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Sonya Marshall
Secretary/Treasurer
Artesian Bore Water Users Association
New South Wales
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Dear Sonya,

Thank you for the opportunity to provide a review of the Klohn Crippen Berger report: 'Southern and Eastern Recharge Groundwater Sources: Literature Review and Recommended Recharge Rates' (February 2020).

I understand Klohn Crippen Berger Ltd (KCB) were retained by the NSW Department of Industry, Planning and Environment (DPIE) to '*conduct a literature review of published recharge mechanisms and collate existing estimates of recharge for the Great Artesian Basin (GAB), focusing on the Southern and Eastern Recharge Groundwater Sources in New South Wales'*. As a result of their review, KCB recommended recharge volumes in the Southern and Eastern Recharge Groundwater Sources should be increased.

The primary concern the Artesian Bore Water Users Association (ABWUA) has is the increase in extraction limits for the Southern and Eastern Recharge Groundwater Sources, when the GAB artesian pressure is still finding its equilibrium as the result of the 'cap and pipe' project. The proposed increase in the existing 2008 LTAAELs has been based on recommended increased recharge volumes by KCB. The DPIE have stated that LTAAELs for the Eastern and Southern Recharge Groundwater Sources are equivalent to 70% of the net recharge. DPIE have stated that their '*policy position also remains that 30% of net recharge is committed as environmental water and 70% is the volume that is able to be extracted (i.e. the extraction limit)*'.

ABWUA have retained me to review whether KCB used the best available methods and science in arriving at their recommendations. My comments regarding the KCB report are as follows:

1. KCB have completed a literature review of 17 reports, most of which are CSIRO and/or Geoscience Australia reports. KCB stated: 'The literature review included in Appendix 1 is not a technical critique of the work done to reach the conclusions in each individual report, nor is it an exhaustive review of all reports published or issued on recharge in the GAB. Supporting content is accepted as correct and current effort in this review was placed solely on gathering knowledge and practical tools in understanding and translating the conceptual understanding of recharge processes.'

   No comment was given by KCB on why they chose these particular reports. Is this a representative sample? Did they cherry-pick? Were there no research publications from any Australian universities which are traditionally independent researchers? I believe the UNSW Connected Waters Initiative Research Centre; UNSW School of Biological, Earth and Environmental Sciences; and Royal Melbourne Institute of Technology, School of Chemical and Environmental Engineering; have and still are investigating in the GAB. I also understand that it is difficult for universities to attract research grants from the State and/or Federal governments.

2. KCB state the main aquifers in the Southern and Eastern Recharge Groundwater Source are the Pilliga Sandstone and the Keelindi Beds. These are included in the Hooray Sandstone and equivalent aquifer groups, and the Cadna-owie–Hooray Sandstone and equivalent aquifer groups. The Hutton Sandstone is not hydrogeologically equivalent to this group. Based on this KCB use recharge rate research undertaken in Queensland within stratigraphically equivalent groundwater units to estimate recharge rates and volumes in the Pilliga Sandstone and Keelindi Beds aquifers in NSW. However, topography, landuse, vegetation, soil and climate are important factors also influencing recharge rates These were not presented in the KCB report in enough detail to determine recharge rates and volumes, and to allow an increase in groundwater use as proposed in the Draft NSW GAB WSP (2020).

3. KCB discussed the four main recharge mechanisms in the Southern and Eastern Recharge Groundwater Source:
   a. Diffuse recharge (rainfall over the landscape)
   b. Preferred pathway flow (fractures along Pilliga Sandstone bedding planes, paleochannels)
   c. Localised recharge (via 'losing' reaches of the Namoi River, etc.)
   d. Mountain system recharge (via fan deposits)

KCB noted '*The study by Barron et al (2010) indicated that annual rainfall was a major factor influencing recharge: however, rainfall intensity was more of a contributing factor. This was a common theme across the majority of literature reviewed: preferred pathway flow, which requires episodic, high-rainfall events, is the dominant recharge mechanism in the intake beds, especially compared to diffuse recharge. Estimating recharge using % of rainfall only does not fully capture these events*.'

KCB noted that evaporation is higher than rainfall therefore extreme rainfall events are a major factor in recharge by one, some, or all, of the above recharge mechanisms. KCB concluded the dominant recharge mechanism in the Pilliga Sandstone aquifer, in the Southern and Eastern Recharge Groundwater Sources, is by preferred pathway flow with high intensity rainfall (150mm to 200mm continuous 30 days). This is because the regolith above preferred pathways needed to be fully saturated before they could recharge the Pilliga Sandstone aquifer. However, high intensity climate is not prevalent in the Eastern and Southern Recharge Groundwater Sources, as they are located in the temperate climate zone, whereas the sub-tropical climate zone occupies the northern NSW GAB and into the Queensland GAB where some of the references KCB were reviewing were based.

4. KCB summarised the various recharge estimation methods as follows:
    a. Saturated Zone chloride mass-balance method (covers all the groundwater recharge pathways: diffuse recharge, preferred pathway flow, localised recharge via 'losing' streams, and mountain system recharge)
    b. Unsaturated Zone chloride mass-balance method
    c. % of Annual Rainfall (Rainfall is not the only mechanism affecting recharge: topography, land use, vegetation, soil or surficial geology, and the hydraulic properties of the subsurface need to be considered. % of annual rainfall is too simplistic).
    d. Groundwater Hydrograph Analysis (best for unconfined aquifers in localised recharge from streams and rivers)
    e. Radiocarbon and stable isotope dating (can determine groundwater velocities, which in some situations may be related to recharge rates; preferred pathway flow is supported by the occurrence of modern groundwater, as shown by age dating, at considerable depth in some bores, indicating a relatively quick recharge mechanism…but the bore construction details would need to be known as poorly sealed bores are often conduits to recharge from surface water).

KCB looked at diffuse recharge, preferred pathway flow and localised recharge separately based on Kellett et al (2003) studies in Queensland intake beds because some aquifers are contiguous with the Pilliga Sandstone aquifer. KCB state they are relevant to NSW '*but may require adjustments for factors such as climate and geology*'. Habermahl et al (2009) did similar studies and compared diffuse recharge with preferred pathway flow. They found preferred pathway flows were higher than diffuse recharge. KCB went along with Kellett et al. (2003) and decided the best way to estimate recharge is using the saturated zone chloride mass-balance method. I agree this is a good approach for Southern and Eastern Recharge Groundwater Sources as it covers all the groundwater recharge pathways (diffuse recharge, preferred pathway flow, localised recharge via 'losing' streams, and mountain system recharge). Smerdon et al (2012a) estimated recharge rate using data from a 2011 map of chloride deposition for Australia (Leaney et al 2011), and chloride concentration in groundwater from Kellett et al (2003) and Habermahl et al (2009). I would like to know whether Leaney et al (2011) mapped any parna-rich sediment (aeolian deposits transported from the inland) in the Eastern and Southern Recharge Groundwater area, as these deposits have a high concentration of chloride, as found in the NSW Southern Tablelands.

KCB made a point of saying they are not critiquing the historic work which they are using to provide new groundwater recharge estimates in the Eastern and Southern Recharge Groundwater Sources. KCB calculated the total recharge rates (mm/yr) provided in Table 5.2 by summing the recharge rates from Smerdon et al (2012a) for the updated recharge areas of the Southern and Eastern Recharge Groundwater Sources provided in Table 5.1 and Figure 5.1. Kellet et al (2003) was based on Queensland studies in equivalent hydrostratigraphic units as the Pilliga sandstone located in the NSW GAB, but the topography, etc is not the same. KCB state there must be adjustments made for factors such as climate and geology but did not state how they adjusted for climate and geology.

5. KCB wrote that across the majority of the Southern and Eastern Recharge Groundwater areas the recharge rate is less than 10mm/yr. However, they stated that up to 47.8mm/year is interpreted in the Pilliga National Park and Pilliga State Conservation area which are undeveloped and would receive greater recharge. I presume KCB are inferring this is because of the exposed Pilliga Sandstone intake beds in this area? Recharge rates are also higher in Eastern Recharge Groundwater Source and attribute this to a change from native to summer crops and irrigation in this area. I understand this is because irrigation allows the soil to remain mostly saturated, allowing high intensity rainfall to recharge via preferred pathways flow.

6. KCB found the recharge fluxes calculated for the Southern and Eastern Recharge Groundwater Sources '*are an order of magnitude comparable to the recharge fluxes used to calculate long-term average net recharge in the current WSP for the NSW GAB Groundwater Sources (DWE, 2014)'*. These were 106,000 ML/year and 47,500 ML/year for the Southern and Eastern Recharge Groundwater Sources, respectively. However, KCB did not state in their Table 4.1 how DWE estimated recharge fluxes. So how does KCB know DWE did not calculate recharge fluxes for the Eastern and Southern Recharge Groundwater Sources using the same method? If they both used the same method and are an order of magnitude in difference then this would highlight there is an order of magnitude variability in using this method of recharge estimation NOT that DWE underestimated recharge and therefore KCB believe there is more groundwater available.

7. KCB state in Section 4.3 *'limited information available regarding the impact of future climate variation on groundwater resources is currently insufficient to predict future recharge rates and fluxes'*. Given the Draft 2020 GAB WSP is a document for the 'future' then I find this statement to be unsatisfactory.

Yours sincerely,

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