendation 3 - *A hydro-metrology study be initiated to investigate the hydro-geomorphic relations within the catchment of Thirlmere Lakes and to gather the information required to develop a robust hydrology model.*

Recommendation 4 - *The existing private bores to the east of the lakes be monitored for water levels and pumping volumes and groundwater hydraulic information be obtained in order to: a) develop a robust groundwater model for the lakes and immediate area, and b) to investigate the relation between longwall mining and groundwater in the region.*

Recommendation 6 - *Undertake ecological investigations to address gaps in the information about the lakes and their surrounds*

Recommendation 7 - *It is recommended that a Supervisory Committee be appointed to assist in the implementation and management of the programs of research.*

The Inquiry Report recommendations include studies in the areas of socioeconomics, geomorphology, geohydrology, hydro-metrology, hydrology and ecology, to be overseen by a Supervisory Committee. The Inquiry has also put forward priorities and ordering of the activities.

The Inquiry Report provides recommendations for these studies to be conducted on the Lakes based on the findings of the Inquiry and uncertainties in the current understanding of the system including data gaps. Some of the data gaps include weather and rainfall data in the catchment, ongoing water level/head measurements in the Lakes and groundwater.

The Inquiry Report, and submissions, also highlights new sources of data that are available but not systematically obtained, such as groundwater data available from water bores to the East of the Lakes. The Inquiry Committee as well as Pells Consulting (and others) have undertaken water censuses to input into modelling; however moves to automate and quality assure this data capture would be worthwhile.

Sources of data rest with many organisations and individuals in the region, including water bores owned by landholders, Xstrata, NSW Office of Water, and weather stations around the region. The Supervisory Committee would champion and coordinate the ongoing collection of these and other sets of data, including related quality assurance activities.

CSE Recommendation 4:

That the Supervisory Committee recommended by the Committee be bought together to refine and coordinate the data collection and research program for Thirlmere Lakes. The Supervisory

Committee should include key stakeholders (including residents, NPWS officers, council, and Xstrata) and experts. This should draw on the significant work from the Inquiry (recommendations and realisations) and other studies, to fill data gaps and undertake further modelling of the Lakes once sufficient data is available.

Based on their submission to the Inquiry, Xstrata Coal is also improving its groundwater monitoring network and has commissioned Dr Merrick (Heritage Computing) to develop and maintain a regional groundwater model. Making the data and findings of these activities available to the Supervisory Committee would be a valuable contribution to the work agenda.

The Commonwealth Government's Bioregional Assessment methodology, which is being developed through the Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development and the Department of Sustainability, Environment, Water, Population and Communities (SEWPAC), may provide a useful tool for the Supervisory Committee to inform future work regarding the research plan for the Lakes and surrounding area including data collection and modelling. Bioregional assessments are a scientific analysis of the ecology, hydrology and geology of an area for the purpose of assessing the potential risks to water resources in the area as a result of the direct and indirect impacts of coal seam gas development or large coal mining development (Independent Expert Scientific Committee on Coal Seam Gas and Large Coal Mining Development 2013).

CSE Recommendation 5:
Investigating the installation of automated water level monitors and rain gauges should be undertaken to begin collecting data on Thirlmere Lakes as suggested by Gilbert & Associates (2012), a consultant for Xstrata, and the Inquiry Report (Section 9.2.3). These recommend that automated water level monitoring in each lake, rain gauge facilities, and other hydrology meters should be established within the catchment. The monitoring devices should be Internet Protocol-enabled to allow for near to real time data and this data could be made available online through a government website (e.g. Office of Environment and Heritage, NSW Office of Water or NPWS) to provide data to the community, government and researchers.

Management approaches
Recommendation 5 - *Review existing Thirlmere Lakes National Park management approaches and nominate the lakes for listing under the Ramsar Convention on Wetlands.*

The Inquiry recommends that a review of the Plan of Management for the Thirlmere Lakes National Park be conducted. The current Plan of Management was developed in 1997 and is due for review in 2014. The review could be brought forward to begin looking at future management of the Lakes and integration of a research program into that management.

CSE Recommendation 6:
That the review of the Plan of Management for Thirlmere Lakes National Park be brought forward (the review is currently due in 2014). The Plan of Management should integrate any research programs that emerge from the Inquiry or the subsequent Supervisory Committee to improve the management of the Lakes.

The Report recommends that the Lakes should be listed under the Ramsar Convention on Wetlands as a Wetland of International Importance (a Ramsar Site). The pros and cons, and cost benefit of a Ramsar application should be considered in the future by OEH and NPWS. However before embarking on this application, other priorities for the Lakes should be addressed such as improved data collection, and the review of the Plan of Management. The application for a site to be added to the Ramsar list requires a considerable body of information and resourcing. The nomination requires considerable documentation including: Ramsar Information Sheet; boundary description and map(s); an ecological character description; a management plan or system; and a

summary of consultative outcomes for the nomination. The final decision to add a site to the Ramsar List lies with the Australian Government Environment Minister.

Potential remediation
There is value in investigating the opportunity of developing a 'groundwater mound' to minimise groundwater loss to the east from the lakes if investigations prove it to be a viable management strategy.

a. *The groundwater mound could be formed readily via aquifer injection.*
b. *The water for the re-injection could be supplied from the treated water presently discharged by the mine into the Bargo River.*

Further the Inquiry recommends that a 'water mound' be investigated as a potential for remediation. It is felt that a better understanding of the Lakes and groundwater system would be required to understand whether the proposed remediation, and required infrastructure, would have a net benefit for the Lakes and surrounding region.

CSE Recommendation 7:
Remediation options should be investigated after further research is conducted on the Lakes. Investigation of remediation options could form a component of the research program overseen by the Supervisory Committee.

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Thirlmere Lakes Inquiry Terms of Reference and Independent Committee Membership

Terms of Reference

Under the authority of the Minister for the Environment, the Thirlmere Lakes Inquiry Committee is authorised to inquire into and report on the following matters concerning recent variations in water level in Thirlmere Lakes:

1. Historical, paleo-climatogical, and other scientific records regarding lake levels, rainfall events and other natural or land management data related to the condition and circumstances of the Thirlmere Lakes
2. Identification of patterns in the relationship between water levels in the Thirlmere Lakes and known rainfall events, land management practices or other factors
3. An assessment of current water levels in Thirlmere Lakes against identified patterns
4. Recommendations for management actions to address the factors identified as likely to have a direct or indirect effect on lake levels and/or on the natural and cultural values of Thirlmere Lakes National Park.
5. Recommendations for future studies to better understand the hydrology of the Thirlmere Lakes and provide better information for future management.
6. Any other matters the Inquiry Committee considers relevant to the reasons for or responses to water levels in the Thirlmere Lakes.

In preparing its recommendations the Thirlmere Lakes Inquiry Committee may have reference to a wide range of information sources including, but not limited to: scientific data and studies including paleo-climatological studies; expert opinion; climate or other modelling; comparative information across the region; data from similar water bodies; historical information; private records (such as family photos or private data collections); and submissions from the public.

Committee membership

The committee was comprised of:

- Dr Steven Riley
- Max Finlayson
- Dr Wendy McLean
- Dr Damian Gore
- Kevin Thomas

Full details of the background of the committee members was provided in Appendix 2.2 of the Inquiry Report and provided is on the inquiry website, http://www.environment.nsw.gov.au/water/thirlmerelakesinquiry.htm.