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WATER FACT SHEET

U.S. GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

EFFECTS OF CONTROLLED AGRICULTURAL PRACTICES ON WATER QUALITY IN A MINNESOTA SAND-PLAIN AQUIFER

Recent studies of Minnesota's sand plains indicate that ground-water chemistry is related to agricultural practices. Surficial sand-plain aquifers cover 8,000,000 acres of Minnesota and are a major source of water for domestic use, irrigation, and some municipal systems. The sand-plain aquifers consist of sand and gravel deposits that are from 20 to greater than 100 feet thick and are covered by a thin sandy loam that generally is less than 2 feet thick. Sand-plain aquifers are recharged by the downward percolation of precipitation through the soil root zone and the unsaturated zone in the sand to the water table. The water table is the upper surface of the zone of saturation and forms the top of the sand-plain aquifer. Sand-plain aquifers are susceptible to contamination by agricultural chemicals (fertilizers and pesticides), if downward-percolating recharge water contains these chemicals. The concentrations of nitrate, pesticides, and some other chemical constituents fluctuate seasonally and differ with depth below the water table (Anderson, 1989). Despite the availability of water-quality data for about 260 wells that were collected during previous studies in three U.S. Geological Survey (USGS) project areas in Minnesota, it is not known how concentrations of agricultural chemicals in ground water relate to the rate and timing of fertilizer and pesticide application or to the tillage practices used. Field-scale research is needed to determine the effects of different farming practices on the concentrations of nitrate, pesticides, and other agricultural chemicals in ground water in the unsaturated and saturated zones.

ROSHOLT RESEARCH FARM

The Rosholt Research Farm in west-central Minnesota overlies a sand-plain aquifer typical of those in the central and western parts of the State. The USGS, in cooperation with the University of Minnesota Center for Agricultural Impacts on Water Quality, the Legislative Commission on Minnesota Resources, and Pope County Soil and Water Conservation District (SWCD), began research on the effects of agricultural chemicals on the unsaturated zone and the sand-plain aquifer, which underlies the Rosholt Research Farm, in the fall of 1986. The University of Minnesota and Pope SWCD have established six test plots about 1 acre in area on the upgradient (southwestern) side of the farm (fig 1.). Three different cropping procedures were duplicated in the six plots:

(1) Continuous corn using 160 lbs N/a (pounds of nitrogen fertilizer per acre) (2) continuous corn with above-average fertilization (214 lbs N/a), and (3) corn-soybean sequence with 160 lbs N/a applied for corn production. Soil moisture is maintained above a minimum level for crop development using irrigation, and "best management practices" are followed. Ideally, the test plots would have been alined in the direction of ground-water flow, but this orientation was prevented by the existing irrigation system. The movement of water and chemicals in the unsaturated zone is monitored with five different types of lysimeters installed and monitored by the University of Minnesota.

Ground-water movement and changes in chemistry in the sand-plain aquifer are monitored in 46 two-inch diameter, galvanized-steel observation wells completed with 2- or 3-foot-long screens. Twenty-five wells are screened at the water table, 16 in the middle of the aquifer, and 5 at the base of the aquifer. Eleven wells at six sites are upgradient from the test plots to monitor water movement toward the test area. Twenty-four wells at 12 sites are located in the test plots to monitor ground water under the plots, and 7 wells are located downgradient from the test plots to monitor water levels and chemistry in the adjacent area. Four wells were installed within 200 feet of the irrigation well at the northwestern corner of the farm to monitor drawdown during an aquifer test.

Agricultural practices described above were conducted during two growing seasons (1987 and 1988). Water samples were collected from all wells in the aquifer and were analyzed for concentrations of major and minor ions, nutrients, and triazine herbicides. Some samples were split for comparative analysis among several laboratories. Water levels were measured and water samples were collected biweekly during the spring and summer for analysis of nitrate and atrazine, which are the two most commonly detected agricultural chemicals in previous Minnesota sand-plain studies (Anderson, 1989).

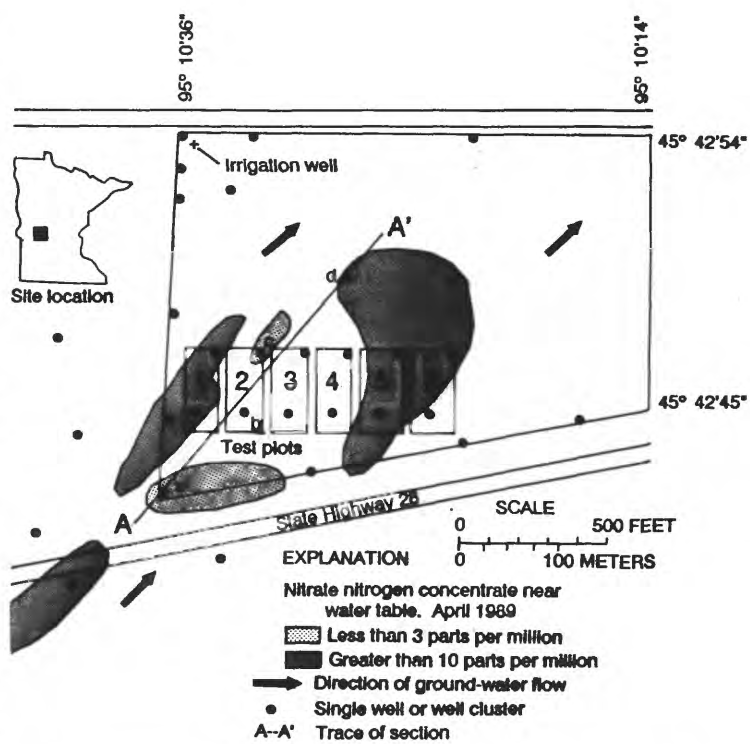

Figure 1.--Rosholt Research Farm showing test plots and areas of high and low nitrate concentrations

PRELIMINARY RESULTS

Movement of Ground Water

Short-term rises in the water table indicate that some local recharge occurred during 1987 and 1988, although the drought during that period provided no appreciable amount of water for downward percolation through the monitored areas beneath the test plots. Slight local depressions in an otherwise flat land surface tend to collect water during rainstorms, spring snowmelt, and periods of irrigation. These shallow land-surface depressions are thought to be areas of focused recharge.

The flow of water in the aquifer was used to help understand the distribution and concentration of agricultural chemicals measured. The altitude and slope of the water table was determined by measuring water levels in wells. Maps prepared from several water-level surveys during this study show that the slope of the water table (and, therefore, the direction of ground-water movement) generally is toward the northeast at a low gradient of about 2.8 feet per mile. At times, the water table slopes to the north in response to seasonal pumping from the research-farm irrigation well and to the effect of seasonal changes of regional water-table levels related to changes in water levels of local streams and drainage ditches.

A 31-hour aquifer test was conducted in July 1988 at the farm irrigation well to estimate hydraulic properties of the aquifer. On the basis of a pumping rate of 360 gallons per minute and analysis of drawdown measured at four observation wells, the average transmissivity of the 17.5-foot-thick aquifer is 22,500 feet squared per day and the average specific yield is 0.10. These properties were used in mathematical models of ground-water flow to estimate average seepage velocity along hydrogeologic section A-A' (fig. 2). Assuming an aquifer porosity of 27 percent and a uniform recharge rate of 9 inches per year (about 36 percent of average annual precipitation), a particle of water would travel about 660 feet horizontally and 2.5 feet downward in 165 days after entering the water table beneath a test plot. These concepts of ground-water flow beneath the research farm were used to plan the depth and location of additional observation wells needed to track potential migration of nitrate and atrazine beneath the test plots.

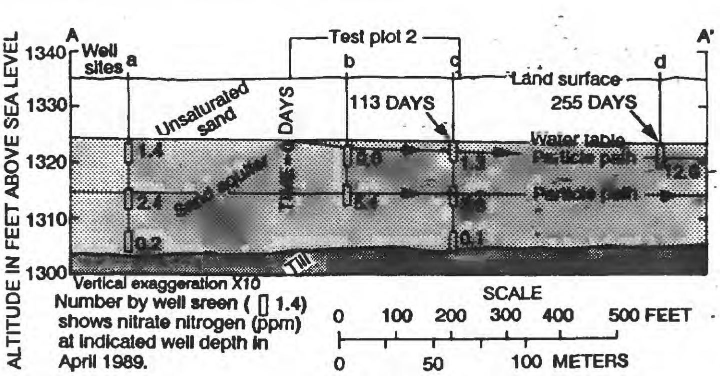

Figure 2.--Hydrologic section A--A' along the direction of ground-water flow. [Average travel time of a water particle is shown along a pathline].

Agricultural Chemicals In The Aquifer

Water samples collected beginning October 1986 through June 1988 indicate that only small quantities of nitrate and atrazine applied to the six test plots reached the water table (fig. 3). During October 24, 1986, and June 16, 1988, the median concentration of nitrate (nitrate-nitrogen) near the water table below the test plots was 7.4 ppm (parts per million, equivalent to milligrams per liter). This concentration falls within the range of nitrate concentrations measured upgradient and downgradient from the test plots. On the basis of a national survey, Madison and Brunett (1985) suggest that nitrate concentrations above 3.0 ppm represent the influence of human activity. The median concentration of atrazine for the same period of time was 0.2 ppb (parts per billion, equivalent to micrograms per liter). Because the test plots had been inactive for 2 years before 1987, the concentrations measured in 1986 and early 1987 represent baseline reference conditions for this study. Although crop irrigation was large at times during the drought, analysis of available data indicates that it was insufficient to cause nitrate and atrazine to reach the sampling points in either the unsaturated sand or near the water table. In July 1988, the median concentration of nitrate and atrazine increased to 12 ppm and 0.4 ppb, respectively. Locally nitrate and atrazine concentrations increased from 2 to 10 times the baseline concentrations beneath isolated areas where water ponded in shallow surface depressions after a combined irrigation and rainfall event.

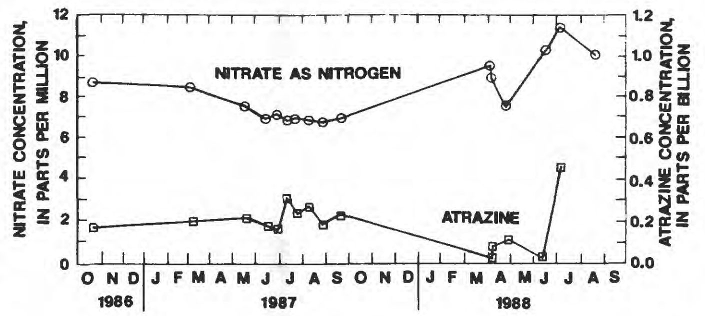

Figure 3.--Median concentration of nitrate and atrazine in water-table wells beneath test plots

A complete sampling of all wells in April 1989 indicated zones containing high and low concentrations of nitrate not related to controlled agricultural treatment at Rosholt (see map and in section A-A' along the ground-water-flow path beneath the test plots). On the basis of maps prepared for March and August 1987, July 1988, and April 1989, nitrate appears to enter the aquifer beneath cultivated fields located upgradient from the Rosholt Research Farm. Nitrate measured in the middle depth of the aquifer beneath Rosholt Farm probably reached the water table several years before 1989 and originated several thousands of feet upgradient from the farm . Furthermore, water collected from the bottom of the aquifer is several years older than water from the middle of the aquifer and originated from a still greater distance upgradient.

The April 1989 map also shows that localized recharge may dilute nitrate concentrations near the water table. The zones mapped as having nitrate concentrations of less than 3.0 ppm coincide with topographic lows along the ditch of State Highway 28 and along the irrigation travelway between plots 2 and 3. Because nitrogen fertilizer was not applied to these depressions, only a low concentration of soil nitrate would be present for transport by percolating snowmelt.

SUGGESTIONS FOR FUTURE RESEARCH

The complete set of hydrologic, chemical, and agricultural data from this study needs to be analyzed to relate controlled agricultural practices to ground-water quality. The location of sampling points and the methods of ground-water sampling need to be selected in relation to chemical sources, their storage and transport. The effects of isolated and uncontrolled recharge events also need to be studied.

SELECTED REFERENCES

Anderson, H.W., Jr., 1989, Effects of agriculture on water in surficial sand-plain aquifers in Douglas, Kandiyohi, Pope, and Stearns Counties, Minnesota: U.S. Geological Survey Water-Resources Investigations Report 87-4040, 45 p.

Madison, R.J., and Brunett, J.O., 1985, Overview of the occurrence of nitrate in ground water of the United States *in* National water summary 1984--Water-quality issues: U.S. Geological Survey Water-Supply Paper 2275, p. 93-105

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