XXXVIII IAH Congress

Groundwater Quality Sustainability

Krakow, 12–17 September 2010

Extended Abstracts

Editors:
Andrzej Zuber
Jarosław Kania
Ewa Kmiecik

University of Silesia Press 2010

abstract id: **160**

topic: **1**
Groundwater quality sustainability

1.4
Groundwater quality and agriculture

title: **Alluvial groundwater response to variable rainfall recharge and prolonged pumping: lower Lockyer catchment, Queensland, Australia**

author(s): **Malcolm E. Cox**
(1) Biogeosciences, Faculty of Science and Technology, Queensland University of Technology, Brisbane,
(2) National Centre for Groundwater Research and Training, Australia,
m.cox@qut.edu.au

Julie Picarel
Biogeosciences, Faculty of Science and Technology, Queensland University of Technology, Brisbane, Australia

keywords: alluvial groundwater, Lockyer Valley Queensland, hydrochemistry, stable isotopes

The Lockyer Valley in southeast Queensland, Australia, is around 80 km west of the capital Brisbane and drains to the Brisbane River, which flows to the coastline. The valley supports intensive irrigation of market garden crops and fodder based on groundwater drawn from Quaternary alluvial deposits within channels incised into Mesozoic age sandstone bedrock. The alluvium is mostly less than 2 km in width and 35 m in depth, and much less in smaller tributaries. Alluvial material typically has upper layers of loamy soils and silts, a thicker intermediate zone of mixed layers of silts and fine sands with clays, and a basal layer of coarse sand and gravel which is highly transmissive, but not regionally continuous.

The climate is subtropical and long term average annual rainfall within the valley is around 900 mm and on the surrounding ranges is 1100–1200 mm. Recharge to the alluvial aquifer system is primarily from ephemeral stream flow fed by rainfall on the surrounding ranges, which are capped by Tertiary age basalt flows (Dvoracek and Cox, 2008). Most significant recharge is a result of summer storms. For most of the catchment regular monitoring (e.g. monthly) occurs in observations bores and several automated recorders, only within the central 30% of the catchment are irrigation bores metered. Largely due to this lack of regulation, groundwater levels have been drawn well down over time.

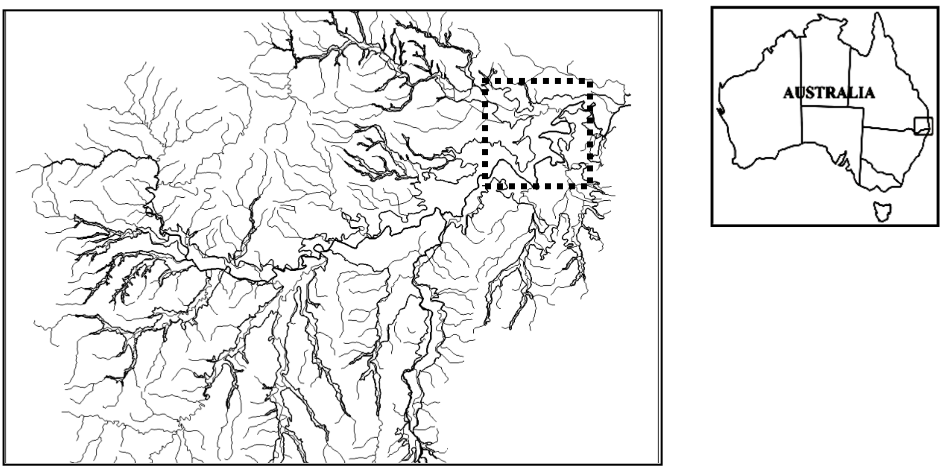

Figure 1. Drainage system of Lockyer Valley showing outline of alluvium. Box shows study area in lower valley (~10 × 10 km); inset shows location in southeast Queensland.

Following almost 15 years of near drought conditions, by 2008 water levels in the whole Lockyer Valley were the lowest for over 20 years. Here we consider the lower section of the catchment where the watertable has been substantially drawn down by pumping locally as well as further upstream. Although water levels clearly respond to high rainfall events, for example in 1996, with limited recharge and continued pumping the long term trend is a decrease. In the study area there are over 200 bores used for irrigation, and around 60 observation bores but regular monitoring only on about 20. Hydrographs (m below surface) for two bores within the central section of the alluvium, 643 and 613, show significant drawdown for the period 1990 to 2009 (Fig. 2). Less so for bore 647 within shallower alluvium of smaller Buaraba Creek which has occasional flow; and bore 625 is towards the edge of the alluvium. Both have much lower pumping rates than 613 and 643.

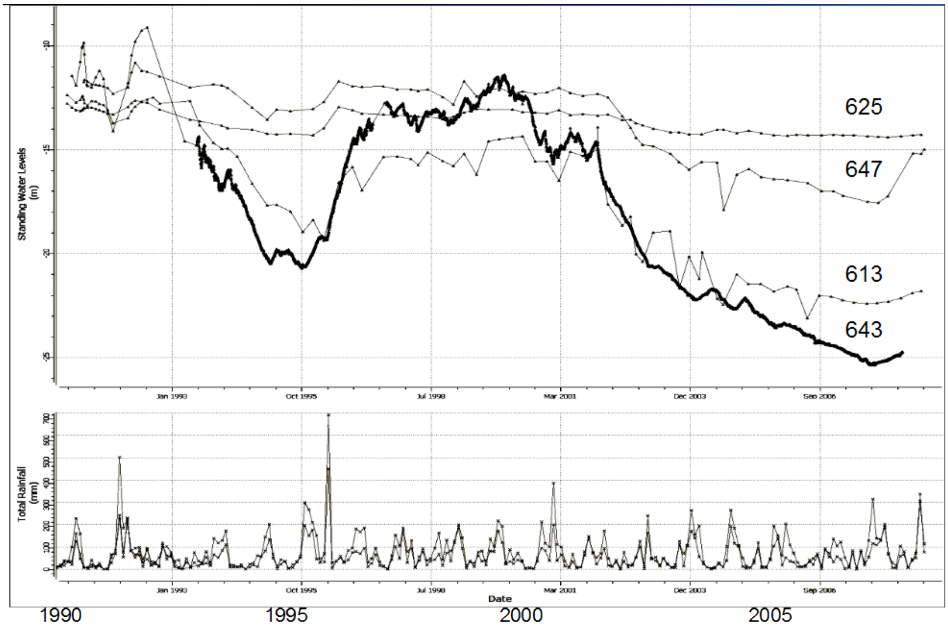

Figure 2. *Top:* hydrographs of 4 bores (locations shown in Fig. 3) for the period 1990 to 2009. *Bottom*: rainfall from two stations in central and lower Lockyer Valley.

In Figure 3 *(right)* the watertable surface for bores in the alluvium (as m above sea level) has been contoured. The contour pattern clearly shows that pumping is actively pulling groundwater from further upstream. Measurements of the alluvial watertable over a 25 km distance in this lower section show a lowering of head of 30 m, which reflects a gradient here of around 1.2 m/km. The zone of greatest drawdown central to the alluvial profile is shown by a continuous line, and of note, is not directly below the meandering stream channel.

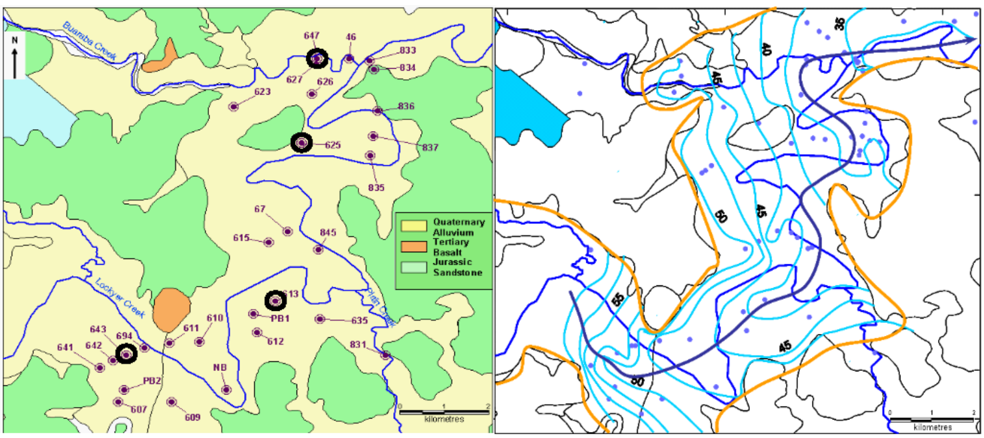

Figure 3. Maps of study area: *(left*) geology and bores measured and sampled, and *(right)* contours of the watertable surface with the deepest zone displayed by solid line.

Within the 25–35 m thickness of the alluvium in the main valley here continued extraction has produced drawdown of well over 15 m and resulted in a saturated thickness of around 5 m, and much of this is central to the main flow path. Typically, bores are drilled < 1 m into the bedrock and are screened in the lower 6 m accessing the basal sands and gravels (see Fig. 4). The relative position of bore 643 is shown with standing water levels of 1995, 2004 and 2009. Of note is that the water level (surface of the saturated zone) is around 15–20 m below the creek bed. With the lack of significant recharge some shallower bores towards the alluvium edges have dried up, for example, 641 in this cross-section (Picarel, 2004).

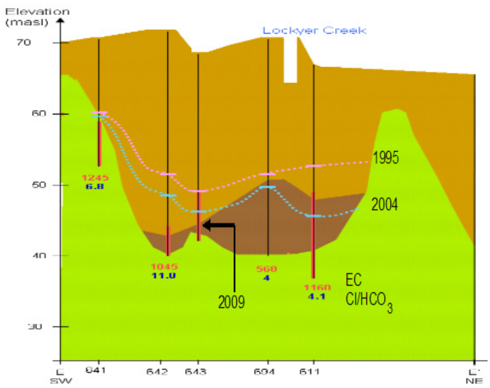

Figure 4. Cross-section of Lockyer Creek (in SW of Fig. 3) showing bedrock morphology and alluvium with coarse sands at base. Bore screens shown in red.

Most groundwater extraction is from the lower layers of coarse sands and gravels within the alluvium, and the lower valley is becoming degraded due to continued local and upstream extraction, and the effects of the decade-long drought. The alluvial groundwater typically has an EC of 800 to 2,000 μScm^{-1} and sandstone groundwaters an EC of 1,500 to 8,000 μScm^{-1} (Fig. 5). One bore in alluvium, 637, has an anomalous EC of 27,000 μScm^{-1}. Bores screened in both alluvium and gravels reflect mixing in their EC and chemical composition, as shown in Figure 4 (EC range 568 to 1245 μScm^{-1}).

Hydrochemical and isotopic analyses have enabled determination of recharge processes and the mixing of groundwaters within this area. Most groundwater sampled is of Na, Mg–Cl,HCO_3 type, with $Na^{+}>Mg^{2+}>Ca^{2+}$ (Picarel, 2004). The chemical analyses indicate 4 major groups of water: A, recharging surface water and bores close to the stream; B, groundwater in the alluvial gravels, some near the bedrock interface; C, groundwater in middle and upper alluvium, mostly distant from the stream; and D, bores also extracting from the sandstone bedrock (Gatton Sandstone). These groupings are also displayed in a plot of HCO_3 vs Cl (Fig. 5); the ratio Cl/HCO_3 is found to be a useful discriminator (also see Fig. 4). Group C (main alluvial aquifer) receives recharge from rainfall-sourced stream flow; Group B includes weathered sandstone and reflects the interaction with stream recharge and alluvium. Group D waters are from sandstone aquifers here. Groundwater contribution from the sandstone bedrock is shown to be enhanced by pumping when groundwater levels are low. The high salinity bore 635 is shown, however, the bore does not extract from sandstone.

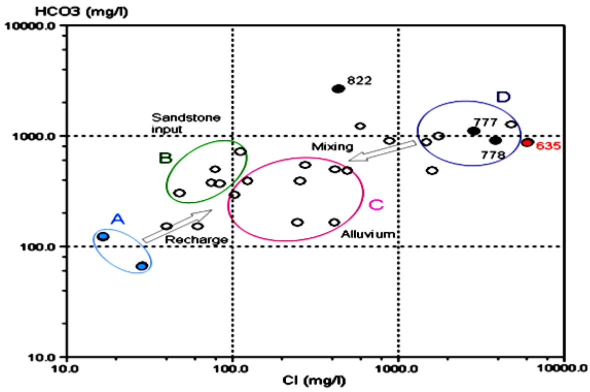

Figure 5. Log plot of HCO3 vs Cl for groundwaters in lower Lockyer Creek, showing grouping. Note high salinity alluvial bore #635. Blue: surface waters; black: bedrock.

Isotopic studies support hydrochemical groupings and identified two main sources of recharge to the alluvial aquifer system of the lower catchment. Groundwaters fall along the (Craig) Global Meteoric Water Line, and display those with direct recharge from stream flow (δ^2H ~ -22‰ and δ^{18}O ~ -4.4‰) plus those slightly more depleted values with recharge and mixing from sandstone bedrock. These sandstone groundwaters are indicated to be substantially older, and themselves are recharged at some distance. In areas close to the stream, δ^2H and δ^{18}O values indicate that the groundwater receives modern meteoric recharge. Alluvial bores more distant from the stream are relatively enriched along the global MWL; other bores further from the river fall along a slope showing strong evaporative enrichment. Many of these bores are distant from the river where the alluvium is thinner, and this is considered to be partly due to some recycling of irrigation waters (Cox, Wilson, 2006).

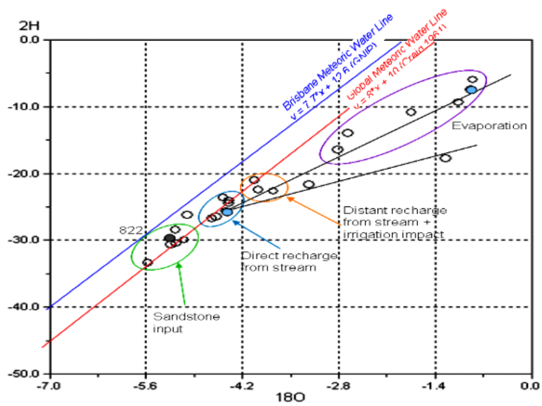

Figure 6. Plot of stable isotopes δ^2H and δ^{18}O reflecting processes related to mixing, recharge and evaporation. Blue: surface waters; black: bedrock.

Very high salinities in several bores appear due to ponding of groundwater in basement depressions. For the most saline bore 635 (EC = 27,000 μS·cm^{-1}) this is a long term condition, and combined chemical and isotopic data and drillhole geology logs suggest that the salinity is not due to evaporative processes or to substantial recharge from the sandstone (δ^2H value = –23.6‰). It may be related to the morphology of the bedrock where a depression may lead to groundwater stagnation and concentration of dissolved salts.

SUMMARY

The primary recharge to the alluvial aquifers of the lower Lockyer Valley is from flow in the drainage system as a result of heavy storms in the surrounding ranges. There is a lesser amount from lower quality groundwaters from bedrock sandstones, and this can be enhanced by low water levels and continued extraction. Due to a combination of prolonged dry conditions, continued pumping for irrigation and the location at the lower end of the catchment, this area has substantially degraded groundwater resources. Degradation is both due to increases in salinity ($\gg$2000 $\mu S \cdot cm^{-1}$) and substantial drawdown of water levels into the basal layers of the alluvium.

Current water levels are 15–20 m below the stream bed and there is around 5 m of saturated alluvium. To give this some context: to fill the alluvium to the stream bed, a very rough calculation for 30 km of stream, of average alluvial section 1050 × 14 m, with porosity 25% (poorly sorted sands) gives a volume of 110 GL. The current situation is not sustainable for resource integrity. Several factors therefore need to be considered, (a) future impacts of climate change, (b) potential of artificial recharge and introduction of treated waste waters, and (c) strict management and monitoring.

ACKNOWLEDGEMENTS

We thank the Queensland Department of Environment and Resources Management (DERM) for access to the groundwater database. We appreciate the assistance given by Vivienne McNeil, Andrew Wilson, Pavel Dvoracek, Amy Hawke and Ashley Bleakley.

REFERENCES

Cox M.E., Wilson A.S., 2006: *Use of geochemical and isotope plots to determine recharge to alluvial aquifers.* Lockyer Valley, Queensland, Australia. ISMAR 2005, 5th International Symposium Aquifer Recharge, Berlin, 12-17 June, 2005. 8pp. UNDP publication, p. 253–263.

Dvoracek P., Cox M.E., 2008: *Monitoring of groundwater in alluvial aquifers with ephemeral recharge and intensive irrigation.* Laidley Creek catchment, Queensland, Australia. Proceedings of 36th IAH Congress, October, 2008, Toyama, Japan, Integrating Groundwater Science and Human Well-Being, 9p.

Picarel J., 2004: *Groundwater Salinity in the Lower Lockyer Creek Catchment.* BAppSc Honours Thesis, School of Natural Resource Sciences, Queensland University of Technology, Brisbane and University of Montpellier, France.

International Association of Hydrogeologists

AGH University of Science and Technology

2-vol. set + CD
ISSN 0208-6336
ISBN 978-83-226-1979-0