Ground Water Monitoring at Livestock Waste Control Facilities in Nebraska
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In May 2002, the University of Nebraska - Lincoln (UNL) completed a study of ground water monitoring at 12 livestock waste control facilities (LWCFs) across the state (NDEQ, 2002; Mariappan, 2001). This study was done to try to get an early understanding of the impact livestock waste control facilities were having on ground water quality. This study showed a negative impact to ground water quality at two of the twelve sites studied. Isotope analysis of ground water samples confirmed animal waste as the source at the two operations with ground water quality impacts.

The Nebraska Department of Environmental Quality (NDEQ) has been reviewing livestock construction and expansion permit applications for ground water vulnerability and ground water monitoring requirements since October 1997. When the UNL study was undertaken, very few ground water monitoring results had been received or scrutinized by NDEQ staff. This short report follows up on the UNL study with a summary of some of the results from ground water monitoring at permitted facilities. The facilities discussed here show evidence of negatively impacted ground water quality.

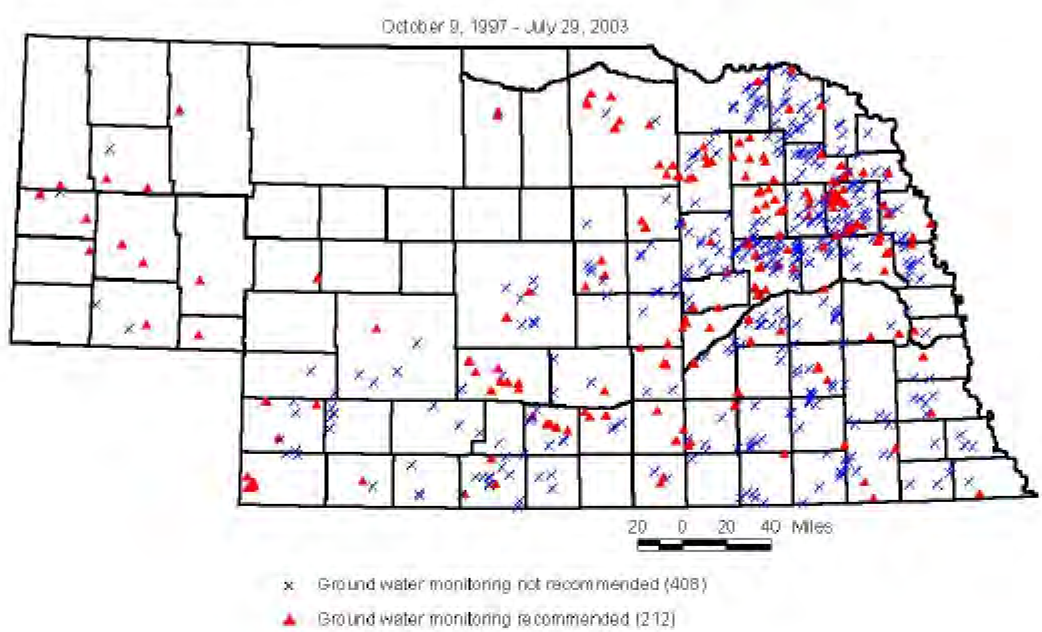

Figure 1. LWCF reviewed for ground water vulnerability, October 1997 through July 2003.

Ground Water Monitoring Requirements

NDEQ's Ground Water Unit has reviewed over 630 new and expansion livestock construction permit applications for ground water monitoring concerns since October 1997. The bar graph in Figure 2 indicates approximately 34% of reviewed livestock waste control facilities have been recommended for ground water monitoring. However, due to construction delays, funding issues, or other reasons, livestock operations have only submitted 94 ground water monitoring plans that have been approved. When monitoring is required, an approved monitoring plan is necessary for a state operating permit.

The vulnerability of ground water to contamination is influenced by many site-specific factors. The decision on whether or not to recommend ground water monitoring at a LWCF is based on following:

- Depth to ground water; generally, less than 50 feet is considered vulnerable.
- Type of unsaturated sediments between the land surface and the water table; generally, sandy sediments which allow faster movement of contaminants are considered more vulnerable than clay-rich sediments. Clay rich sediments not only slow down contaminants, but also have more ion-receptor sites, which "tie-up" some contaminants before leaching to ground water. Soils characterized as silty loams can easily transmit contaminants or slow them down, depending on the particular environment.

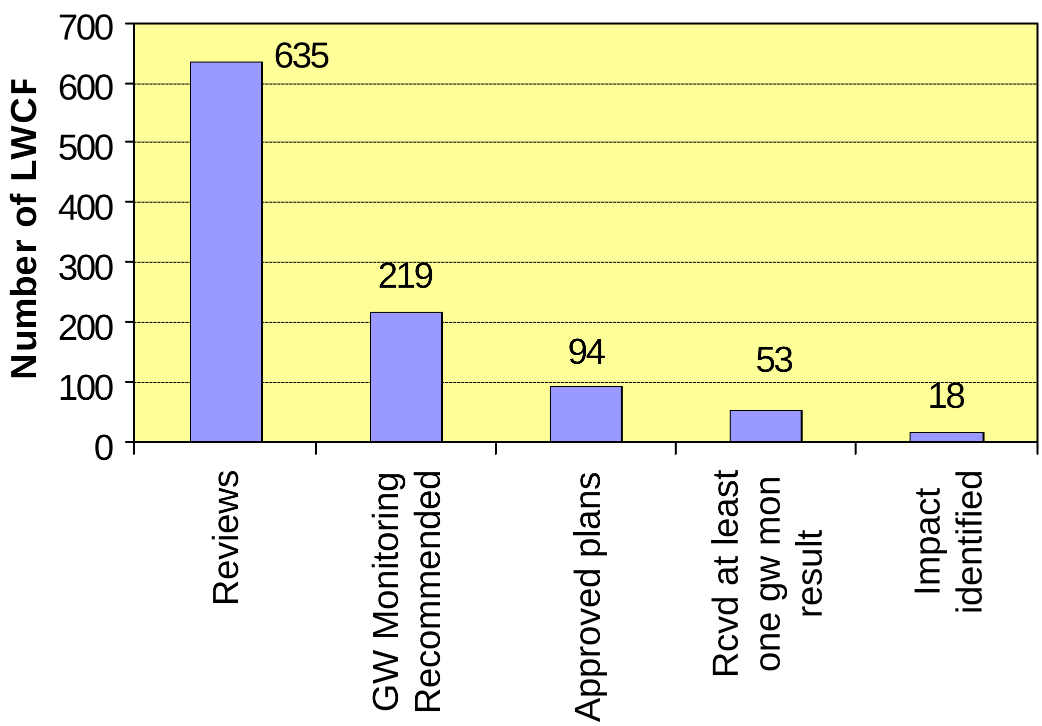

Figure 2. Summary of reviews for ground water monitoring recommendations, plans received, and probable impact to ground water (10-97 through 12-03). "GW" = Ground Water, "Rcvd" = Received, "mon" = monitoring.

- Use of ground water for drinking water in the area; a LWCF in a public water supply's Wellhead Protection Area is likely to have ground water monitoring requirements.
- Other beneficial uses of ground water in the area; for example, if ground water flows directly to a Coldwater Class A stream, a ground water monitoring requirement is more likely.

At least three monitoring wells are necessary at a LWCF where ground water monitoring is required (NDEQ, 2001a; NDEQ, 2003). Based on local ground water flow direction, one well must be located up gradient of the LWCF and at least two wells must be down gradient, very near the LWCF (see Figure 3, below). The landowner who owns the facility or a certified/licensed person (NHHS, 2002) samples the wells at least twice a year, usually in the spring and fall. Water levels in wells are measured prior to sampling. Water samples are analyzed at a laboratory for nitrate as nitrogen, ammonia as nitrogen, and chloride, at a minimum. A duplicate sample is collected from one monitoring well (minimum) and analyzed for quality assurance, along with a "field blank". Sample results and water level measurements are submitted to NDEQ within 45 days of the sampling event.

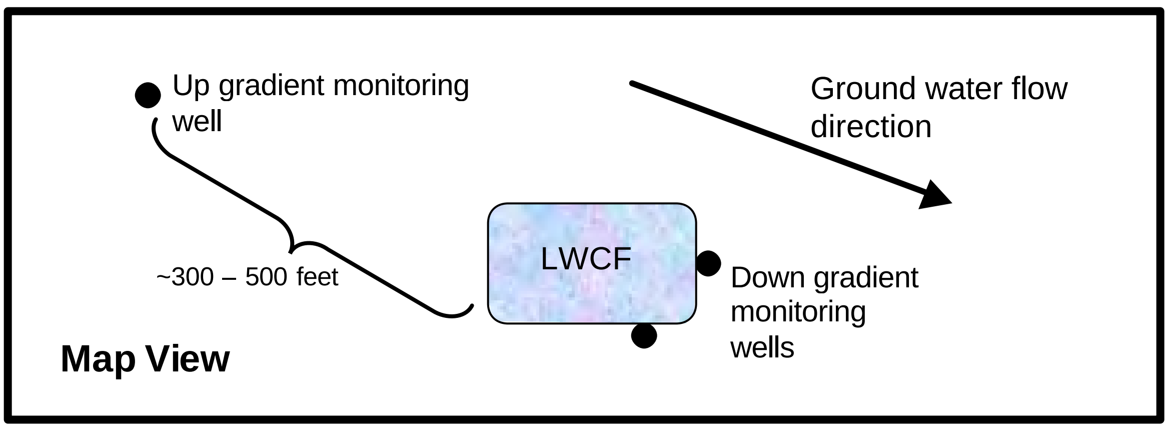

Figure 3. Generic layout of ground water monitoring wells at LWCF (NDEQ, 2003).

Chemical Constituents in Livestock Waste

Waste from swine and cattle make up the majority of the uses of LWCFs in Nebraska. Many livestock operation management procedures have significant impacts on the concentrations of ammonia, nitrate, chloride, and other waste constituents in the LWCF. These impacts include the number of times per year the LWCF is pumped down, how feedlots or animal-housing are cleaned out, the type of feed, and whether one or multiple stage lagoons are used, etc.

Ammonia as nitrogen (NH_4-N) concentrations ranged from below 1 mg/l (in an "overflow" or second stage lagoon) to over 2000 mg/l in the 12 LWCFs (not the monitoring wells) studied by UNL (Mariappan, 2001). Nitrate as nitrogen (NO_3-N) was always below the lab detection limit of 0.1 mg/l, and chloride (Cl) ranged from around 50 to over 1500 mg/l.

A study done by the Minnesota Pollution Control Agency (2001) researched chemical constituent concentrations for both liquid and solid manure (Table 1).

Chemical	Solid Manure Cattle mg/kg (dry weight basis)	Solid Manure Dairy Cattle mg/kg (dry weight basis)	Solid Manure Swine mg/kg (dry weight basis)	Liquid Manure Dairy Cattle mg/l	Liquid Manure Swine mg/l
Ammonium	3488	13346 – 14586	2628 – 4550	165	679 – 1000
Nitrate	496	—	10 – 28	1.5	1 – 2
Chloride	8447	9061	4440	215	300
Total nitrogen	15800	40037 – 41436	10600	420	778 – 1500

Table 1. Median concentrations of chemicals in solid and liquid manure (MCPA, 2001).

It is important to note that Nebraska ground water does not naturally have ammonia present, nitrate background concentrations (not influenced by man-made causes) are usually considered at or below 2 mg/l (personal communication, Spalding 1990), and natural chloride levels range from 10 to 100 mg/l (Engberg and Spalding, 1978). Compare these levels and the concentrations in Table 1 to the federal drinking water standards and Title 118 - Ground Water Quality Standards and Use Classification (NDEQ, 2001b).

Nitrate – N	Ammonia – N	Chloride
10 mg/l	No drinking water standard	250 mg/l

Table 2. Federal Drinking Water Standards and Title 118 Ground Water Standards

Livestock waste control facilities are often earthen-lined, anaerobic lagoons (note: older LWCFs were not built according to "modern" regulations and may not have a constructed liner). Anaerobic lagoons have little or no dissolved oxygen and act as biological reactors. The nitrogen in solid and liquid manure is partially mineralized or "reduced" through biological activity in the oxygen poor environment. Nitrate is highly unstable in anaerobic conditions and quickly converts to nitrous oxides and nitrogen gas. This is the reason no nitrate was detected in the LWCFs in the UNL study.

Impact of LWCF on the Environment

Many Nebraskans have expressed concerns about the impact of waste control facilities (holding ponds, lagoons, debris basins, etc.) on the environment. Specifically, ground water quality impact is often mentioned first in the public's list of anxieties. This is a valid concern, considering that as much as 85% of the state's population relies fully or partially on ground water for drinking water purposes.

After initial construction of a new LWCF, it is surmised that the solids from the waste entering the facility act as an extra sealant to prevent contaminants from entering the sediments and ground water below. Where the liner is compromised due to inadequate construction, roots or burrows, wind or rain induced erosion, desiccation or freeze-thaw cracks, or other factors, excess seepage can and does occur. Quade, et al, (1996) found that seepage from Iowa LWCFs was indicated in water quality results from monitoring wells (Table 3).

The Iowa study did not find increases in ammonia-N concentrations but a Minnesota Pollution Control Agency study (2001) of ground water quality near liquid manure storage systems discovered ammonia levels above 200 mg/l more than 300 feet down gradient from a LWCF (Table 3).

Study	Indication of contamination
Quade (1996)	Sharp decline in nitrate-N concentrations in down gradient wells compared to up gradient wells
Quade (1996)	Slow decline in sulfate concentrations, due to sulfate's instability in anaerobic conditions, much like nitrate
Quade (1996)	Increase in chloride concentrations in down gradient wells compared to up gradient wells
MCPA (2001)	Increase in ammonia-N concentrations in down gradient wells compared to up gradient wells

Table 3. Indicators of impact to ground water quality from LWCFs, Iowa (Quade, et al, 1996) and Minnesota (MCPA, 2001).

Ammonia is not a regulated contaminant in either drinking water or ground water, but it can have negative or even deadly impacts on fish and aquatic plants in surface water. Additionally, the biggest concern regarding ammonia in ground water is its down gradient transformation to nitrate-N. When ammonia begins traveling in natural ground water flow away from the LWCF, it begins to mix with more oxygen rich water with an increase in biological activity. It is then converted on a nearly one-to-one ratio to nitrate.

Ammonia (NH_3) readily picks up a hydrogen ion (H^+) to become ammonium (NH_4^+), although the two (ammonia and ammonium) are often used interchangeably in the literature. The process shown in the formula below moves both ways, depending on the pH of the soil or water present.

$NH_3 + H_2O$ « $NH_4^+ + OH^-$

Nitrification occurs when ammonium (NH_4^+) is converted to nitrate (NO_3^-) by bacteria in oxygen rich soils or ground water.

$2NH_4^+ + 3O_2$ ® $2NO_3^- + 8H^+$

This may occur very close to the LWCF (shown by high nitrate levels in down gradient monitoring wells) or several hundred feet further down gradient. Nitrate in drinking water is a health concern to babies and pregnant women, and has even been shown to be harmful to very young farm animals.

Site Specific Data from Nebraska LWCFs

Ground water monitoring results for at least 18 LWCFs in Nebraska have one or more of the four characteristics detailed above indicating seepage. Ground Water Unit staff examine a minimum of three sampling events (usually over 18 months) that have one or more of the noted characteristics (Table 3) before determining whether or not a negative impact to ground water may be coming from the LWCF. The map in Figure 4 shows the approximate locations of these sites. All but two are feeder cattle operations; one of the others is a dairy operation and the other is swine. Depth to water at all sites was generally shallow, with most being 10 to 30 feet below ground surface.

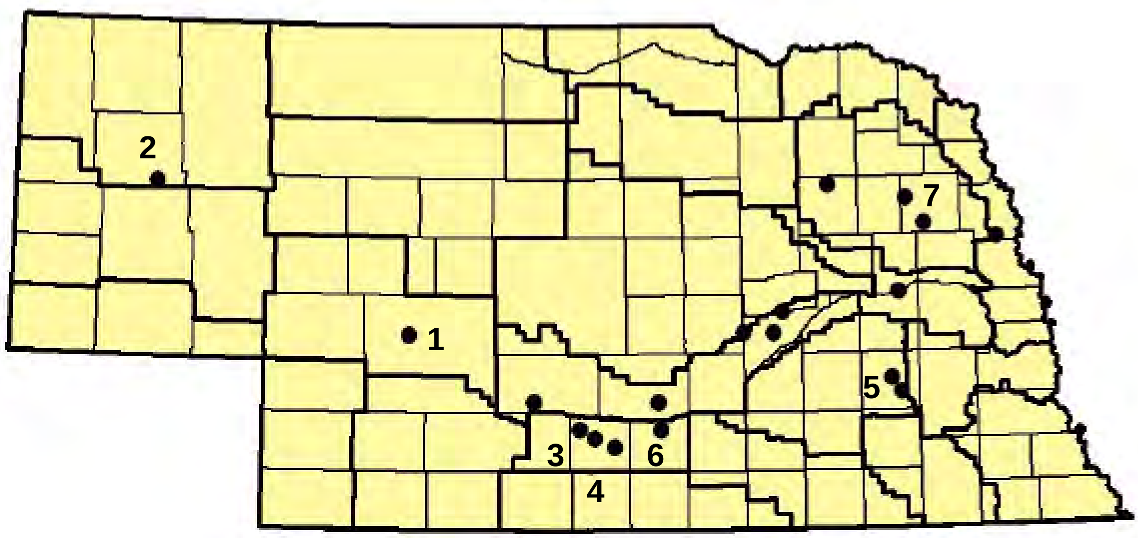

Figure 4. Locations of LWCF with possible impact to ground water quality, as of December 2003. Numbers refer to ground water monitoring results and graphs that follow. County and Natural Resources District boundaries shown.

Several examples of monitoring results were randomly chosen from the 18 identified LWCFs with possible impact to ground water. The following graphs and tables summarize the facts from the LWCFs. Notice that scales on the graphs vary according to the data presented, and there is variation in ground water monitoring results. This type of variation is typical for ground water quality; all aquifers are dynamic, constantly changing systems, dependant on factors such as rainfall, well pumping and sources of contamination near by, and geologic characteristics of the aquifer.

Site 1.
Lincoln County, ~ 12,000 feeder cattle. Operation established in 1973. Approximately 10 feet, depth to ground water. Sand and gravel sediments between land surface and ground water table. Well 1 is up gradient of the LWCF.

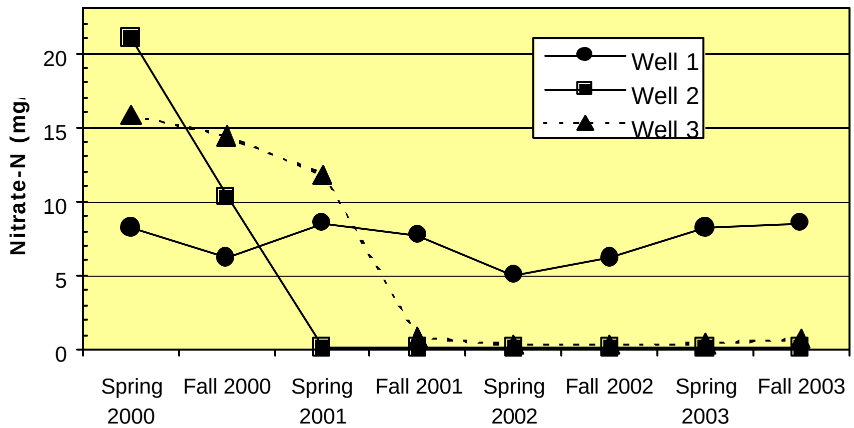

Figure 5, to the left. Nitrate-N results from 3 monitoring wells, Site 1. Well 1 is up gradient.

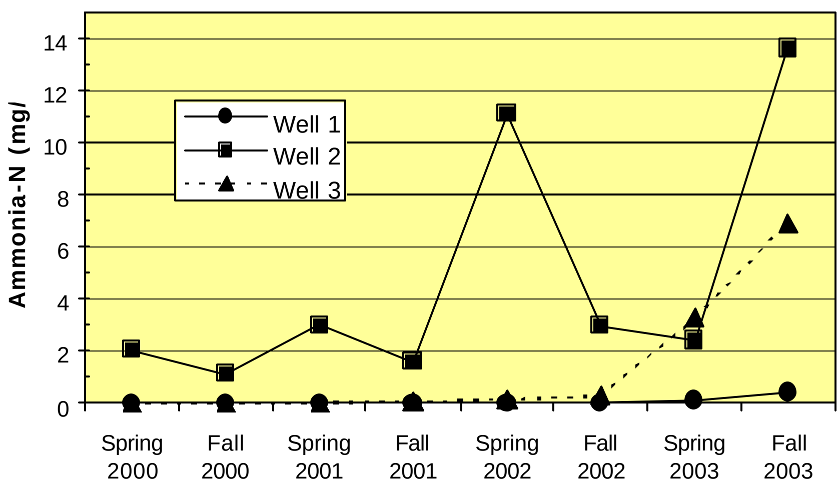

Figure 6, to the left. Ammonia-N results from 3 monitoring wells, Site 1. Well 1 is up gradient.

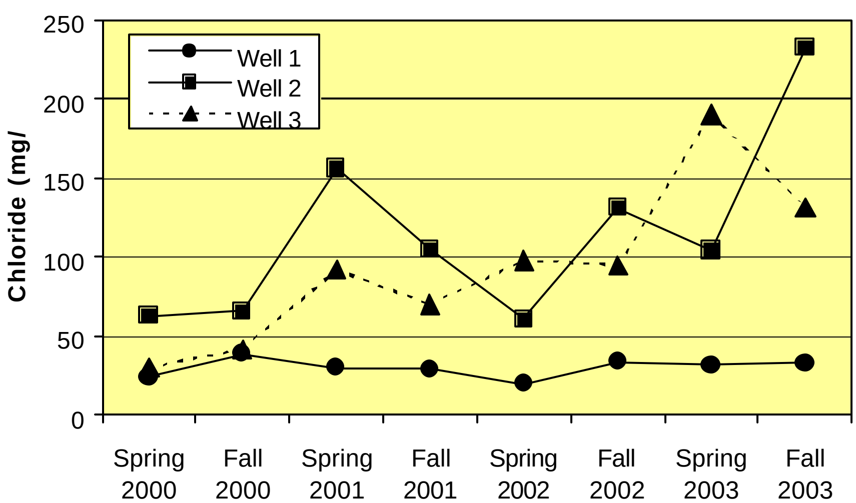

Figure 7, to the left. Chloride results from 3 monitoring wells, Site 1. Well 1 is up gradient.

Site 2.
Box Butte County, ~ 19,000 feeder cattle. Operation established in 1971. Approximately 40 feet, depth to ground water. Fine sand sediments between land surface and ground water table. Well 1 is up gradient of the LWCF.

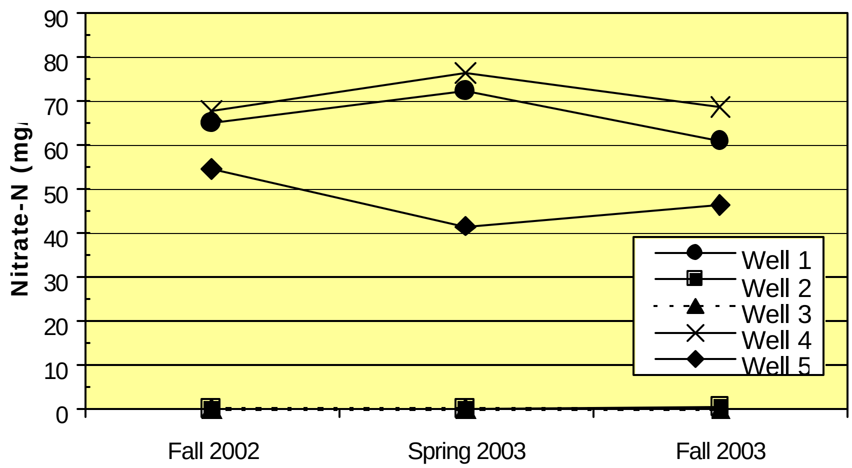

Figure 8, to the left. Nitrate-N results from 5 monitoring wells, Site 2. Well 1 is up gradient.

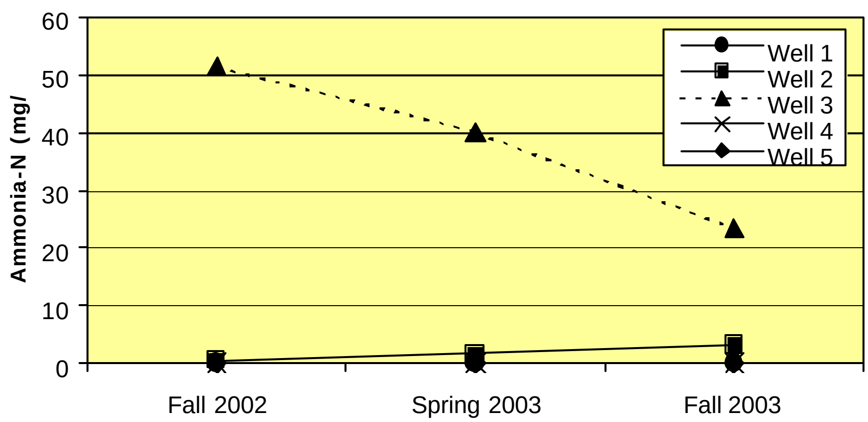

Figure 9, to the left. Ammonia-N results from 5 monitoring wells, Site 2. Well 1 is up gradient.

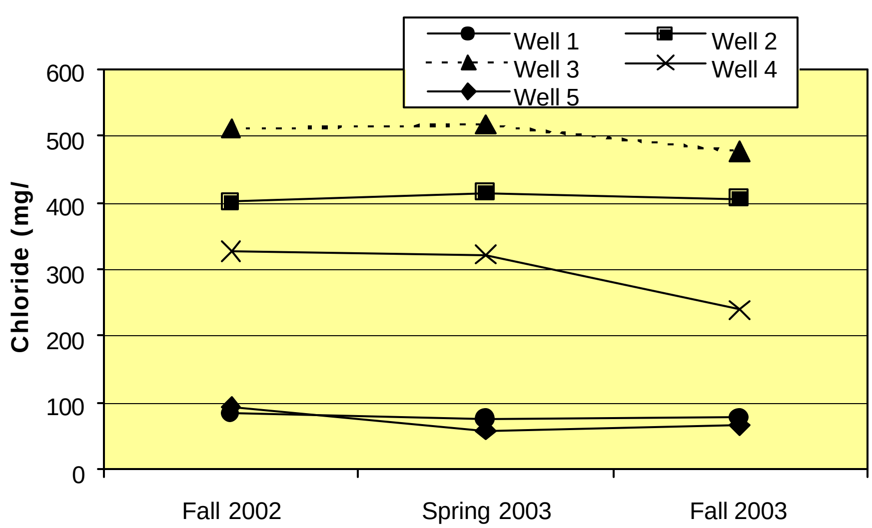

Figure 10, to the left. Chloride results from 5 monitoring wells, Site 2. Well 1 is up gradient.

Site 3.
Phelps County, ~ 15,000 feeder cattle. Operation established in 1999. Approximately 25 feet, depth to ground water. Sandy silt sediments between land surface and ground water table. Well 1 is up gradient of the LWCF.

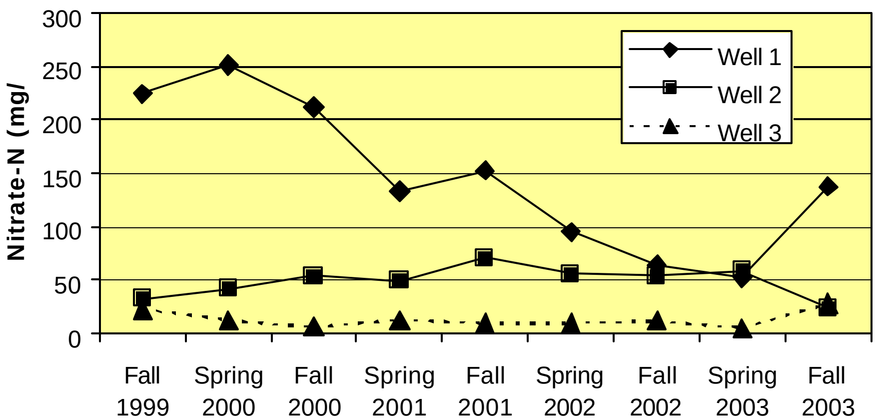

Figure 11, to the left. Nitrate-N results from 3 monitoring wells, Site 3. Well 1 is up gradient.

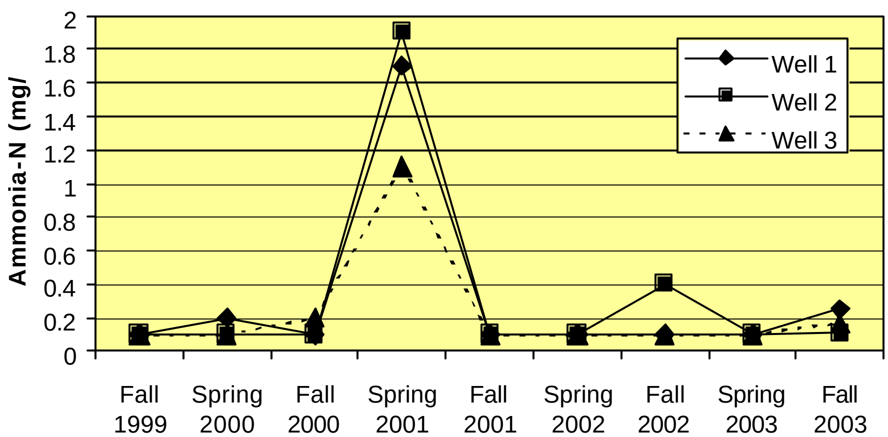

Figure 12, to the left. Ammonia-N results from 3 monitoring wells, Site 3. Well 1 is up gradient.

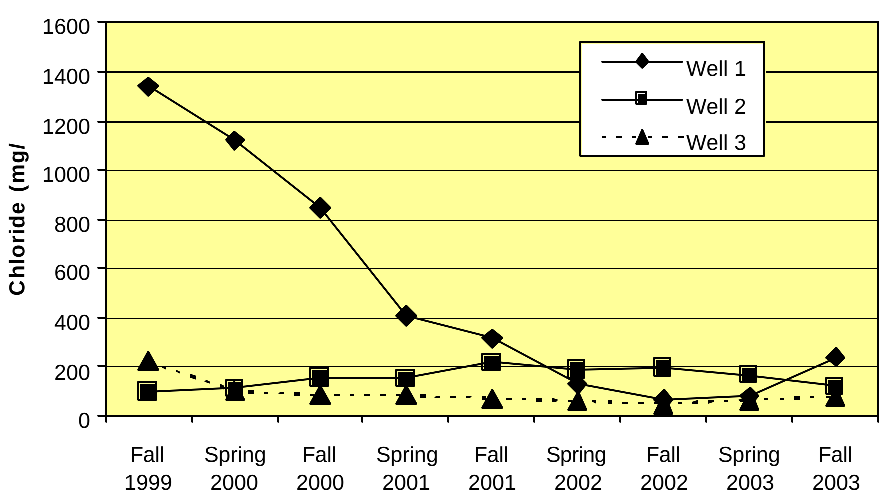

Figure 13, to the left. Chloride results from 3 monitoring wells, Site 3. Well 1 is up gradient.

Site 4.
Phelps County, ~ 13,000 feeder cattle. Operation established in 1988. Approximately 15 feet, depth to ground water. Sand and clay sediments between land surface and ground water table. Wells 1 and 6 are up gradient of the LWCF.

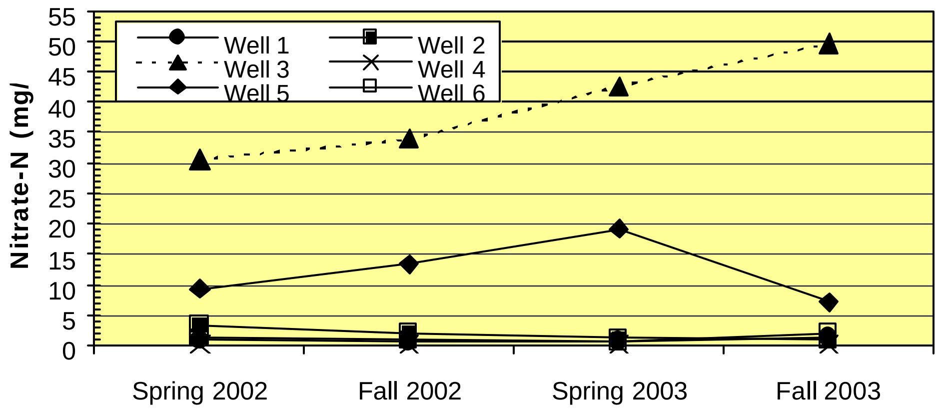

Figure 14, to the left. Nitrate-N results from 6 monitoring wells, Site 4. Wells 1 and 6 are up gradient.

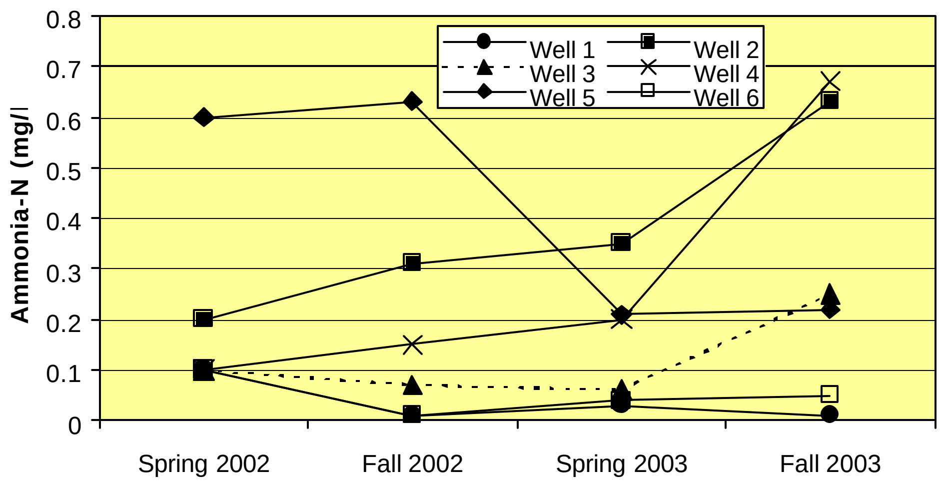

Figure 15, to the left. Ammonia-N results from 6 monitoring wells, Site 4. Wells 1 and 6 are up gradient.

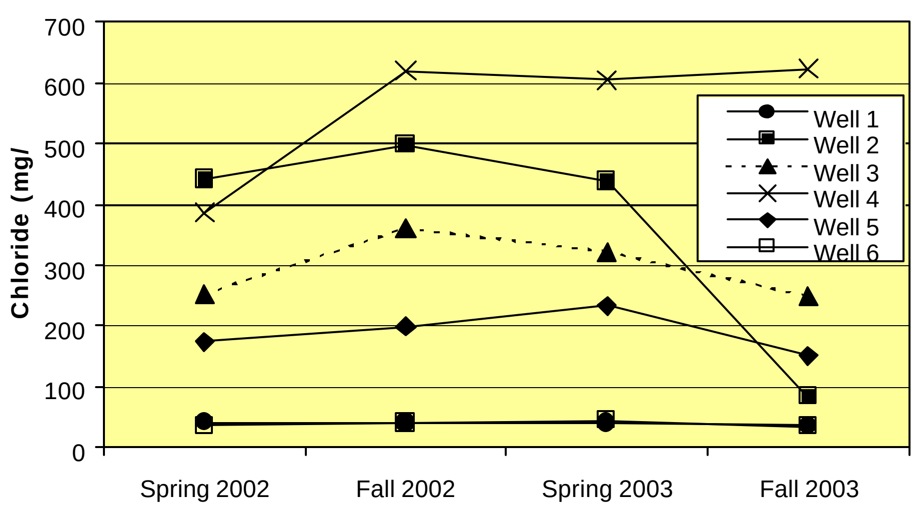

Figure 16, to the left. Chloride results from 6 monitoring wells, Site 4. Wells 1 and 6 are up gradient.

Site 5.
Seward County, ~ 15,000 feeder cattle. Operation established in 1972. Approximately 10 feet, depth to ground water. Sand, silt, and clay sediments between land surface and ground water table. Well 1 is up gradient of the LWCF.

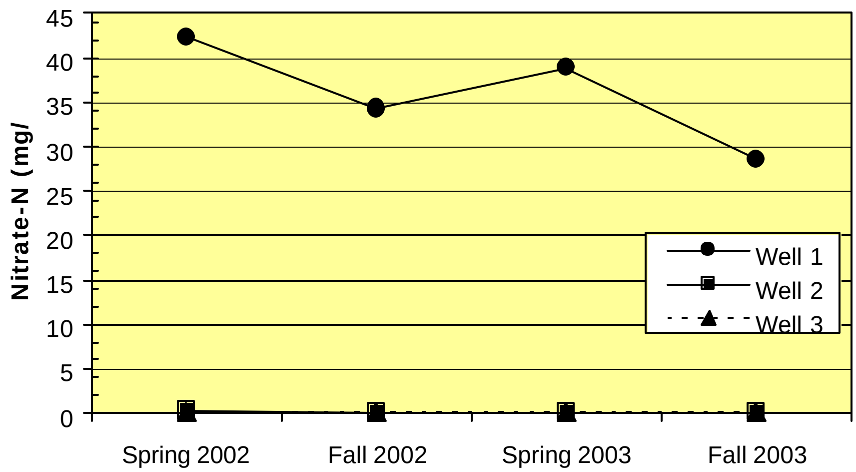

Figure 17, to the left. Nitrate-N results from 3 monitoring wells, Site 5. Well 1 is up gradient.

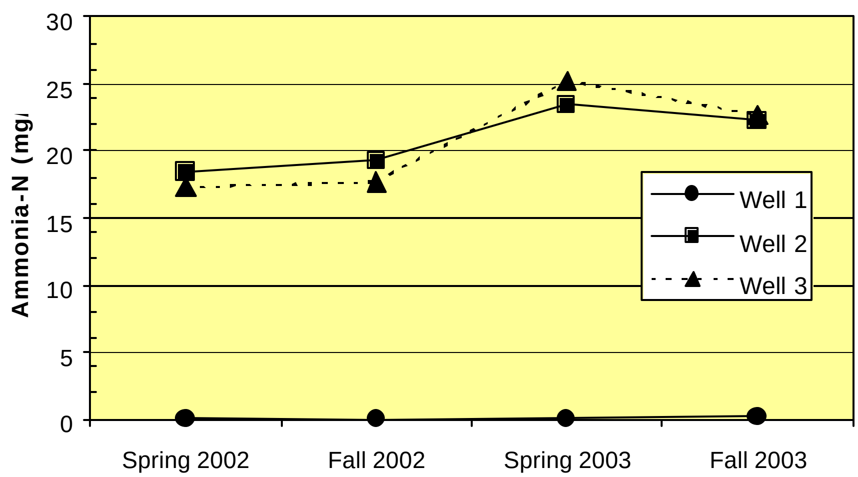

Figure 18, to the left. Ammonia-N results from 3 monitoring wells, Site 5. Well 1 is up gradient.

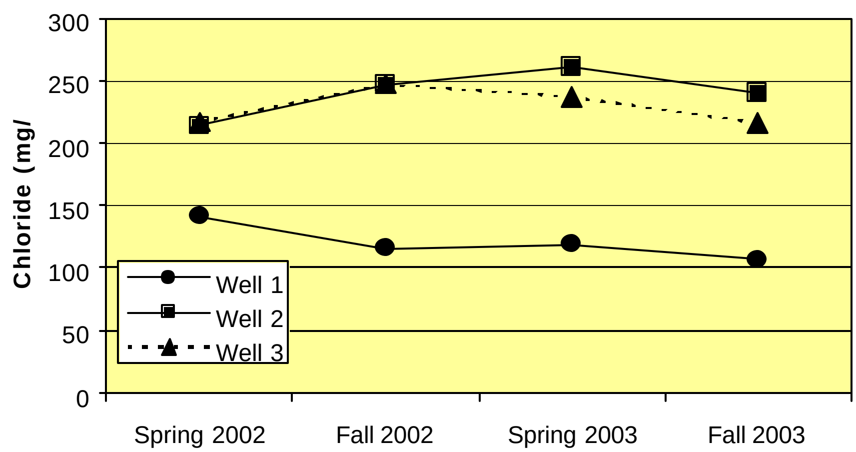

Figure 19, to the left. Chloride results from 3 monitoring wells, Site 5. Well 1 is up gradient.

Site 6.
Kearney County, ~ 35,000 feeder cattle. Operation established in 1972. Approximately 19 feet, depth to ground water. Sandy sediments between land surface and ground water table. Well 1 is up gradient of the LWCF.

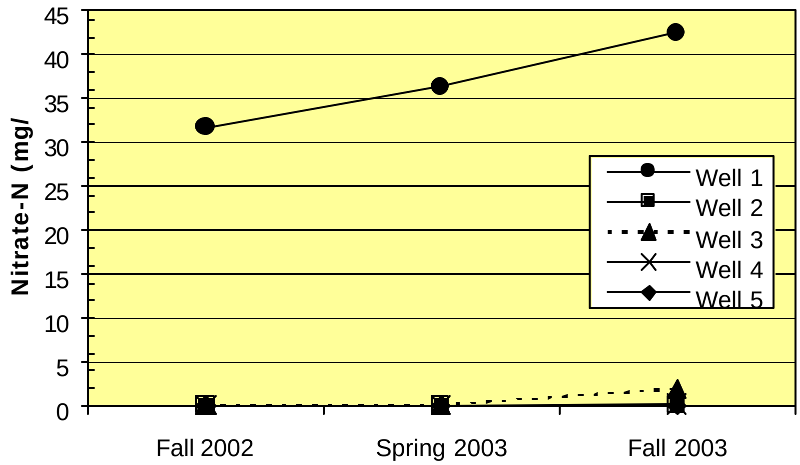

Figure 20, to the left. Nitrate-N results from 5 monitoring wells, Site 6. Well 1 is up gradient.

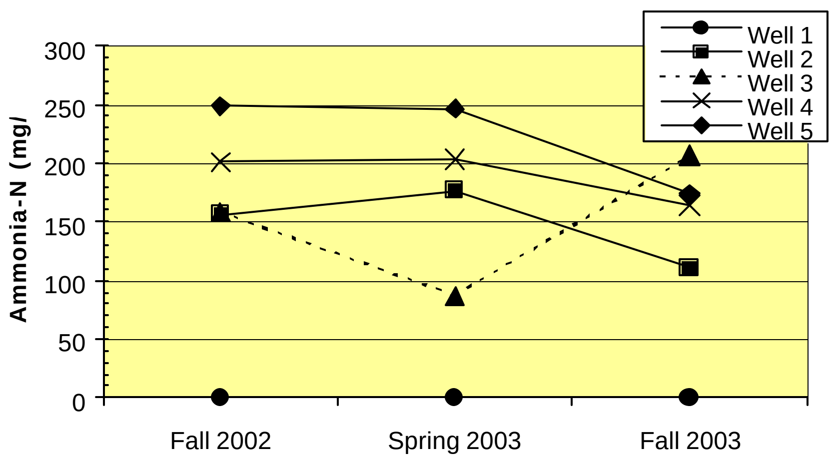

Figure 21, to the left. Ammonia-N results from 5 monitoring wells, Site 6. Well 1 is up gradient.

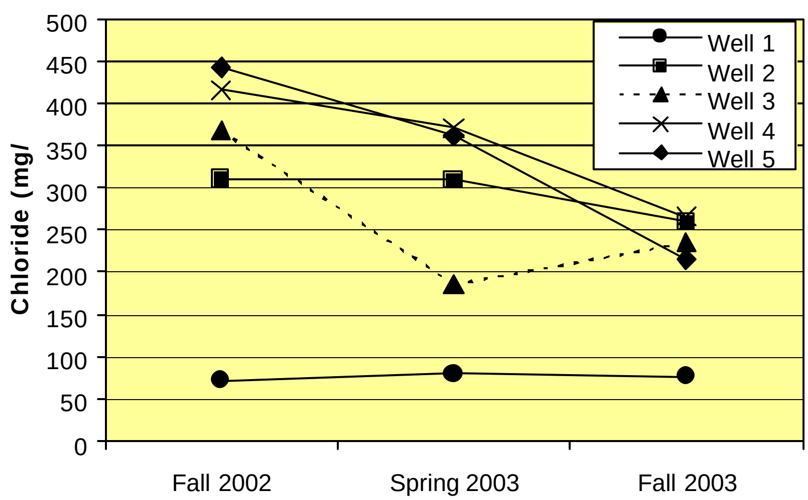

Figure 22, to the left. Chloride results from 5 monitoring wells, Site 6. Well 1 is up gradient.

Site 7.
Cuming County, ~ 2000 feeder cattle. Operation established in 1973. Approximately 40 feet, depth to ground water. Silt and clay sediments between land surface and ground water table. Well 1 is up gradient of the LWCF.

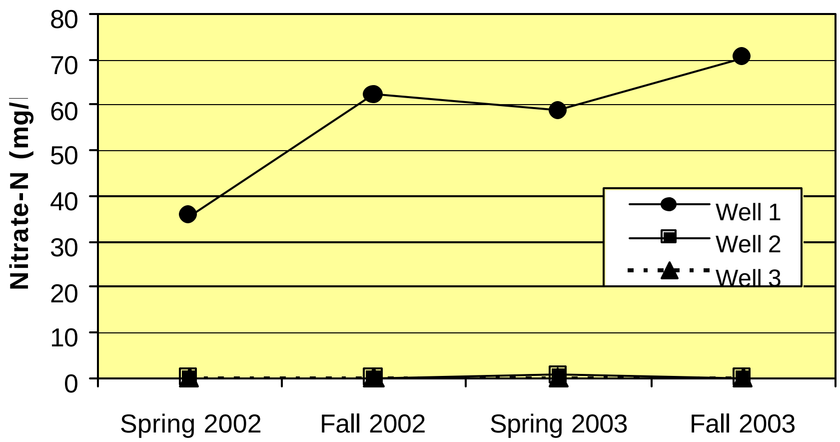

Figure 23, to the left. Nitrate-N results from 3 monitoring wells, Site 7. Well 1 is up gradient.

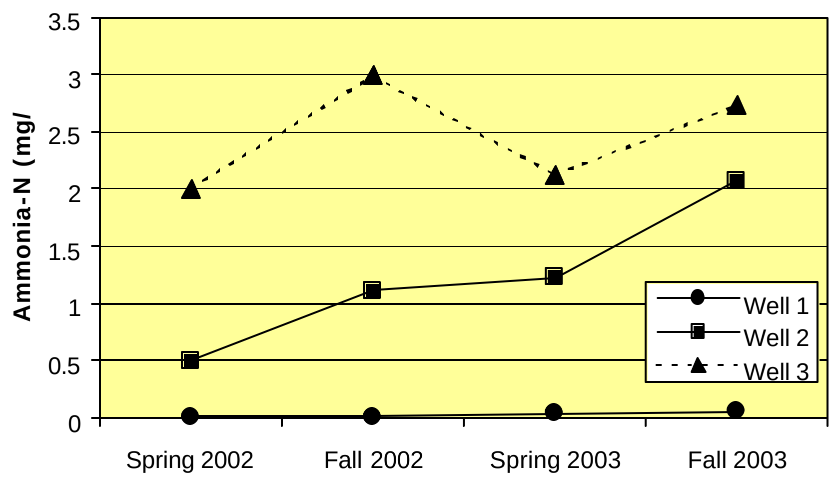

Figure 24, to the left. Ammonia-N results from 3 monitoring wells, Site 7. Well 1 is up gradient.

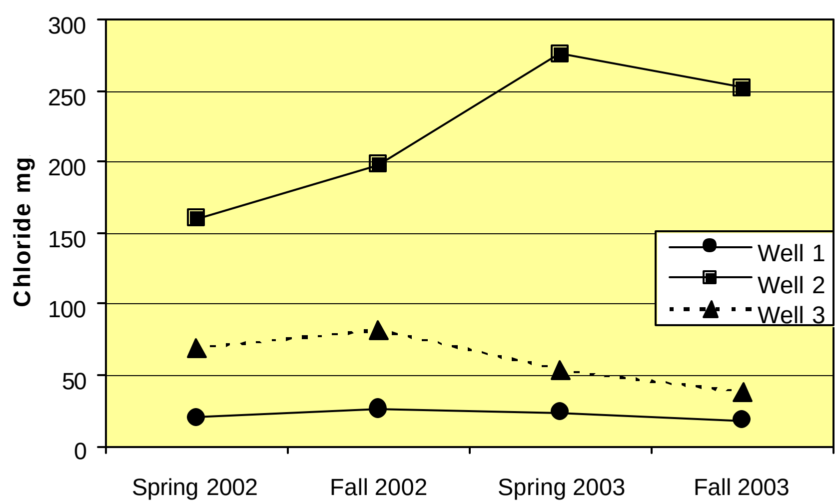

Figure 25, to the left. Chloride results from 3 monitoring wells, Site 7. Well 1 is up gradient.

Next Steps

The NDEQ has identified at least 18 LWCF that appear to be negatively impacting ground water quality. Before taking further action, the NDEQ will attempt to find out more details about the livestock operation, including (but not limited to):

- ✓ Any LWCF construction details known by the facility owner or operator,
- ✓ Name of LWCF construction contractor,
- ✓ Date of construction of LWCF, and
- ✓ Management of the operation and LWCF, such as pumping schedule, wash down schedule, pen scrapping, pipe repair, spill history, etc.

The livestock operation will be asked for the above information and be informed of the Title 118 Remedial Action Classification (Appendix A, Title 118) for this LWCF.

After the site-specific details of the operation (monitoring well construction, ground water flow direction, LWCF construction, etc.) are compiled, the operation may be required to do one or more of the following actions (but not limited to):

- Provide alternate drinking water source, in the event a down gradient domestic or public water supply has been impacted,
- Add more monitoring wells and/or more sampling events,
- Inspect and/or drain LWCF to find cracks or leaks,
- Reconstruct LWCF with impermeable liner or thicker clay/bentonite liner,
- Propose a new location for LWCF, and/or
- Complete a Title 118 Step 7 (plume extent identification) and Step 8 (remediation).

NDEQ will attempt to complete all procedures in a cooperative manner with each livestock operation; however, if necessary, NDEQ will pursue regulatory actions through Administrative Order, Court Injunction, or other legal actions as needed to protect the State's ground water resources.

For further information about this report or ground water monitoring at livestock facilities, please contact NDEQ.moreinfo@Nebraska.gov. General information about ground water quality, Nebraska's livestock program, and other things is available at http://deq.ne.gov/

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