Report for 2003OR29B: Investigation of Nitrate Transport Across the Willamette Silt of the Southern Willamette Valley

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Report Follows

Problem and Research Objectives:

Nitrate in groundwater in Oregon's SWV has been a concern for several years, with more than 7% of domestic wells in 2001 reporting concentrations exceeding the USEPA's Maximum Contaminant Level of 10 ppm [*Aitken et al.*, 2003]. However, not all groundwater is equally affected, due to differences in land use, agricultural practices, and particularly geology. The Willamette Silt, which overlies much of the Willamette Aquifer, acts as a hydraulic barrier to nitrate transport and, more importantly, acts as a natural biogeochemical "reactor-bed" for denitrification. Prior work [*Iverson and Haggerty*, 2002; *Iverson*, 2002] in the Northern Willamette Valley shows that nitrate does not penetrate beyond a redox front in the Silt approximately 25 ft below ground surface, providing very effective protection to the Aquifer. Across the Willamette Valley wherever the Willamette Aquifer is overlain by the Willamette Silt nitrate concentrations are generally low [see data in *Hinkle*, 1997, p. 23]. The SWV has been more susceptible to groundwater contamination than the Northern Valley even though the Willamette Silt is also the surface unit in much of the Southern Valley.

Few studies have attempted to characterize and quantify the nitrate attenuation capacities of geologically young aquitards even though the phenomenon has been noted previously. Our objectives were (1) to quantify critical nitrate-attenuating geochemical characteristics of the Willamette Silt in the SWV, including nitrate concentrations, pH, and at selected sites manganese, organic matter, and ferric and ferrous iron; (2) to map the reduced zone of Willamette Silt that is correlated with the attenuation of nitrate; and (3) to propose a geochemical model for denitrification in these sediments.

Methods, Procedures, and Facilities:

Continuous core samples were taken at 30 sites in the SWV with the ODEQ push-probe rig. Nitrate and pH profiles were taken at all sites and manganese and organic matter measurements were taken at selected sites. Cores were stored on dry ice in the field, and then taken back to the lab to be stored in a freezer until they could be sampled for chemical analysis. Chemical analyses were performed by Central Analytical Laboratories on the Oregon State University campus. Locations and thickness of Willamette Silt were compared to USGS data and found to be in agreement without much new location information. Maps of the reduced zone of Willamette Silt were produced for the SWV, and using data collected previously and data from the Oregon Department of Geology and Mineral Industries (Ian Madin, pers. comm., 2003) a map of the reduced zone in the Northern Willamette Valley was also created. The majority of cores obtained are stored in a freezer at Oregon State University for use in future research.

Principal Findings and Significance:

Our study suggests that nitrate attenuation is strongly correlated with a reduced zone of Willamette Silt that is present in much of the Northern Willamette Valley but that is present in only a small area in the SWV. The reduced zone is geochemically important because of the reduced iron it contains. It is this reduced iron that seems to be the geochemical barrier to nitrate transport in the Willamette Valley. Carbonate minerals appear just below the top of the reduced zone and are visually identifiable from the blue-gray color, differentiating it from the red-brown oxidized silt above. Nitrate and nitrite, where they were found in detectable quantities just above the reduced zone, reached non-detect levels just below the redox boundary. The redox boundary, as identified by the color change, sharp increase in pH, and in some locations by dominant valence state of iron, was usually found only in Willamette Silt thicker than 5.2 m (17 ft).

Biological denitrification tests in the Northern Valley turned up no significant denitrification potential, leading us to believe that chemical reduction by reduced iron is the main mechanism of nitrate attenuation in the Willamette Silt.

Biological denitrification, often suggested as the principal method of nitrate attenuation in shallow sediment, was found not to be a factor in our study. Instead, chemical denitrification by reduced iron appears to be the main mechanism of nitrate reduction in the Willamette Silt. The blue-gray color of the reduced silt acts as a visual marker for the geochemical boundary, allowing groundwater resource managers to easily identify areas like to be resistant to nitrate loading from readily available sources such as domestic well logs. Mapping of the reduced zone of Willamette Silt in the Southern Valley increases the data available for Willamette Valley groundwater resource managers such as the Oregon Department of Environmental quality.

Publications: We intend to submit a manuscript, now in draft form, to *Ground Water*.

Student Support (# and degree level): 3 students, all MS

Arighi, Louis, Quantification of the Nitrate Attenuation Capacity of Low-Permeability Missoula Flood Deposits in the Willamette Valley of Oregon, MS in Geology, Dept. of Geosciences, Oregon State University, Corvallis, Oregon. Defended April, 2004. Grant provided major support for this thesis.

Craner, Jeremy. Tentative title: Regional Flow Model of the Southern Willamette Valley Groundwater Management Area. MS in Geology, in progress. Grant provided minor support in aspects relating to nitrate transport data collection.

Mutti, Glenn. Tentative title: Nonpoint Source Nitrogen Dynamics in the South Willamette Valley, Oregon. MS in Geology, in progress. Grant to provide nitrate sample support in Southern Willamette Valley.

References

Aitken, G., J. Arendt, and A. Eldridge, Southern Willamette Valley Groundwater Assessment 2000-2001 Nitrate Study, pp. 37 p. plus appendices, Oregon Department of Environmental Quality, Salem, Oregon, 2003.

Hinkle, S.R., Quality of shallow ground water in alluvial aquifers of the Willamette Basin, Oregon, 1993-95, 48 p., US Geological Survey, Portland, Oregon, 1997.

Iverson, J., Investigation of the Hydraulic, Physical, and Chemical Buffering Capacity of Missoula Flood Deposits for Water Quality and Supply in the Willamette Valley of Oregon, MS thesis, Oregon State University, Corvallis, Oregon, 2002.

Iverson, J., and R. Haggerty, Investigation of the hydraulic, physical, and chemical buffering capacity of Missoula Flood Deposits for water quality and supply in the Willamette Valley of Oregon, in *9th Annual Meeting, Cordilleran Section, Geological Society of America*, pp. A-109, Geological Society of America, Corvallis, Oregon, 2002.