Using groundwater models to explore how beaver-mimicry stream restoration affects dynamic seasonal water storage

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Beaver-mimicry stream restoration (BMR) seeks to simulate the effects of beaver activity on stream ecosystems. One common objective of this type of restoration is to increase seasonal water storage, which will in turn increase late-summer stream flows. However, the specific hydrologic mechanisms by which BMR would promote higher late summer flows remain poorly understood.

We used GMS and MODFLOW to develop relatively simple numerical models of groundwater and surface water exchanges in fluvial systems, and assessed the magnitude and timing of changes in dynamic seasonal storage and stream flow resulting from BMR. Models were loosely based on headwater streams with a snowmelt-driven hydrograph and a valley gradient of about 0.005. Baseline models were developed for three different groundwater connection scenarios, where the simulated reach was gaining, losing, or strongly losing. A control and five types of BMR treatments were simulated in each setting, including: (1) no BMR, (2) creating a pond in the active channel, (3) activating a proximal and a (4) distal remnant side-channel, (5) inundating the flood plain, and (6) creating surface water storage ponds connected to the channel only by groundwater flow paths. Thus, a total 18 of models were developed and used to calculate differences in net late-summer stream gains before and after restoration. Finally, sensitivity analyses using the baseline and distal channel reactivation scenarios in the gaining, losing and strongly losing settings evaluated the effects of substrate composition and evapotranspiration on the late-summer stream flow changes created by BMR.

Active-channel ponds caused calculated late-summer net stream gains to increase by 0.06 Ls-1 (0.9 gpm) for the gaining stream, to increase by 0.07 Ls-1 (1.1 gpm) for the losing stream, and to decrease by 0.02 Ls-1 (0.3 gpm) for the strongly losing stream. Additional effects from activating remnant side-channels, or inundating the floodplain during high flows were modest, with the greatest gain being 0.01 Ls-1 (0.2 gpm) more than from the pond alone. Creating surface-water storage was more effective at increasing late-summer flows, with net stream gains increasing from 0.35 to 0.50 Ls-1 (5 to 8 gpm) above baseline. It should be noted that while these changes are calculable, they would be difficult to measure.

Sensitivity analysis showed that aquifers composed of silty sand to coarse sand provided the best conditions for increasing late-summer flows. Similarly, stream beds composed of silty sand to sand provided for the greatest increase in late-summer flows. Simulation of evapotranspiration effects showed that the increase in groundwater table elevations (increased storage) created by BMR may allow more subsurface water to be used by riparian plants, potentially resulting in slight reductions in late-summer stream flow.

In general, modeled scenarios suggest that BMR designs that recharge the aquifer farther from the channel lead to more seasonal storage. Creating seasonal storage in ponds that are connected to the main channel only through the subsurface strongly increases the potential for dynamic seasonal storage.