Focused flow near irrigation wells as a possible mechanism of regionally enhanced chemical migration in the High Plains, Central U.S.

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Groundwater quality data and unsaturated zone chemistry profiles provide evidence of preferential flow on a regional scale, but the process has remained elusive. An on-going study of the High Plains regional aquifer, conducted by the U.S. Geological Survey's National Water Quality Assessment (NAWQA) Program, has identified elevated levels of nitrate, pesticides, and other agrichemicals in groundwater resulting from the introduction of irrigated agriculture in the mid- 20^{th} century. Unsaturated zone chemistry profiles from the High Plains indicate that percolation rates beneath agricultural fields are enhanced by irrigation, but the magnitudes of chemical flux are not sufficient to explain the high levels of contaminants in the underlying groundwater given 50 years of transport. Here, we present modeling work using the USGS code VS2DT, which simulates flow and transport in variably saturated porous media, to explore a mechanism for focusing flow near irrigation wells. There are approximately 128,720 registered irrigation wells over an area of 451,000 km^2, which produce the necessary water to support irrigated agriculture across the semi-arid High Plains. During periods of irrigation, water has been observed to pond around the well, at the pivot, in center-pivot tire tracks, and in natural depressions in the land surface. Transient model simulations designed to represent seasonally wetter conditions within a 1-m radius of the irrigation well indicate that migration of a conservative chemical to the water table is possible in <50 years. A sensitivity analysis revealed the most important factors influencing nitrate (and other agrichemical) migration to groundwater, which include hydrological conditions near the well during irrigation, soil hydrologic properties, and water table depth. Additional modeling work using various combinations of the controlling factors generated a subset of simulations that yielded positive (nitrate reaching groundwater in <50 years) results in 40% of the 336 tested permutations. Controlling factors associated with this subset are compared to field conditions to assess the plausibility of this focused flow phenomenon in the High Plains region. If applicable over substantial areas, our findings have implications for groundwater quality and agricultural management practices.