Submission by Robert H. McNaught of the Astronomical Society of Coonabarabran

SUMMARY

- Measurements of the sky brightness reported in Appendix K of the RTS are unreliable. They cannot be used to indicate that the non-routine safety flares will not impact sky brightness at the Observatory. The Observatory director was told by SANTOS that should a sky brightness problem be identified, the **safety** flare could be shielded, but the DPIE suggest this might not be possible.
- Safety flares have the potential for causing a fire due to combustible material being blown through the flame by wind or dust devils. This applies to both the 1.5m pilot and 30m non-routine flame heights, so is a constant threat. Any appraisal flares will pose the same threat.
- There appears to have been no consideration of the earthquake history of the region as no mention is made in any of the project documents of a mag 5 earthquake in 1969 in the southern Pilliga. Additionally, the geologically very recent (neotechtonic) Walgett scarp was likely caused by a M7 thrust fault on a section of a longer fault line. A similar earthquake in section of the fault to the immediate SE of the Walgett

scarp would cause significant damage in the wider region including the project area, but more specifically, crosses the proposed route of the APA western slopes pipeline.

Introduction

My name is Robert McNaught and I worked at Siding Spring Observatory for 30 years, but I've been involved in astronomy for 50 years. My passion is observing the night sky and citizen science and I've retired to Coonabarabran to live under the Observatory's dark sky umbrella. I also lived in Narrabri for 10 years, was involved with community biodiversity surveys in the Pilliga, was active with the Pilliga Birders and am a member of Coonabarabran Landcare. Following the huge Pilliga fire in 1997, I assisted with injured wildlife rescue.

In my spoken presentation, I concentrated only on the effect gas flares have on sky brightness, but here I flesh out those arguments and deal with other concerns regarding flares and fire, and also earthquakes in the region.

1) SKY BRIGHTNESS

Coonabarabran amateur astronomers started long-term measurements of sky brightness several years ago to assess changes in light pollution and to monitor the infrequent natural events that change the sky's brightness. More recently we obtained a grant to expand the network of automated monitors around the region.

Legislation to protect the existing dark sky conditions around the Observatory also allowed the creation of the Warrumbungle Dark Sky Park. To retain its status as a dark sky park, it is a requirement to measure the sky brightness within the park and its surroundings and the Astronomical Society of Coonabarabran are conducting these measures. We can thus assess the potential influence of the gas flares.

The original EIS for the gas field had a cursory assessment of the lighting impact so I took measurements around the Tintsfield and Bibblewindi pilot flares. These measurements formed the basis of my 2017 submission to the DPIE. It was clear that the effect of the pilot flares was detectable overhead out to 4km.

Appendix K of the RTS has conclusions that are dramatically discrepant from my measures. I believe there are four reasons for this.

1) The flares have a much lower flow rate at the time of the Appendix K measurements compared to the quoted average flow rate. Their quoted values are about one eighth the average, suggesting the flame was tiny.

The claimed average flow rate of gas in pilot flares is stated in the RTS, Appendix K (p5) at 3 to 5 million standard cubic feet/day (MMCSFD) with a 4m high flame, but at the time of the Santos' consultant's measurements, the stated flow rates were (RTS Appendix K, p19) 0.36 MMCSFD at Bibblewindi, 0.82 MMCSFD at Dewhirst and 0.48 MMCSFD at Tintsfield and no flame height was stated. I can only assume that the flame at that time was tiny. Trying to estimate the effects of the 30m safety flare thus becomes problematic. The safety flare is stated as having a flow rate of 244 MMCSFD (Appendix K, p6), or ~500 times greater than the pilot flare measurements and thus prone to huge uncertainty in the extrapolation.

2) The measurement device they used has double the uncertainty in the measurements over the device I used, as I pointed out in my earlier submission. Their data shows significant scatter and their measures of the

Milky Way should be systematically brighter than the other measures, but aren't.

They used a hand-held version of the same sky monitor that I used. My personal experience with two of those hand held units indicates they give around double the scatter in the measurements compared to the logging versions. This is clearly the case from the scatter in their measures. Additionally, their measures pointing towards the Milky Way are not differentiable from their overhead measures, but this makes no sense as overhead is the darkest part of the sky and the Milky Way is brighter than the general sky background by an amount larger than the measurement scatter.

3) The measurements were made without regard for tree obscuration. Their measures were made with hand held units within the forest. This precludes making valid measures at 30degrees above the horizon which they claim they did.

Their measurements were made at undisclosed locations so it is not possible to assess how much the tree canopy may have interfered, but they do note that '*the sampling locations from the flares were surrounded by 20 m tall eucalypt forest*' (RTS Appendix K, p18). With hand-held units, it seems unlikely the

measures were taken without tree interference except perhaps overhead and it seems absurd that could have obtained valid measurements at 30deg above the horizon. From my previously reported measurement at specified locations, measurements at 30deg elevation would have been meaningless due to tree shielding. As I stated in my original submission, the flicker from the flame was visible in the sky at over 3 km distance, to the unaided eye. Appendix K however, states that their measurements overhead reached ambient sky brightness within 1km!

4) This effect of tree shielding of the pilot flare is not incorporated into their extrapolation to estimate the non-routine safety flare brightness when there is up to a 30m flame. The safety flare sits well above the trees. In Appendix K (p21), referring to skyglow caused by the safety flare:

'The horizontal decay rate of light will be the same as the existing flares and consistent with Raleigh's Inverse Square Law'

but the safety flares have no tree shielding, so the results from the tree-shielded pilot flares cannot be validly applied. Thus, their conclusions on the extent of the spread of light from the safety flare will be significantly underestimated.

Other Visual Effects

Different measures are made in the RTS Appendix K (p22) to estimate the direct brightness of a safety flare *flame* as seen from the Observatory. Based on the Bibblwindi safety flare location, they write '*The illuminance reaching the Observatory would be 0.0001 lux*'. At m_v = -4.2, this is brighter than the *average* brightness of Venus. Using this value, the apparent brightness at closer distances to the flare is simply calculated using the inverse square law. At 1.8 km, it would be the brightness of an *average* full moon (m_v = -12.7). Viewing the Leewood flare from the closest point on the Newell Highway would make it ~10 times brighter still. Thus, for about a 2km stretch along the Newell Highway either side of Leewood, should the flame from a full safety flare be directly visible, it would be brighter than the full moon. When not directly visible, the flicker and brightness would be vividly evident in the sky and treetops for tens of kilometres.

There is no assessment of such an extremely bright flickering flame as a potential distraction for night time drivers on a dangerous section of road. This is supposedly covered in Recommended Condition B62, 'Additional Visual Mitigation', but there is no specific mention that this refers to the flame from the safety flare. Unquestionably though, when a non-routine flare is active at Leewood, drivers on the Newell Highway will either think they are travelling

through an industrial area, or that the glow is from a bushfire. It would seem appropriate for signage along the highway, but then there is the possibility that a *real* bushfire could be mistaken for the flare. These concerns must be dealt with by TfNSW, but it is disappointing that there is no explicit recognition in the EIS, RTS or Final Assessment that the non-safety flare will be a visual issue for drivers, leaving it all to the TfNSW.

Artificial Light at Night (ALAN) and other disruptors

ALAN has become a major topic in biology in the last decade with six annual international conferences [ref 1] and departments forming in universities. While it is still not a commonplace topic, some aspects, particularly related to disruption of sleep patterns in humans, is well understood by the public.

Humans and wildlife have evolved in a night-time environment of darkness and lunar cycles. There are numerous examples of this relationship in circadian rhythms. For wildlife whose physiology is 'expecting' about half of all night-time hours to be dark, the presence of ALAN results in a number of effects from disruption of sleep [ref 2], changed behaviour relating to mating or plant pollination (notably from moths, bats and small mammals), and increased predator-prey interactions. General surveys of these effects appear in refs 3

and 4. Many nocturnal flying animals (moths, bats or migrating birds) are attracted to light and can die from being ‘trapped’ in the light-- unable to see outside the illuminated area and flying until they become exhausted.

ALAN is only one aspect of the disruption as it typically goes hand in hand with habitat fragmentation and the boundary effects of new roads, traffic, fencing, infrastructure and its surrounding clearing, plus increased human presence. These all put significant stresses on wildlife. In the case of 850 wells, the habitat fragmentation has to be described as major, so any conclusion that the impact will be minimal is nonsense.

Some species, like introduced rats, mice and cockroaches, have had a long relationship with human habitation, as they are less affected by these stressors. Antechinus and geckoes are notable local examples of native species that are less affected by human presence, but the majority of species lose out. Such human incursion into a large contiguous forest will continue the loss of diversity across the region.

Cumulative Effects

The current sky brightness guidelines are problematic in that progressive developments will have less and less leeway as the cumulative sky brightness

increases. If the Vickery extension was also approved, the problems could be significant. How can any assessment of light pollution be made of one project without considering the cumulative effect of both?

Appreciation of the Sky

The significance of sky is not just relevant to indigenous peoples worldwide. For me, the night sky has been a driving force throughout my life. I grew up in Scotland a few hundred metres from a colliery pithead. Every house had a coal fire and the night sky was a mixture of smoke and light pollution, but I learned the constellations nevertheless. The first time I saw the sky from a dark country location, I was lost in awe. I couldn't recognise a single constellation for the myriad of stars. It is too easy for people to forget that what we can experience in rural NSW just by going outdoors, is unavailable to the vast majority of the world's population. We must not take it for granted and throw away the astonishing treasure we have here.

Some final comments related to my personal involvement in understanding the issues of flares is given in a footnote.

2) GAS FLARES AND FIRE

In my original response to the EIS, I raised the possibility that dust devils (willy-willies), or other wind events, could blow combustible material through a gas flare. This was not investigated in the RTS or the Final Assessment, being dismissed as of little consequence.

A dust devil is a vertical column of rotating air which can raise debris from the ground, several hundred metres into the air, but have been known to rise over a kilometre. They can be from a few metres to several tens of metres in diameter with an average height of ~200m [ref 5]. Although they can occur at any time of the year, even over snow, they are by far most common over cleared ground during the hottest summer days [ref 6].

It is common to see multiple dust devils at any one time in flat desert areas during summer. With warmer summers and longer fire seasons into the future, there will be a significant increase in the incidence of dust devils.

Formation of a dust devil typically occurs under low wind conditions (1 - 7.5 m/s) over hot open ground [refs 7,8]. Turbulence created within the air flow over the ground can start rotation within a rising mass of hot air and this can develop into a dust devil. Cleared areas within a forest, plus the turbulence in the air flow at the forest/clearing boundary, will create circumstances for the formation of a dust devil.

The significant wind speeds and the rising air column within a dust devil, can pull combustible material from the ground to many tens of metres above the ground. If this material encounters a flame, it can start to burn and be deposited some distance from the flame in a similar manner to the way spot fires can occur significant distances ahead of a fire front.

The clearest way to demonstrate that dust devils are a *mechanism* by which fire can be transferred from a flare to the surroundings, is by looking at videos of dust devils interacting with flames. [Note that a 'fire devil' refers to a rotating flame created *by and within* a fire, but essentially the same phenomenon will result from a dust devil moving into a fire.] The first example is of a dust devil passing into a low intensity hazard reduction burn during autumn in Colorado:

Article with video: https://gizmodo.com/controlled-burn-spawns-a-fiery-dust-devil-1554883262

Video only: https://www.youtube.com/watch?v=uAvb3wLivRk

The second and third videos below, show the specific interaction of a dust devil with a gas flare:

https://www.youtube.com/watch?v=WZLBrQ7dKus

https://www.youtube.com/watch?v=lcY2XLUvLcs

It will be difficult to completely remove the possibility of a dust devil carrying combustible material into a flare, as this can be pulled in from the surrounding

uncleared area and the flare itself causes an updraft into the flame. It is also not the case that the threat from a safety flare only results from a non-routine 30m flame – it only takes a match to light dry material, so the constant 1.5m tall pilot flame is all that it takes.

In the Q&A between the IPC and DPIE on Aug 1, it was clear that the DPIE had little knowledge or understanding of the issue of dust devils, often referring to them as 'twisters'. This is a colloquial term for a tornado, something vastly less common than dust devils. Regardless of this, I mentioned in my initial response to the EIS that tornadoes have been witnessed in this region, including a 300m wide EF3 tornado during a severe storm near Coonabarabran on 2005 Jan 20.

The photo above by the writer shows the damaged, stripped, and fallen trees in the path of the tornado beside the Oxley Highway. In the adjoining paddocks over a dozen sheep, three cattle and a foal died, with many animals injured. Fortunately, it crossed no houses otherwise they would have been destroyed and any occupants killed.

A final comment on this section refers to the necessity to factor in climate change in assessing future threats. The increased number of storms, and dust devil frequency and intensity, is an obvious consequence. If the current threat is incorrectly framed, the future threat will be understood even less.

Wilga Power station and the 6 appraisal flares.

During the Q&A at the IPC public hearing on 2020 Aug 01, David Kitto said:

But as I said earlier, the appraisal flares that are proposed in the EIS, the department doesn't believe they are necessary and certainly, you know, have every intent, through the equality and greenhouse gas plan and through the field development plan, not to allow that and certainly we have no objection to having a condition saying, no – no appraisal flares because they can avoid it. So, you know, if you are looking to be consistent with those plans and to strengthen that obligation, certainly the conditions can be revised to do that.

But, you know, consistent with reducing lighting emissions and, you know, fire risks and – and greenhouse gas emissions, you know, it would be standard practice to, to, to, to cut those out of the project if it was possible and in this case, with the Wilga Park Power Station it is possible. So I think we can have a hundred per cent compliance with the World Bank initiative from, you know – encapsulated in any conditions for the project and ..... obligation.

If SANTOS or the DPIE were committed to removing the appraisal flares from the plans and channelling the gas to the Wilga power station why was there no reference to this in the EIS, RTS or Final Assessment? If removing the appraisal flares was a real commitment, and not just a last-minute attempt to overcome a possible barrier to the approval of the Narrabri gas project, then SANTOS should commit to removing appraisal flares from *all* their operations.

Additional to their waste of gas, open flares are a fire threat from combustible material being blown through the flame as explained in detail above. Having an open flare within the Pilliga forest (or any forest) has been a contentious issue for many years [ref 9] but it was only when the IPC Commissioners took an interest last week, that the DPIE has openly shown any concern for this situation in the Pilliga.

Between 2018 and 2019, Australia increased its volume of flared natural gas by over 60% according to the World Bank [ref 10] suggesting a lack of commitment by the industry and government to minimising overall emissions. If the IPC were to approve the project, it should be made a condition that the appraisal flares are never built, with a recommendation that no appraisal flares are used anywhere in NSW.

3) EARTHQUAKES

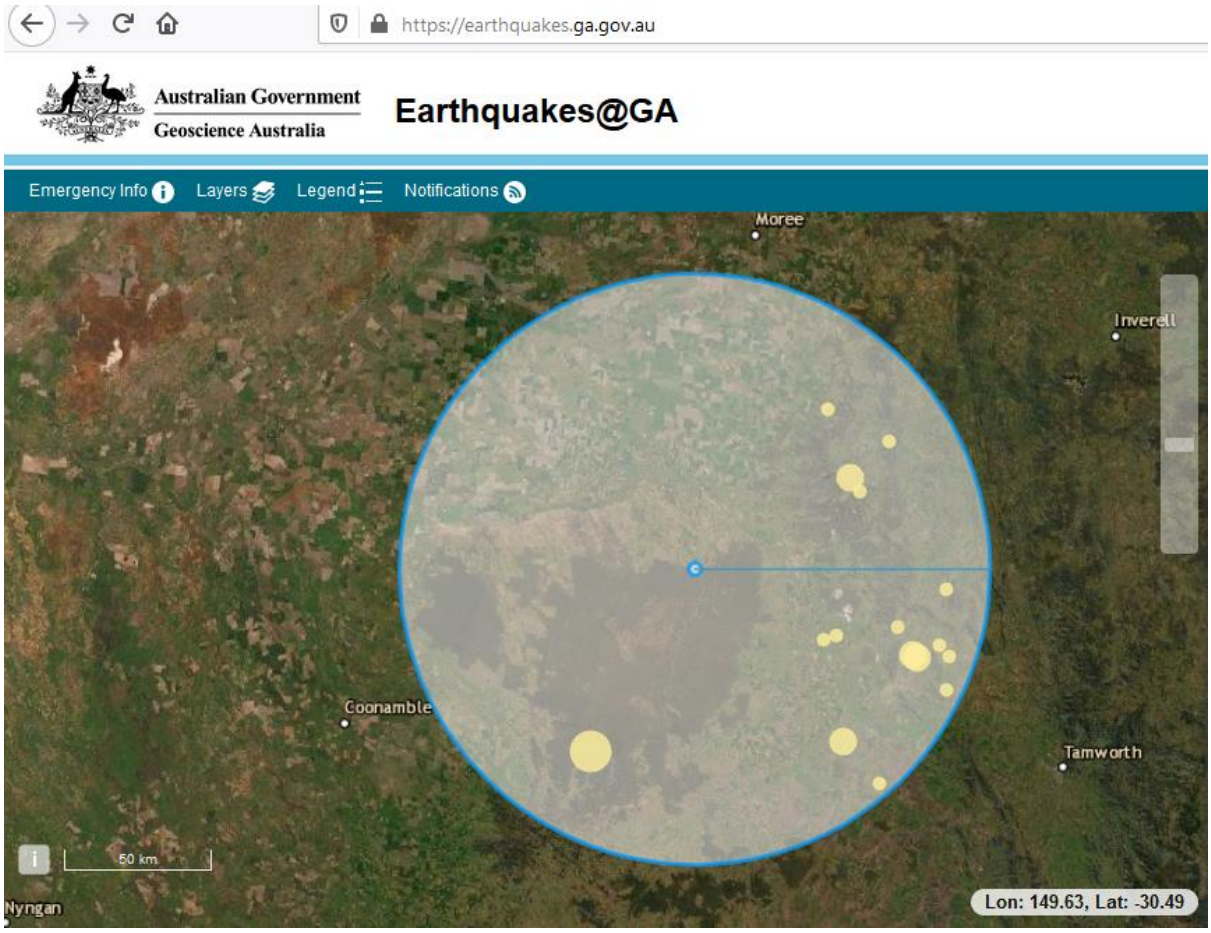
There is no mention of earthquakes or seismic activity in *Appendix H1 Hazards and Risks Expert Advice* and the DPIE Final Assessment, Expert Water Panel Report, (p20) states "*The Geoscience Australia earthquake database indicates no earthquakes in the Narrabri area exceeding 1.5 magnitude*".

I and other local amateur astronomers operate seismographs, so naturally have an interest in local seismology. A search of the Geosciences Australia (GA) website for all earthquakes within 100km of Leewood, produces 16 earthquakes larger than M1.5, 15 of which are larger than M2.0.

Pilliga Earthquake 1969 Jan 1

The most notable earthquake in this list is a M5 event in the southern Pilliga in the early hours of the New Year 1968/9.

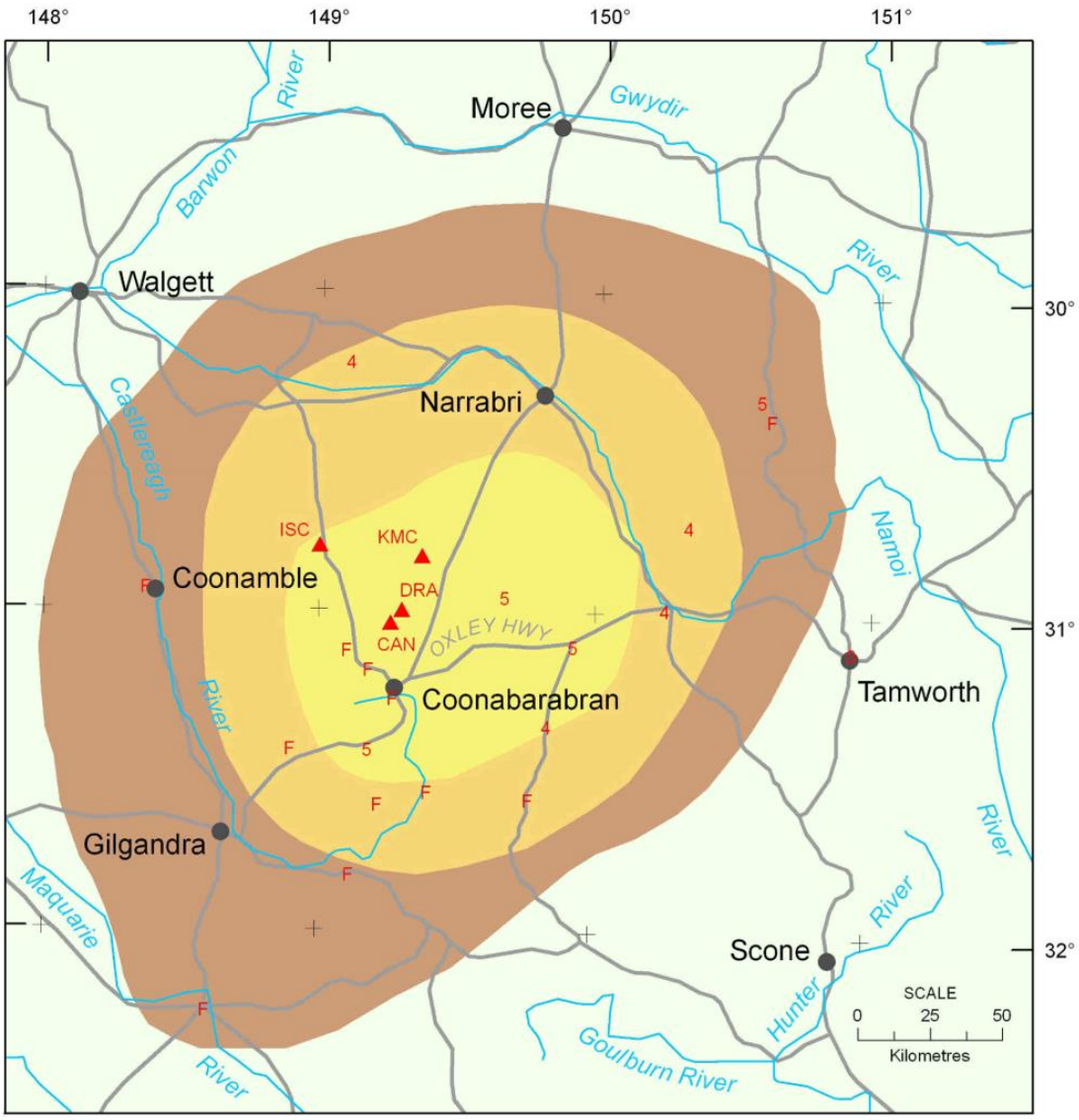
+



Magnitude	UTC	Latitude	Longitude	Depth(Km)	Location
2.4	11/11/2015 18:03:36	-30.72	150.49	0	Near Gunnedah, NSW.
2.7	20/02/2015 20:00:59	-30.10	150.32	10	NE of Narrabri, NSW.
2.1	13/08/2014 15:03:59	-30.75	150.53	0	Near Manilla, NSW.
2.5	24/02/2014 15:12:57	-30.85	150.52	10	NE of Gunnedah, NSW.
4.1	08/06/2012 11:32:39	-30.75	150.40	0	NW of Tamworth, NSW.
4.2	08/06/2012 11:31:00	-30.76	150.41	0	NW of Tamworth, NSW.
2.6	28/09/2000 05:46:57	-30.00	150.10	0	Barraba, NSW
2.8	18/02/2000 01:02:18	-30.69	150.13	0	Boggabri NSW
2.7	25/05/1999 07:31:01	-30.25	150.21	0	Boggabri NSW

Magnitude	UTC	Latitude	Longitude	Depth(Km)	Location
3.1	25/05/1999 00:44:21	-30.21	150.18	0	Boggabri NSW
1.8	24/03/1998 22:10:26	-31.14	150.28	10	Gunnedah NSW. Damage claim by homeowner on Camberwell Coal who claim there were no blasts at the time.
2.8	11/12/1996 00:43:30	-30.70	150.08	12	Keepit Dam N.S.W.
2.5	19/10/1993 17:37:15	-30.66	150.34	0	BARRABA, NSW
2.9	19/10/1993 15:51:39	-30.55	150.52	0	BARRABA, NSW MORE EVENTS ARECORDED BY AGSO
3.9	30/04/1972 17:11:23	-31.01	150.15	0	
5.0	31/12/1968 16:08:33	-31.04	149.26	0	Oxley Basin NSW

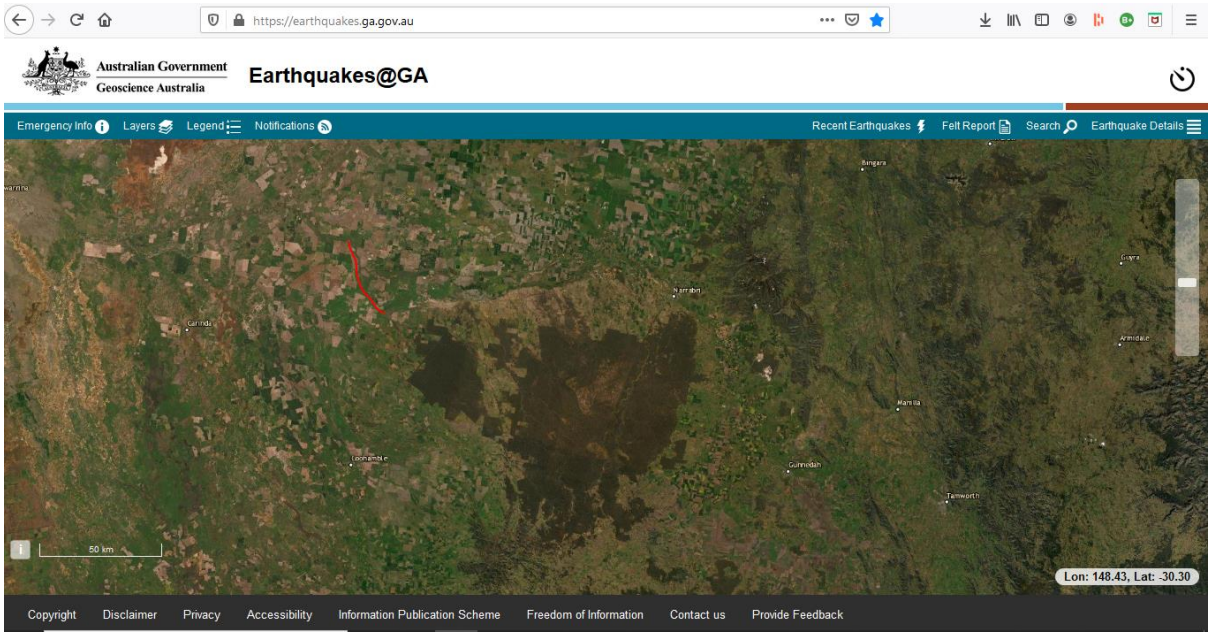
Some minor structural damage from this earthquake occurred in Coonabarabran, ~25km from the epicentre coordinates in the GA table above. A discussion of this earthquake was made by local seismologist Dr Andre Phillips [ref 11]. In 2011, Prof K. McCue [ref 12] assessed first hand reports of damage and ground movement for this earthquake and reanalysed all available seismometer traces to produce the intensity map below. The southern part of the Narrabri gas project is within the region of M5 intensity, with the SW corner of the project area ~45km from the epicentre.



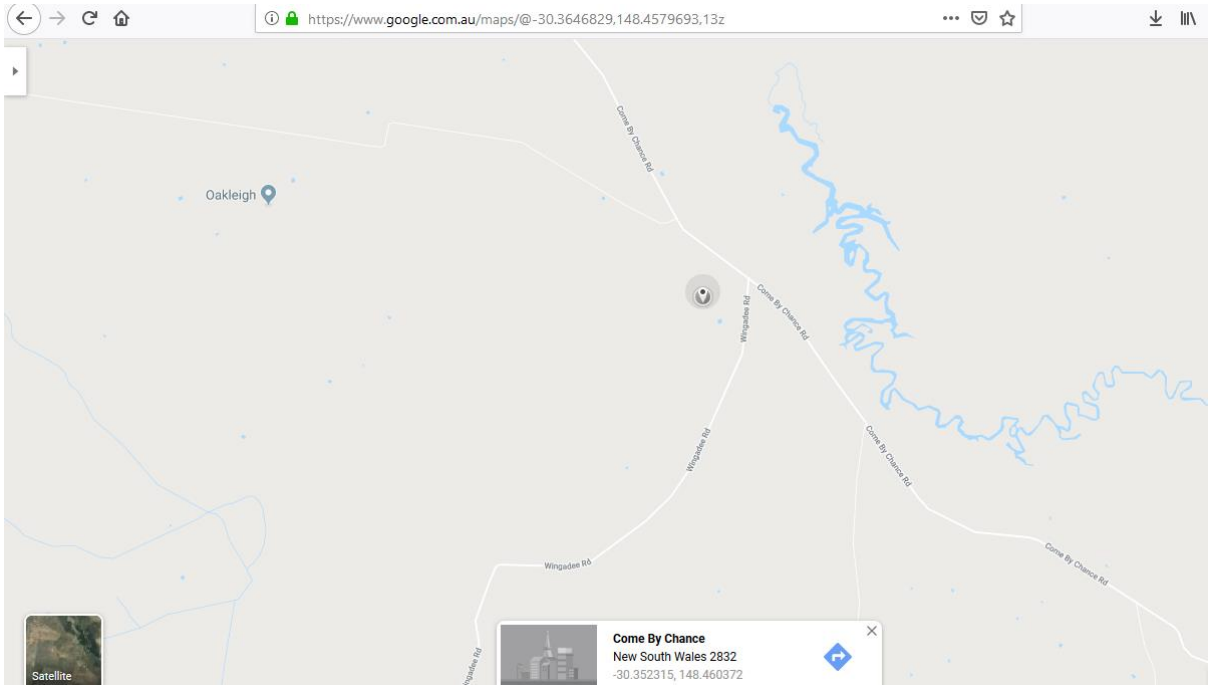
Walgett Scarp

A notable feature to the west of the Pilliga region is the Walgett scarp, a long, thrust fault most obvious around Come By Chance, 105 km from Leewood (marked in image below). It is known locally in the region as 'Bulgan Ridge'. It can be displayed on the GA website by choosing > Layers > Neotechtonic

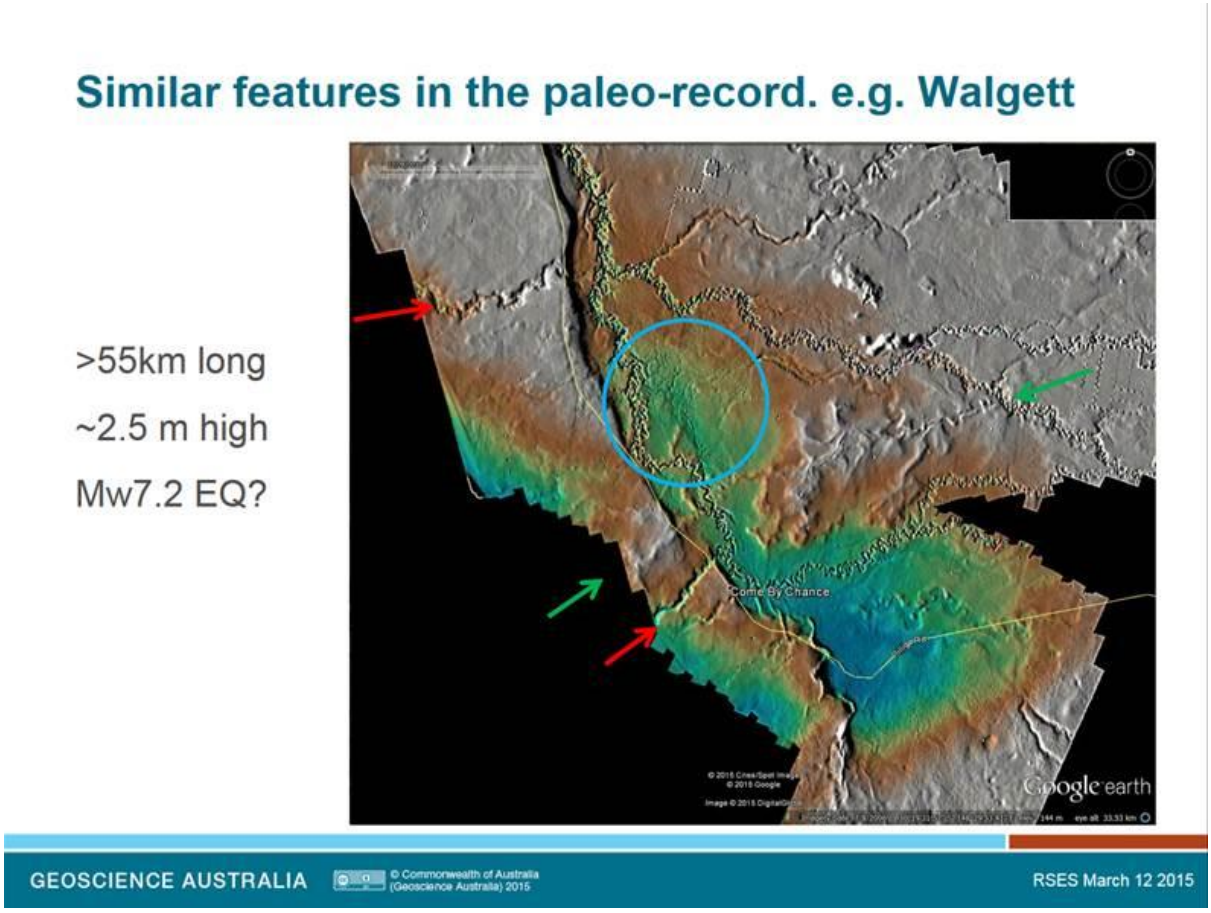
features.



Against the flat landscape, the scarp is dramatically obvious looking NW from the north end of Wingadee Rd, near Come By Chance (marked below), based on my own experience.

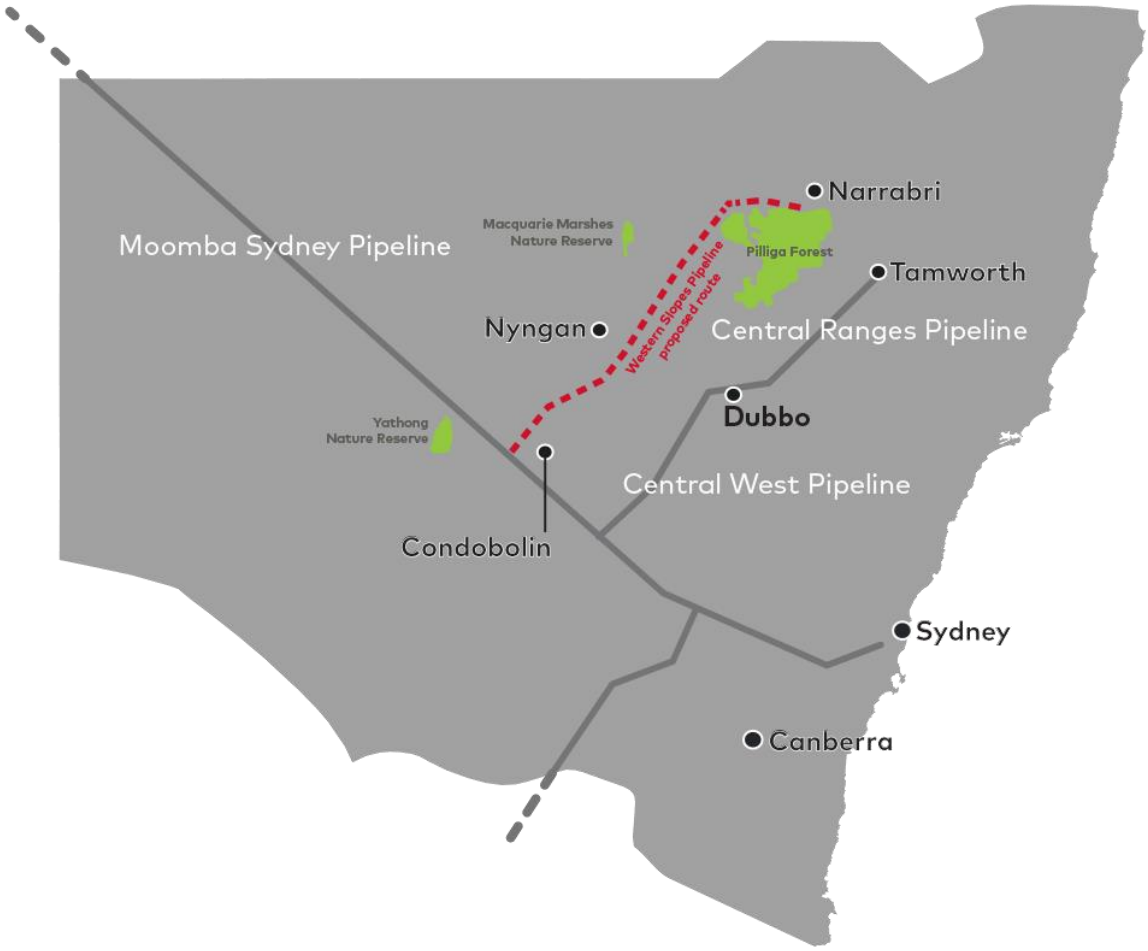


This scarp resulted in the river courses, including the Namoi river, to be diverted from their original westerly course, NW towards Walgett, along the eastern side of the raised scarp.

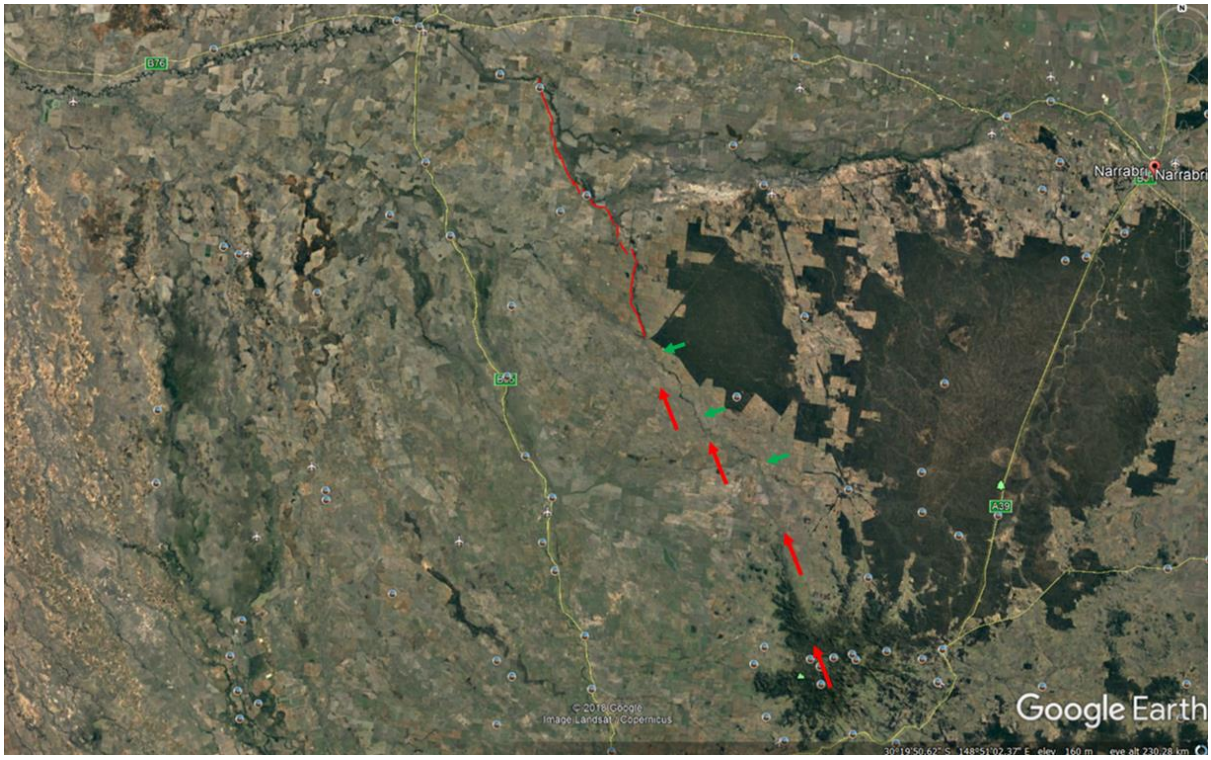


The historical watercourses west of the scarp (arrowed in the above image, courtesy of Dr D. Clark, Geosciences Australia) are still visible from the air, indicating a very young geological age (likely less than tens of thousands of years, but as yet unstudied). The magnitude of this event would have been of the order of M7 and would have caused widespread damage across the general region, including the project area. The section of the fault to the

immediate SE of the Walgett scarp, crosses the planned path of the APA western slopes pipeline. [ref 13]



A more recent analysis of Lidar data by Dr Clark, indicates a 63km total length for the Walgett scarp. Additionally, linear features (arrowed in the image below, courtesy of Dr D. Clarke, Geosciences Australia) suggest the extension of the fault line SE into the Warrumbungle mountains.



Such intraplate earthquakes [ref 14] have been recorded throughout SE Australia since recent settlement, often reaching M6, but the Walgett scarp is clearly a much larger event on a fault that has been regularly active in recent history. The images above, and additional information, were provided by Dr M.A. Phillips who is preparing a local history of the Walgett scarp.

It seems unusual that neither of these events are discussed in any of the project documentation and this must surely be an issue of concern.

Conclusion

Given the above concerns, I would urge the Commissioners to reject this proposal.

Footnote

The Observatory has to police its own dark sky regulations and as such must liaise with local councils and proponents of any new major developments to educate and potentially enforce these regulations to keep the Observatory viable. In the early 2010s, a colleague at the Observatory was told by a senior Observatory staff member, who was involved in discussions with SANTOS and the DPIE, that the gas field was a '*done deal*'. Subsequently it seemed clear that the Observatory has been uncritical in assessing the SANTOS EIS and RTS relating to lighting issues. In an email to me from David Kitto of DPIE on 2018 Oct 07, he stated:

'*we had received correspondence from the Director of the observatory accepting the findings of the study Santos commissioning on the potential flaring impacts of the project.*'

[The acceptance appears in the Supplementary Response to Submissions, 2.10 Siding Spring Observatory, 2.10.1 Acknowledgement]

In my response to David Kitto and Observatory director A/Prof Lidman, on the same day, I offered to demonstrate the effects of the appraisal flares writing:

'I could provide additional data confirming this, but would this also be ignored? There needs to be some independent examination. Do you require confirmation from the observatory Director that the effects I'm stating are true? If so, I can arrange that the Observatory join me on tests'.

Kitto did not respond and Lidman emailed:

'It would not be appropriate for me to join you on a field trip to measure the sky brightness of the Pilliga flares, so I will not do that.'

In late 2018, I spoke directly with A/Prof Lidman, about the potential threat of the *safety* flares based on my sky brightness measurements around the appraisal flares. He said that, should a *safety* flare breach the sky brightness limits at the Observatory, SANTOS had agreed to shield them. This however seems to be questioned by David Kitto in the Q&A with the IPC Commissioners on Aug 1 when he states:

'So I guess in terms of shielding the safety flares, you know, I – it may be possible but it would really depend on what you were trying to achieve and whether that was reasonable and feasible given, you know, what the outcomes you were trying to achieve.'

I have no confidence that light pollution from this project is being properly assessed given that the Observatory have made no measurements of flare brightness themselves (or if they have, they have not made those known) and the measurements done for the proponent (RTS Appendix K) are flawed as detailed above.

With regard to personal concerns, I have to discuss how an apparent 'submission' from me appeared on the IPCN webpages on 2020 July 25. This was a misdirected email to a friend who had sent me the speaker list for the public hearings as I didn't want to miss anything related to fire. On checking, I discovered that I had actually received the very same email, but thought it only covered the first two days of the public hearings when I was to speak in Narrabri. My reply mistakenly went to the original IPCN email when I clicked on that open tab rather than my friend's forwarded email. The content of the email requires explanation. I had been discussing the potential presentation of research on the thermal flux of rotating flames, but doubted it was of significance. With the publication of that email, it is necessary to elaborate on this. The SANDIA National Laboratories, Fire Science and Technology Dept. had been studying the much-increased thermal flux from a flame when it rotates: https://cbrnecentral.com/sandia-thermal-test-complex-fire-models/5408/

so, I asked one of the researchers involved about whether, for a fixed gas flow, the rotation of a gas flare could produce an increased thermal flux. My thinking was that the absorption bands in the thermal IR of the unburnt methane might have some impact. One of the SANDIA researchers, Dr Anay Luketa, replied '*It will to a relatively minor amount due to enhanced mixing, but since the fuel flow rate is fixed it won't increase significantly* ' and '*It's a combination of gas band and soot emission, the balance of which will shift based upon the level of complete combustion.*' This effect may not alter the heat flux above the required safety limit at the periphery of a clearing around a flare, so I would not have raised this but for my misdirected email.

The reference to "anti-CSG RFS" was with regard to RFS members that I'd met, but whose names I didn't know, who were concerned about consequences the project posed for fire. It was *not* a reference to the organisation.

References:

Ref 1: http://www.artificiallightatnight.org/

Ref 2: Dr A. Aulsebrook, Uni of Melbourne, https://phys.org/news/2020-07-wide-pollution-magpies-pigeons-tossing.html

Ref 3: Bogard, P., 2013, The End of Night, pp125-157 'The Ecology of Darkness' Little, Brown and Company

Ref 4: K. Xavia, 2019, Australian Science, 40, 4, 28-31, The Ecological Cost of Artificial Light

Ref 5: http://glossary.ametsoc.org/wiki/Dust_devil

Ref 6: T.J. Lyons, U.S. Nair, I.J. Foster, Journal of Arid Environments 72 (2008) 1918–1928, Clearing enhances dust devil formation

Ref 7: A.M.C. Oke, N.J. Tapper, D. Dunkerley, Journal of Arid Environments 71 (2007) 201–215, Willy-willies in the Australian landscape: The role of key meteorological variables and surface conditions in defining frequency and spatial characteristics

Ref 8: A.M.C. Oke, D. Dunkerley, N.J. Tapper, Journal of Arid Environments 71 (2007) 216–228, Willy-willies in the Australian landscape: Sediment transport characteristics

Ref 9: https://independentaustralia.net/environment/environment-display/santos-csg-flaring-on-the-pilliga-makes-a-mockery-of-total-fire-ban,8468

Ref 10: http://pubdocs.worldbank.org/en/503141595343850009/WB-GGFR-Report-July2020.pdf

Ref 11: Phillips, M.A., Coonabarabran Times, 2011 May 19, p2

Ref 12: Phillips, M.A., (2011) Presentation to the International Union of Geodesy and Geophysics, 25th General Assembly, Melbourne, http://iugg.org/archive/iugg2011/tourhosts.com.au/live/iugg2011/abstracts/pdf/abstracts/81106015Abstract05981.pdf

Ref 13: https://www.apa.com.au/about-apa/our-projects/western-slopes-pipeline/

Ref 14: https://www.researchgate.net/publication/270822696_Australia's_seismogenic_neotectonic_record_A_case_for_heterogeneous_intraplate_deformation/link/54b748be0cf24eb34f6e9eae/download