USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Evaluation of Recharge Mechanisms and Rates Through Loess in the Moscow-Pullman Basin Using Environmental Tracers and Soil Stratigraphy

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Statement of Critical Regional or State Water Problems

Groundwater is the principal water supply for the Moscow-Pullman Basin of eastern Washington and northern Idaho. Municipal water use by Pullman, Moscow, and the two universities has resulted in a continual decline in the regional basalt aquifer system since 1890 and a steady decrease of 1.5 ft per year in response to pumping from 1976 to 1985 (Barker, 1979). Recent models predict groundwater declines of 93 ft in Pullman and 96 ft in Moscow between 1976 and 2000 (Lum et al., 1990). Concerns regarding this diminishing water supply have prompted several models and studies that propose a wide range of recharge estimates, but with still-uncertain recharge mechanisms.

We believe a major reason that groundwater recharge rates and recharge flow mechanisms are poorly understood is because of the lack of combined stratigraphic and hydrologic research directed toward the mantle of loess blanketing most of the Moscow-Pullman Basin. Most studies and all groundwater recharge models incorrectly assume that the loess mantle is a single homogenous unit. However, limited studies have demonstrated that the Palouse loess deposits in the Pullman-Moscow basin are not a homogenous unit, but rather a complex sequence of buried soils (Busacca, 1989; McDonald and Buscacca, 1992; McDaniel and Falen, 1994; Kemp et al., 1998). Moreover, it has also been shown that these buried soils may dramatically affect near-surface hydrological processes and the resulting redistribution of precipitation (McDaniel and Falen, 1994; Reuter et al., 1998). It is therefore essential that estimates of recharge rates and flow mechanisms through loess into the two underlying municipal basalt aquifers incorporate this information. Recently, environmental tracers - Cl-, 18O, and 3H - have been used to estimate recharge rates and develop a better understanding of

recharge mechanisms in the Moscow-Pullman Basin (O'Brien et al., 1996; Larson, 1997). Although promising, these studies have not examined the stratigraphic context that ultimately is needed to extrapolate results to a basin-wide scale.

Statement of Results or Benefits

Because approximately 75% of the Pullman-Moscow Basin is covered by loess (Williams and Allman, 1969), it is essential that hydrological studies adequately address the nature of this loessial blanket. The Palouse loess deposits represent loess accumulation and soil formation over the last 2 million years, and serves as an archive that documents past and present hydrologic and climatic regimes of the Pullman-Moscow Basin. We propose to utilize this record in conjunction with environmental tracers to improve our understanding of recharge rates and mechanisms within the Basin. With chronologic and stratigraphic control, environmental tracer profiles within the vadose zone can provide a powerful tool to estimate recharge rates, enhance our understanding of hillslope flow mechanisms, establish relative ground water ages, and contribute much-needed data for future aquifer recharge models (Allison and Hughes, 1983; Allison et al., 1994; Stone, 1992). Thus, the unique nature of the loessial deposits coupled with an understanding of paleo-reconstruction techniques together offer a unique opportunity to apply environmental tracers to assess contemporary and paleo-recharge of the Pullman-Moscow Basin.

The proposed research will analyze and compare Cl-, 18O, and 3H distributions in the upper 5-12 meters of representative loessial uplands in the western and eastern portion of the Basin. This information will then be used to help identify recharge mechanisms and rates. More specifically, tracer distributions, in concert with stratigraphic interpretations, will help us attempt to answer several important questions about recharge through loess in the Basin:

- How do recharge rates vary according to a mean annual precipitation gradient?
- To what extent does lateral flow associated with impermeable soil layers affect recharge rates and fluxes?
- Does appreciable recharge occur through loessial uplands of the Basin? o What types of paleosol features contribute to bypass flow?
- Based on isotopic signatures, what are the relative ages and origins of deep pore waters?

Nature, Scope, and Objectives of the Research

Because much of the Moscow-Pullman Basin is covered by loess, most aquifer recharge scenarios of appreciable extent involve infiltration through the loessial blanket. The major exceptions to this are the case of losing streams and recharge along the basin margins via the sediments of Bovill (Lin, 1967), but these mechanisms are of limited areal extent. Therefore, a detailed understanding of how the loessial blanket affects the hydrologic processes within the Basin is critical to developing regional recharge models. To better understand these hydrological processes, we must study the ability of the loess

strata to accommodate water to the aquifer at representative sites within the basin, data which can then be extrapolated on a basin-wide scale. This can be accomplished by focusing on two lines of research: 1) a detailed assessment of the loess stratigraphy at designated research sites within the context of regional stratigraphic units, utilizing a combination of biostratigraphy, paleopedology, paleomagnetism, and soil mineralogical techniques , and; 2) the use of environmental tracer (^{18}O, ^{3}H, Cl^-) depth profiles to identify flow paths of contemporary and paleo- pore water to estimate recharge fluxes and mechanisms in the vadose zone.

In order to make solid interpretations of environmental tracer depth profiles, a detailed survey of loess stratigraphy is needed at selected study sites. The western portion of the basin represents the drier areas that receive ~500 mm of mean annual precipitation (MAP); the eastern portion of the basin, in contrast, receives greater MAP (~700 mm). We feel it is important to select and characterize sites from these climatic extremes for three reasons. First of all, the two sites will represent the MAP extremes that drive contemporary recharge and soil-forming processes as well as those that have existed during the Pleistocene (Busacca, 1989). Secondly, loess stratigraphy is better expressed in areas receiving lower MAP. As a result, the drier sampling site will likely provide the most detailed stratigraphic control in which to interpret tracer depth profiles. Secondly, the wetter, eastern part of the basin represents the area where the majority of aquifer recharge is believed to take place (Lum et al., 1990), but is also characterized by loessial uplands where soil stratigraphy is not conducive to deep, downward percolation of infiltrating precipitation (McDaniel and Falen, 1994). Ancient buried soils (paleosols) such as the Washtucna Soil and the Sand Hills Coulee Soil formed during different climatic regimes and have ages of ~50,000 and 9,000 yrs respectively (McDonald and Busacca, 1992). One or both of these paleosols can provide stratigraphic and age control in the upper 3 m of loess that can be traced over most of the Moscow-Pullman Basin. Representative hillslopes having stratigraphic control will be sampled and analyzed for environmental tracers and depth profiles will be constructed.

The specific objectives of the proposed research are to:

1. select two hillslopes that are representative of the loessial uplands of the eastern and western portions of the Moscow-Pullman Basin and determine their stratigraphic and chronologic contexts;

2. determine environmental tracer (^{18}O, ^{3}H, and Cl^-) depth profiles in the loess sections at each site, and;

3. estimate modern-day and paleo-recharge of water through the loess mantle to the basalt aquifers in the Pullman-Moscow Basin using loess stratigraphic and chronologic boundaries in concert with Cl^-, ^{18}O, and ^{3}H depth profiles.