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GROUNDWATER RECHARGE AND NUTRIENT TRANSPORT IN A TILE DRAINED FIELD: THE LAS NUTRIAS GROUNDWATER PROJECT LAS NUTRIAS, NEW MEXICO

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INTRODUCTION

With the rapid growth of the Albuquerque region, groundwater contamination from nonpoint sources has become an increasing concern. Agriculture, one major land usage of the basin area, can be responsible for the leaching of nutrients and chemicals to shallow groundwater via irrigation return flows. Even so, there is almost no available information regarding agricultural impacts on groundwater quality in New Mexico. The major objective of this project has been to develop a data base pertaining to this issue.

The Las Nutrias project field site is located on a commercial farm at the southern end of the Albuquerque Basin, approximately halfway between Albuquerque and Socorro, New Mexico (Figure 1). Although structural features of the basin complicate the regional groundwater flow patterns, overall recharge to the site occurs as inflow from the eastern mountain uplifts and as drainage of the valley from the north.

The field site is characterized by alluvial floodplain soils with moderate drainage capabilities. A shallow water table exists due to the fact that the site is at a low elevation relative to the Rio Grande. Therefore, in 1979, the landowner installed a subsurface tile drainage system. Tile drains are commonly used in areas with naturally high water tables to reduce salt accumulation in the soil

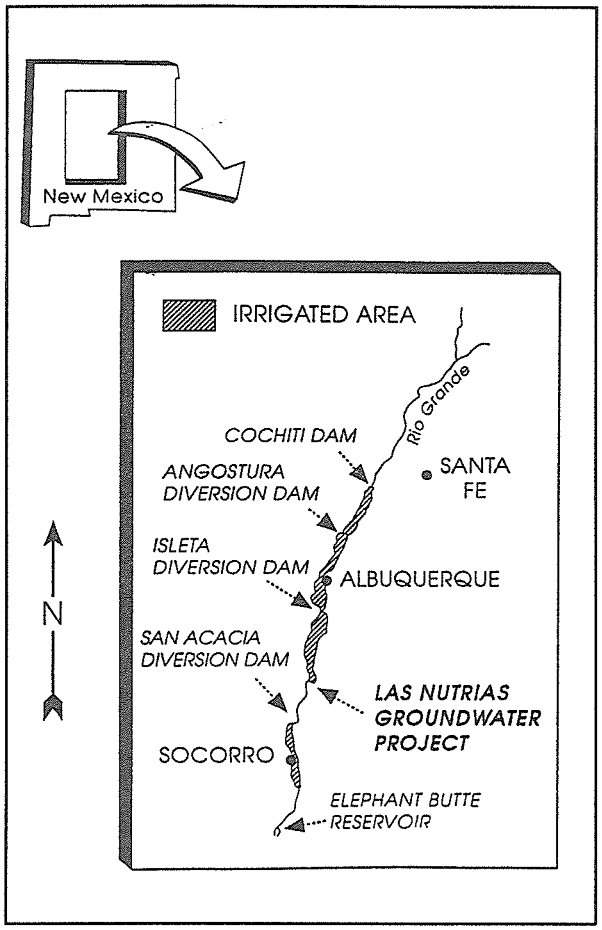

Figure 1. Las Nutrias groundwater project field site location.

profile. Drainage systems also provide an excellent way to assess chemical and nutrient leaching to groundwater since they collect leachate from a large area, integrating the effects of spatial variability often seen at the field scale. A few studies have been done on experimental plots with tile drainage systems where the researchers had absolute control over nutrient, chemical, and water inputs (Baker and Johnson 1981; Kladivko et al. 1991; Owens et al. 1994; Vinten et al. 1994). In addition, these studies have been done in different geological and climatological settings. Data from the Las Nutrias Groundwater Project is therefore a more realistic representation of the impacts on New Mexico groundwater quality due to typical farming practices in the Rio Grande Valley.

The main goals of this project are:

- to adapt the tile drainage system to allow for the collection of irrigation return flows on an actual, operating farm
- to utilize the tile drain sampling system to quantify nutrient and pesticide levels in the irrigation return flow
- to determine the local hydrology in and around the field site
- to use the collected field data to test the two-dimensional water flow and chemical transport model (CHAIN 2-D)

FIELD INSTRUMENTATION AND METHODS

Figure 2 shows a plan view of the Las Nutrias field site. A concrete-lined irrigation canal is located along the northern border. The site is divided into three sections by two berms. These fields are referred to as the East, Center, and West benches. Since the time the project began in the summer of 1992, the East Bench has been planted to alfalfa, while the Center and West Bench crops have included corn, winter wheat, and a sorghum-sudan cross. Currently all three benches are planted to alfalfa.

The drains are installed approximately 4 to 6 feet below ground surface, collecting irrigation water which drains below the soil surface as well as shallow groundwater flowing in from off site. The individual tiles connect to a single collection drain which empties into an off-site surface canal.

An 800-foot section of a central tile drain has been isolated by installing two manholes, one on the eastern berm and one on the western berm. This allows us to measure the quantity and quality of water entering and leaving a single drainage line. The manholes currently are equipped with pumping systems and automatic water samplers (Figure 3). Water is allowed to enter the manhole until a pressure transducer senses the high water level, at which time the pump is activated. The pump shuts off when the transducer senses the calibrated low water level. The data logger records these pump cycles over time, which allows us to determine the amount of water flowing through this tile drain.

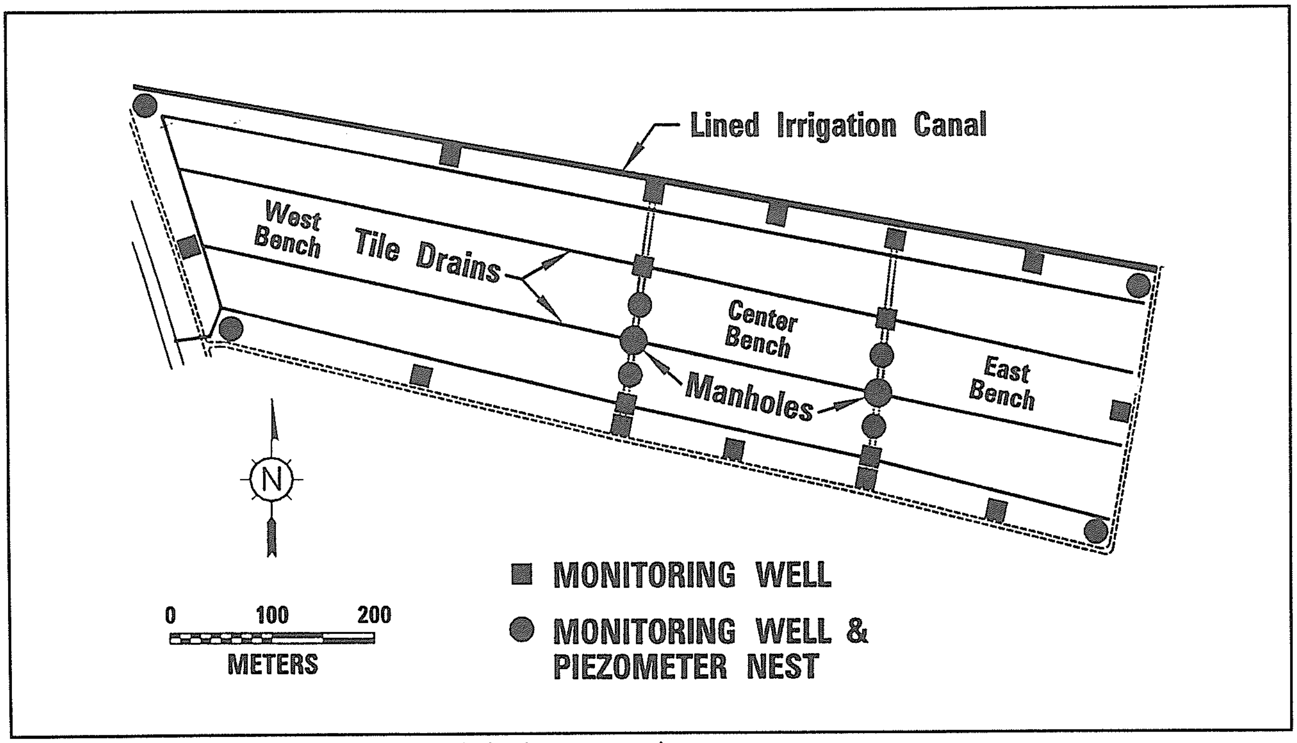

Figure 2. Plan view of Las Nutrias field site instrumentation.

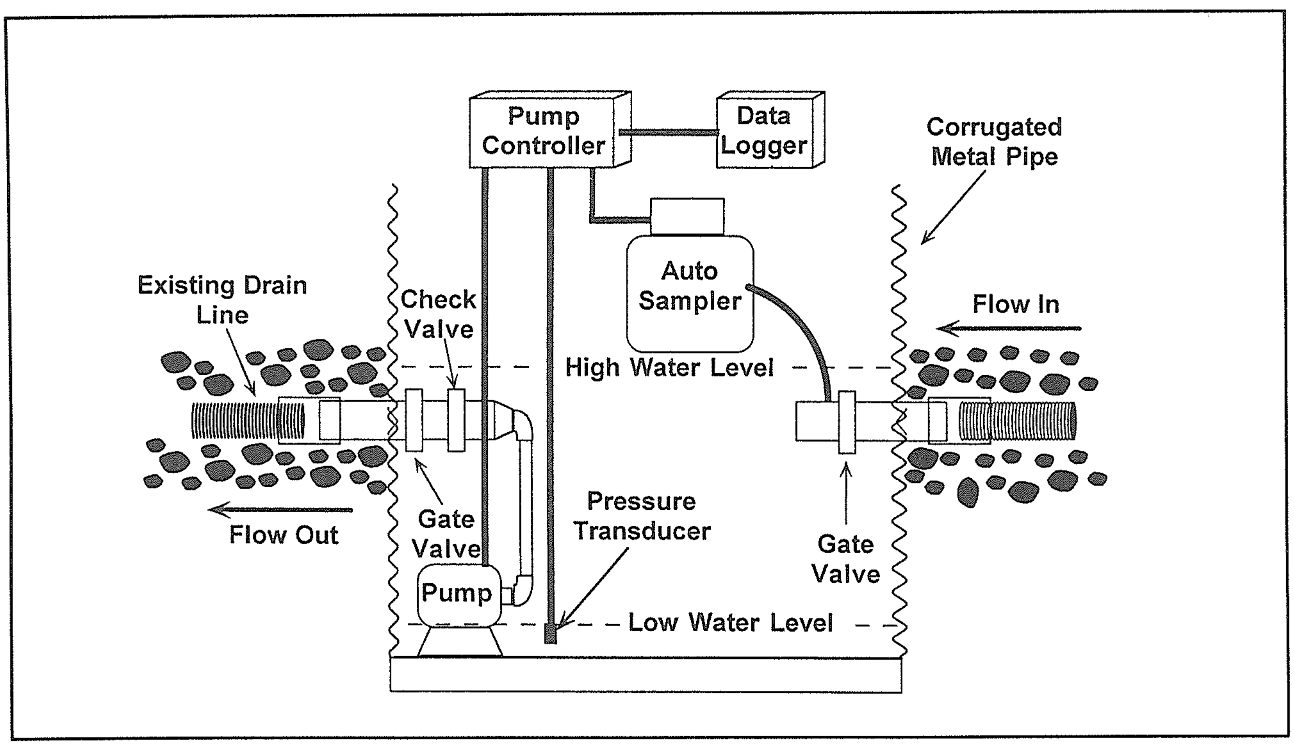

Figure 3. Manhole schematic.

The automatic water samplers were installed in each manhole in early May 1994. Since then, samples have been collected on a daily basis. During an irrigation event, the autosamplers are programmed to sample on a four-hour interval or less, which has allowed us to obtain more detailed information of the nitrate fluctuations in the drainage water as a result of surface water inputs.

Monitoring wells and piezometer nests are located along the border of the field site and along both berms (Figure 2). The monitoring wells are installed to a depth of 2 meters; the piezometers are nested at 3, 5, and 7 meters. Water level measurements in all wells are taken periodically to measure the fluctuating water table elevations. This type of information is being used to differentiate between the local and regional groundwater flow components. All wells and piezometers are sampled on a weekly basis to determine the spatial distribution and temporal variations of nitrate concentrations in the shallow groundwater.

The irrigation canal is equipped with two circular weirs, one for the Center Bench and one for the West. These are used to measure the net volumetric flow rate of water applied to the Center Bench during an irrigation. Rain gauges also have been installed at several locations around the field site to measure the amount of water input from precipitation.

RESULTS/DATA

The depth to water measurements made in the monitoring wells are used to generate groundwater contour maps. Figure 4 shows the water table before and after an irrigation event. Prior to irrigation, groundwater flow directions represent the regional patterns. Here, we see a southwesterly trending gradient due to the mountain recharge, and a strong southern gradient due to the close proximity of the Rio Grande. Following an irrigation, hydraulic gradients have shifted. Flow in the Center and East benches has shifted to a south-southeasterly direction, showing the influence of greater water infiltration near the irrigation canal at the north end of the field. Flow in the West Bench has shifted more westerly, probably reflecting sandier soils and hence greater infiltration in the north-central portion of the field. These shifting hydraulic gradients indicate that groundwater recharge rates are influenced by several factors, such as the tile drainage system, regional flow components, and the heterogeneity of the soils.

The sandy areas have consistently shown approximately 3-4 inches of ponded water for several days after an irrigation. An interesting correlation between high soil salinities and the ponded areas has been observed. To further quantify this, electromagnetic induction surveys using a Geonics EM38 have been performed. The Geonics instrument measures soil salinity at two relatively shallow depths within the unsaturated portion of the soil profile. Measurements are made periodically along north-south transects at 10 meter intervals. This data is then contoured, enabling us to view the soil salinity distribution. High soil salinities almost always correspond to the ponded areas, and these areas also yield the lowest crop production. Aerial photographs taken in October 1993 also reveal the correlation between ponded areas, high soil salinities, and poor crop yield.

Preliminary geostatistical analyses show that spatial and temporal correlations exist between the nitrate concentrations in the wells. Higher concentrations are consistently observed in the northeast area of the site. More recently, the multilevel piezometer nests have been sampled to determine if there are any vertical nitrate gradients present. This will indicate the presence or absence of a regional contribution to the local nitrate concentrations.

Figure 5 shows the breakthrough of nitrates in the tile drainage water over the 1994 irrigation season. During the winter months, background concentrations were within the range of 0.5-2.0 mg/l nitrate. In March 1994 irrigation season began. Rapid increases in nitrate concentration in the tile lines occur within a day of the irrigation. Concentrations return to background levels approximately 4-5 days later. Generally, as the season progressed, each subsequent irrigation resulted in a greater increase of nitrate concentration in the tile lines. The EPA maximum contaminant level of 44.3 mg/l nitrate was exceeded several times. Such a rapid response of increased nitrate concentrations during a water input event indicates the presence of preferential flow paths within the soil profile. Therefore, the CHAIN 2-D flow and transport model has been adapted to include this phenomenon.

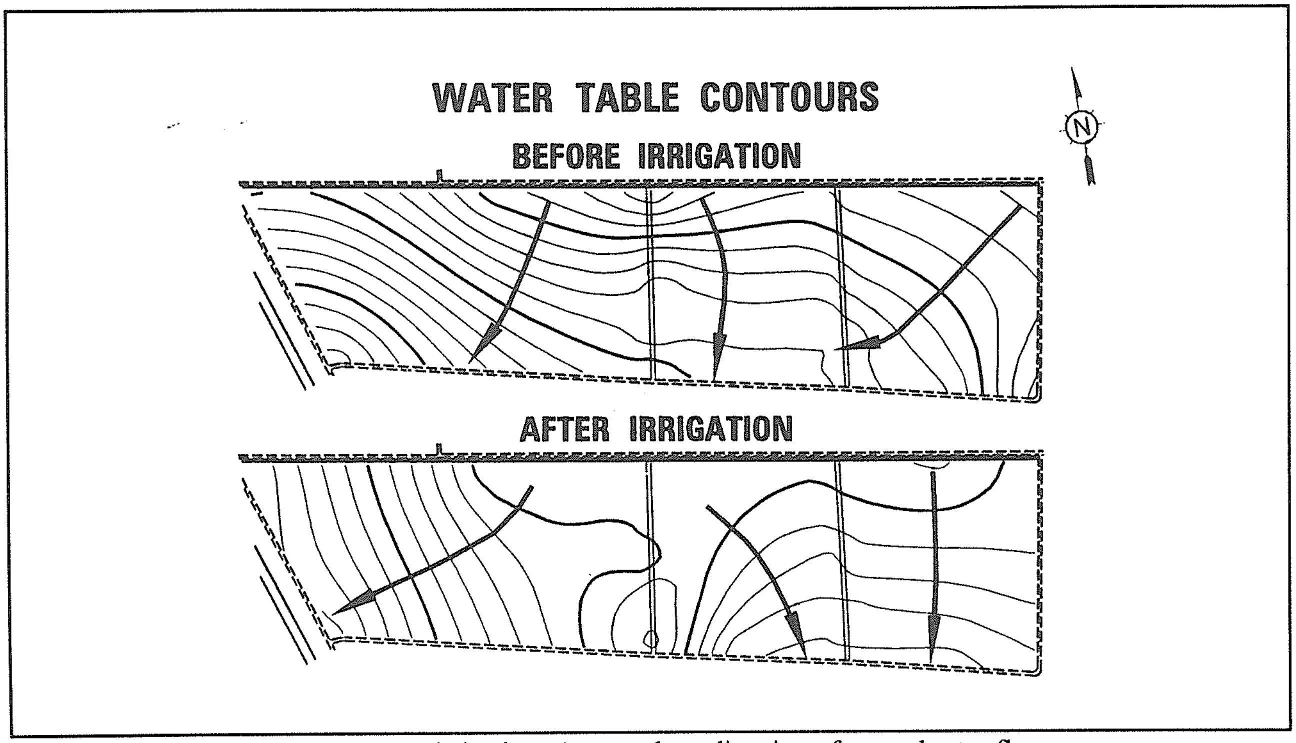

Figure 4. Water table response to an irrigation. Arrows show direction of groundwater flow.

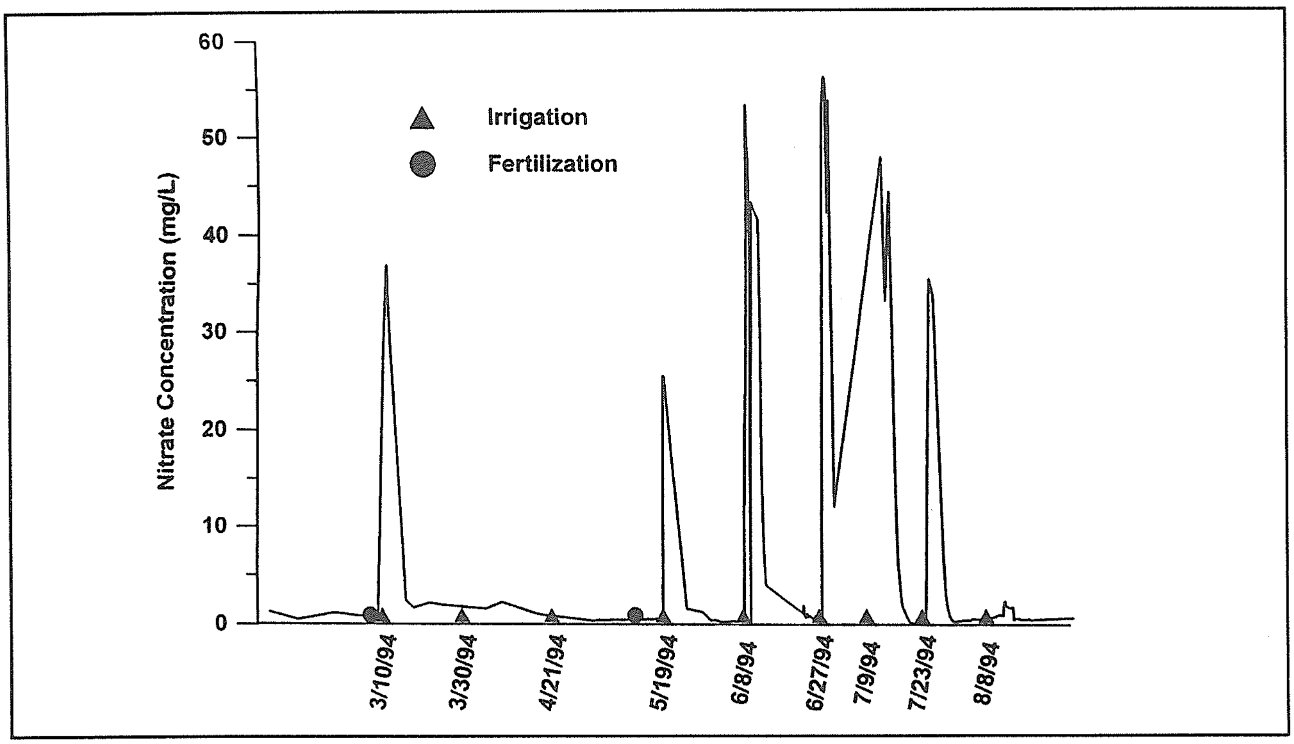

Figure 5. Nitrate concentrations in the West Manhole tile drain for the 1994 irrigation season.

Fertilization occurred twice during the season (Figure 5). Yet, we see a significant increase of nitrate in the tile drain immediately following each irrigation even when no recent fertilization has occurred. We believe these observations may be explained as follows. Between irrigations, tile drainage water is dominated by collection of low-nitrate, regional groundwater flow. There is relatively little contribution from high-nitrate recharge water draining from the soil. During and just after an irrigation, high-nitrate water flushing through the soil to the tile drain constitutes a much greater proportion of total drain flow, causing the observed spikes in tile drain water concentration.

Many factors could have contributed to high nitrate concentrations seen in the tile drain. During the winter of 1993-94, the Center Bench wheat crop did not grow well. Therefore, there was essentially no crop uptake of applied nitrogen fertilizers on this bench. When the irrigation season began, this excess nitrogen was easily flushed through the soil profile. This is, of course, influenced by several factors, such as variable crop uptake rates, residual nitrate in the soil profile from previous growing seasons, variations in precipitation, and the seasonal changes in the tile drain discharge rates (Kladivko et al. 1991).

Nitrate concentrations in the collection drain also are monitored regularly. Generally, the background concentrations are in the range of 20-25 mg/l nitrate. Increases up to 60 mg/l nitrate or more have been observed after an irrigation of the field site. These overall higher concentrations most likely reflect the fact that the three unmonitored tile drains also collect leachate which may contain a higher concentration of nitrate.

CONCLUSIONS

The tile drainage system at the Las Nutrias field site has allowed for the investigation of the impacts to shallow groundwater associated with agriculture. Field experiments and data evaluation have so far shown that:

- water table contours and groundwater flow directions change rapidly in response to irrigations
- soil salinities and poor crop yields are somewhat influenced by soil heterogeneities
- nitrate inputs to shallow groundwater occur rapidly following an irrigation, even in the absence of nitrogen fertilization

Given that similar soil types are found along the valley, and that agricultural practices are similar, the information obtained through the Las Nutrias Groundwater Project can be a valuable tool for assessing agricultural impacts to the shallow groundwater within the entire Albuquerque Basin.

FUTURE WORK PLANNED

The Las Nutrias Groundwater Project will continue into the 1995 season. Field data will be used to test a two-dimensional variably saturated water flow and solute transport model being developed for tile drainage systems. In order to help accomplish this, our future plans include:

- performing tracer tests using bromide and fluorobenzoates to determine solute travel times
- performing in-depth statistical analyses to further quantify spatial and temporal variations in the nitrate concentrations in the monitoring wells and soil profile
- conducting an image analysis to quantify the distribution of macropores at the soil surface
- expanding the water chemistry analyses to include pesticides (chlorpyrifos, terbacil, carbofuran, 2, 4-D) used on the field and surrounding farms
- performing laboratory experiments to determine pesticide sorption and degradation characteristics

ACKNOWLEDGEMENTS

Many agencies and individuals have contributed to the Las Nutrias Groundwater Project. Primary financial support has come from the U.S. Bureau of Reclamation and from a special water quality grant from the Cooperative State Research Service of the U.S. Department of Agriculture. We would also like to thank the landowner for the use of his fields. Field work and preliminary model runs done by Baukie Sijtsma are greatly appreciated. Special thanks to Monty Flinch for his assistance with constructing the figures.

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