Hydrol. Earth Syst. Sci. Discuss., 9, C6020–C6023, 2012
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Hydrology and Earth System Sciences Discussions

Interactive comment on "Agricultural groundwater management in the Upper Bhima Basin, India: current status and future scenarios" *by* L. Surinaidu et al.

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Received and published: 24 December 2012

We are very thankful to the three anonymous reviewers for their constructive comments and general appreciation of our work.

Referee1

Response to specific comments

1. The authors have mentioned that data from 135 pumping tests tested on dug and bore wells were interpreted using Jacob and Theis equations – The validity of these

methods for estimation of specific yield (particularly for dug wells) is questionable- How it is justified The authors have attributed relatively high sp yield used in the model to predominantly dug wells that bias the upper most weathered part of the aquifer.

Response: The referee has correctly identified that dug wells and bore wells were interpreted using Jacob and Theis equations. This was not described accurately in the manuscript and has been revised in the current version of the manuscript. The data has been analyzed only by the Jacob method and estimated storage coefficient derived. For the unconfined aquifers it is virtually the same as the specific yield. The GSDA data set used in this analysis is the most comprehensive data available for the region. We have considered the hydrostatic unit that is the most important with respect to groundwater development. This discussion has now been included in the revised manuscript.

2. In the study area, the weathering is generally limited to 20 m only, whereas the depth considered is 50 m in the study. The S value is low in the zone lying below weathered zone down to 50 m, whereas the same value (as applicable in weathered zone) is taken for entire zone- Needs explanation. The Deccan trap basalts constitute complex, anisotropic and, multi layered systems. Since the area is vast and consist of different flows and aquifer characteristics vary widely both spatially and laterally. In the present study a generalisation was made into 3 sections, limiting the study to top 50 m (weathered zone with sub-horizontal sheet joints), which was considered as single and uniform zone throughout the area- Broadly averaged inputs were given for different parameters without considering the complexities – Needs justification.

Response: We agreed with these statements that there are large uncertainties in the sub-surface systems of hard rocks, especially basalts (weathered and fractured thickness, and its specific yield). However, it is highly difficult to get information at the local level for the whole basin, and further, it is very difficult to synthesize and model the data using any numerical model. The model calibration outputs support the basis of the equivalent porous media conceptual model, and at the large scale modeled, local

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scale heterogeneity is not appreciable. Initially the model was developed as single layer aquifer with 20m thickness, but several locations in upstream and downstream areas drying of cells was evidenced during the simulation and hence the model thickness was increased to 50m thick. This is a compromise between reality and the proper functioning of the model for whole simulation period. Hence we finally generalized the sub-surface system as a single 50m thick unit with uniform property values backed by previous studies. The top layer is the predominant groundwater- bearing portion of the subsurface. The lower portions (below 50m) are much less transmissive overall and less interconnected on a regional scale. Given the relative differences it was considered to be acceptable to only model the upper 50 m portion as a single unit, especially given the scale-averaging in this study.

3. The rainfall in the area (46,000 sq km) is highly variable- both spatially and temporarily (as given in page 10661)- Entire area is taken as single unit and recharge inputs are averaged in the model and the return irrigation component is excluded- How do they reflect ground situations in varying recharge situations. The recommendations are not given at watershed/microlevel and given at whole sub-basin level-which presents diverse hydrogeological, hydrological and developmental situations- In such background, how to apply these recommendations at particular watershed/microlevel-even these may not be applicable in all areas considering diverse situations. The authors may give limitations of the study and its recommendations Calibration was done for three observations only- Given such huge area with complex hydrogeological systems, more representative wells could have been given.

Response: The reviewer correctly notes that varying recharge situations will occur. Groundwater recharge and extraction was based on groundwater and draft budgets calculated by the GSDA for the sub-watersheds within the Bhima basin. To account for the influence of varying rainfall, the GSDA data was weighted based on the annual rainfall data for the period 1997 to 2007. The derived equations are the expressions of the relationship between rainfall–weighted recharge and annual rainfall. The derived

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groundwater recharge coefficient of 11% is confirmed by other sources that report coefficients for this geological setting. The application of uniform recharge across the basin for each time period is supported by the model calibration results, and therefore considered defensible. Calibration was performed for all observation wells, although only three wells are displayed. For illustration purposes we present relative groundwater changes from upstream to downstream with three representative observation wells. Whilst it is acknowledged that the model is not sufficiently able to give detailed results at a micro level, the aim of the model was to make an assessment of the relative change in groundwater levels in the whole Upper-Bhima basin under different climate change and demand management options. In this respect, the broad averaging of parameter is justified for such a large scale. As suggested, the model limitations and rationale are now better justified in the revised MS.

4. Page no: 10662, line 7-8: "or dug-cum-bored wells screened in the weathered portion of the basalt"- to be modified Some sentences need corrections: eg.page : 10658 line 6- "model predictions of different climate change.. .. " line 26 " : The limit of groundwater development: " needs to be checked. To be uniform: Upper Bhima basin, Southern India or Upper Bhima basin (as given in page 10659), southwestern India (as given in fig.1) rain fall- to be corrected (page 10665)

Response: Errors have been duly noted and corrected in the revised manuscript. The whole manuscript has been carefully edited for improved sentence formulation and clearer structure.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 10657, 2012.