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On potential fast contaminant flow paths to the White Rock springs through the regional aquifer beneath Pajarito Plateau

Velimir V Vesselinov

The saturated zone beneath the Pajarito Plateau forms a complex three-dimensional groundwater flow system. Based on the available hydrogeological data and observations it is possible to make the following suppositions about the structure of the groundwater flow (cf. [*Vesselinov*, 2004]):

- The top of the saturated zone is predominantly under water table conditions.
- The long-term monitoring (since 1950's) demonstrates minor changes in the water-table elevations; even more negligible are changes in the magnitude and direction of the "water-table" hydraulic gradients.
- Due to the natural structure of the groundwater flow, ambient hydraulic gradients in the "water-table" (phreatic) zone are substantial (i.e. the slope of the water table is very high); on the order of 0.01.
- Recent pumping tests also confirm that the groundwater flow in the phreatic zone experiences a limited impact by the pumping of the water supply wells that are tapping deeper portions of the aquifer.
- Pumping test data also suggest pronounced hydraulic separation between the shallow (phreatic) and deep (pumped) portions of the regional aquifer.
- Contaminants, originating from the LANL sites, move through the unsaturated zone and reach the regional aquifer at the water table.
- By definition, the water-table is a contaminant flowpath. That is, physics requires that the contaminants reaching the water-table will move predominantly along the sloping water-table.
- The springs along the White Rock canyon potentially discharge water predominantly from the phreatic zone.
- As a result, there is a fast contaminant flow path along the phreatic zone to the springs.

This type of flow mechanism potentially allows for flowpaths through the upper, phreatic (under water-table conditions), portion of the regional aquifer at rates higher than those in the lower, confined, portion of the regional aquifer.

An important demonstration of the separation between the upper and lower portions of the regional aquifer is the independence of the spring rates to the intensive pumping in their vicinity, particularly at the Buckman wellfield. If the aquifer were comprised of relatively uniform medium, the substantial drawdowns of the pressure heads due to the pumping would have substantially decreased or completely ceased the groundwater discharges at the springs. The spring discharge rate independence to the heavy pumping also demonstrates that the substantial (major) portion of the groundwater discharged at the springs comes from the shallow portion of the aquifer while a neglectable (minor) portion of the groundwater discharged at the springs comes from the deep portion of the aquifer.

A particular area of interest is the region between the boreholes TW-1/O-1 and Spring 2B (CCNS). The data for TW-1 demonstrate that there is a substantial increase of the observed hydraulic head since 1997 [*Koch and Rogers*, 2003; *Koch, et al.*, 2004]. The increased heads are much higher than the head observed at the well when it was drilled in 1950. Similar head increase is not observed in O-1 which is located in very close vicinity to TW-1 but taps a deeper portion of the regional aquifer. Pumping at O-1 also does not affect shallow hydraulic heads at TW-1.

Koch et al. [*Koch, et al.*, 2004] suggest that the head increase at TW-1 is due to greatly increased discharges (since 1980) of the Los Alamos Bayo sanitary wastewater treatment plant into the Pueblo Canyon upstream of TW-1. This hypothesis they also confirm by geochemical data. The mounding of the perched zone in the vicinity of TW-1 cannot be expected to be a horizontally localized feature. There is no information about the existence of a structure in the flow medium which can cause such a localized effect. Therefore, the mounding should extend over a substantial horizontal distance.

The groundwater flow medium between TW-1 and Spring 2B consists of the Puye Formation and the Totavi Lentil. The Puye cross-section includes both Fanglomerate (finer-grain) and Pumicious (coarser-grain) materials. At this area of the Pajarito Plateau, the outcrop and borehole data suggest that the Totavi Lentil is horizontally continuous (Broxton, 2004). Both the Pumicious Puye and the Totavi Lentil are highly permeable/low storativity units, which can be facilitating the groundwater flow. Therefore, these units can be expected to have important impact on contaminant transport as well.

We can compute the hydraulic gradient between the hydraulic head elevation at TW-1 and the discharge elevation at Spring 2B. These elevations at TW-1 and Spring 2B are approximately 1790 and 1670 m, respectively. The horizontal distance between TW-1 and Spring 2B is about 6000 m. Therefore, the hydraulic gradient is 0.02. Assuming effective permeability and porosity of the flow medium between the two points of interest are 8.5 m/d (10^{-12} m^2) and 0.1, respectively, we obtain average groundwater pore velocity equal to 617 m/a. Therefore, the mean advective travel time for contaminants from TW-1 to Spring 2B could be about 10 years.

This travel time is a good estimate of the peak arrival of the contaminants at the spring. Due to naturally occurring dispersion during the contaminant transport through the

porous medium some contaminants will be arriving faster and slower than the advective travel-time estimate.

This analysis assumes that there is a groundwater flowpath between TW-1 and Spring 2B. There is not enough information about the aquifer to confirm or reject this assumption. Nevertheless, even if the flowpath from TW-1 is directed more to the north (more probably based on the existing limited data) of Spring 2B, some of the contamination can be reaching Spring 2B due to transverse dispersion of the contaminant plume.

Vesselinov & Keating [*Vesselinov and Keating*, 2002] provided a model prediction about the transport in the regional aquifer of the water releases from the Los Alamos Bayo sanitary wastewater treatment plant. Their modeling study demonstrated that most of the released water will be capture by the Pajarito water-supply wells. However, their conceptual and numerical models were not accounting for the phreatic zone in the upper portion of the aquifer which will allow for the potential contaminants to move laterally rather then been pulled in the deeper portions of the aquifer due to the pumping.

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