Narrabri Gas Project

Presentation to the NSW Independent Planning Commission

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by

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I am representing the **Artesian Bore Water Users Association**

I am a Senior Hydrogeologist trading under the name Groundwater Solutions International as part of Gradient Limited. I have 28 years experience working in the groundwater industry in Australia and New Zealand.

I worked for the formerly named NSW Department of Water Resources from 1992 until 1995 as a Project Hydrogeologist and was located in Gunnedah/Sydney.

As a result of my work I obtained a good understanding of the hydrogeological processes that occur within, and between, the southern Surat Basin and Gunnedah Basin geological units, having undertaken an intense property-by-property three year study of bores. Data collected and reviewed included bore hydraulic, hydrographic and water quality records; geological records from both the groundwater bores and mining exploratory bores; hydrological data from creeks and rivers; and climatic data. I ran educational workshops for property owners and government employees working in the area.

Since returning to New Zealand I have reviewed and provided comment on the groundwater impacts of mining operations in NSW, Queensland and the Northern Territory; at the request of community groups, conservation groups, Namoi Water, the Environmental Defence Office and the formerly named NSW Department of the Environment. I participated on a Panel of Expert Scientists as part of the Coal Seam Gas Science and Law Forum, March 2014, NSW Parliament House, Sydney, NSW. I maintain a professional interest in respect to any hydrogeological investigations, and other relevant scientific studies, undertaken in the Namoi Valley Catchment.

'Despite some uncertainties, mostly due to a lack of detailed information about the deeper geological strata …'
(DPIE Assessment Report – Executive Summary (Page xi)

'Santos has addressed these uncertainties by using conservative assumptions in its modelling.'
(DPIE Assessment Report – Executive Summary (Page xi)

'...there is some dispute regarding the geometry of the base of the Surat Basin. For example, in some areas, the Purlawaugh Formation, an aquitard, occurs at the base of the formation, but this is not the case everywhere, which in turn may have implications to connectivity.'
(Water Expert Panel Report Page 28)

‘When considered within the context of the HSU classifications (Table 5.1 GIA, Appendix F) there are some anomalies in the existing adopted values of Kv; for example, the Blythesdale Group (Keelindi Beds) has been assigned values of Kv typical of a poor aquifer while it is generally considered to be an aquitard consisting of clayey sandstone, siltstone and conglomerate.’

(CDM Smith comparing Table 5-1 with K values presented in Table 5-2 for the Narrabri Coal Mine - CDM Smith, GIA Appendix F, EIS)

Table 5-1 Hydrostratigraphic unit classification

Province	Period/ Epoch	Division	Group	Sub-group	Formation	Lithology and Hydrogeological Classification
Namoi Alluvium Vocanics	Pleistocene				Narrabri fm	Clay and silt with sand lenses
	Pliocene				Gunnedah fm	Gravel and sand with clay lenses
	Miocene				Cubbaroo fm	Gravel and sand with clay lenses
					Warrumbungle Vol	Basalt, dolerite
	Eocene				Liverpool Range Vol	Basalt, dolerite
Surat Basin	Cretaceous	Middle	Blythesdale Gp (Keelindi Beds)		Bungil Fm Mooga Ss Orallo Fm	Clayey to quartzose sandstone, subordinate siltstone and conglomerate
		Early			Pilliga Ss	Fluvial, medium to very coarse grained, quartzose sandstone and conglomerate. Minor interbeds of mudstone, siltstone and fine grained sandstone and coal.
	Jurassic	Late				
		Middle			Purlawaugh Fm	Fine to medium grained sandstone thinly interbedded with siltstone, mudstone and thin coal seams
		Early Late	Garrawilla Volcanics			Dolerite, basalt, trachyte, tuff, breccia
		Middle			Deriah Fm	Sandstone
					Napperby Fm	Interbedded fine sandstone, claystone and siltstone

Table 5-2 Hydraulic conductivity measurements for the Narrabri Coal Mine (after Aquaterra 2009)

Hydrostratigraphic Unit	Hydraulic Conductivity, *K* [m/d]	Test Type
Pilliga Sandstone	0.029–0.19	Falling head
Purlawaugh Formation	0.001–0.41	Falling head
Garrawilla Volcanics	0.047–0.11	Falling head
Napperby Formation	0.0006–0.09	Falling head
Digby Formation	0.063	Petroleum well testing

Comparing Table 5.1 with K values presented in Table 5.2 for the Narrabri Coal Mine - CDM Smith, GIA Appendix F, EIS

‘The existing ranges of values for Kv adopted for all strata of the…GOB are mainly typical of consolidated sandstones, and do not reflect literature values for aquitards containing shale, mudstone and siltstone, which are typically within the range 1E-8 to 1E-4 m/d.’

(CDM Smith referring to Table 5-3, Figures 5-4 and 6-19 - CDM Smith, GIA Appendix F, EIS)

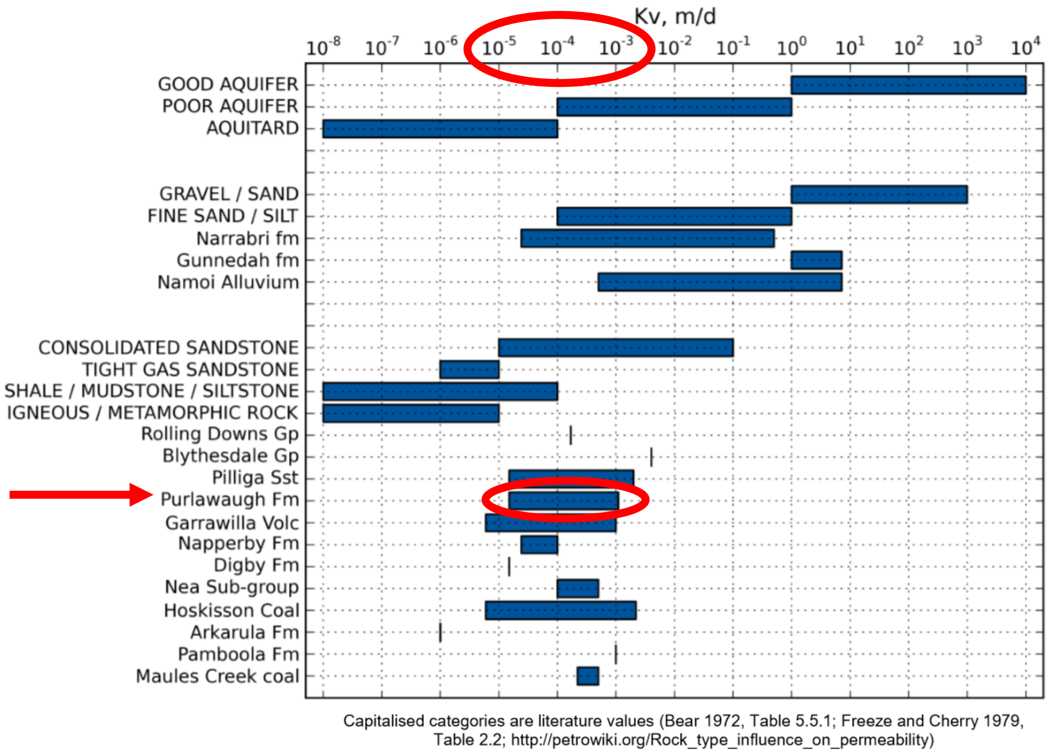

Figure 5-4 Vertical hydraulic conductivity from Table 5-3 and selected hydrogeological literature

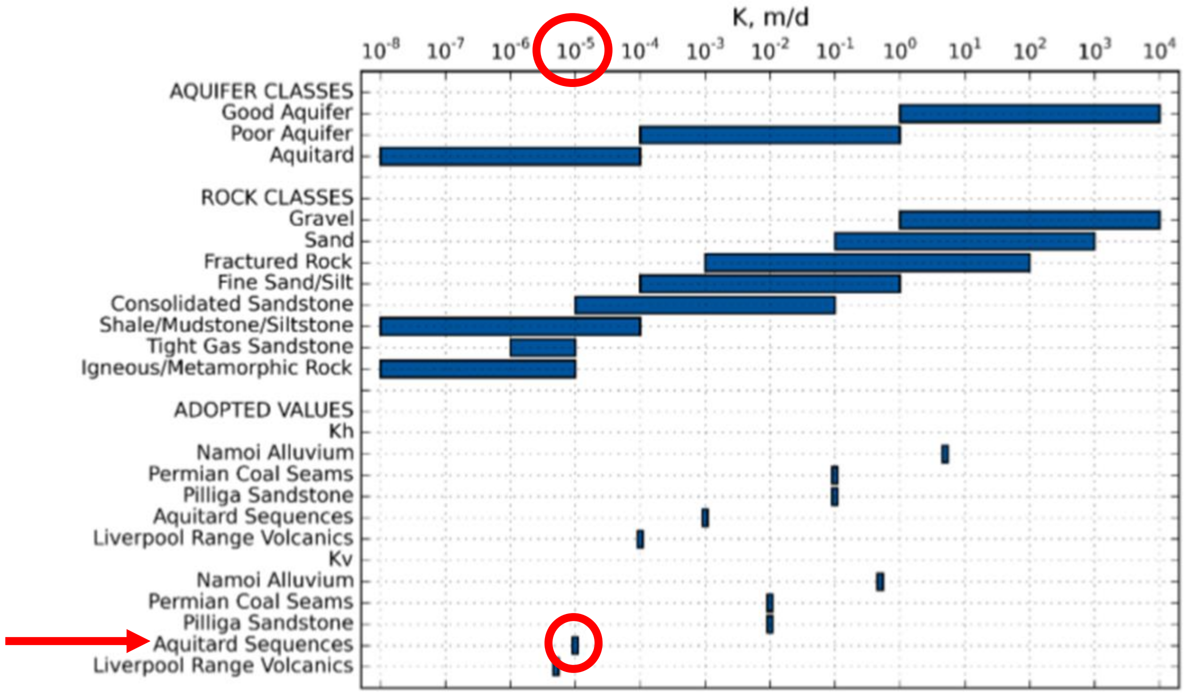

Figure 6-19 Comparison of the adopted values of hydraulic conductivity and literature values

Comparing Purlawaugh Formation Kv values used for the Narrabri Coal Mine (Figure 5-4) with the adopted Purlawaugh Formation Kv values for the Narrabri Gas Project (from CDM Smith, GIA Appendix F, EIS).

Table 6-4 Correlation between geologic basins, geological ages, stratigraphic units, geological model layers, hydrostratigraphic units (HSU) and numerical model layers

Basin	Period	Stratigraphic Unit			Geological Model Layer	HSU	Model Layers
		Group	Sub-group	Formation			
	Cenozoic			Narrabri (informal)	1	Aquifer	1
				Gunnedah (informal)			
				Liverpool Range Volcanics	2	Aquitard	
Surat GAB	Cretaceous	Rolling Downs Gp		Wallumbilla Fm			2
		Blythesdale Gp (Keelindi Beds)		Bungil Fm	3		3
				Mooga Ss			4
				Orallo Fm			5
				Pilliga Ss	4	Aquifer	6
	Jurassic			Purlawaugh Fm	5	Aquitard	
				Garrawilla Volcanics	6		7
Gunnedah	Triassic			Deriah Fm	7		
				Napperby Fm			8
				Digby Fm	8		
	Late Permian	Black Jack Group	Nea	Trinkey Fm	9		9
				Wallala Fm			
			Coogal	Breeza Coal Mbr			10
				Clare Ss			
				Howes Hill seam			11
				Benelabri Fm			12
				Hoskissons Coal (Late Permian coal seam targets)	10	Aquifer	13
			Brothers	Brigalow Fm	11	Aquitard	14
				Arkarula Fm			15
				Melvilles Coal Mbr			16
				Pamboola Fm			17
	Middle Permian	Millie		Watermark Fm	12		18
				Porcupine Fm			19
	Early Permian	Bellata		Maules Creek Fm	13	Aquitard	20 21
				Early Permian coal seam targets	13	Aquifer	22
				Maules Creek Fm	13	Aquitard	23 24
				Goonbri Fm	Model Basement		
				Leard Fm			
Base		Basement		Boggabri Volcanics			
				Werrie Basalt			

(Section 5.2 defines the relative transmissive context in which the terms aquifer and aquitard are applied in the table above)

(reproduced from CDM Smith, GIA Appendix F, EIS)

'...the current piezometer network is not sufficient either in plan position or vertically, to provide data for the groundwater flow models in order to predict future impacts of CSG activities particularly relating to water licensing considerations.'
(Water Expert Panel Report Page 42)

Table 2-1: Model confidence level classification—characteristics and indicators

Confidence level classification	*Data*	*Calibration*	*Prediction*	*Key indicator*	*Examples of specific uses*
Class 1	• Few or poorly distributed existing wells from which to obtain reliable groundwater and geological information. • Observations and measurements unavailable or sparsely distributed in areas of greatest interest. • No available records of metered groundwater extraction or injection. • Climate data only available from relatively remote locations. • Little or no useful data on land-use, soils or river flows and stage elevations.	• No calibration is possible. • Calibration illustrates unacceptable levels of error especially in key areas. • Calibration is based on an inadequate distribution of data. • Calibration only to datasets other than that required for prediction.	• Predictive model time frame far exceeds that of calibration. • Temporal discretisation is different to that of calibration. • Transient predictions are made when calibration is in steady state only. • Model validation* suggests unacceptable errors when calibration dataset is extended in time and/or space.	• Model is uncalibrated or key calibration statistics do not meet agreed targets. • Model predictive time frame is more than 10 times longer than transient calibration period. • Stresses in predictions are more than 5 times higher than those in calibration. • Stress period or calculation interval is different from that used in calibration. • Transient predictions made but calibration in steady state only. • Cumulative mass-balance closure error exceeds 1% or exceeds 5% at any given calculation time. • Model parameters outside the range expected by the conceptualisation with no further justification. • Unsuitable spatial or temporal discretisation. • The model has not been reviewed.	• Design observation bore array for pumping tests. • Predicting long-term impacts of proposed developments in low-value aquifers. • Estimating impacts of low-risk developments. • Understanding groundwater flow processes under various hypothetical conditions. • Provide first-pass estimates of extraction volumes and rates required for mine dewatering. • Developing coarse relationships between groundwater extraction locations and rates and associated impacts. • As a starting point on which to develop higher class models as more data is collected and used.

(*Refer Chapter 5 for discussion around validation as part of the calibration process.)

Barnett et al, 2012, Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra

293. However, the WEP recommends that Santos should be required to:

- upgrade the model to a transient model, based on ongoing monitoring, within 3 years;
- make this update available for public comment; and
- update the model every 3 years thereafter.

(DPIE Assessment Report, 2020)

Table 2-1: Model confidence level classification—characteristics and indicators

Confidence level classification	*Data*	*Calibration*	*Prediction*	*Key indicator*	*Examples of specific uses*
Class 3	• Spatial and temporal distribution of groundwater head observations adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported. • Spatial distribution of bore logs and associated stratigraphic interpretations clearly define aquifer geometry. • Reliable metered groundwater extraction and injection data is available. • Rainfall and evaporation data is available. • Aquifer-testing data to define key parameters. • Streamflow and stage measurements are available with reliable baseflow estimates at a number of points. • Reliable land-use and soil-mapping data available. • Reliable irrigation application data (where relevant) is available. • Good quality and adequate spatial coverage of digital elevation model to define ground surface elevation.	• Adequate validation* is demonstrated. • Scaled RMS error (refer Chapter 5) or other calibration statistics are acceptable. • Long-term trends are adequately replicated where these are important. • Seasonal fluctuations are adequately replicated where these are important. • Transient calibration is current, i.e. uses recent data. • Model is calibrated to heads and fluxes. • Observations of the key modelling outcomes dataset is used in calibration.	• Length of predictive model is not excessive compared to length of calibration period. • Temporal discretisation used in the predictive model is consistent with the transient calibration. • Level and type of stresses included in the predictive model are within the range of those used in the transient calibration. • Model validation* suggests calibration is appropriate for locations and/or times outside the calibration model. • Steady-state predictions used when the model is calibrated in steady-state only.	• Key calibration statistics are acceptable and meet agreed targets. • Model predictive time frame is less than 3 times the duration of transient calibration. • Stresses are not more than 2 times greater than those included in calibration. • Temporal discretisation in predictive model is the same as that used in calibration. • Mass balance closure error is less than 0.5% of total. • Model parameters consistent with conceptualisation. • Appropriate computational methods used with appropriate spatial discretisation to model the problem. • The model has been reviewed and deemed fit for purpose by an experienced, independent hydrogeologist with modelling experience.	• Suitable for predicting groundwater responses to arbitrary changes in applied stress or hydrological conditions anywhere within the model domain. • Provide information for sustainable yield assessments for high-value regional aquifer systems. • Evaluation and management of potentially high-risk impacts. • Can be used to design complex mine-dewatering schemes, salt-interception schemes or water-allocation plans. • Simulating the interaction between groundwater and surface water bodies to a level of reliability required for dynamic linkage to surface water models. • Assessment of complex, large-scale solute transport processes.
Class 2 *Cont'd overleaf*	• Groundwater head observations and bore logs are available but may not provide adequate coverage throughout the model domain.	• Validation* is either not undertaken or is not demonstrated for the full model domain. • Calibration statistics are generally reasonable but may suggest significant errors in parts of the	• Transient calibration over a short time frame compared to that of prediction. • Temporal discretisation used in the predictive model is different from that used in transient	• Key calibration statistics suggest poor calibration in parts of the model domain. • Model predictive time frame is between 3 and 10 times the duration of transient calibration. • Stresses are between 2 and 5 times greater than those	• Prediction of impacts of proposed developments in medium value aquifers. • Evaluation and management of medium risk impacts.
Class 2 *Cont'd*	• Metered groundwater-extraction data may be available but spatial and temporal coverage may not be extensive. • Streamflow data and baseflow estimates available at a few points. • Reliable irrigation-application data available in part of the area or for part of the model duration.	model domain(s). • Long-term trends not replicated in all parts of the model domain. • Transient calibration to historic data but not extending to the present day. • Seasonal fluctuations not adequately replicated in all parts of the model domain. • Observations of the key modelling outcome data set are not used in calibration.	calibration. • Level and type of stresses included in the predictive model are outside the range of those used in the transient calibration. • Validation* suggests relatively poor match to observations when calibration data is extended in time and/or space.	included in calibration. • Temporal discretisation in predictive model is not the same as that used in calibration. • Mass balance closure error is less than 1% of total. • Not all model parameters consistent with conceptualisation. • Spatial refinement too coarse in key parts of the model domain. • The model has been reviewed and deemed fit for purpose by an independent hydrogeologist.	• Providing estimates of dewatering requirements for mines and excavations and the associated impacts. • Designing groundwater management schemes such as managed aquifer recharge, salinity management schemes and infiltration basins. • Estimating distance of travel of contamination through particle-tracking methods. Defining water source protection zones.

Barnett et al, 2012, Australian groundwater modelling guidelines, Waterlines report, National Water Commission, Canberra

DPIE **Groundwater Model Condition B37** states:

'The Applicant **must** periodically update the groundwater model for the development, to the satisfaction of the Planning Secretary. The model update **must**...
… (e) include all **reasonable and feasible** measures to improve the model to meet the requirements of a Class 2 and Class 3 confidence level model (as per the Australian Groundwater Modelling Guidelines) as soon as is **reasonable and feasible**;…

291. Santos accepts that the model is a Class 1 model under the guidelines but notes that **it is not technically feasible to achieve all of the Class 2 or Class 3 model attributes within the project Narrabri Gas Project (SSD 6367)…**
(DPIE Assessment Report, 2020)

In conclusion:

- the conceptual and numerical models are weak

- there is not enough real data

- the impacts will potentially not be visible for many years

Thank you