Perched Aquifer Hydrology–Ecological Implications

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Surface Water/Groundwater interaction at the Cosumnes, Subsequent to Severe Disconnection between the River and Regional Groundwater-Ecological Implications

- Base-flow in the Cosumnes is greatly diminished because of lowered groundwater levels beneath the river. During high flow, water seeping from the river perches in the vadose zone due to low permeable sediment layers. During low flow, perched water may discharge back into the river and provide base-flow for fish migration.

- After the Cosumnes River stops flowing, perched and regional groundwater discharges to ponds within the channel. These ponds can last throughout the dry season and provide dry-season refuges for aquatic wildlife.

Background

- Overdraft of groundwater in Sacramento County has severely depressed regional groundwater levels and depleted base flows along the Cosumnes River. Continued overdraft may negatively impact riparian vegetation and threaten fall migration of endangered Chinook salmon.

Objectives

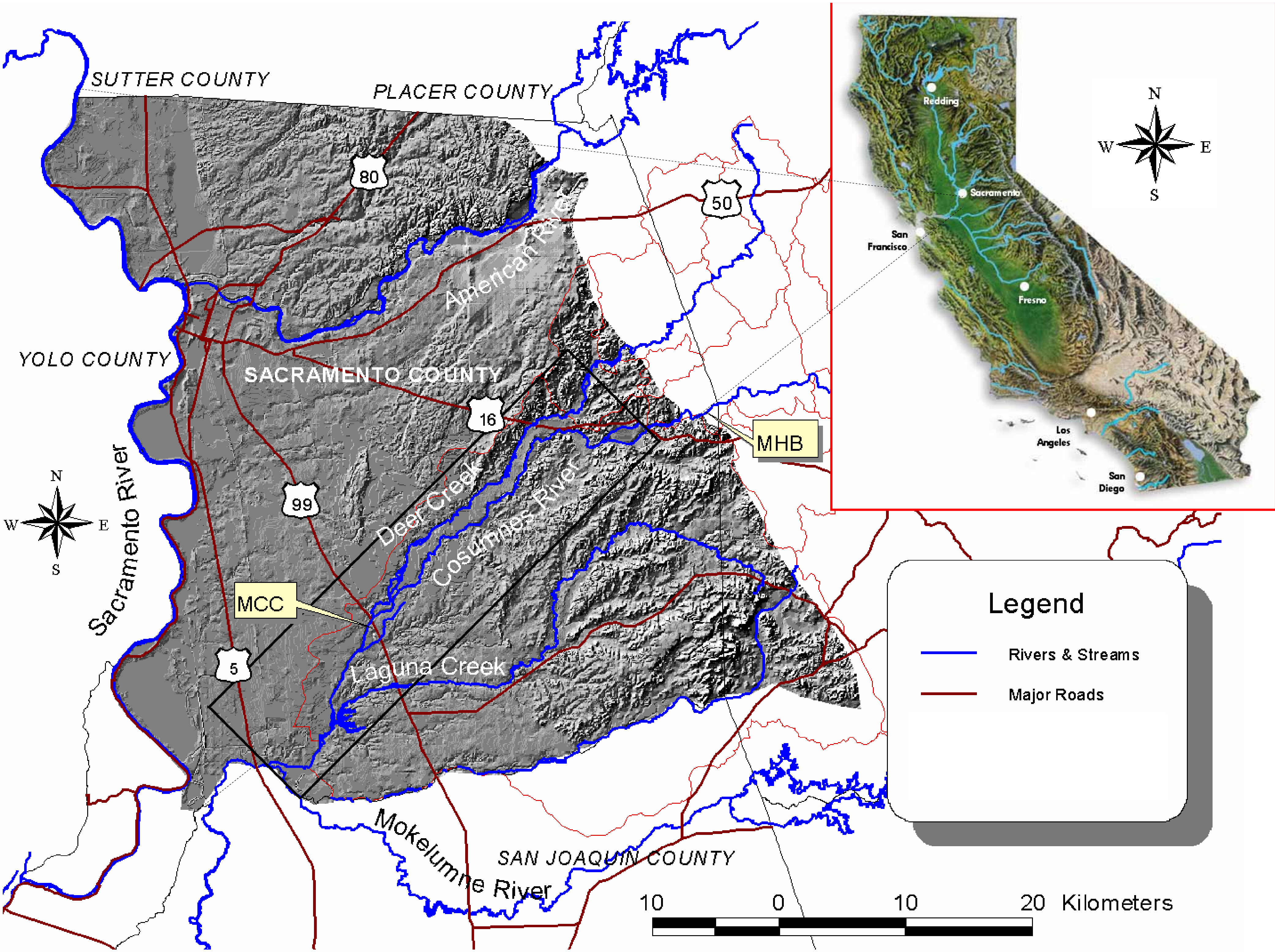
- Determine if perched aquifers and/or saturated conditions in the vadose zone contribute significantly to baseflow and determine how they can be managed to enhance their benefit to wildlife.

- Determine the hydrogeologic constraints on the formation of perched aquifers.

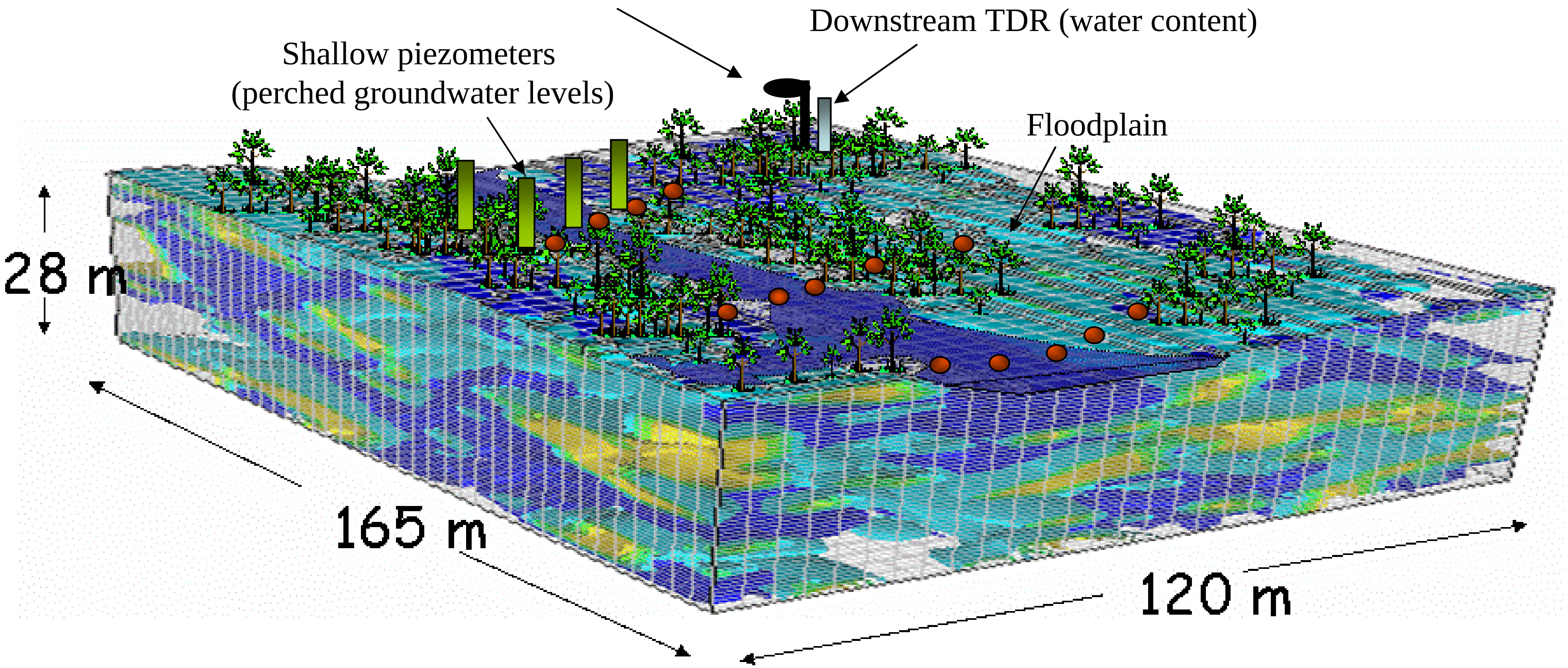
- Determine the quantity of baseflow that can be contributed by perched aquifers for several types of hydrogeolical conditions.

Methods

- Develop and implement a monitoring approach to investigate surface water/perched groundwater interaction at the Cosumnes.
- Use a variably-saturated three-dimensional flow model (TOUGH2) to evaluate surface water/perched groundwater interaction.


SUTTER COUNTY
PLACER COUNTY
YOLO COUNTY
SACRAMENTO COUNTY
SAN JOAQUIN COUNTY
American River
Sacramento River
Deer Creek
Cosumnes River
Laguna Creek
Mokelumne River
80
50
16
99
5
MHB
MCC
N
W
E
S
Redding
Sacramento
San Francisco
Fresno
Los Angeles
San Diego
Legend
Rivers & Streams
Major Roads
10
0
10
20
Kilometers

Monitoring hdyrogeolical conditions at the Cosumnes



Micrometeorological
Station
(evapotranspiration)

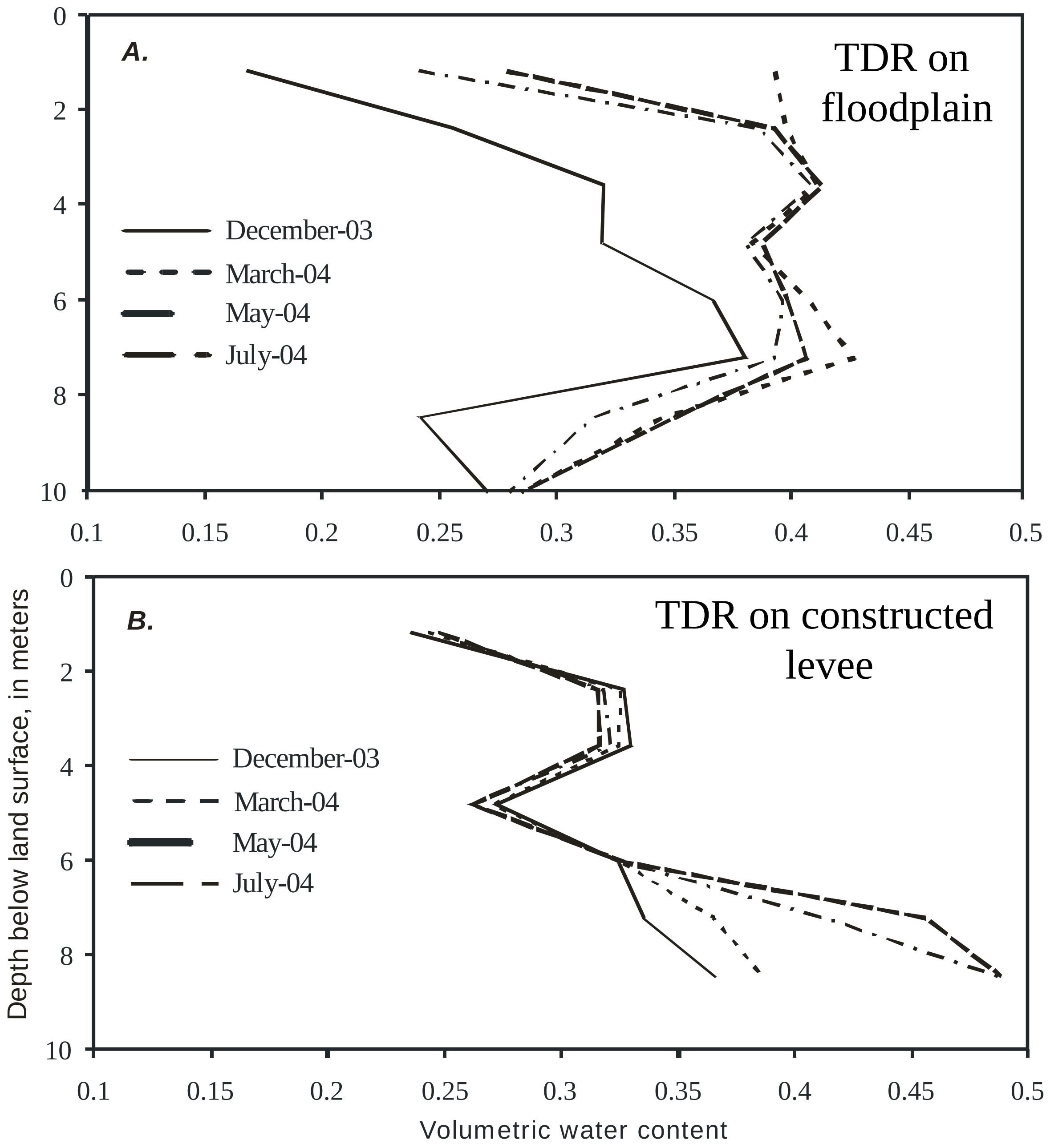
Downstream TDR (water content)

Shallow piezometers
(perched groundwater levels)

Floodplain

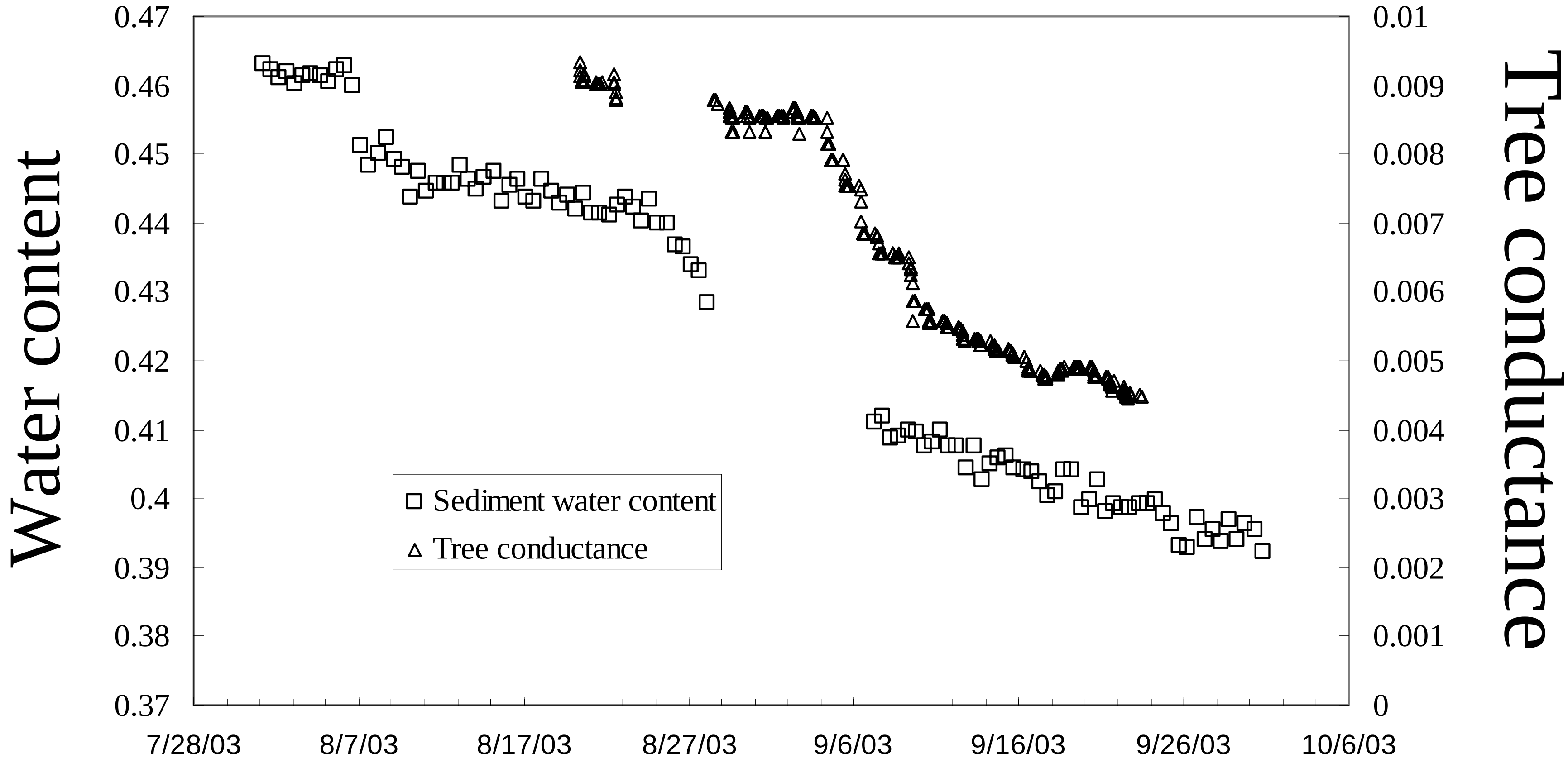
● = Subsurface nests of thermocouples (temperature)

Sediment Water Content Below Riverbank for 2002-03



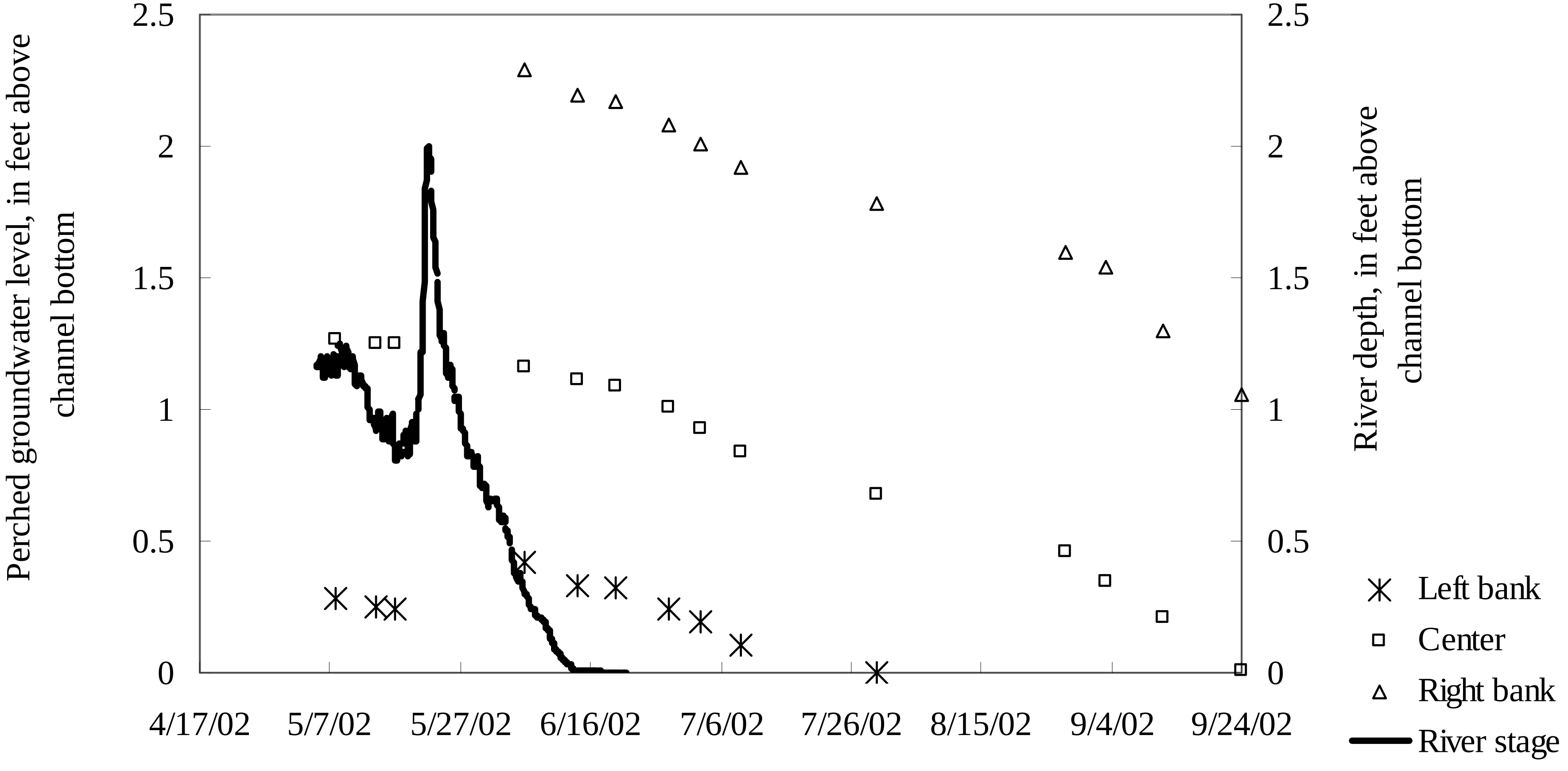
The floodplain was inundated in 2003-04. A great proportion of water in the vadose zone is due to floodplain infiltration. More water available in shallow sediment makes it easier for plant uptake. Vegetation may be less stressed during years of flooding.

Riparian Vegetation in the Riverbank is Supported by Perched Groundwater



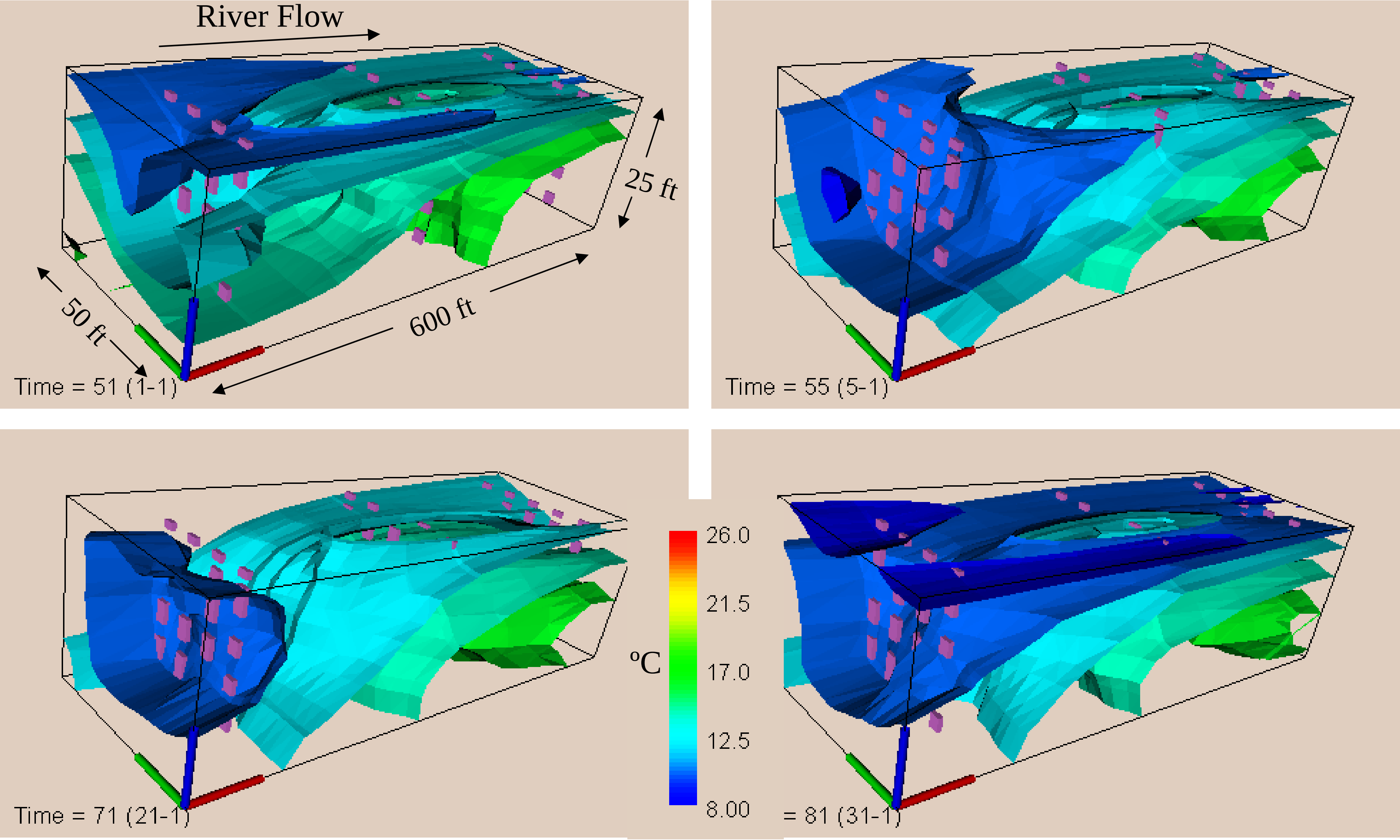
Tree conductance is shown decreasing in response to a draining perched system.

Perched Groundwater Levels Below Channel Suggest Gaining Conditions

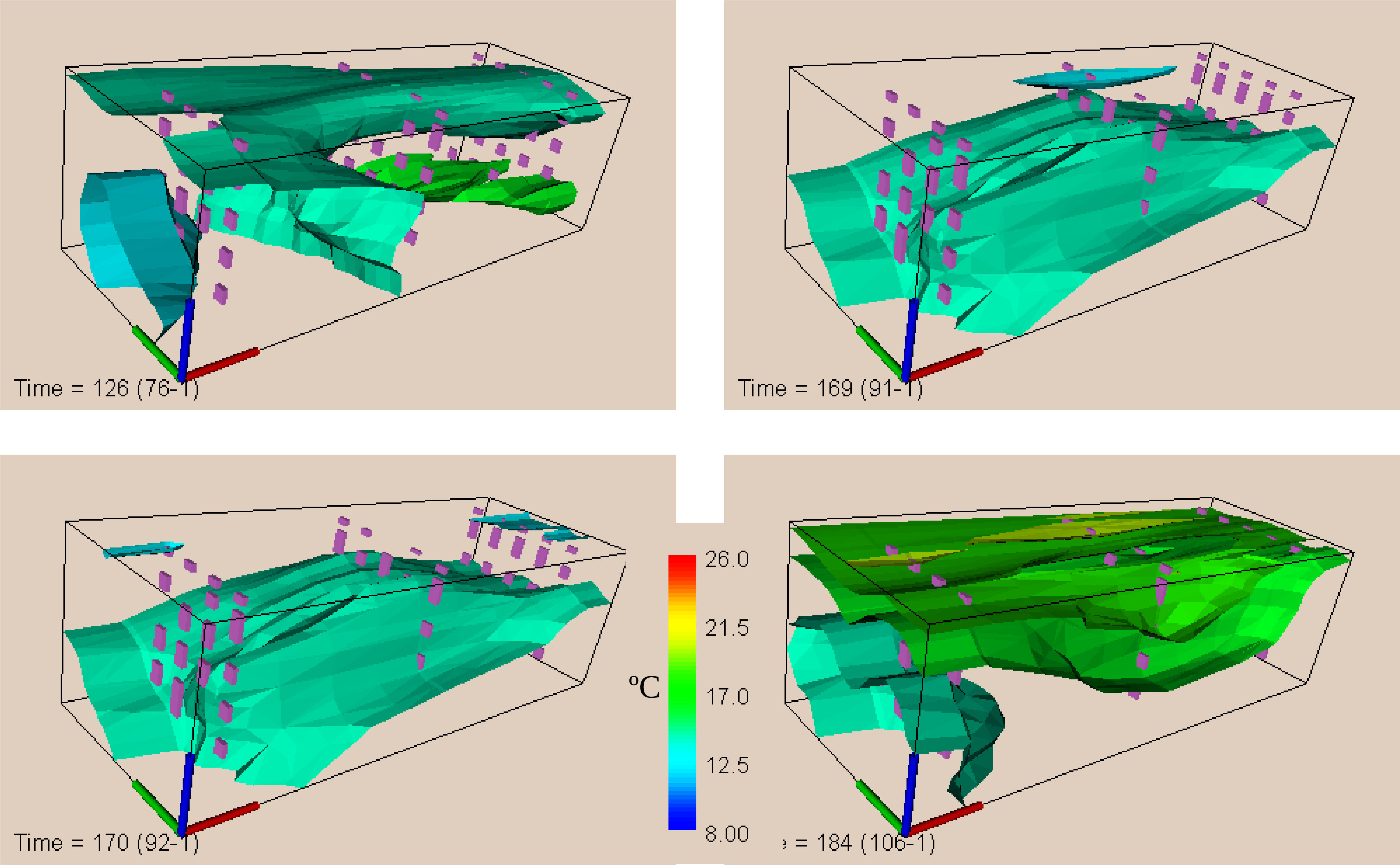


Subsurface temperature used to track the movement of water beneath the channel

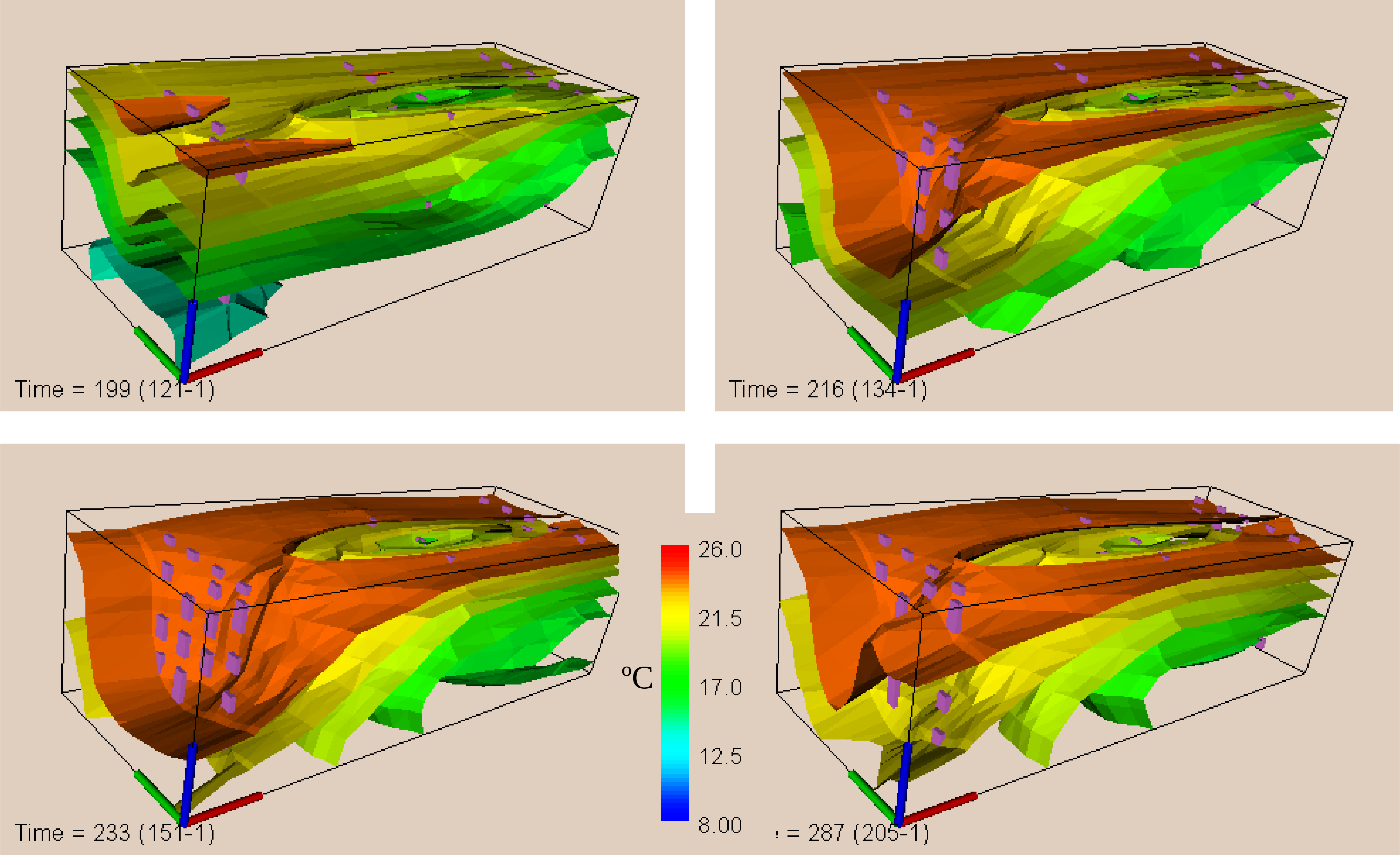
Winter-Onset of Flow



Early Spring-High Flow
Floodplain inundation

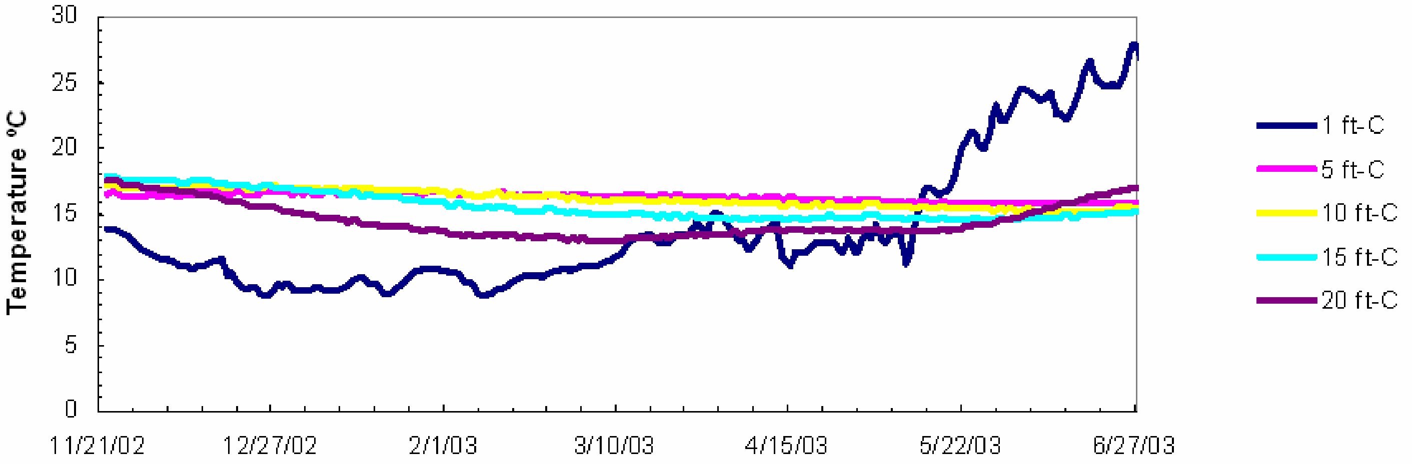


Late Spring-Flow subsiding

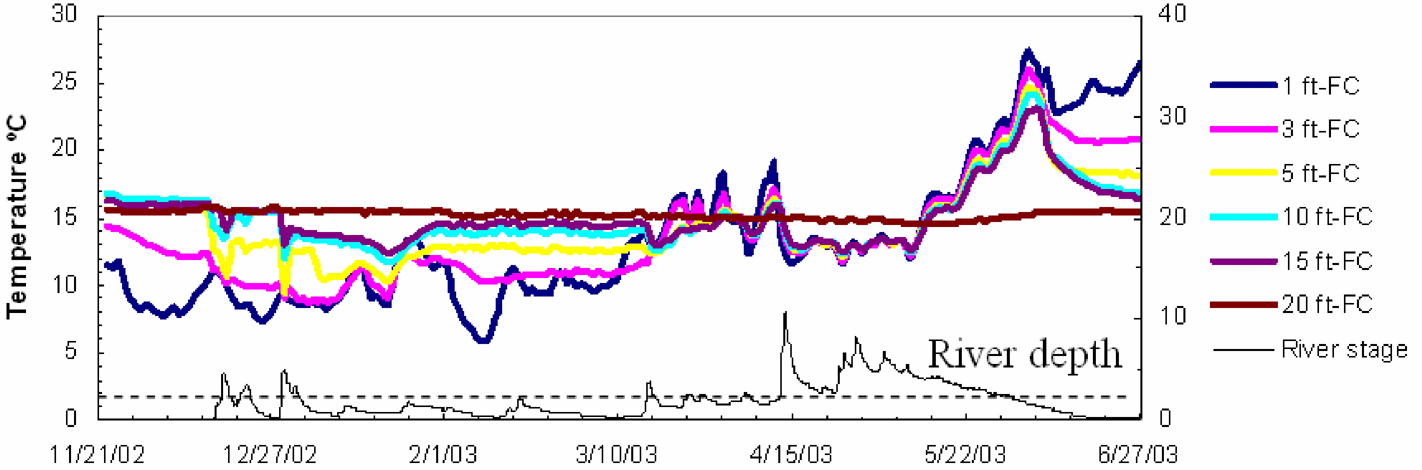


Subsurface Temperatures Below Flood Plain Show Rapid Infiltration

Below channel – low infiltration



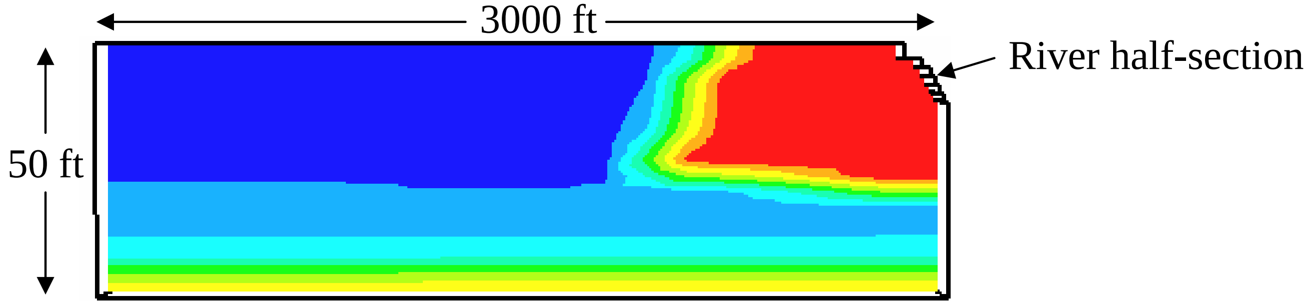
Below floodplain – high infiltration



* Dashed line represents river depth where flow submerges land surface above thermocouples.

3-D Variably-Saturated Flow Modeling of River/Perched Groundwater Interaction

- Model assumed symmetry along river thalweg.
- River was represented by a time varying pressure boundary condition.
- Models were constructed with varying perching layer and aquifer hydraulic properties and perching layer dimensions.
- Model was run representing bank full river flow for two months to establish initial conditions.
- The river was set to low flow conditions (1.5 ft depth) and perched groundwater was allowed to drain back into the river.

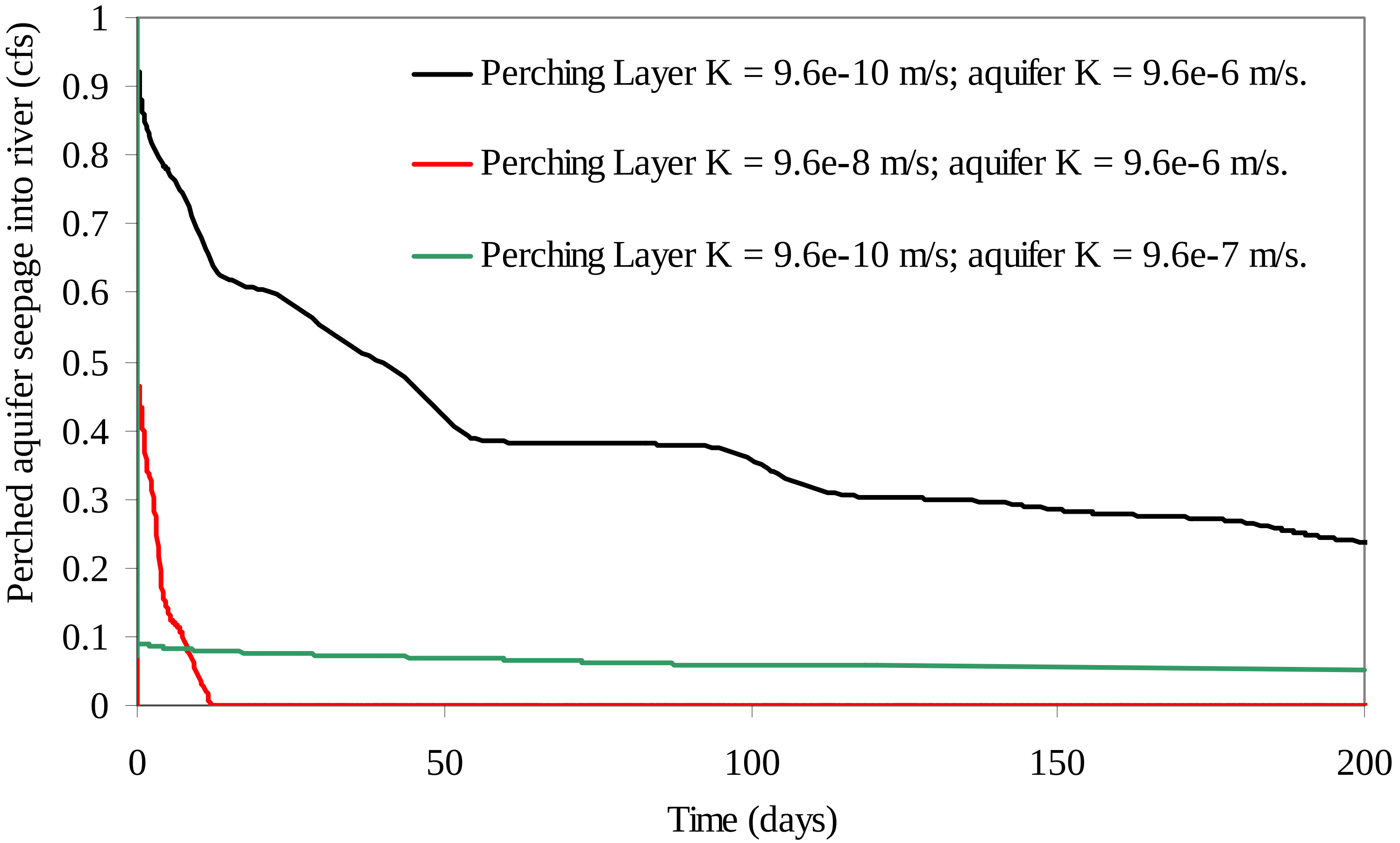


Initial conditions for one model. Colors represent sediment saturation (red is saturated).

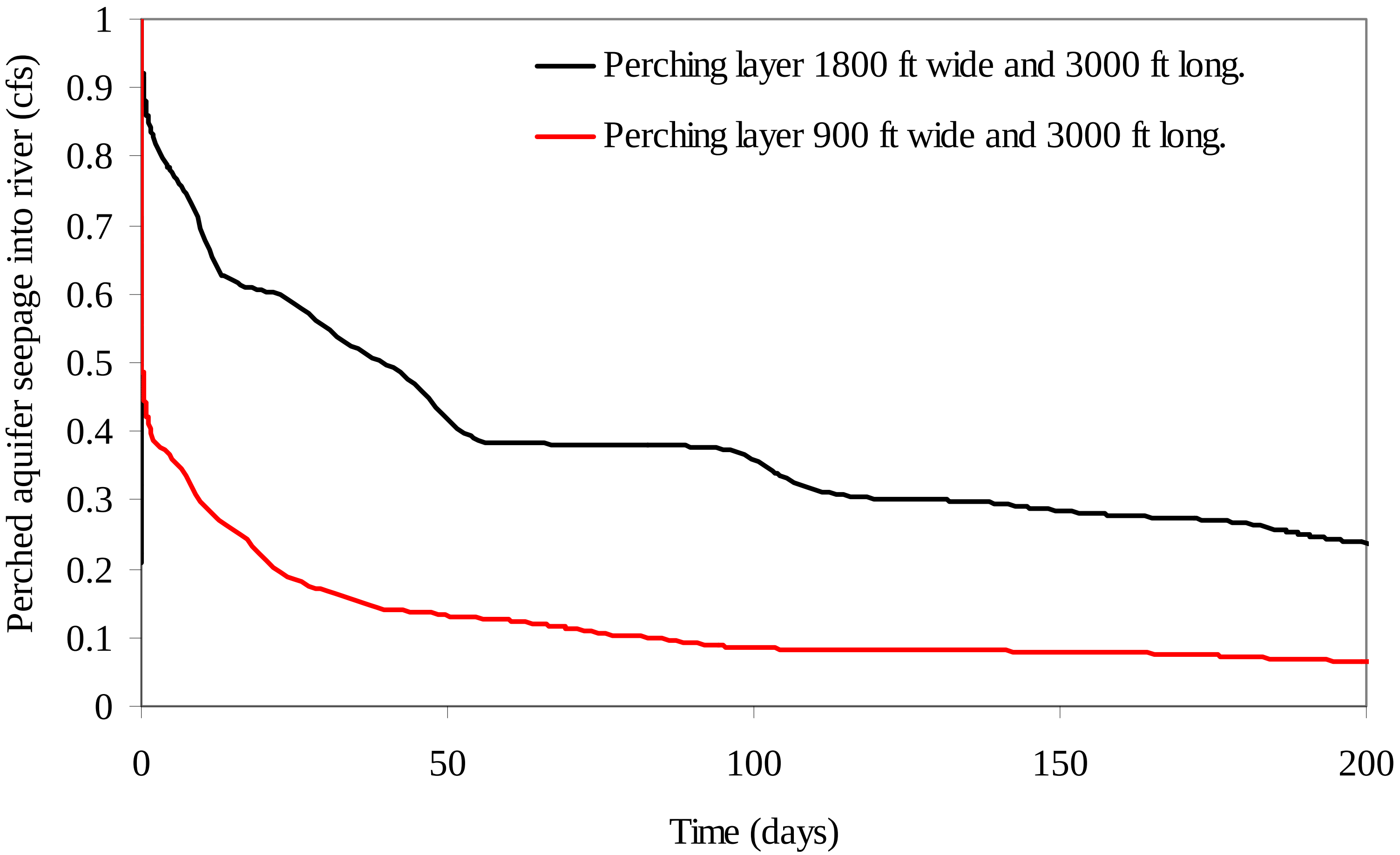
Amount of Base Flow Contributed by Perched Aquifer

- All simulations consisted of a 5000 foot reach of a river that is similar in size to the Cosumnes.
- Analyzed the effects of different permeability for the perching layer and aquifer material.
- Analyzed the effects of different perching layer widths.
- All modeling was done using 3-d domains with TOUGH2 (Pruess et al., 1999)

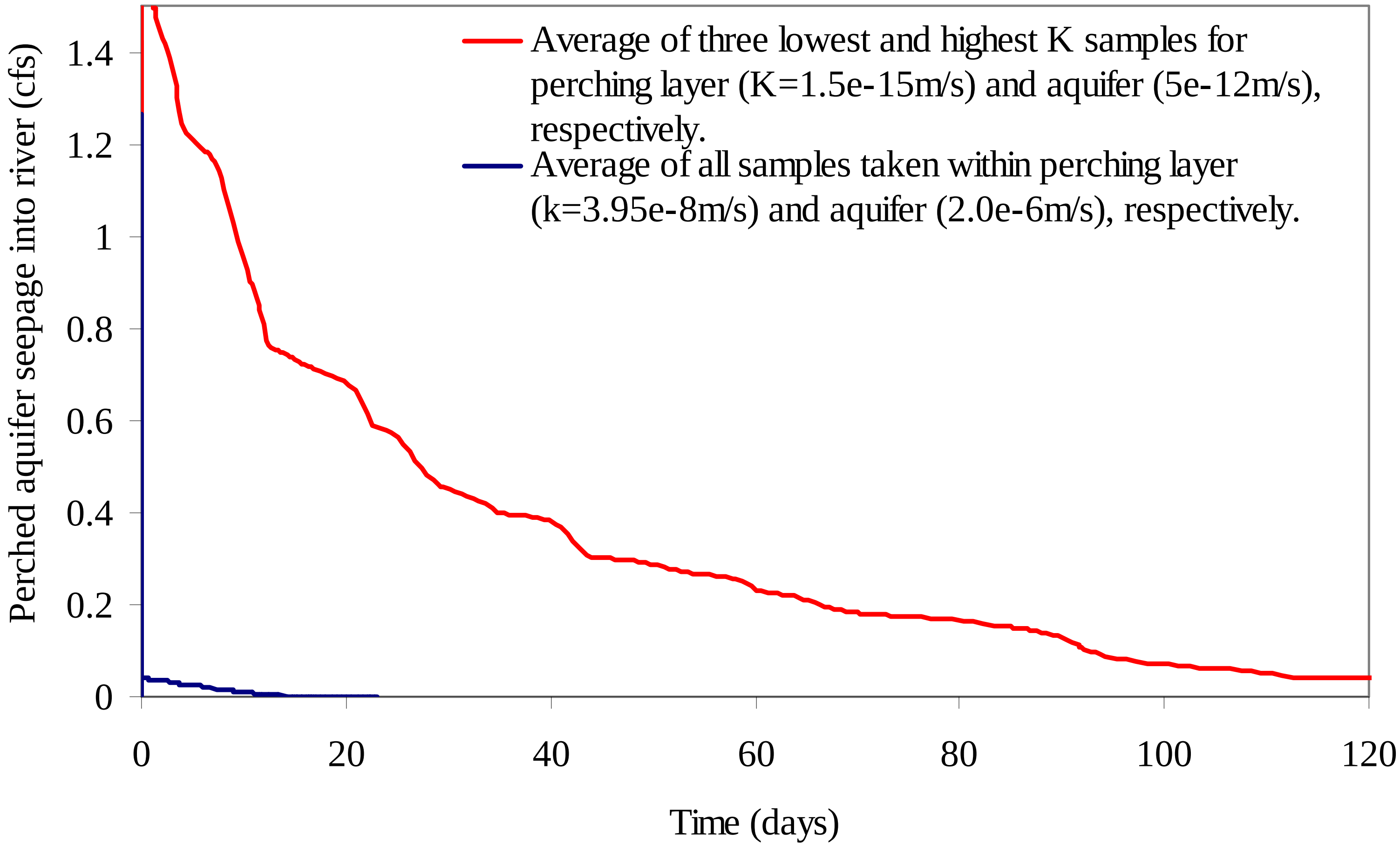
Effects of Sediment Permeability on Base Flow



Effects of Perching Layer Size on Base Flow



Estimates of Base Flow Contribution from Perched Aquifer at the Cosumnes



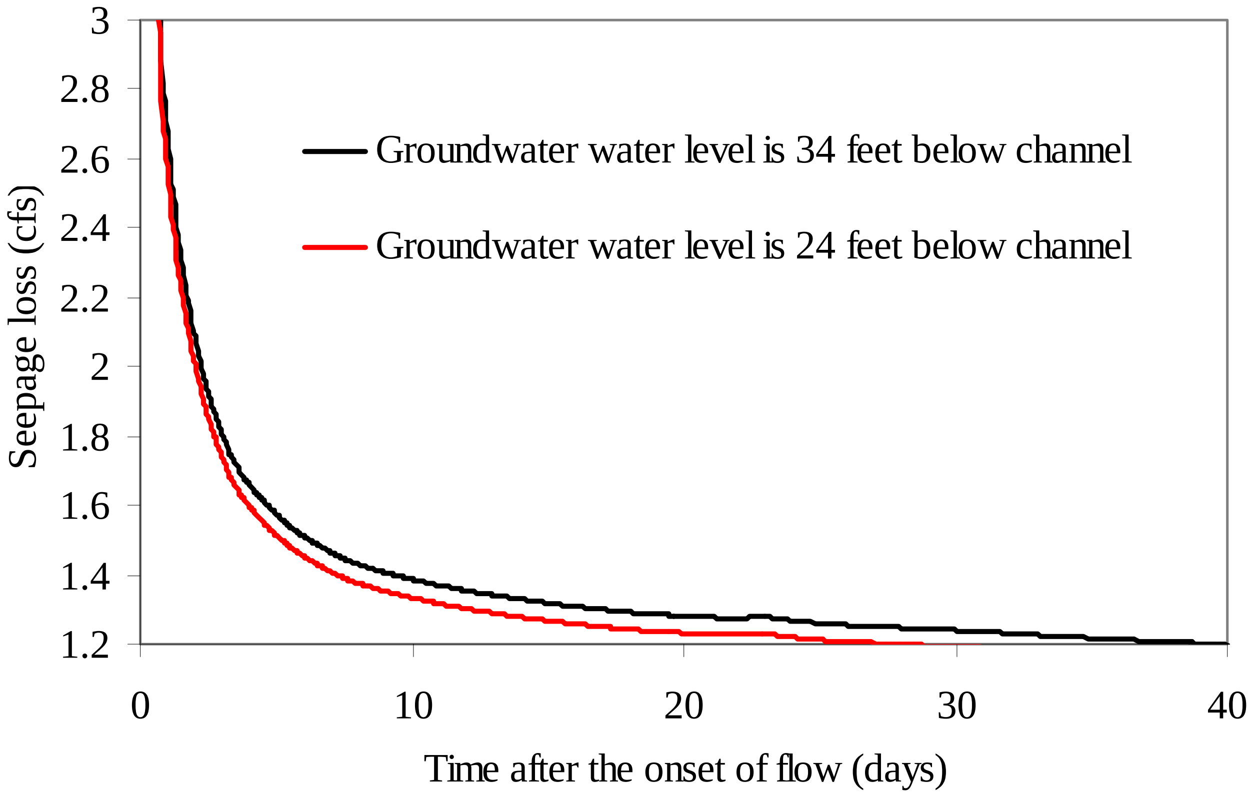
*Measurements of hydraulic conductivity were made in the lab on seven sediment samples from the perching layer and aquifer using the falling head method.

Effects of Further Decline of Regional Groundwater Levels on Seepage Loss from the Cosumnes

- Geostatistical model (TPROGS; Carle and Fogg 1997) was used to create distributions of hydraulic conductivity based on core-log information sampled within study area.

- A flow record from the Cosumnes in 2002 was used to represent the onset of flow in the river. The total seepage loss over a 160 m reach of the river was analyzed.

Seepage Loss is Effected by Further Declines in Regional Groundwater Levels



*Modeling analyzes a 160 m reach where the regional groundwater level ranges between 30 and 35 feet below the channel.

Management Implications

- Perched aquifers recharge quickly but drain slowly. Perched aquifers are recharged the most during floodplain inundation. Removing sections of the levee would increase the occurrence of floodplain inundation.

- The vadose zone is a storage reservoir that is filled with river water after the onset of flow. If groundwater levels continue to decline, more river water will become seepage loss. This may result in a longer period without flow in the river.

- Managing artificial flows and enhancing the occurrence of flood plain inundation may decrease the stress on riparian vegetation and increase base flow during fish migration. Irrigation next to the river where perched aquifers occur may recharge perched aquifers. Hydrologic models may be used to enhance the benefit of management practices.

References

Carle, S. F. and G. E. Fogg (1997), Modeling spatial variability with one and multidimensional continuous-lag Markov chains, Mathematical Geology 29(7):891-918.

Pruess, K., C. Oldenburg, G. Moridis (1999), TOUGH2 user’s guide, version 2.0, Report No. LBNL 43134, Ernest Orlando Lawrence Berkeley National Laboratory, Ca, USA.