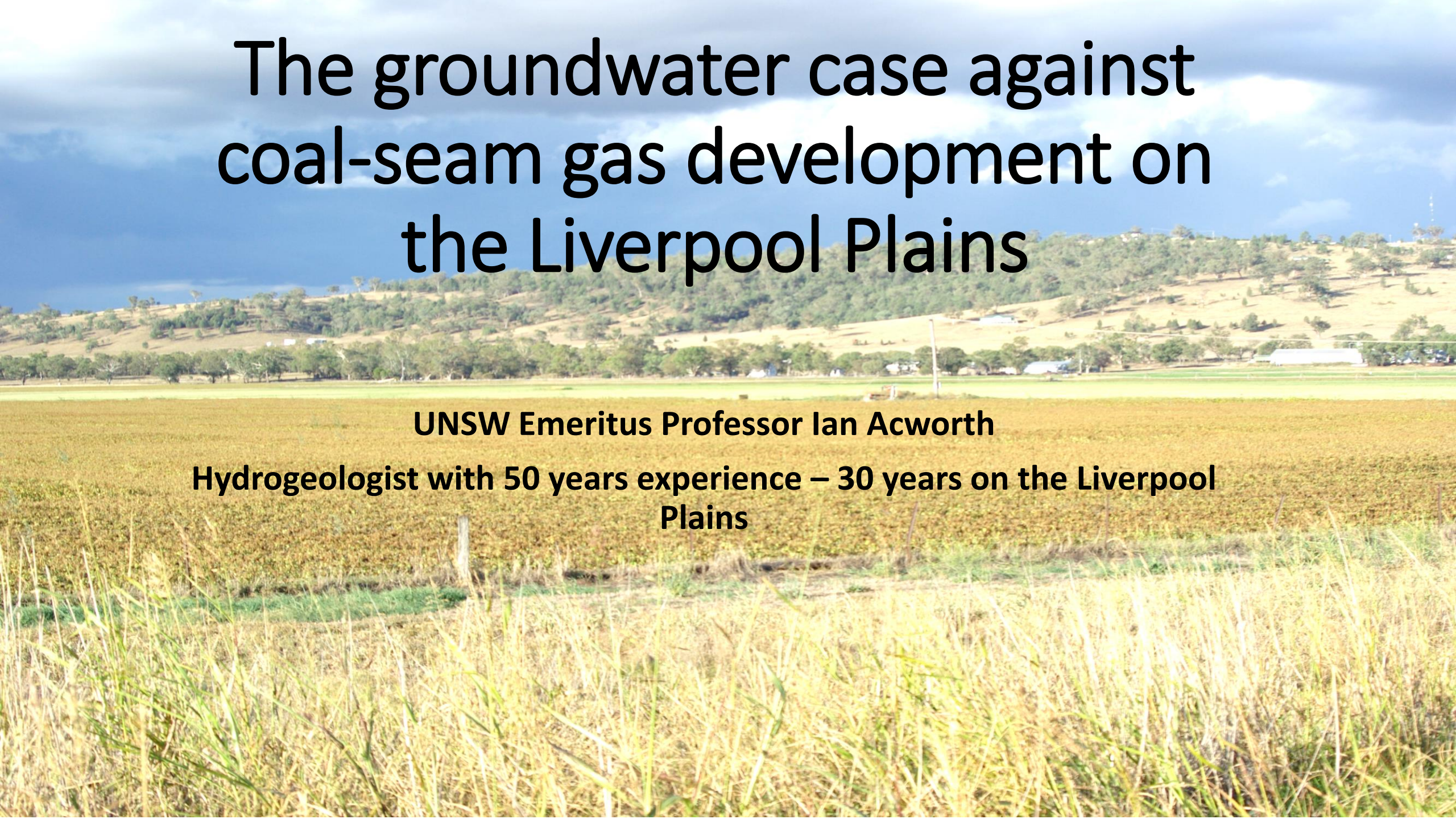
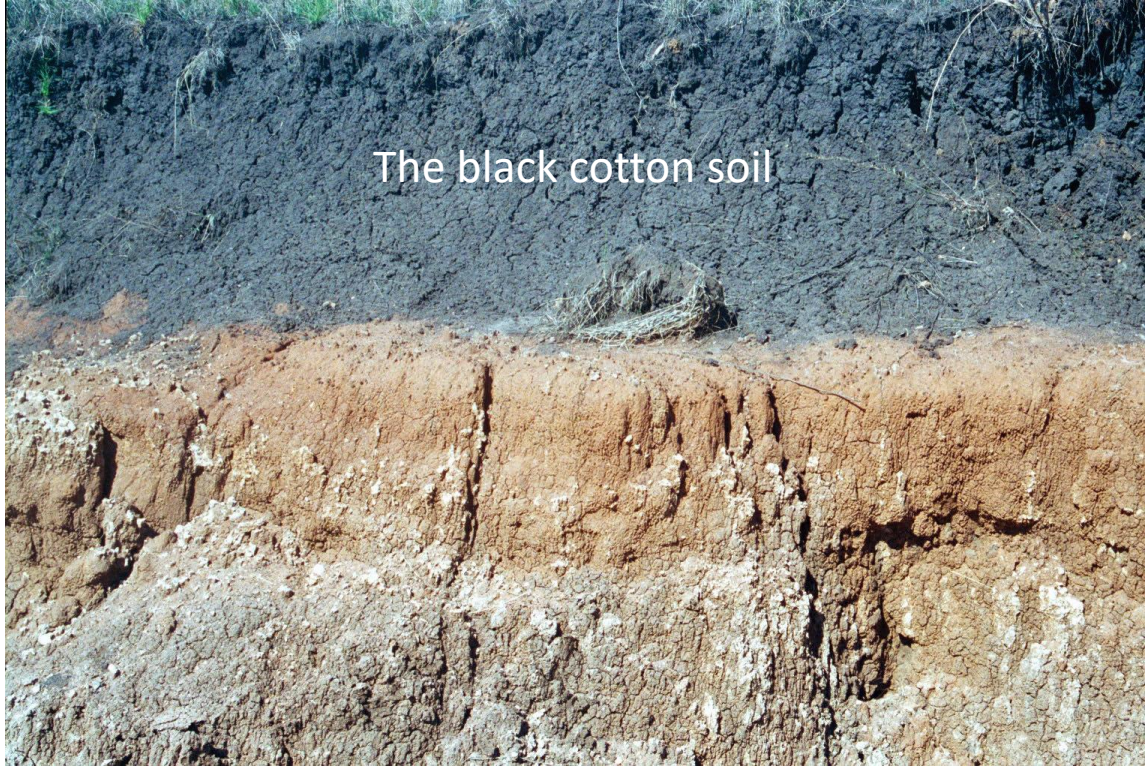
The groundwater case against coal-seam gas development on the Liverpool Plains



UNSW Emeritus Professor Ian Acworth

Hydrogeologist with 50 years experience – 30 years on the Liverpool Plains

Where we are at – July 2023



Gas development by SANTOS has been approved by the NSW Government in the Narrabri Gas Project situated in the Pilliga State Forest south-west of Narrabri. This approval was subject to many restrictions including:

no fracking

the existence of a new gas pipeline to handle the production and

significant environmental and biophysical restrictions.

SANTOS have purchased the licence to investigate and build the new pipeline from Queensland to Newcastle Port. A branch line would connect the regional pipeline to the Narrabri Gas Project. The gas could then be exported through Newcastle - *despite commitments that the gas will be used to supply New South Wales*. Design and route selection work is now underway to construct this pipeline and SANTOS are clearly moving to develop the Narrabri Gas Project.

Where we are at – July 2023 - continued

Despite the fact that the Narrabri Gas Project is thought capable of supplying more than 50% of NSW gas requirements – it seems that additional supplies are required to make the project economically viable. Consequently, the NSW Government is allowing fresh prospecting for gas to occur, with the Liverpool Plains a prime target. The new pipeline will pass down the length of the Liverpool Plains and that makes the development of new gas supplies close to the pipeline route particularly economically attractive.

The Liverpool Plains are therefore again in the crosshairs of the minerals industry.

Time is short for SANTOS, as the economic opportunity will only exist for a limited time as the world moves away from methane generation and use in the battle against global warming – particularly as the dangers of methane leakage are now better recognised.

Agricultural resources of the Liverpool Plains

There are two fundamental reasons why the Liverpool Plains are a major agricultural resource:

- Incredible deep soils that store water and have the ability to support two high-yielding crops a year
- access to groundwater resources that are sufficient to allow irrigated farming. Even in drought years, crops can still be grown.

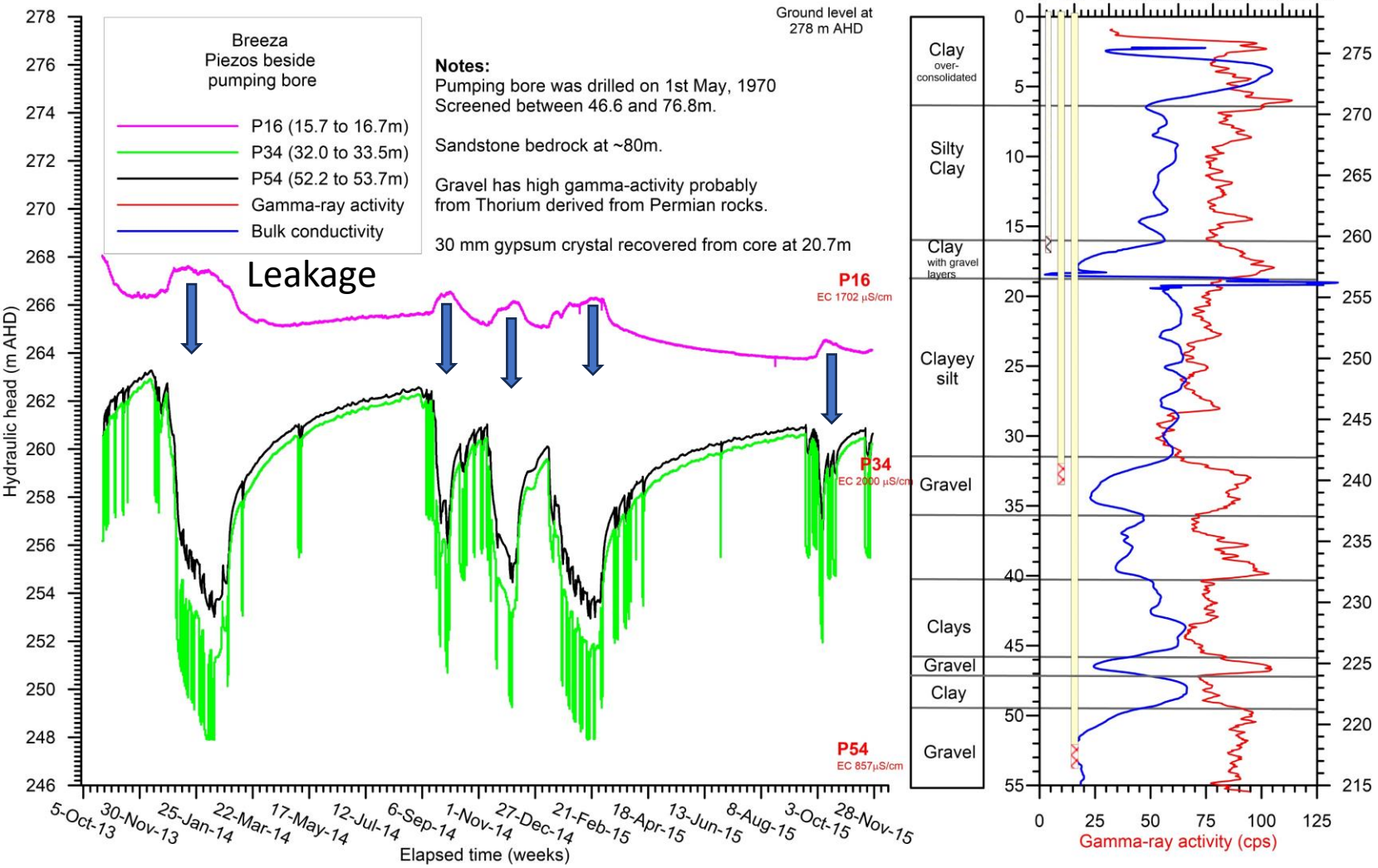
But – there are also problems:

Groundwater abstraction started in earnest in the 1980s and since that time, groundwater levels have been falling each year. From a hydrogeological perspective, this means that the groundwater resource is **being mined** and unless abstractions are reduced significantly, the aquifers will eventually be emptied. The NSW government has recognised that problem and has started to reduce allocations.

The first groundwater supplies to be impacted will be the shallow stock and domestic supplies – but then yields from the deeper aquifers will be impacted. This will have a major impact on the economic well being of the area. The Council will recall the costs of trucking water into communities. That will become a regular feature of Council expense accounts!

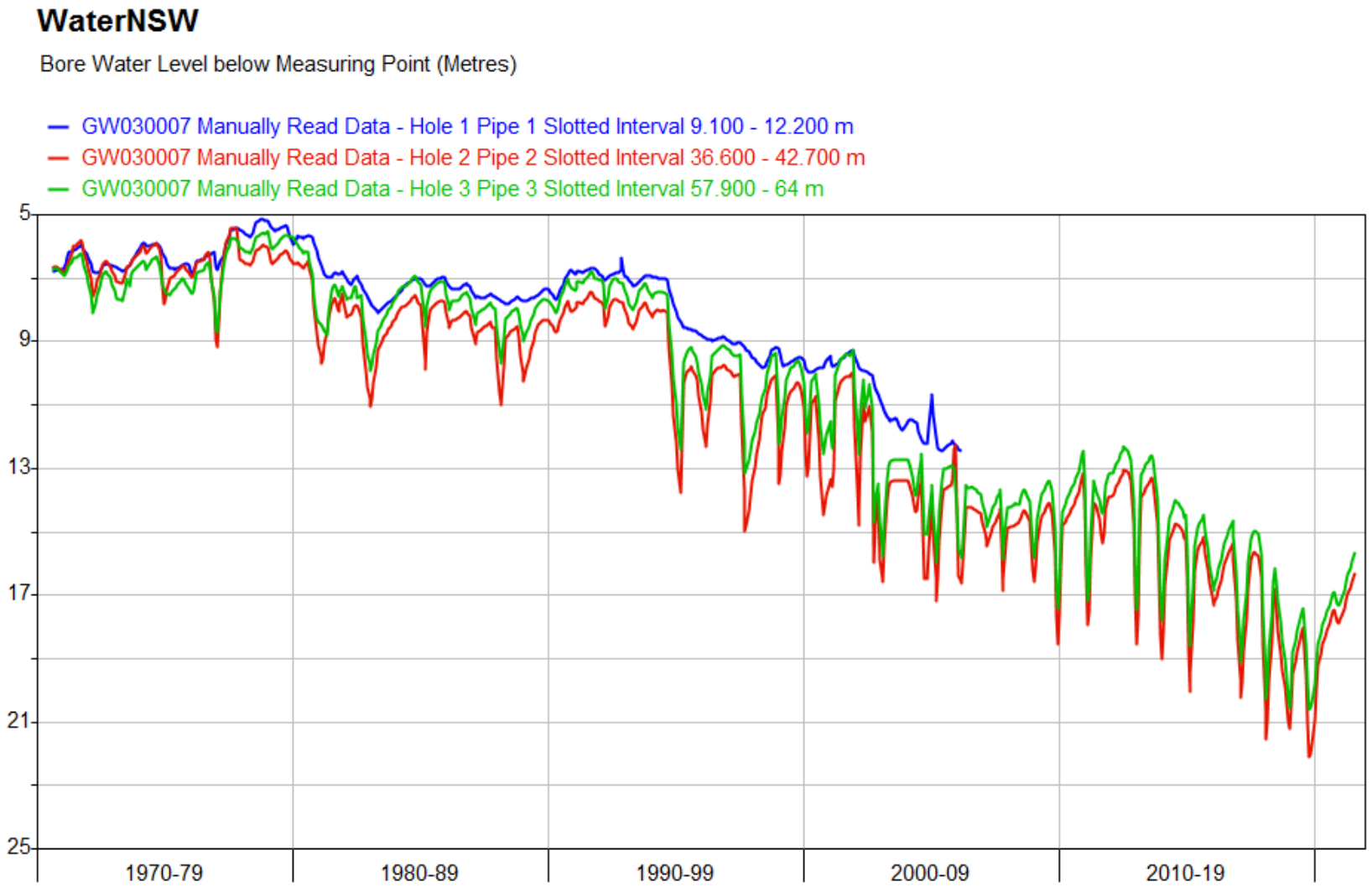
But that is a small factor compared to the loss of agricultural productivity.

Groundwater occurrence at Breeza



Not a simple layer cake of clay over gravel over bedrock

Groundwater levels on the Liverpool Plains 1970 to 2023
GW030007 on Mystery Road



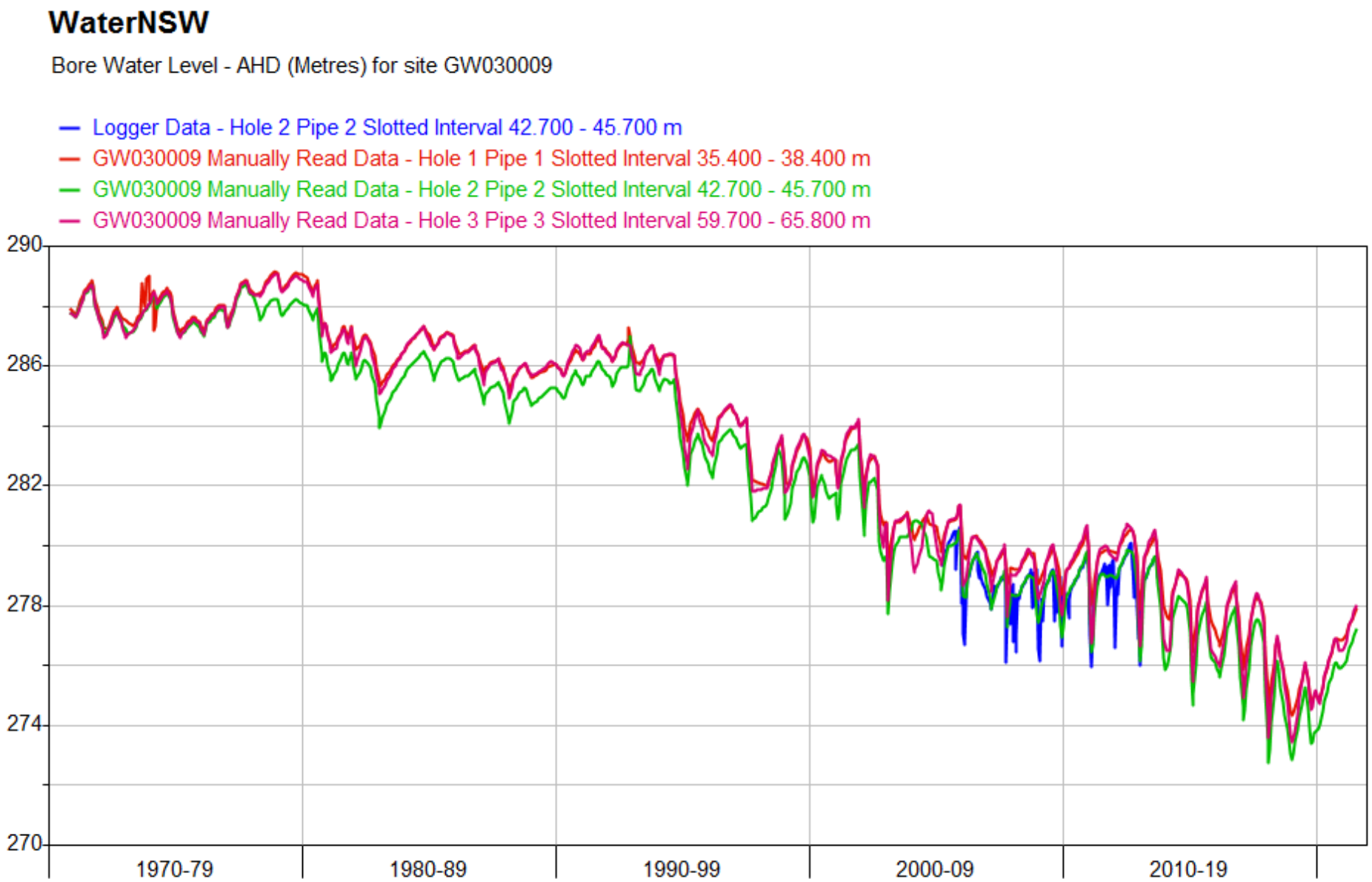
The upturn in the last couple of years Could be caused by a number of factors:

Lower abstraction as allocations have been reduced

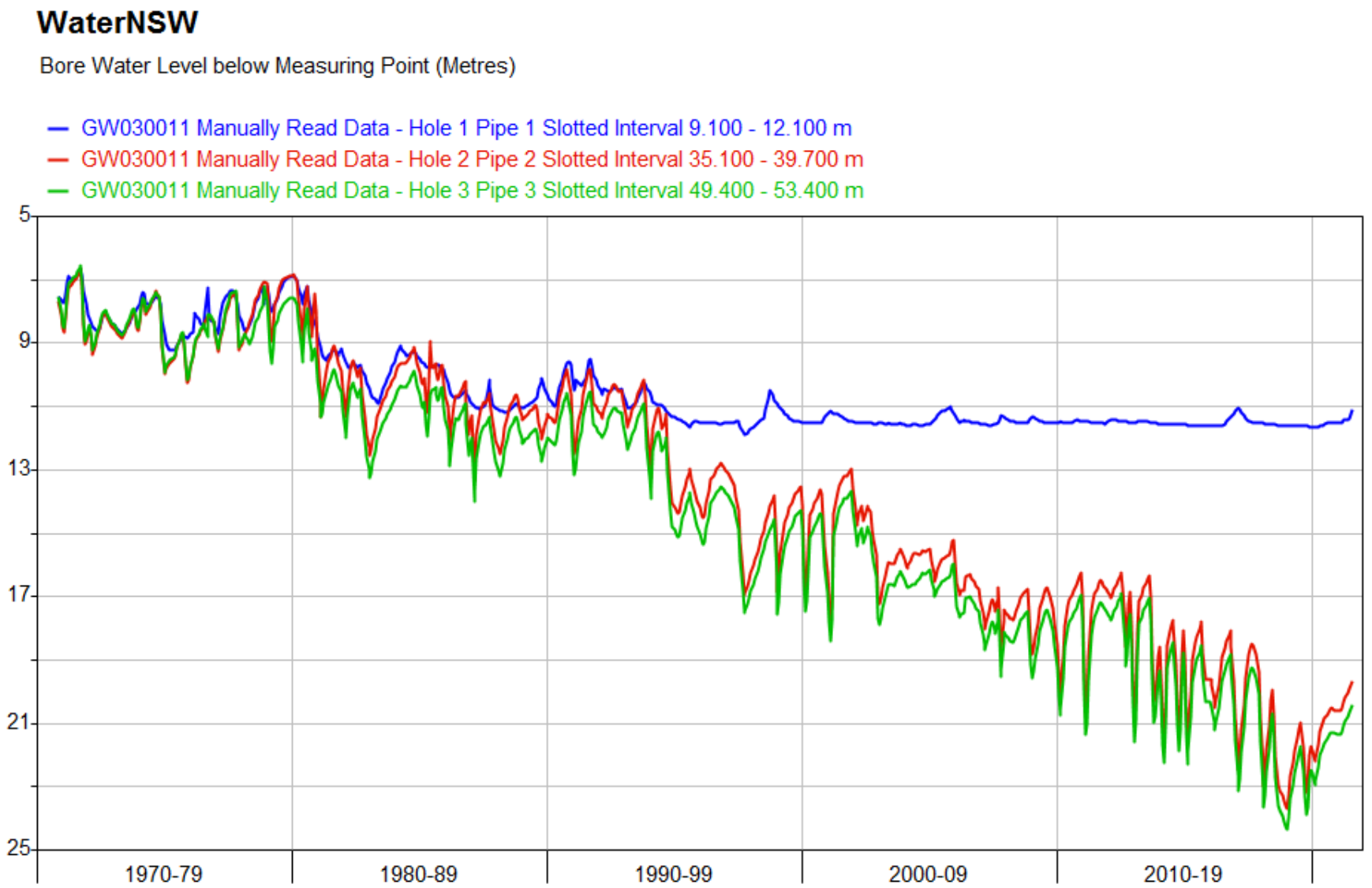
and/or

increased recharge during the recent period of heavier than average rainfall.

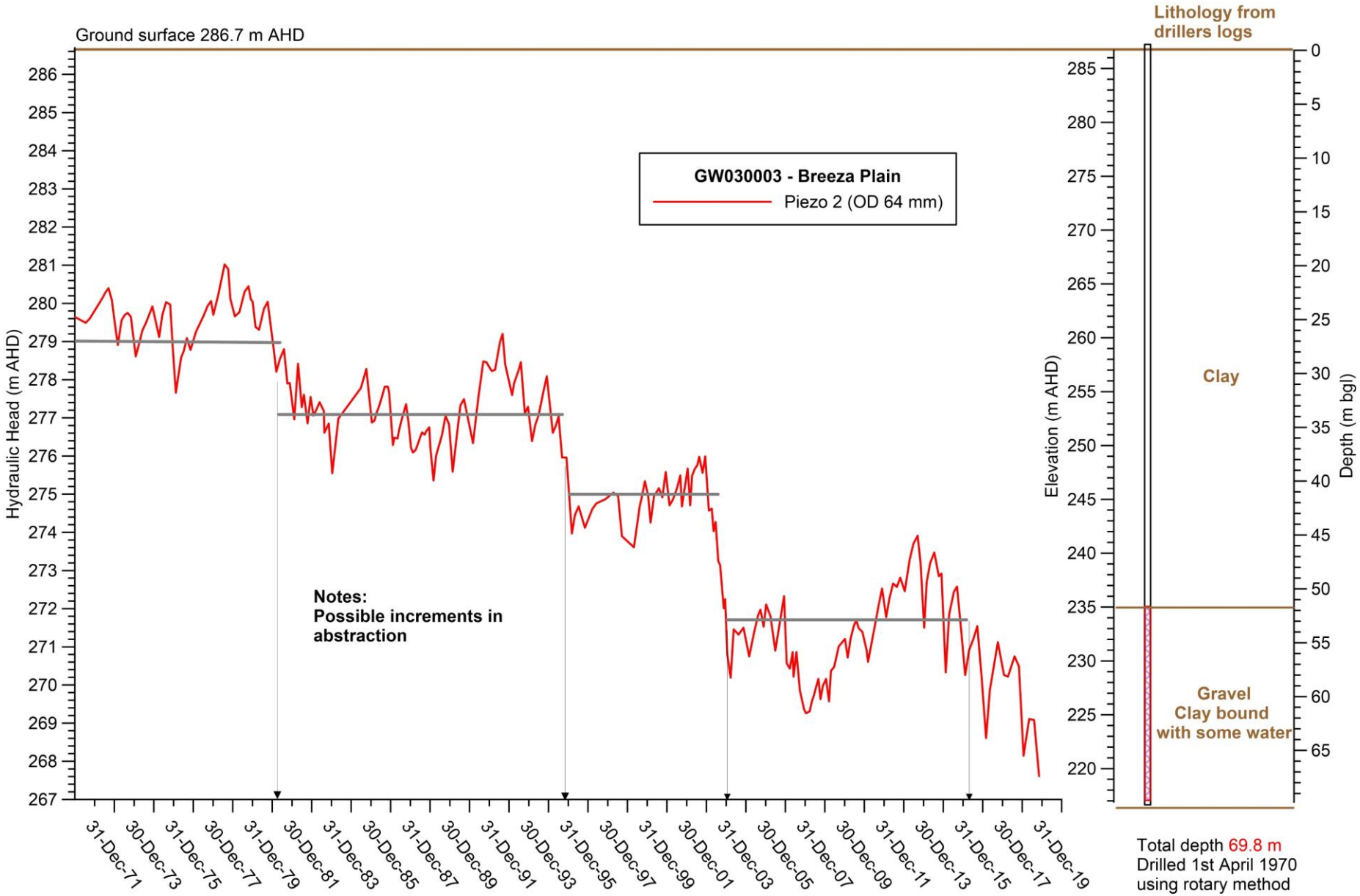
GW030009 on Mystery Road



GW030011 on Mystery Road

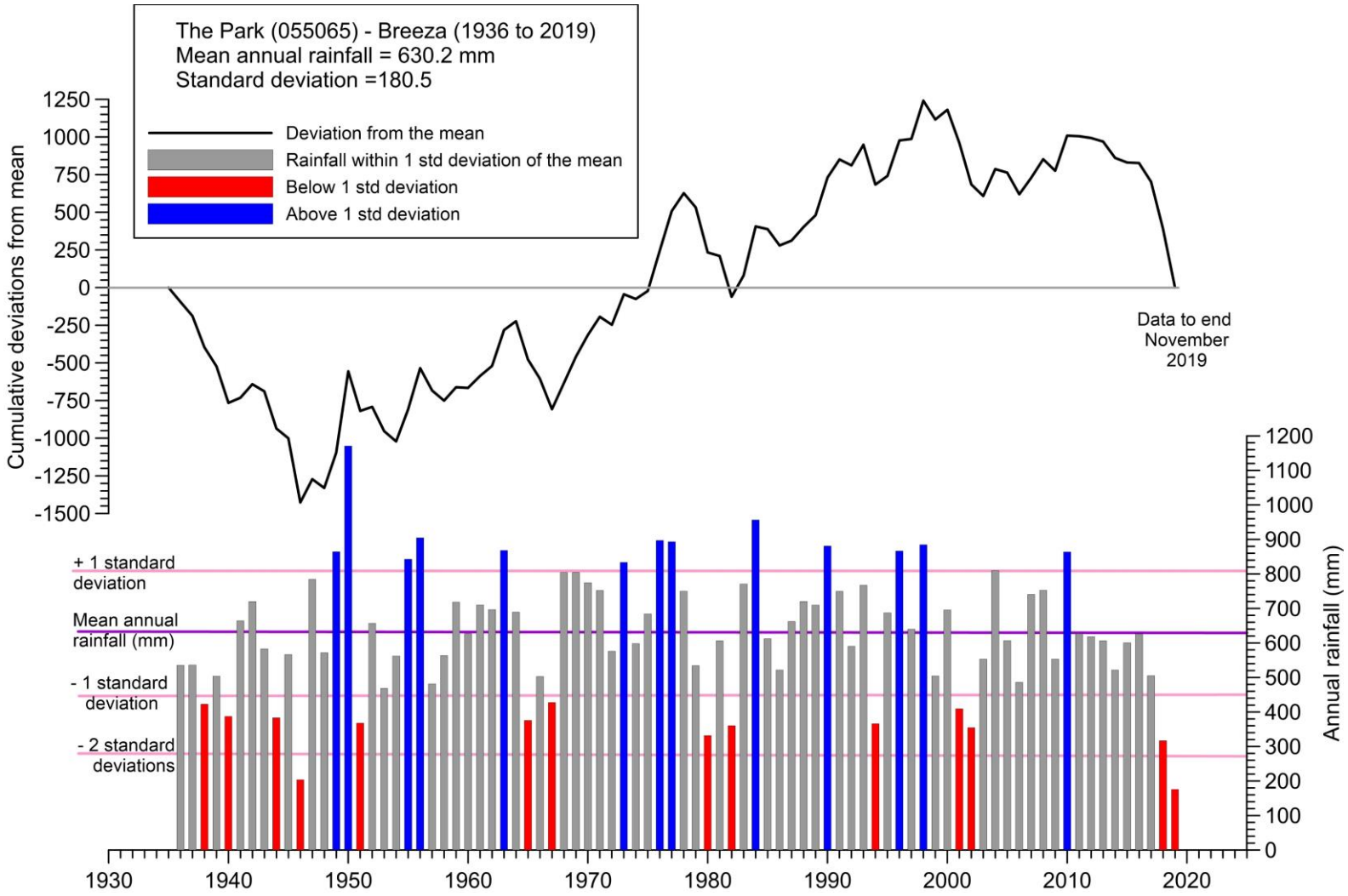


Groundwater Levels at Breeza



There are clear steps in the downward progression probably representing increased abstraction by additional abstraction wells.

Rainfall at Breeza 1935 to 2020



The falling groundwater levels are NOT caused by reduced rainfall. Wet and dry periods have come and gone since 1970 but the overall trend of declining levels that commenced in 1980 and has continued independently of changes to rainfall.

This is a characteristic of groundwater mining.

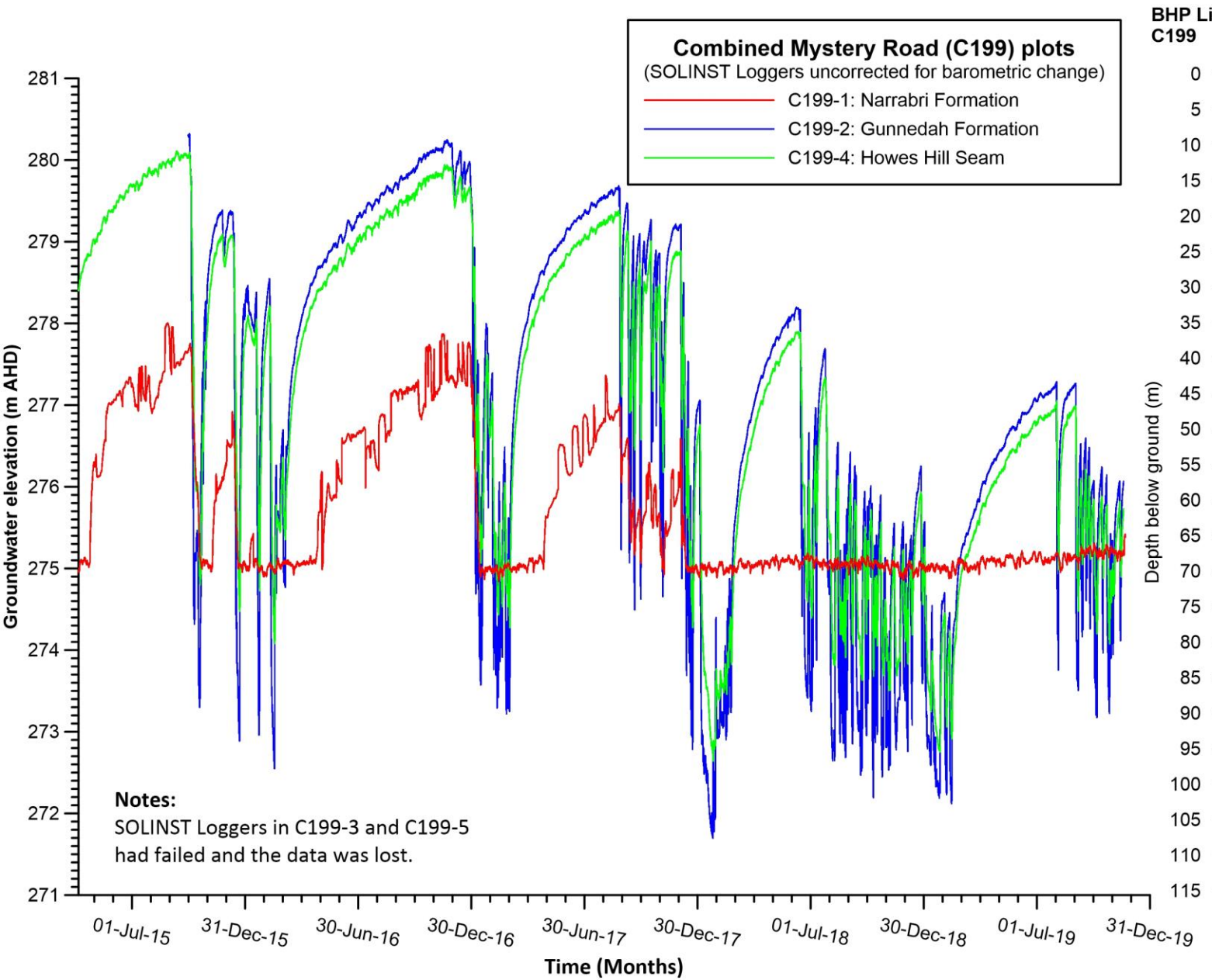
What is the link to the underlying coal seams?

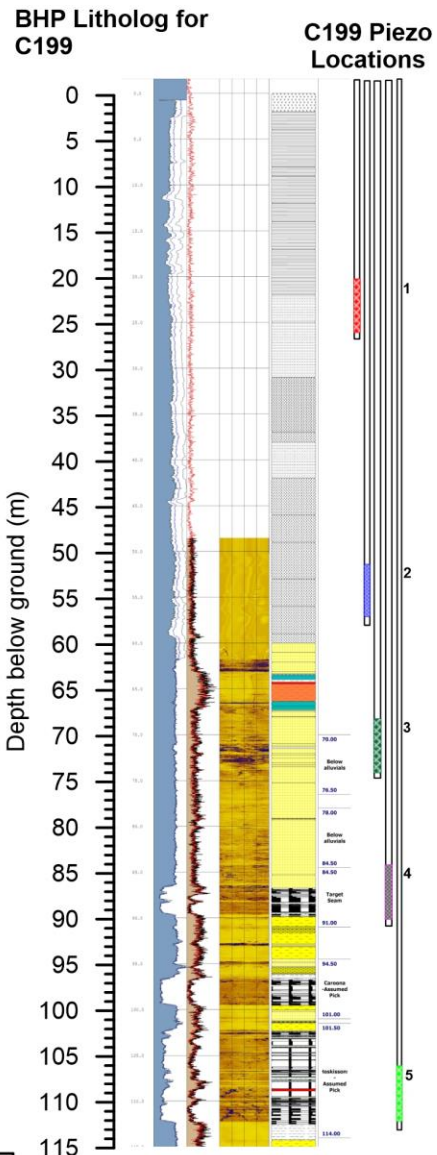
The Mystery Road bores installed by BHP as a part of the Caroona Investigation.

There very many bore records available on the WaterNSW web site. It is possible to construct a vertical cross section to better understand the geology and hydrogeology.

This is what it looks like below. Coal from the Hosskinson Seam being loaded into a dumper truck at Wollar.

The Mystery Road Boreholes – Groundwater level record

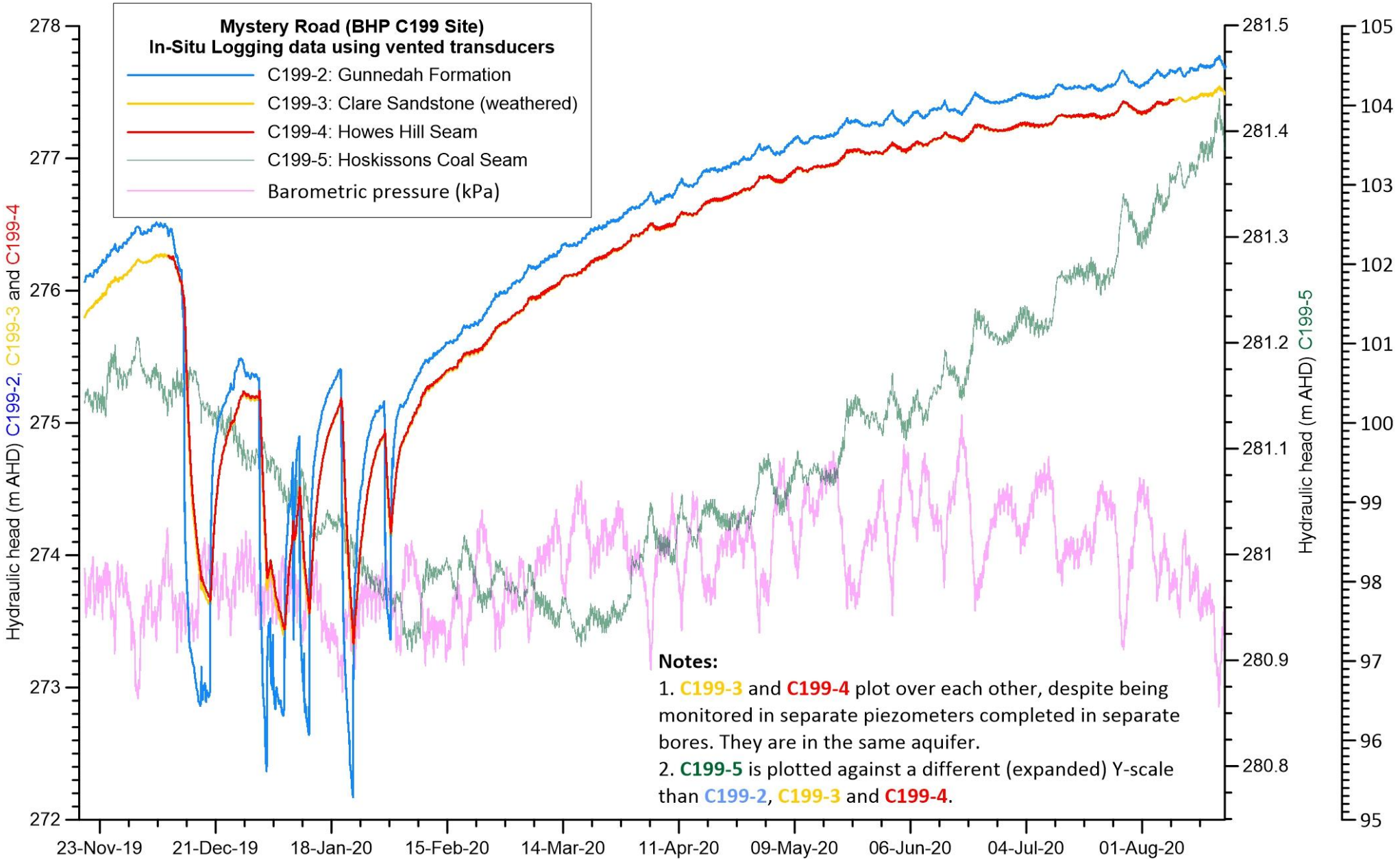




The loggers left behind by BHP hanging in the C199 bores had the data shown to the left.

Interpretation:
The hydrograph for the unconsolidated Gunnedah sands and gravels (blue line) is almost identical to the hydrograph for the top coal seam – the Howes Hill Seam (green line).

Detailed monitoring at C199 for 3 months



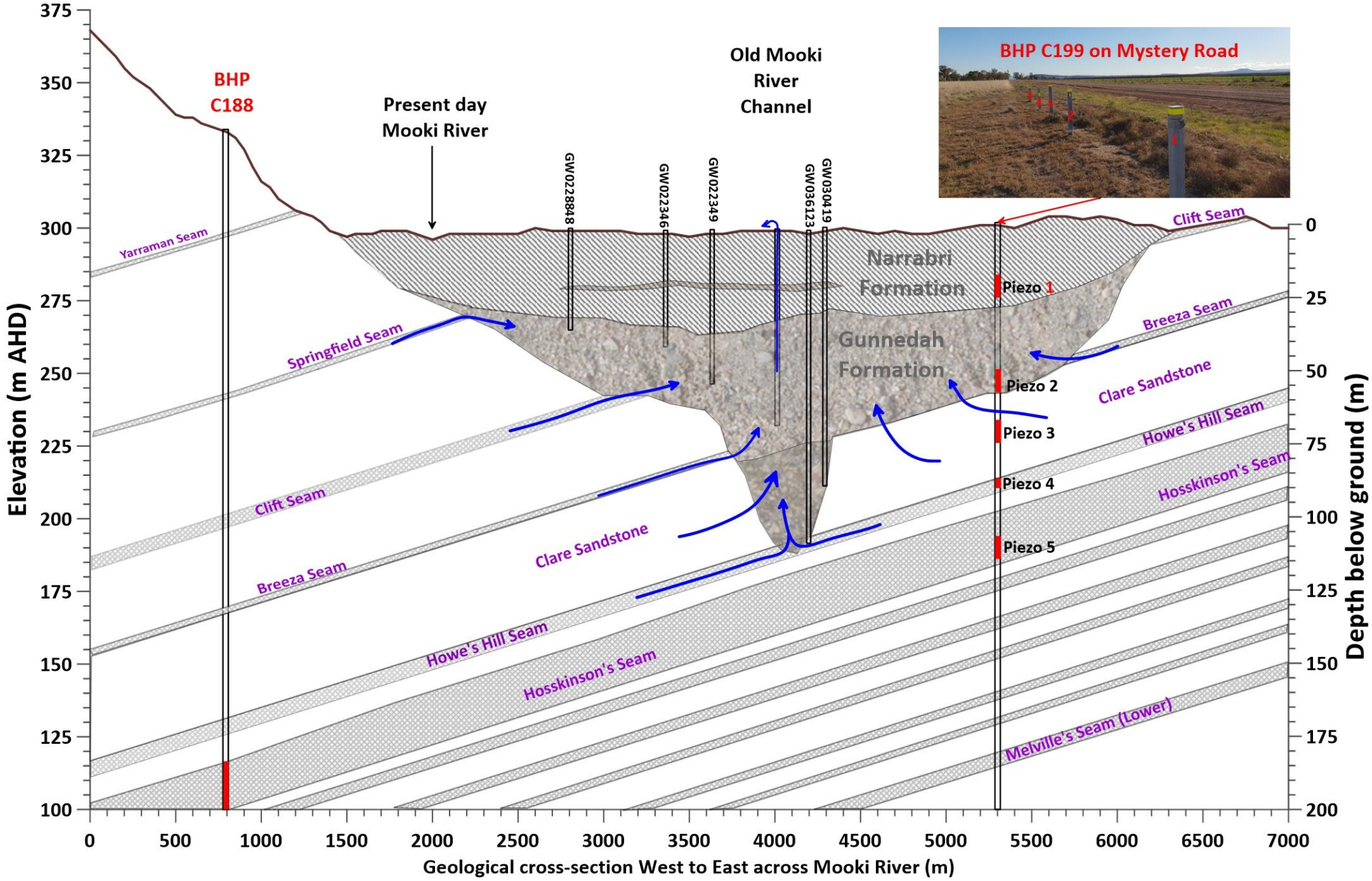
The response in January and February is to pumping from a farm borehole 45m away with a screen set in the Gunnedah Formation.

Note that water moves down from the Gunnedah to the Clare Sandstone when there is no pumping. This movement is reversed during pumping. They are connected!

A geological cross-section constructed west to east between two BHP bores at Mystery Road between Caroona and Breeza.

The old channel of the Mooki River is seen to extend downwards at least 100m and cuts into the Permian coal Measures.

Leakage between the Gunnedah Formation aquifer and the underlying coal measures is shown.



Nice pictures - What are the implications?

The groundwater resource in the area is not just the sands and gravel fingers in the unconsolidated Gunnedah Formation. Water drains down from the overlying silts (Narrabri) into the sands and gravels. Surface pollution is therefore a potential problem!

The old Mooki river system has eroded down into the Permian coal measures. The erosion probably happened in the Early Cenozoic so the coal measures have been exposed to erosion for many millions of years. They are significantly weathered. So weathered in fact that the Water Resources Commission drillers in the 70s and 80s frequently could not determine if they had drilled to the base of the Gunnedah Formation. This weathering has created a bigger aquifer system with water in the surface silts moving down into the gravels and the gravels and underlying Permian formations (sandstones and coal seams) acting hydrogeologically as a single unit. The larger aquifer explains the fact that there are many very high yielding bores close to the old Mooki Channel.

But….

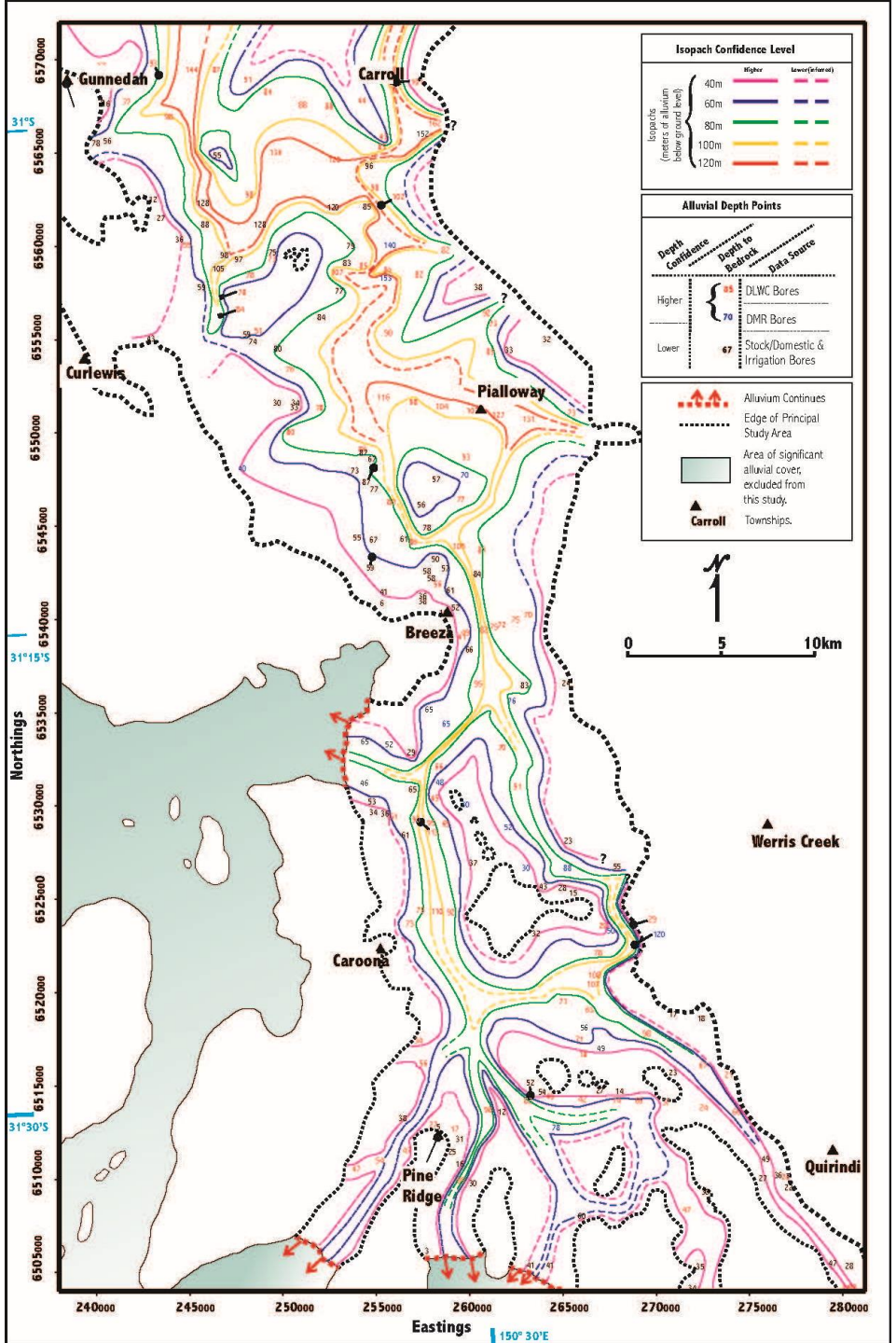
Abstraction of groundwater from the coal seams to enable recovery of gas will immediately impact the whole groundwater resource – dropping levels even more dramatically than they already are. Irrigation supplies will not be sustained for very long and shallow farm domestic supplies will rapidly dry out.

Where is this going to happen?

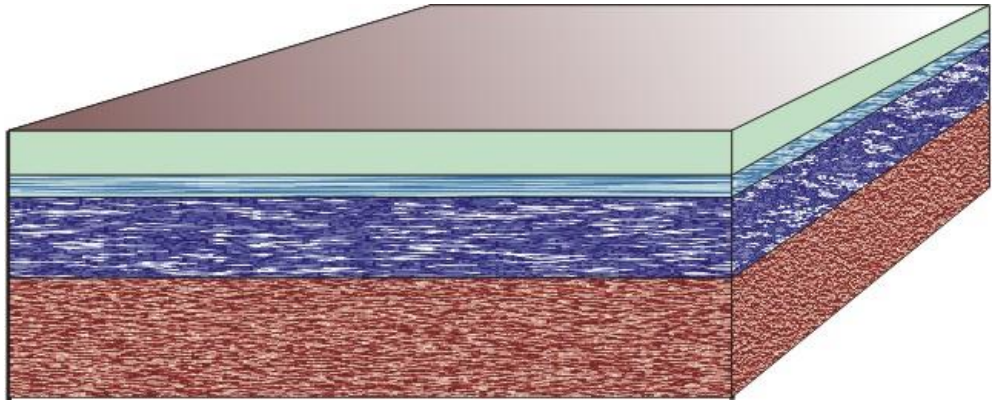
Throughout the eastern Liverpool Plains where the old Mooki River system has eroded down into the shallow coal seams. The extent of the old system was determined by drilling in the 1970s and 80s and maps compiled by researchers such as Neil Lavitt – who compiled the figure shown here more than 20 years ago.

At the Narrabri Gas Project Site, the coal seams are more than 1000 m down – with, it is argued, competent cap rock separating the impacts of abstracting water from the coal seams from reaching to the surface.

Beneath the Liverpool Plains, the coal seams are frequently less than 100 m down and sometimes crop out at the surface. There is **NO competent caprock** to prevent interconnection. Interconnection and all that that means is therefore - inevitable.



Implications for groundwater Modelling



Groundwater modelling has previously used a conceptual model of horizontal layers with different hydraulic properties.

It is assumed that each layer represents a separate geological entity - so there is a layer of lower hydraulic conductivity on top that represents the Narrabri Formation (the black soils);
then a Layer of higher hydraulic conductivity representing the Gunnedah Formation that, in turn, overlies bedrock (The Permian Formation) that includes the coal seams.

It is clear that the conceptual model used to construct the groundwater model, is not supported by the new data from Mystery Road.

The conceptual model therefore requires a complete overhaul.

The aquifers are not simply related to the geology but have been extended by weathering and fracturing to include a much greater volume that includes the coal seams in the immediate area. This has increased the volume available to the existing abstractors but also means that pumping water to reduce coal-seam gas pressure to recover the gas, will inevitably affect the existing users.

Reasons to repeat the groundwater modelling

- Better replicate the hydrogeology. Represent the actual groundwater occurrence not just the geological layering.
- Leakage does occur through the Black Cotton soils. The are not a separate lithological formation with specific hydraulic properties. There is significant lithological variation present.
- Use realistic values of specific storage to represent the unconsolidated sands and gravels (Gunnedah Formation). They are not confined if the water table is above the top of the formation and therefore **Specific Storage** has to be less than the theoretical maximum of **1.3×10^{-5}** . Using a higher value is physically impossible and automatically (usefully) reduces the predicted drawdowns.

Why have the misunderstandings occurred?

It is a fair question to ask - ***why have we got this far before we realise that there is such a great problem****?*

A major reason is the lack of communication between those interested in the shallow groundwater resource and those interested in the underlying coal/gas resources. It is perpetuated in Government where different Ministries control activities for mining and agriculture. It is perpetuated in Universities where different Faculties are usually involved in training students. It is perpetuated by the rise in popularity of groundwater modelling with the belief that actual site investigation is no longer required to establish a relevant conceptual model (groundwater modelling is so much cheaper).

As an example of this lack of communication – consider that all of the many hundreds of groundwater investigation bores installed by the Water Resources Commission **intentionally** stopped when they reached the Permian bedrock. The great majority of coal/gas investigation bores never made a note of conditions in the unconsolidated materials, **casing them off** and concentrating on observation of the rock types and pressures in the deeper Permian coal units.

The two agencies seem to have never met and compared notes.

The result: the interconnectivity was ***never suspected***; ***never looked for***; ***never modelled*** and therefore, the system was ***never understood*** **…… until now!**

Now it is understood, we must not proceed with extracting coal or seam gas from these areas –
unless we are prepared to cruel the shallow groundwater aquifer and the environment for many long centuries.

Questions please

Biogenic Fairway Detail

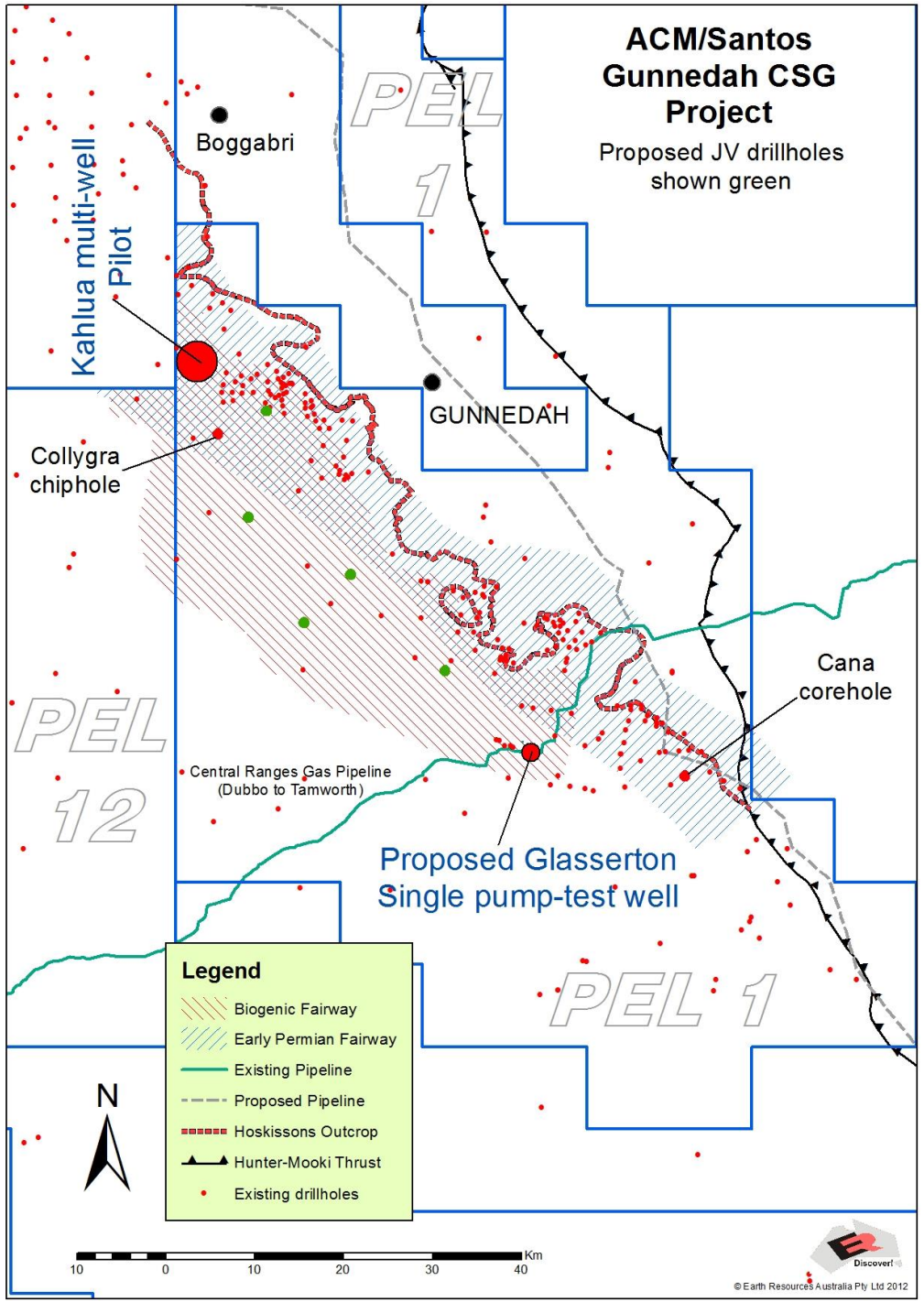
http://www.carbonminerals.com.au/carbon_final_draft_012.htm

In 2003 PELs 286 and 10 were relinquished due to the lack of detailed geological knowledge coupled with *minimum target seam depths in excess of 1,000 metres.*

During the 1990s gas was recognised in coal seams of the Powder River Basin (PRB), USA, in a geological environment that did not fit the thermogenic model. These low maturity coals contained relatively low gas contents but their very high seam permeability allowed good gas production from more widely spaced wells and without the need for fraccing.
This gas is produced by microbial action within relatively shallow seams. Generation of this **biogenic gas** occurred in recent geological time and may indeed be ongoing in many cases.

The potential for a "biogenic fairway" zone at relatively shallow depth paralleling coal seam outcrop was recognised. Methane gas detected during pump testing by ACM of landholder water bores in the northern parts of PEL1 provided evidence for such a zone which was confirmed by the drilling of the Longlea #1 well in the northeast of PEL12, also during 2006.

The biogenic fairway is a geological zone that starts at the Hoskisson's coal seam subcrop and continues down dip – as shown on the map.



Biogenic Fairway Project Area Resource Potential

As was announced progressively during the course of the initial FIA work by Santos, both PEL 12 and the Maules Creek Sub-Basin within PEL 1 have had their seam gas potential regionally diminished, but importantly, gas potential within both the Biogenic and Early Permian fairways has been progressively enhanced.

A Biogenic Fairway contains gas produced by microbial action within relatively shallow seams. One is known to exist in the area to the south-west of Gunnedah. The biogenic fairway was discovered in 2004 and seems to be the only target of any real value across PELs 1 and 12 with many of the exploration wells showing low CH^4 and high CO_2, a problem that detracts from the economic viability of the Narrabri Gas Project as well. *Quote from https://nwprotectionadvocacy.com/carbon-minerals-to-reactivate-on-the-liverpool-plains-a-stab-in-the-heart/*

As presently defined, these zones embrace vast areas, being some 1,400 and 1,100 square kilometres respectively. ACM's technical adviser, Earth Resources Australia Pty Limited (ERA) has advised the company that possible gas initially in place in potentially producible target seams within the biogenic fairway (Hoskissons Coal regionally, and the Melvilles and Breeza Seams more locally), and to a cut-off depth of 500 metres, is about **2.5 trillion cubic feet** (Tcf - or approximately **2,250 petajoules** - PJ), based on an estimated aggregate coal thickness of 9 metres, an assumed gas content of 4.5 cubic metres per tonne, and an assumed gas composition of 90% methane. ERA considers these assumed parameters to be conservative.

In the 2010 Annual Report for Carbon Minerals,the ERA advised the Company that "...results from the Kahlua Pilot drilling are excellent and have confirmed the commercial potential of the Late Permian shallow biogenic gas play." ERA estimated GIIP in the 11+ metre thick aggregate Hoskissons/Melvilles targets of approximately 3 PJ per square kilometre.

Much of the gas will be at or close to pipeline quality, at relatively shallow depths, at good saturation levels, and in seams exhibiting high to very high permeability.

CO_2 gas and black clay soils do not mix well

In research carried out in the late 1990s at a site on Elroi Downs to the west of Lake Goran – it was found that escapes of CO_2 gas through the overlying high smectite clay (black clay) soils led to instability in the clays whereby the clay was mobilised out of the ground into mud mounds. This work was published internationally in the Journal of Hydrogeology

Hydrogeological investigation of mud-mound springs….(2002) by Acworth and Timms (DOI 10.1007/s10040-003-0278-0).

The site at Elroi Downs lies in the biogenic fairway now under investigation by SANTOS. The Hosskisons Seam is at a depth of approximately 300m with a layer of basalt overlying the coal. This basalt would be expected to form a cap rock preventing the escape of biogenic CO_2. However, in 1989, gas began escaping through the basalt that led to the growth of mud mounds. There was also a much elevated pH (8.2) of the water in shallow (10m) bores drilled to investigate the phenomenon. Extensive detail of the investigation is presented in the 2002 paper.

The significant fact here is that the gas was most likely released as a result of a reduction in the hydrostatic pressure.

This is a direct parallel to the abstraction of water from the coal seam that occurs to promote gas production. As the coal seams in the biogenic fairway are known to be of high hydraulic conductivity but low specific storage – it can be expected that the impacts of pressure reduction will be felt over large areas – leading to further gas production and possible escape to the surface – leading to the probable creation of mud mounds more regionally. These could cover roads, fences and in extreme cases, even buildings. Liability for such damage will be problematical.

Elroi Downs

The Belatta Mud mound

More than 40 similar sites reported