Influences of Natural and Man-Made Sources of Contamination on Water Quality Trends in the Seymour Aquifer: A 2007 Status Report

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Executive Summary

By all accounts, the Seymour Aquifer is vulnerable to contamination. For example, sandy soils are widespread in the region, the aquifer is unconfined, and water tables are shallow throughout much of this system. It is also apparent that the Seymour Aquifer has consistently suffered from poor water quality—most often associated with high levels of nitrate-nitrogen.

What cannot be affirmed is the extent to which water quality problems in the Seymour Aquifer can be attributed to natural sources or human activities.

Over the past decade, researchers affiliated with several universities and agencies have investigated the sources of nitrate contamination in the Seymour Aquifer and the extent to which changes in land use practices may improve groundwater quality in the region.

Finding the answer to this problem through research is important for several reasons. Most importantly, policy makers and the citizens of Texas need to know the capability of best land management practices to reduce groundwater contamination in the region. If, however, it is found that groundwater contamination is a naturally occurring phenomenon in the region, policymakers and the public may conclude it is not feasible to achieve high water quality in the Seymour Aquifer System.

Introduction

One of the central issues regarding water quality in the Seymour Aquifer is the extent to which contamination by nitrates is a result of natural processes or man-made influences. Knowing the answer to this question is essential. If anthropogenic factors have worsened the quality of water in the Seymour Aquifer, these activities can be curtailed and water quality may be improved. If, on the other hand, poor water quality is a result of natural processes, the way in which this aquifer is managed may have to be modified to reflect this reality.

In its 2005 report to the Texas Legislature, the Groundwater Protection Committee (GWPC) recommended that collaborative research between agricultural scientists and hydrogeologists be conducted to evaluate transport processes of nitrate from soils to underlying aquifers. Describing the problem, the report states the following [pages 16-17]:

> "Elevated nitrate concentrations are widespread in Texas aquifers, particularly in the Seymour, the Southern High Plains, and the Southern Gulf Coast aquifers...Natural sources of nitrate have been attributed to large accumulations of nitrate in soils prior to cultivation and release of these nitrates caused by cultivation. This process has been invoked to explain high nitrate levels in the Seymour Aquifer...Very limited studies of natural settings in Texas do not reveal large accumulations of nitrate that could explain current elevated nitrate levels in the aquifers. *Additional studies of soil nitrate in natural settings are required to further evaluate the potential for natural source of elevated nitrate levels in aquifers in Texas."*

The GWPC also noted that studies in Nevada and Kansas suggested that natural conditions—not man-made activities—may be responsible for degraded water quality. These same natural effects may degrade water quality in the Seymour Aquifer and other groundwater systems in Texas.

Walvoord et al. (2003) postulate that natural sources of nitrogen in desert ecosystems in Nevada include nitrate and ammonium in precipitation, the deposition of nitrate salts, and biological assimilation of atmospheric nitrogen by plants. Natural mechanisms of nitrogen removal include plant uptake, nitrogen volatilization to ammonia, wind erosion and denitrification. They suggest that in these desert lands nitrate gradually accumulates in the subsoil, and these subsoil nitrate reserves may be leached to groundwater when the desert lands are irrigated.

Roadcap, Hackley & Hwang (2002) cautioned that it may be difficult to utilize nitrogen isotope ratios to differentiate between different nutrient sources in field-scale studies of large watersheds. Microbial processes or widespread natural variations in nitrogen isotope values throughout a watershed can make it hard to firmly associate specific nitrogen isotope ratios with sources of contamination.

Townsend (2001) describes the use of a nitrogen-15 isotope analysis method to identify sources of groundwater impairment in Kansas. Townsend et al. (2005) used these analytical methods and suggest that certain areas of the High Plains aquifer in Kansas have been impacted by both anthropogenic and natural sources.

In a 1992 report describing water resources in the Rolling Plains, Duffin & Beynon suggest that, as with nitrates, it is difficult to know whether groundwater salinity in the Seymour and Blaine aquifers is the result of natural influences or human activities (page 23). They hypothesize the following:

> "During the severe drought of the 1950s, many farmers terraced their land in an effort to conserve as much water as possible by altering the natural drainage patterns to prevent runoff and erosion. In the next decade, rainfall returned to normal, and the water table began rising, eventually to within a few feet of the surface. Evaporation began which concentrated the salts dissolved in the ground water and caused them [the salts] to precipitate from the water into the soil. When the next rain occurred, this salt was dissolved and carried from the original evaporation site to

> start the process again. Salinization from the evaporation of shallow ground water is a process which can cause water wells to 'go bad' and kill vegetation."

Price (1979) suggested that elevated nitrate levels throughout the Seymour Aquifer may have occurred when native rangelands were plowed by farmers.

Kreitler & Browning (1983) and Kreitler (1979) suggested that tracers could be used to differentiate between various sources of nitrogen. These studies focused on determining if differences in the concentrations of various nitrogen isotopes could provide clues to help policymakers distinguish between how natural and human influences affect water quality. More recently, Scanlon has used groundwater tracer techniques to quantify recharge rates. She suggests that groundwater tracer technologies are the most reliable tools to estimate recharge because the distribution of tracers reveals the dates that waters first flowed to aquifer formations.

Water Resources Conditions in the Seymour Aquifer

Nine groundwater districts manage groundwater resources that make up the Seymour Aquifer region. However, the entire area of the Seymour Aquifer is not managed by groundwater districts. Groundwater districts that manage parts of the Seymour Aquifer include the Lower Seymour, Panhandle, Tri-County, Rolling Plains, Clear Fork, and Wes-Tex Groundwater Conservation Districts (GCD); the High Plains Underground Water Conservation District Number 1, and the Collingsworth County and Salt Fork Underground Water Conservation Districts.

Recently, the Texas Water Development Board published a technical report that thoroughly assesses water quantity and water quality conditions in the Seymour Aquifer (Ewing, Jones & Pickens, 2004). The report describes efforts to develop a three-dimensional groundwater model for the Seymour as part of groundwater availability modeling (GAM) efforts. The report states that high nitrate levels may result from the conversion of native rangelands and grasslands to agricultural production; contamination from on-site wastewater treatment systems; and the use of nitrogen fertilizers on croplands. Some of the highlights of this study are briefly captured here:

- The Seymour Aquifer is comprised of isolated remnants or "pods" of unconsolidated alluvial deposits. The Seymour Aquifer overlies Permian-age deposits. The underlying Blaine Formation and Blaine Aquifer are important water supply sources in the region.
- The Seymour Aquifer covers a 23-county area that includes north-central Texas and the Texas Panhandle. The area overlying the Seymour stretches roughly 180 miles east-to-west and 208 miles north-to-south.
- In 1997, groundwater use was estimated at 120,000 acre-feet (AF) annually. Under drought conditions, the maximum amount of water available from the Seymour Aquifer was estimated at 250,000 AF per year.
- The average recharge rate over the Seymour Aquifer is estimated, using GAM models, at 2 inches per year. Average precipitation rates over the aquifer range from 12 to 31 inches annually, Modeling results show that recharge accounts for roughly 94% of the aquifer inflow. Major discharges from the aquifer include losses to streams (35%), evapotranspiration (20%) and other outflows (20%).
- Many wells throughout the region suffer from impaired water quality:
    - More than half the wells in the Seymour Aquifer exceed the primary maximum contaminant level (MCL) for nitrate of 10 milligrams per liter (mg/l). In the Blaine Aquifer, 12% of the wells exceed the MCL for nitrate.
    - Approximately 41% of wells in the Seymour Aquifer and 94% of wells in the Blaine Aquifer exceed the secondary MCL of 1,000 mg/l for total dissolved solids (TDS).
    - Roughly 17% of wells in the Seymour Aquifer and 94% of wells in the Blaine Aquifer exceed the secondary MCL of 300 mg/l for sulfates,

    - Approximately 17% of the wells in the Seymour Aquifer and 26% of the wells in the Blaine Aquifer exceed the secondary MCL of 300 mg/l for chlorides.
    - Roughly 14% of wells in the Seymour Aquifer exceed the secondary MCL for fluoride of 2 mg/l.
    - Approximately 5% of wells in the Seymour Aquifer and 8% of wells in the Blaine Aquifer exceed the primary MCL of 15 picocuries per liter for naturally occurring radionuclides.
- Water quality also limits the use of waters from the Seymour Aquifer for agricultural irrigation. For example, 91% of wells in the Seymour Aquifer are classified as high salinity hazards for irrigation (i.e., an electrical conductivity of more than 750 micromhos). Chloride levels in the region that limit crop production (i.e., concentrations greater than 1,000 mg/l for extended time periods) are consistently exceeded in 6% of wells in the Seymour Aquifer and 8% of wells in the Blaine Aquifer.

In 2003, researchers at the Bureau of Economic Geology at the University of Texas at Austin (Scanlon, Reedy & Kier, 2003) examined nitrogen loadings in the Seymour Aquifer region. They report that nitrogen inputs are variable and the risk of groundwater contamination is significant in the region. In 75% of the groundwater wells tested in the Seymour Aquifer, nitrate levels exceed the federal drinking water standard of 10 milligrams per liter (mg/l) for nitrate-nitrogen. In some wells in this region, nitrate-nitrogen levels have exceeded 35 mg/l. Scanlon, Reedy & Keese (2003) reported that median nitrate concentrations in wells in Haskell County range from 7 to 44 mg/l.

Throughout the mid-1990s, The United States Geological Survey assessed sources of nitrogen and nitrate levels in the Seymour Aquifer. This project sampled 16 wells near the town of Gilliland for the presence of nitrogen and other nutrients as well as such contaminants as nitrate, arsenic, cadmium, and pesticides. In 13 of the 21 wells that were sampled, the maximum contaminant level of nitrate nitrogen was exceeded. Bartolino (1994) notes that nitrate concentrations in Seymour Aquifer groundwater exceeded maximum contaminant levels in the 1950s, well before the widespread use of ammonia fertilizer in the region in the 1960s. As a result, Bartolino suggests that nitrate problems were present in the region, perhaps due to natural sources, prior to human activities that could raise nitrate levels. Bartolino commented on the possible relationship between the clearing of nuisance brush species and groundwater impairment in the Seymour Aquifer watershed, stating the following:

> "The clearing of the mesquite and cultivation of the land surface augments oxygenation of the soil and mobilizes the nitrogen as nitrate. Additionally, infiltration of precipitation is enhanced due to the absence of phreatophytic mesquite and the advent of plowing and terracing. The increased infiltration carries the mobile nitrate to shallow ground water."

In 1992, Duffin & Beynon evaluated water resources in the Rolling Plains region, including the Seymour and Blaine aquifers, in a report developed for the Texas Water Development Board. They suggest that it is difficult to determine if nitrate in the region's groundwater is the result of natural conditions or man's activities.

> "Abnormally high nitrate concentrations occur in ground water over a wide geographic area, especially in Haskell and Knox Counties…[Previous studies] indicated the wide-spread distribution of nitrate in ground water may be the result of leaching of soil and humus in agricultural areas once covered by nitrogen mixing vegetation such as grasses and/or mesquite groves. Some of the nitrate in the ground water might be the result of excessive nitrogen fertilizer applied to the soil,…organic matter attributed to poorly functioning septic systems or infiltration of animal wastes from barnyards."

In 1978, R.W. Harden and Associates developed a report about water quality in the Seymour Aquifer. Some of the major findings of the report are shown here:

- At the time of the report, more than 3,200 pollution sources were identified in Seymour Aquifer watershed,
- The Seymour Aquifer was recognized as being vulnerable to pollution, due to the widespread occurrence of sandy soils and the shallow depth to the groundwater table at many locations,
- Most of the nitrate in the Seymour Aquifer was thought to result from leaching of natural soil nitrate due to cultivation,
- Farming began to be a major activity in the region in the 1890s. The first irrigation wells were developed in the 1930s. By 1978, more than 105,000 acres in the area supported irrigated agriculture, while another 160,000 acres were used for dryland agriculture,
- Existing man-made pollution was thought to stem from the management of oilfield brine and runoff from septic tanks and drainfields,
- Only about 2% of waters in the Seymour Aquifer were thought to be affected by pollution from oil and gas exploration, septic systems, and agricultural activities. In addition, the portions of the aquifer affected by contamination were localized and not spread throughout the system.

Contributions of University Research

The Texas Water Resources Institute is now working with the Texas Agricultural Experiment Station and the Texas State Soil and Water Conservation Board to carry out a research, monitoring, demonstration, and education project to determine if helping agricultural producers in Haskell, Knox, and Jones counties convert to more water-efficient drip irrigation systems may lessen nutrient inputs into the Seymour Aquifer. In a related effort, the United States Department of Agriculture Environmental Quality Incentives Program is offering financial assistance to promote natural resources conservation practices to protect water quality throughout the Seymour Aquifer region.

Researcher Cristine Morgan and graduate student Omar Harvey of the Texas A&M University Soil and Crop Sciences Department are now working with John Sij of the Texas Agricultural Experiment Station at Vernon to investigate the extent to which the widespread use of drip irrigation (instead of center pivot irrigation methods) may lessen deep percolation which could transport nutrients and pesticides to the aquifer. Major tasks of this research project include using field and laboratory studies to assess the extent to which converting from center pivot to drip irrigation may affect soil water and nitrate levels.

In a related effort, Sij and researchers Jeffrey Slosser and David Bordovsky of the Texas Agricultural Experiment Station at Vernon (2005) are currently developing a subsurface drip irrigation system at the Chillicothe Research Station. This drip system will be used to educate producers about the potential of the widespread use of efficient irrigation systems to protect water quality. The project hopes to prove the extent to which the use of drip irrigation may mitigate nitrate movement within the soil profile while conserving scarce water supplies.

Bridget Scanlon, a researcher in the Bureau of Economic Geology at the University of Texas at Austin, has led several recent studies that provide new insights into the water quality of the Seymour Aquifer.

Scanlon is now leading a study for the Texas Commission on Environmental Quality to assess whether there are high nitrate concentrations in soils beneath rangeland settings in the Seymour Aquifer that may have contributed to original nitrate contamination. In addition, profiles will be drilled in different agricultural settings to assess nitrate loadings from various agricultural practices. Deep boreholes will be drilled in areas where different irrigation systems are now being utilized. Sites of irrigation systems where deep boreholes will be drilled are now being identified in research by Cristine Morgan of Texas A&M University. Nitrogen isotope studies will be conducted for source identification, and additional age dating may be conducted to evaluate aquifer residence times.

In 2003, Scanlon led an investigation to determine if linkages could be established between groundwater recharge trends and aquifer vulnerability. Recharge was estimated using limited field studies in irrigated and dryland areas near sand dunes that overlie the Seymour Aquifer. One-dimensional flow modeling was utilized to develop recharge data for other major groundwater systems. Results suggest that land use (farming or range management) and soil texture affect recharge rates and water quality. The results also show that less recharge occurs when the dominant land use is rangeland rather than cropland. This suggests that maintaining rangeland may reduce the likelihood of contamination of shallow groundwaters.

In another 2003 research project, Scanlon led an investigation to evaluate nitrate contamination in major porous media aquifers throughout Texas, including the Seymour Aquifer. A number of attributes were used as inputs to determine sources of nitrogen loadings, including atmospheric deposition, precipitation, fertilizer use, the presence of sewage and septic systems, land uses, and irrigation. Aquifer susceptibility to contamination was estimated from topography, runoff and drainage, the presence of organic matter, and the clay content of soils. Results suggest that nitrate concentrations and the risk of groundwater contamination are greater in the Seymour Aquifer than in other aquifer formations throughout the state. Groundwater in the Seymour Aquifer was dated using tritium-helium and resulted in ages ranging from 3 to 23 years. Scanlon says this data suggests that elevated nitrate levels are more likely related to recent agricultural practices than the original conversion of rangeland to agriculture. The report suggests that more salts may build up in the soil root zone as irrigation applications are reduced. When very efficient irrigation systems are used, Scanlon suggests that in the root zone nutrients may increase (depending on plant uptake) and that other salts may increase by a factor of 20.

At the University of North Texas, researchers in the Geography Department utilized historical data, computer models, and geographic information systems (GIS) to assess the potential for nitrate contamination in the Seymour Aquifer (Hudak, 2000; Hillin & Hudak, 2003). In 2000, research Paul Hudak compiled, mapped, and evaluated regional patterns of the occurrence of nitrate in groundwater systems throughout Texas. Results show that nine counties in the Seymour and High Plains groundwater systems exhibited median nitrate concentrations above the maximum contaminant level of 44 mg/l. The analyses showed that the median nitrate level in the Seymour was the highest in the state at nearly 60 mg/l. Hudak suggests that the Seymour Aquifer is especially vulnerable to contamination since this groundwater system is shallow and unconfined. In a subsequent study (Hillin & Hudak, 2003), Hudak used the Texas Water Development Board groundwater database to gather information on water quality and well depths and locations. This information was correlated with land use and GIS data. Results suggest that nitrate concentrations were generally higher in areas beneath cropland than sites with other land uses. Hudak inferred that cultivation is a likely source of nitrate. The data also suggest that agricultural deep percolation and the disposal of oilfield brines may be responsible for higher than normal levels of chloride and bromide.

Thomas Boutton, a researcher in the Texas A&M University Rangeland Ecology and Management Department, has led recent studies throughout Texas to assess nutrient dynamics associated with rangeland vegetation (McCulley et al., 2004). Boutton suggests that few studies have been carried out to focus on the extent to which brush clearing has the potential to boost nitrate levels. Boutton suggests it is essential that such studies be done to definitively answer whether brush management may be a source of increased nitrate levels in some groundwater systems.

In 1995, Thomas Evans and David Maidment of the Center for Research in Water Resources at the University of Texas at Austin used geographic information system (GIS) tools to assess the vulnerability of the Seymour Aquifer and other major Texas groundwater systems to nitrate contamination. Analyses of modeling results suggest that the Seymour Aquifer is much more likely to suffer from nitrate contamination than the other aquifers studied (i.e., the Carrizo-Wilcox, the Hueco-Mesilla Bolson, the Ogallala, and the Edwards).

In 1994, B.L. Harris of the Texas Agricultural Extension Service and the Soil and Crop Sciences Department led the Seymour Aquifer Hydrologic Unit Project. The purpose of the project was to develop monitoring and education programs to protect water quality and prevent aquifer contamination. The project developed recommendations about best management practices agricultural producers and homeowners could implement to protect water quality in the aquifer.

In a related project, Texas A&M University Agricultural Economics Department researchers Monzoor Chowdhury, Ron Lacewell, Bruce McCarl and Teo Ozuna

(Chowdhury et al., 1994) evaluated possible linkages between farming practices, agricultural profits, and groundwater quality in the Seymour Aquifer. The study explored whether such innovative economic strategies as a “nitrogen tax” or a “nitrogen subsidy” could offer the promise of encouraging farmers to adopt practices that would limit nitrogen inputs, thus protecting groundwater quality. Lacewell et al. (1993) described how the erosion productivity impact calculator (EPIC) model could be used to simulate how farming practices may affect nitrate leaching to soils and aquifers. Later, Chowdhury and Lacewell (1996) described the use of a biophysical simulation model to analyze the relationships between agricultural production practices and nitrate levels in the Seymour Aquifer and other groundwater systems.

In 1986, Berend Richter and Charles Kreitler of the Bureau of Economic Geology investigated the geochemistry of groundwater in the Texas Rolling Plains, including the Seymour and Blaine aquifers. The study provides insights into the spatial extent and flow of saline waters throughout the region.

In 1983, Charles Kreitler of the Bureau of Economic Geology at the University of Texas at Austin developed a technique to utilize nitrogen isotope analyses to differentiate between natural and anthropogenic sources of nitrate and between different nutrient sources. Results suggest that nitrate levels in the Edwards Aquifer can be attributed to natural sources (Kreitler & Browning, 1983). However, subsequent studies suggest that it may be difficult to differentiate between natural and man-made nitrate inputs using isotope analyses (Roadcap, Hackley & Hwang, 2002; Townsend, 2001).

Conclusions

Research results show that the Seymour Aquifer is vulnerable to nitrate contamination and high levels of nitrate are present at some sites within the aquifer. As a result, groundwaters in the Seymour Aquifer are sometimes of too poor quality to be used for drinking water.

The source of high nitrate levels in the Seymour Aquifer cannot be determined at this time. Some studies suggest that natural conditions may play a significant role (Texas Groundwater Protection Committee, 2005; Duffin & Beynon, 1992; Bartolino, 1984;

Kreitler & Browning, 1983). Other research (Scanlon, 2003; Hillin & Hudak, 2003; Hudak, 2000; Harden and Associates, 1978) suggests that such human activities as the cultivation of prairie soils and the use of agricultural chemicals contribute to nitrate loadings. Still other studies (Region B Water Plan, 2006; Duffin & Beynon, 1992) suggest that failing septic systems may be elevating nitrate concentrations at some locations in the Seymour Aquifer.

There is some disagreement about whether the use of water-efficient irrigation systems may contribute to or, on the other hand, help resolve salinity problems. Egg (2007) suggests that drip irrigation may be a viable strategy to make it possible to continue to grow crops in soils that have higher concentrations of salts and that the continuous application of irrigation through drip irrigation can lessen the alternating wet and dry cycles associated with surface irrigation that contribute to salt loadings. Egg also contends that inefficient irrigation systems are more likely to concentrate nutrients and salts below the root zone. In contrast, Scanlon (2003) suggests that nutrient and salinity concentrations in soils and groundwater may significantly increase in the soil root zone as irrigation applications are reduced. More research is needed to better understand these issues.

Research Needs

- Determine the extent to which natural conditions may degrade water quality in the Seymour Aquifer by contributing to nitrate contamination.
- Determine the extent to which agricultural activities may be influencing nitrate levels in groundwater.
- Determine the extent to which drip irrigation can facilitate crop production in soils with elevated salt concentrations.
- Examine the extent to which the use of water-efficient irrigation systems may increase or alleviate salinity problems in soils and groundwater in the region.
- Identify and evaluate the extent to which the use of best management practices can be effective in reducing nitrate loadings, thus protecting groundwater quality.

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