Water budget analysis for a river-reach/floodplain area and the influence of a shallow perched aquifer system

Objectives:

1. Develop a hydrologic model for a river-reach/floodplain area of the Cosumnes River for estimating water budget components, including channel, vadose zone, and bank storage, riparian evapotranspiration, and aquifer recharge. The hydrologic model was designed in light of the presence of perched aquifer systems at the Cosumnes that may function to buffer near stream ecosystems from drought.

2. Provide quantitative analyses of many of the key characteristics governing perched groundwater hydrology, providing insights about processes as well as the foundation for future studies.

Background: Previous hydrologic studies have developed geologic models of the alluvial aquifer systems surrounding the Cosumnes River based on hundreds of driller's logs for the basin (Fleckenstein et al., 2006). These data indicate that the river flows over highly heterogeneous sediment deposits that influence how the river responds to pumping-induced water table decline. The present work builds upon previous investigations that suggest mixtures of sand bodies and low-permeable silts and clays can result in perched aquifer systems and local mounding of the regional groundwater to the level of the river surface. A smaller and more complex model is developed in the present study as compared with the model presented by Fleckenstein et al. (2006) to consider finer-scale field observations of geology and other hydrologic parameters. The model is developed for a 200 m reach located in the lower section of the river where it flows beneath State Highway 99 in Sacramento County just above the McConnell stream gage. The study reach contains a 100 m long and 600 m wide floodplain area that floods to various extents during most years; however, the floodplain drains quickly following inundation. The floodplain area supports patches of riparian vegetation not present in adjacent areas where the river is confined between constructed levees.

Methods: Between December 2002 and Dec 2004, Continuous measurements of river and regional groundwater levels were made on an hourly basis. Additionally, sediment water content and temperature were made on an hourly basis to depths between 7-10 m beneath the river and floodplain areas. Detailed lithologic descriptions of sediment were made from 17 boreholes drilled in the study area. Evapotranspiration was measured using an energy-balance method from willows trees growing along the Cosumnes River (J. Korchendorfer and K. T. Paw U, written communication, 2004). These data were used to calibrate a three-dimensional variably-saturated non-isothermal flow model. Sediment heterogeneity was represented in the model using transition probability-based geostatistical approach. A spatially-distributed demand driven/supply limited root uptake model was also incorporated into the model.

Key Findings:

1. Our analysis indicates that perched aquifers form beneath the Cosumnes and have a significant influence on the hydrologic budget surrounding the river. Perched aquifers

near the river correspond to patches of riparian vegetation not present in adjacent areas along the river.

2. Profiles of sediment water content measured beneath the floodplain indicate that 6-m thick saturated regions (perched aquifers) form beneath the floodplain due to inundation followed by slow desaturation during months of high evapotranspiration. Portions of the vadose zone maintain high saturation throughout the dry season (July-September) following floodplain inundation due to low-permeable sediment layers.
3. Perched aquifers can shift the water budget near the river by maintaining saturated conditions within the riparian root zone, which allows water seeping from the river to be lost as evapotranspiration rather than seeping back to the river or to regional aquifers. The model predicted a 50% increase in ET losses due to the presence of perched aquifers when water availability was used as an indicator of riparian vegetation.
4. The model predicted that perched groundwater within the study area provided 0 to 7 m^3/d of baseflow to the river; however, baseflow contributions declined shortly following the decline of inflow upstream of the study area (early June). Decline of perched aquifer seepage to the river adjacent to the floodplain is attributed to the breached levee in the study area, which results in lower perched aquifer levels adjacent to the river as compared to other areas with steep riverbanks (levees).
5. Hypothetical modeling of perched aquifer systems near a river indicate that perched aquifers can provide significant baseflow to a river (700 to 4300 m^3/d) for variety geologic and geomorphic conditions. Conditions favorable for enhancing baseflow from perched aquifers are high contrasts in hydraulic conductivity between the perching unit and overlying coarser sediment. These conditions are considered likely to occur at the Cosumnes based on field observations. These results indicate that perched aquifers may be important for maintaining minimum flow levels for migrating Salmon at the Cosumnes.
6. Riparian vegetation may diminish baseflow contribution from perched aquifers by as much as 30% where a thick riparian forest exist adjacent to the river and where the riparian root zone extends below the elevation of the channel surface. Tall river banks (levees) can result in a channel bottom elevation that is lower than the riparian root zone, such that perched aquifer systems drain into the channel instead of being lost as ET.

Recommendations for management & monitoring: Management of perched aquifers may enhance river baseflow for migrating salmon and other in-stream biota. Additionally, perched aquifers may be managed to increase the riparian area around the Cosumnes; however, as described increased ET due to riparian vegetation may diminish baseflow. Thus, management of perched aquifers should consider whether the goal is to enhance baseflow for migrating salmon or for restoring riparian forests adjacent to the river. Management of perched aquifers could be done through artificial recharge during periods of water surplus. Perched aquifers could be recharged by releasing water down the channel from Folsom South Canal, by breaching levees to cause floodplain inundation, and by irrigating agricultural fields adjacent to the river. Most important, however, would be to continue field investigations to locate areas favorable for the development of perched aquifers and mounded regional groundwater levels that enhance river baseflow such that management of perched aquifer systems could be maximized.