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This paper examines values associated with the groundwater and management options that may provide a solution to falling levels. Some ocean and river outlet drains have started to be diverted to soakage pits. Treated wastewater is under consideration for managed aquifer recharge and lake beds may be treated to reduce the leakage of stormwater to retain some open water values. There have also been attempts to increase water use efficiencies by both regulatory and educative methods. These efforts may have slowed the fall in groundwater levels but it has not reversed or stabilised them so more will be needed if this valuable but largely unappreciated resource is to be maintained.

466 - Will climate variability reduce dryland salinity risk in the south west agricultural region of Western Australia?

Raper, G.P.[1], Simons, J.A.[2], George, R.J.[1], Speed, R.J.[3], Smith, R.H.[4], Ryder, A.[5], Stainer, G.[4], Kendle A.[3] and Bennett D.L.[1]

Department of Agriculture & Food, Western Australia, Bunbury[1], Esperance[2], Geraldton[3], Merredin[4], Albany[5]

Email - paul.raper@agric.wa.gov.au

Dryland salinity is a hydrologically driven land degradation hazard brought about by replacing deep-rooted, perennial vegetation with shallow rooted, annual crops and pastures. In the late 1990s over a million hectares of farmland In Western Australia was mapped as severely salt affected. It was also estimated that between 2.8 and 4.5 million hectares of agricultural land has a high hazard and could be at future risk from shallow watertables and salinity.

The factors determining salinity risk are time since clearing, hydrogeology, soil-type, rainfall and land-use. Groundwater level trend analysis is considered the most efficient method for predicting future salinity extent because it integrates the system response to the drivers and is a direct predictor of the area likely to be affected and the timing of impact.

Hydrograph data from 1,500 surveillance bores distributed across the region were analysed for the time period 2007-2012, building on an analysis (<1990-2007) published in 2008. Proportional changes in annual rainfall for the periods 2000-07 and 2008-12 relative to historical values were mapped for the study area and accumulated monthly residual rainfall plots for selected rain gauges were prepared for comparison with groundwater hydrographs.

The analysis showed that the highest salinity risk occurs in:

- portions of the northern and central south of the region, where groundwater levels have continued to rise, despite a decade of below average rainfall,
- on the eastern south coast, where rainfall has been above average for the past decade and watertables are already shallow.

Elsewhere, the proportion of bores exhibiting stable or falling trends has increased over the past decade. In the areas cleared the longest, this is most likely due to the system approaching a new hydrological equilibrium. In other areas, especially to the south-west, it appears that rainfall decline is responsible reducing recharge and risk. To the east, the impact may be to extend the expected time to risk and equilibrium.

432 - Impact of structural controls and climate change on the groundwater behavior of hard rock aquifers, Musi River Basin, Andhra Pradesh, India

L. Surinaidu[1], P. Pavelic[1], K.Seshadri[2] and B, George[3]

[1]International Water Management Institute, Hyderabad, India

[2]ISRO-National Remote Sensing Centre (NRSC), Hyderabad

[3]Department of Civil & Environmental Engineering, University of Melbourne, Australia-3010

E-mail: L.Surinaidu@cgiar.org

Hard rock aquifer systems are frequently insufficiently characterized to reliably assess groundwater flow process and sustainable yields. Such characterization is vital for the millions of smallholder farmers who derive their domestic water supplies and livelihoods from these resources in India. Reliable groundwater models are needed that can predict future groundwater behaviour in response to climate change threats and the ever-increasing demands on the resource. To overcome the data constraints an integrated analysis of geomorphology, geology and borewell lithologs was used to characterize and conceptualize the hard aquifer system across the entire 11,257 km² of the Musi River Basin in Andhra Pradesh, India. The analysis of structural features such as dykes and fractures in comparison with groundwater level data indicate the presence of shallow water levels immediately upstream of the dykes. It also reveals a large number of irrigation wells along the fractured zones. Across the Musi Basin about 67% of the area is classified as over-exploited according to Government of India protocols. Observed groundwater levels are slightly ambiguous given that systematic declines in water levels were observed between 1989 to 2004 and increases observed in the years thereafter. A numerical 3-D groundwater flow model is developed to simulate groundwater flow process that incorporated the most important hydrogeological features and calibrated using observed hydraulic heads from 1989-2004 and validated with 2005-2010 data. The water balance results indicate that net storage loss of 228 MCM per year is causing water level depletion and dying-out of the aquifer. The model results indicate the need to enhance the supply by recharge augmentation or reduce the groundwater demand by at least 20% through water saving technologies to ensure sustainability of the groundwater resources in the Musi for agriculture security. The model offers insights in terms of highlighting the interplay between aquifer structure, climate, water demand, landuse and supply augmentation technologies on groundwater availability.

720 - Climate change and impact on public water supply - case study of Ljubljana Field and Mura Valley (Slovenia)

Branka Bračič Železnik[1], Petra Souvent[2] & Barbara Čenčur Curk[3(*)]

[1]Public Water Supply Company JP Vodovod-Kanalizacija d.o.o., Research Department, Ljubljana, Slovenia

[2]Slovenian Environment Agency, Ljubljana, Slovenia

[3]University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geology, Ljubljana, Slovenia

barbara.cencur@ntf.uni-lj.si

The main drinking water supply problems are related to the significant change of groundwater quantity and quality observed in the last decades as an effect of land use practices and very likely also climate change. These topics were studied in the frame of SEE project CC-WaterS (Climate Change and Impact on Water Supply) with the main goal to develop a water supply management system.

In Slovenia the extent of climate change and its impact on water resources was studied on two test sites, Ljubljana field's and Mura valley alluvial aquifers. They differentiate by geometry, yield, land use and response to climate change. The quantity status of Ljubljana field aquifer is good. Water availability in the future will not reduce. The situation is quite different in Mura valley, where in the main part groundwater level trends are negative and the scarcity of water is and will be present. Future water use for different users was estimated with the combination of EUROPOP's and Statistical Agency of Slovenia's trends of future population changes, trends from water use data from water utility companies and expert judgement.

Mura valley has 31.596 hectares of agricultural areas. Where the estimated total N input is larger than 250 kg/ha the risk of N leaching is enlarged. Such areas represent 6,3 % of all agricultural areas. The estimation of total N for Ljubljana field shows that the the risk of leaching is enlarged in 12,6 % of the agricultural areas. The produce type on both test areas are not likely to change in the future and the extent of N leaching could increase for about 5 %.

Finally a water supply management system regarding optimization of water extraction and land use restrictions under climate change scenarios was set up. This was done only for Ljubljana field test area, since in Mura valley water supply is dispersed to several companies. For public water supply of Ljubljana, several management options regarding water quantity were selected and evaluated: reducing water losses on pipelines, establishing of additional waterworks, artificial recharge with infiltration wells and a new well field with river bank filtration. On the other hand, drinking water treatment is another management option to be considered. Due to sufficient water availability management options regarding water quantity are not necessary.

Monday Session Two G

Groundwater and Resource Industries

Agriculture and Groundwater

353 - Catchment water resources under different vegetation and geology in south-western Victoria, Australia

P. Evan Dresel
Department of Primary Industries Bendigo Victoria Australia

John A. Webb
La Trobe University Melbourne Australia

Peter Hekmeijer
Department of Primary Industries Bendigo Victoria Australia

Michael Adelana
Department of Primary Industries Bendigo Victoria Australia

Joshua F. Dean
La Trobe University Melbourne Australia

Fahmida Perveen
La Trobe University Melbourne Australia
evan.dresel@dpi.vic.gov.au

Changing land use in south-western Victoria, Australia has the potential to impact groundwater and surface water resource availability at the catchment scale due to the differences in vegetation water use. This is significant for local and regional water supply and for ecosystem values. State policy has recently been developed to consider impacts on water resources in regulating plantation forestry and potentially agricultural land use.

We have instrumented three paired catchments, pasture and tree plantation, with flow weirs, weather stations, and groundwater piezometers to investigate the effects of vegetation cover on water resources. The catchment pairs are in areas of different geology. Stream flow is intermittent/ephemeral in all catchments.

Groundwater piezometers in the plantation catchments generally exhibit declining water tables and lower seasonal variability than piezometers in pasture catchments, indicating lower recharge than in the pastures due to higher evapotranspiration by the trees. This effect was evident during a period of higher than average rain when the pasture catchments largely had increasing water levels.

The differences in stream flow between catchments are not completely explained by the differences in evapotranspiration and interception from different vegetation types. The percentage of time with stream flow was not directly related to vegetation type. Reduced recharge decreases gradient to the drainage but, perhaps more significantly, decreases groundwater-surface water connectivity. Peak flow was lower in the pasture catchment at one site although greater runoff is expected from pastures. Variation in geologic setting and topography thus have a major influence on how land use relates to stream flow, complicating generalisation of the results.

674 - The importance of topographic controls on groundwater recharge for plantation forestry in southeast Australia

Joshua F. Dean and John A. Webb
La Trobe University, Victoria, Australia
jf3dean@students.latrobe.edu.au

Geraldine E. Jacobsen and Robert Chisari
ANSTO, NSW, Australia

P. Evan Dresel
Department of Primary Industries Victoria, Australia

The trade off between water use and carbon sequestration by plantation forestry is the subject of ongoing debate in Australia. Many tree plantations are planted without consideration for their impact on groundwater recharge. The spatial variation of recharge across a landscape can provide useful information on where to best situate a plantation while minimising its impact on groundwater recharge.

Recharge is generally assumed to take place at topographic high points across a landscape, especially when rocky outcrops occur. This study analysed recharge rates at several points across a small paired catchment site to determine the most prevalent areas of recharge. Water-table fluctuations, Cl^- mass balances, tritium and ^{14}C ages were used to estimate recharge at 23 points across a 0.8 km^2 catchment covered predominantly in a blue gum tree plantation, and an adjacent 0.5 km^2 pasture catchment, in southwest Victoria, Australia. The Cl^- mass balance method and water-table fluctuation methods were modified to better reflect the recharge processes taking place at the study site, including longer term hydrograph fluctuations and input from streams.

Hydrographs from data loggers (since 2009) in bores situated close to the drainage line show considerably more recharge taking place compared to bores situated further upslope. Cl^- mass balances show a similar trend, as do the hydrographs for the past 20-30 years, indicating that the majority of recharge