WATER FACT SHEET

U.S. GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

EFFECTS OF RECHARGE ON THE TRANSPORT OF AGRICULTURAL CHEMICALS AT THE PRINCETON, MINN. MANAGEMENT SYSTEMS EVALUATION AREA (MSEA), 1991-92

INTRODUCTION

Rates of water movement through the unsaturated zone greatly affect the amount and concentrations of agricultural chemicals that may reach the water table. For example, recharge can flush to the water table chemicals that have accumulated in the unsaturated zone during dry periods. A better understanding of how topography influences recharge and the movement of agricultural chemicals is needed. In 1991, the U.S. Geological Survey (USGS), with funding from the USGS Toxic Substances Hydrology Program, began studying the movement of water and agricultural chemicals to the water table at the Management Systems Evaluation Area (MSEA) near Princeton, Minnesota. Instruments were installed to measure the movement of moisture through the soil beneath a corn field. Samples of the recharge water were analyzed for concentrations of agricultural chemicals and tracers. Field recharge and tracer tests were simulated in the laboratory.

DESCRIPTION OF RESEARCH SITES

The research is being conducted in an upland area (topographically high) and a lowland area (topographically low) within the northern most cropped areas at the 160-acre Princeton MSEA (fig. 1). The upland and lowland sites are about 256 feet apart and the difference in elevation between the sites is 4.5 feet. Generally, the unsaturated zone consists of fine-to-medium sand and the saturated zone consists of medium-to-coarse sand. The upper 3 feet of the unsaturated zone at the upland site is slightly coarser, better sorted, and has a smaller percentage of silt- and clay-sized particles than the upper 3 feet of the unsaturated zone at the lowland site. Organic carbon content in the upper 8 inches of topsoil is about 1.0 percent at the lowland site, 0.6 percent at the upland site. There are discontinuous layers of silt and very fine sand as thick as 8 inches in the unsaturated and saturated zones. The water table was about 13 feet below land surface at the upland site and about 9 feet below land surface at the lowland site during October 1991. Saturated hydraulic conductivities generally range between 11 and 230 feet per day. Based on well hydrograph analyses, ground-water recharge rates generally range from 4 to 8 inches per year. Ground-water flow is generally from southwest to northeast beneath the upland and lowland sires at about 3 inches per day.

The herbicides atrazine and alachlor were applied to the research sites at broadcast rates of 1.5 pounds per acre (lb/a) and 2.0 lb/a, respectively, during both May 1991 and May 1992. Nitrogen fertilizer was applied during April to June 1991 and during June 1992 at the rates of 140 lb/a and 110 lb/a, respectively. Herbicides and fertilizers were not applied to the field from 1981-89, prior to the implementation of the MSEA farming systems, when the site was planted in alfalfa.

DYE-TRACING/TRENCHING STUDY AND INSTALLATION OF INSTRUMENTATION

Rhodamine WT dye (a harmless vegetable based solution) was applied uniformly as a tracer to a 12 by 20-ft area of land at both sites. The dye was applied at 10-day intervals from July 5 through September 13, 1991. Total rainfall from July 5 through October 22, 1991 was about 12 inches. Beginning October 22, 1991, a 6 by 10-ft trench was dug in the middle of each dye-application area to a total depth of 6.5 ft to locate the dye and characterize soil properties in the unsaturated zone.

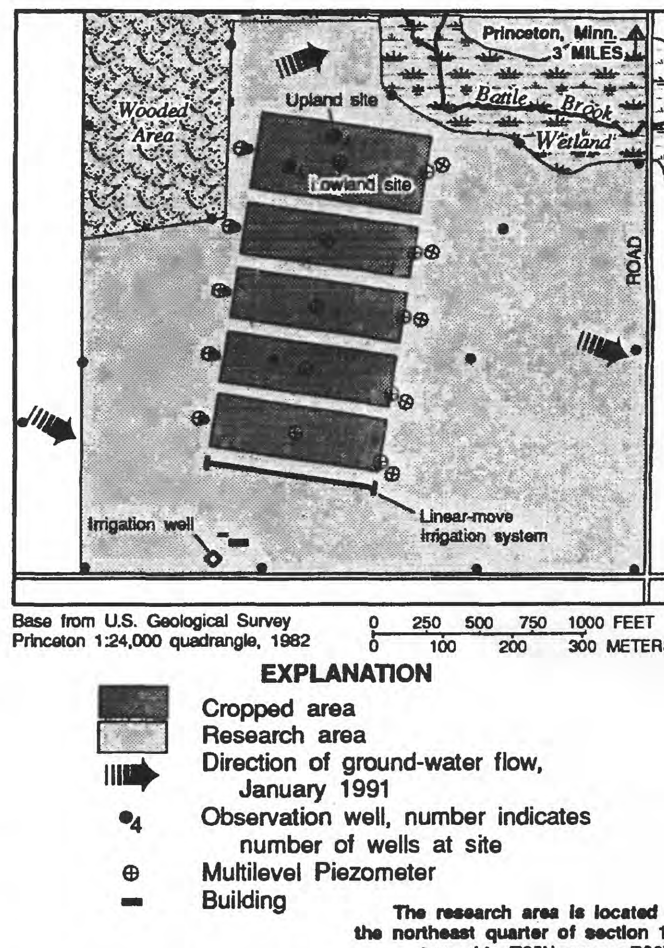

Figure 1.--Layout of the Princeton, Minnesota Management Systems Evaluation Area.

The distribution of dye through the unsaturated zone was highly variable at both sites. Dye movement, as expected, was greatest beneath the furrows and least beneath the corn rows. At the lowland site, the depth of visible dye between the upland and lowland sites likely is due to the higher organic content and finer-textured soil at the lowland site. Concentrations of dye and water in elutions of soil samples at both topographic settings generally were greater than 400 micrograms per liter (μg/L) at land surface, less than 100 μg/L at the 8-inch depth, and less that 1 μg/L below the 20-inch depth. Results suggest the dye moved preferentially is response to tillage patterns, presence of plant roots, and differences in grain size.

Two vertical profiles were instrumented at each site on the basis of the relative presence or absence of dye. Suction samplers to collect water were installed at depths of about 3, 6, and 8 feet below land surface. Instruments to measure soil moisture and temperature were installed at depths of 8, 16, 24, 31, 39, 59, 79, 98, and 118 inches below land surface. A water-table well was installed upgradient of each trench so that concentrations of agricultural chemicals reaching the water table could be determined. Precipitation and ground-water levels were continuously recorded at both sites.

WATER INFILTRATION AT THE UPLAND AND LOWLAND SITES

Infiltration tests at the upland and lowland sites were conducted during 1992 by applying about on inch of water from a sprinkler irrigation system. The movement of wetting fronts through the unsaturated zone to the water table were then evaluated. For the purpose of this study, a wetting front generally was defined as about a 2 percent increase in volumetric moisture content.

Wetting fronts moved more rapidly and penetrated deeper into the unsaturated zone at the lowland site than at the upland site. About 24 hours after one inch of irrigation water was applied on June 9, for example, the wetting front at the upland site had moved to a maximum depth of only about 2.6 ft below land surface (fig. 2). By comparison, the wetting front at the lowland site reached the water table (about 9 ft below land surface) after the same 24-hour period, resulting in ground-water recharge. The lowland site apparently was an area of focused recharge, or funneled flow of water, because the increase in water storage (1.5 inches) exceeded the amount of water applied (1 inch).

WATER QUALITY AT THE UPLAND AND LOWLAND SITES

Water samples were collected from each sampling location (including precipitation, irrigation water, suction lysimeter samplers, and the water-table well) prior to the start of each infiltration test to determine pre-test concentrations of the agricultural chemicals. Following the application of irrigation water, water samples were collected from the suction samplers as the wetting front passed a given sampler elevation, and from the water table after the wetting front reached the saturated zone. The water samples were analyzed for dissolved major anions and for selected herbicides and herbicide metabolites.

Nitrate-nitrogen (nitrate-N) concentrations in water samples collected form the unsaturated zone at the lowland site (median of 35.4 mg/L (milligrams per liter)) were greater that concentrations at the upland site (median of 19.5 mg/L) during 1992. Nitrate-N concentrations at the lowland sites were similar throughout the unsaturated zone. Nitrate-N concentrations in the upper 3 feet of the unsaturated zone at the upland site (median of 5.3 mg/L) were much less than deeper in the profile (median of 22.5 mg/L). The median nitrate-N concentration from the water table at the lowland site (16.6 mg/L) was also greater than the median concentration (13.5 mg/L) at the upland site.

Concentrations of atrazine and atrazine metabolite de-isopropylatrazine in water samples collected from the unsaturated zone at the lowland site were generally greater than concentrations at the upland site during 1992. Atrazine concentrations at the lowland site ranged from 0.07 to 0.42 μg/L with a median of 0.09 μg/L compared to a range of 0.04 to 0.20 μg/L and a median of 0.07 μg/L at the upland site. Similarly, DIA concentrations at the lowland site ranged from 0.0 to 0.49 μg/L with a median of 0.09 μg/L compared to a range of 0.06 to 0.25 μg/L and a median below the reporting limit of 0.08 μg/L at the upland sites. Concentrations of atrazine metabolite de-ethylatrazine at the lowland site ranged from 0.0 to 1.43 μg/L with a median of 0.06 μg/L compared to a range of 0.08 μg/L to 0.35 μg/L and a median of 0.18 μg/L at the upland site. Similarly, the concentration of atrazine in samples from the water table at the lowland site (median of 0.05 μg/L) were also slightly greater that concentrations at the upland site (median below the reporting limit of 0.04 μg/L). Because the detection limit of 5 nanograms per gram for atrazine in soil sample is to large to detect in these herbicide concentrations, these results indicate that full evaluation of the movement of atrazine to ground water samples from the unsaturated zone.

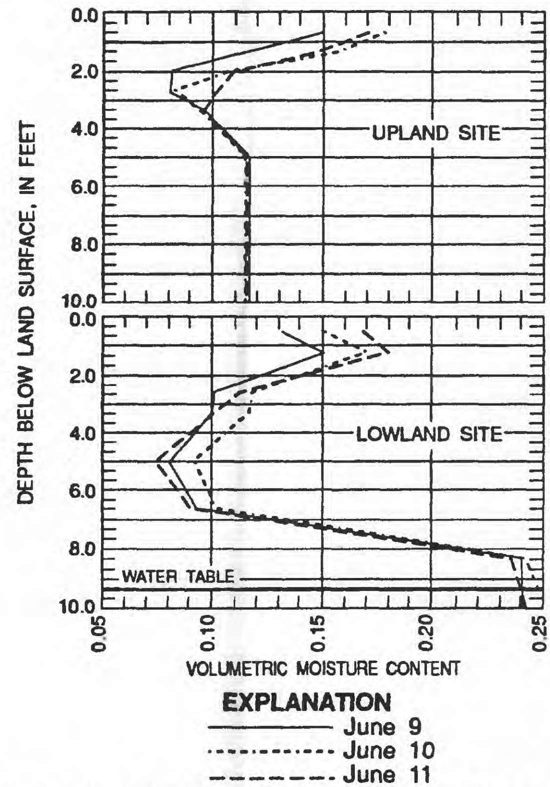

Figure 2.--Soil moisture at the upland and lowland sites, following application of 1 inch of water on June 9, 1992.

Differences in the movement of wetting fronts, agricultural chemicals, and tracers at the upland and lowland sites likely result from a combination of factors including differences in organic content, grain size, macropores and sedimentary heterogenities, antecedent moisture conditions, and topographic relief. These results support the hypothesis that the vertical flux of water and agricultural chemical is increased in lowland sites compared to upland sites.

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