2022 Nebraska Groundwater Quality Monitoring Report

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DEPT. OF ENVIRONMENT AND ENERGY

Groundwater Section

November 2022

Prepared Pursuant
to Neb. Rev. Stat. §46-1304
(LB329 – 2001)

Image on front cover:

A picture of an irrigation pivot in Northeast Nebraska. Pivots in Nebraska use groundwater for irrigation and their wells can be used to collect groundwater quality data. Photo by Emily Case.

Acknowledgements:

This report would not be possible without the cooperation of the agencies and organizations contributing groundwater data to the "Clearinghouse" (formerly Quality-Assessed Agrichemical Contaminant Database for Nebraska Groundwater), most notably the State's 23 Natural Resources Districts. The University of Nebraska must be thanked for their ongoing work on the Database and attention to detail in assessing the quality of data presented for inclusion. Thanks to Amanda Woita for compiling the report, and Laura Johnson for editing (both with NDEE). Direct any questions regarding this report to David Miesbach, Groundwater Section, NDEE, at (402) 471-4982.

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2022 Nebraska Groundwater Quality Monitoring Report

Introduction

The 2001 Nebraska Legislature passed LB329 (Neb. Rev. Stat. §46-1304) which, in part, directed the Nebraska Department of Environment and Energy (NDEE) to report on groundwater quality monitoring in Nebraska. Reports have been issued annually since December 2001. The text of the statute applicable to this report follows:

"The Department of Environment and Energy shall prepare a report outlining the extent of ground water quality monitoring conducted by natural resources districts during the preceding calendar year. The department shall analyze the data collected for the purpose of determining whether or not ground water quality is degrading or improving and shall present the results to the Natural Resources Committee of the Legislature beginning December 1, 2001, and each year thereafter. The districts shall submit in a timely manner all ground water quality monitoring data collected to the department or its designee. The department shall use the data submitted by the districts in conjunction with all other readily available and compatible data for the purpose of the annual ground water quality trend analysis."

The section following the statute quoted above (§ 46-1305), requires the State's Natural Resources Districts (NRDs) to submit an annual report to the legislature with information on their water quality programs, including financial data. That report has been prepared by the Nebraska Association of Resources Districts and is being issued concurrently with this groundwater quality report.

Groundwater monitoring was being conducted years before LB329 was passed. Many entities performed monitoring of groundwater besides the 23 NRDs for a variety of purposes.

Those entities include:

- Nebraska Department of Agriculture
- Nebraska Department of Environment and Energy
- Nebraska Department of Health and Human Services
- Public Water Suppliers
- University of Nebraska-Lincoln
- United States Geological Survey

The Nebraska Departments of Agriculture (NDA), Environmental Quality (currently NDEE) and the University of Nebraska - Lincoln (UNL) began a project in 1996 to develop a centralized data repository for groundwater quality information that would allow comparison of data obtained at different times and for different purposes. The result of this project was the Quality-Assessed Agrichemical Contaminant Database for Nebraska Groundwater (referred to as the Database in this publication). The Database brought together groundwater data from different sources and provided public access to this data.

Dismal River, Thomas County (Lexi Spurlin, Upper Loup NRD)

In 2019, the NDEE and UNL staff worked with a contractor sponsored by the Ground Water Protection Council (GWPC) to develop a new application to present the Database to the public. The Nebraska Groundwater Quality Clearinghouse (referred to as the Clearinghouse in this publication) was developed using the Database as an interactive interface that features data, maps, well construction details and statistics.

The Clearinghouse serves two primary functions. First, it provides the public the results of groundwater monitoring for agricultural compounds in Nebraska as performed by a variety of entities. Second, it provides an indicator of the methodologies that were used in sampling and analysis for each of the results. UNL staff examined the methods used for sampling and analysis to assign a quality "flag" consisting of a number from 1 to 5 to each of the sample results. The flag depends upon the amount and type of quality assurance/quality control (QA/QC) that was identified in obtaining each of the results. The higher the "flag" number, the better the QA/QC, and the higher the confidence in that particular result.

This year's publication utilized the Clearinghouse to present over 1,728,000 samples tested for 271 potential contaminants from over 32,000 public and private wells. Below is information on the groundwater in Nebraska to help the user better understand the data presented in the Clearinghouse and what it means to our State.

Groundwater in Nebraska

Groundwater can be defined as water that occurs in the open spaces below the surface of the earth (Figure 1). In Nebraska (as in many places worldwide), useable groundwater occurs in voids or pore spaces in various layers of geologic material such as sand, gravel, silt, sandstone, and limestone. These layers are referred to as aquifers where such geologic units yield sufficient water for human use. In parts of the state, groundwater may be encountered just a few feet below the surface, while in other areas, it may be a few hundred feet underground. This underground water "surface" is usually referred to as the water table, while water which soaks downward through overlying rocks and sediment to the water table is called recharge as shown in Figure 2. The amount of water that can be obtained from a given aquifer may range from a few gallons per minute (which is just enough to supply a typical household) to many hundreds or even thousands of gallons per minute (which is the yield of large irrigation, industrial, or public water supply wells).

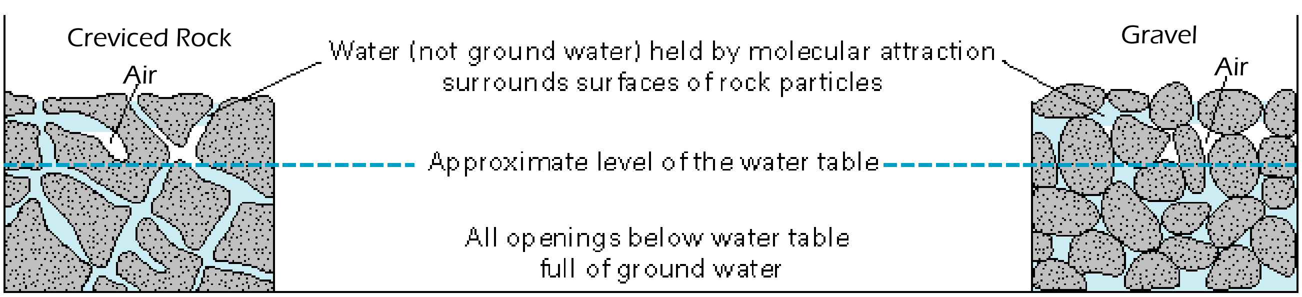


Figure 1. Basic aquifer concepts (U.S. Geological Survey).

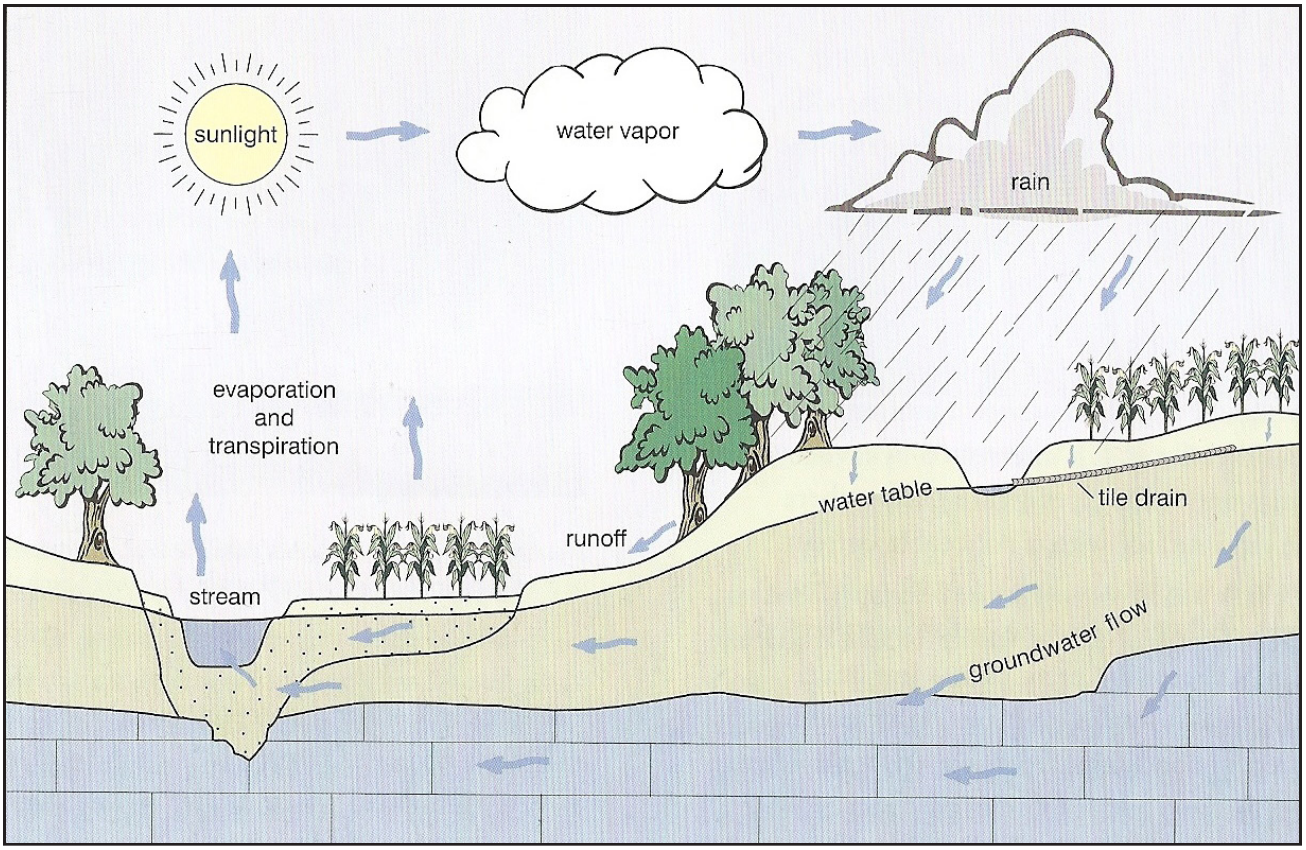


Figure 2. Generalized hydrologic cycle. (Prior, 2003).

Depth & Velocity of Groundwater

The depth to groundwater plays a very important role in Nebraska's valuable water resource. A shallow well is cheaper to drill, construct, and pump. However, shallow groundwater is more at-risk from impacts from human activities. Surface spills, application of agricultural chemicals, effluent from septic tank leach fields, and other sources of contamination will impact shallow groundwater more quickly than groundwater found at depth. The map in Figure 3 shows the great variation of depth to water across the State.

In general, groundwater flows very slowly, especially when compared to the flow of water in streams and rivers. Many factors determine the speed of groundwater and most of these factors cannot be measured or observed directly. Basic groundwater features are shown in Figures 1 and 2. The most important geologic characteristics that impact groundwater movement are as follows:

- The sediment in the saturated zone of the aquifer. Groundwater generally flows faster through gravel sediments than clay sediments.
- The 'sorting' of the sediment. Groundwater in aquifers with a mix of clay, sand, and gravel (poor sorting) generally does not flow as fast as in aquifers that are composed of just one sediment, such as gravel (good sorting).
- The 'gradient' of the water table. Groundwater flows from higher elevations toward lower elevations under the force of gravity. In areas of high relief, groundwater flows faster. A typical groundwater gradient in Nebraska is 10 feet of drop over a mile (0.002 ft/ft).
- Well pumping influences. In areas of the State with numerous high-capacity wells (mainly irrigation wells), groundwater velocity and direction can be changed seasonally as water is pumped.

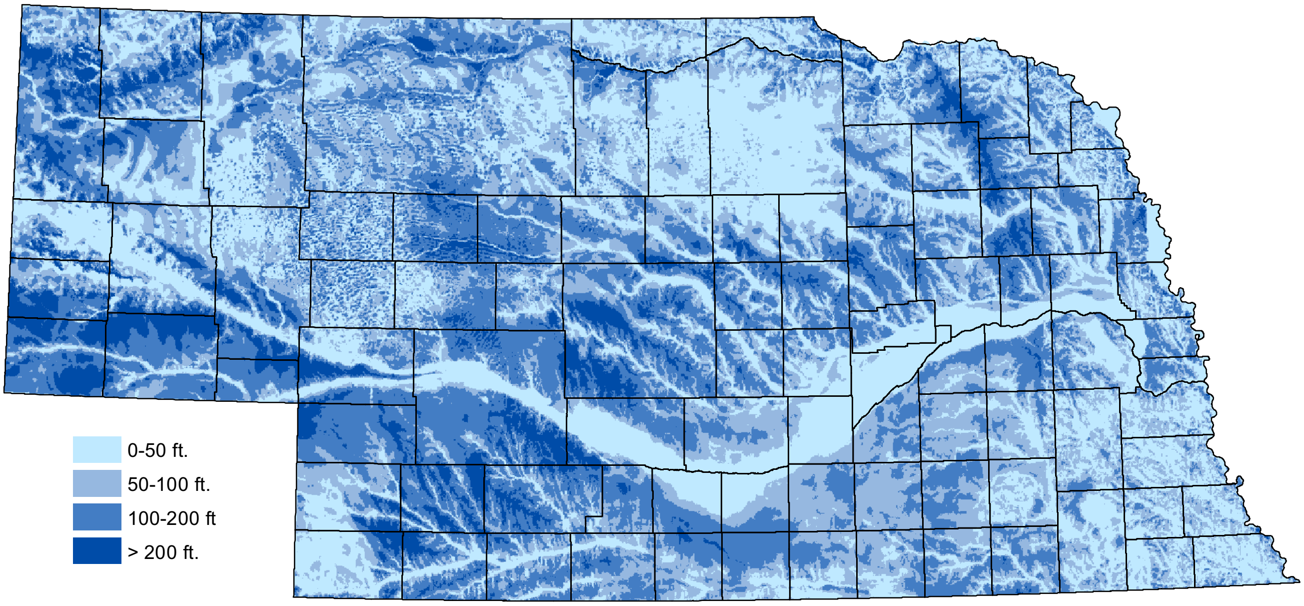


Figure 3. Generalized depth to groundwater.
(Source: University of Nebraska, Conservation and Survey Division, 1998)

Ultimately, groundwater scientists have determined that groundwater in Nebraska can flow as fast as one to two feet per day in areas like the Platte River valley and as slow as one to two inches per year in areas like the Pine Ridge in northwest Nebraska or the glacially deposited sediments in southeast Nebraska.

Geology and Groundwater

Nebraska has been "underwater" most of its history. Ancient seas deposited multiple layers of marine sediments that eventually formed sandstone, shale, and limestone. These geologic units are now considered "bedrock" and underlie the entire State. Limited fresh water supplies can be found in this bedrock mainly in the eastern portion of the State. After the seas retreated, huge river systems deposited sand and gravel eroded from mountain building to the west to form groundwater bearing formations such as the lower Chadron, Ogallala (Figures 4 and 5) and Broadwater. Next, the combination of erosion (statewide) and glaciation in the east introduced new material that was deposited by wind, water, and ice to form the remainder of the High Plains Aquifer (Figure 4 and 5).

The High Plains Aquifer is a conglomeration of many separate groundwater bearing formations such as the Brule, Arikaree, Ogallala, Broadwater, and many more recent unnamed deposits (including the Sand Hills). Many of the unnamed deposits are found mainly within the stream valleys (recent or ancient) and are a common source of groundwater (Figure 6, left pane). No single formation completely covers the entire state. However, when these numerous formations and deposits are combined, they form the High Plains Aquifer, covering almost 90% of Nebraska.

There are parts of eastern Nebraska where the High Plains Aquifer is not present. These areas rely heavily on groundwater from buried ancient river channels (paleovalleys) or recent alluvial valleys (Missouri, Platte, and Nemaha Rivers) (Figure 6, right pane).

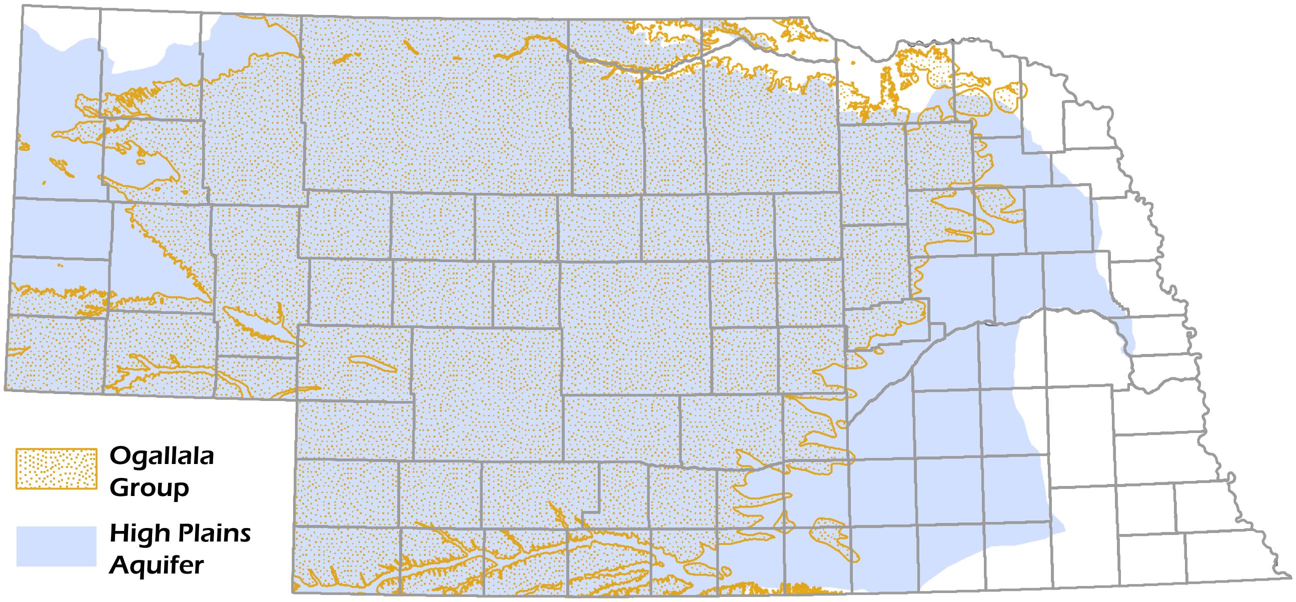


Figure 4. Map of the High Plains aquifer identifying the Ogallala Group.
(Source: University of NE, Conservation and Survey Division, 2013)

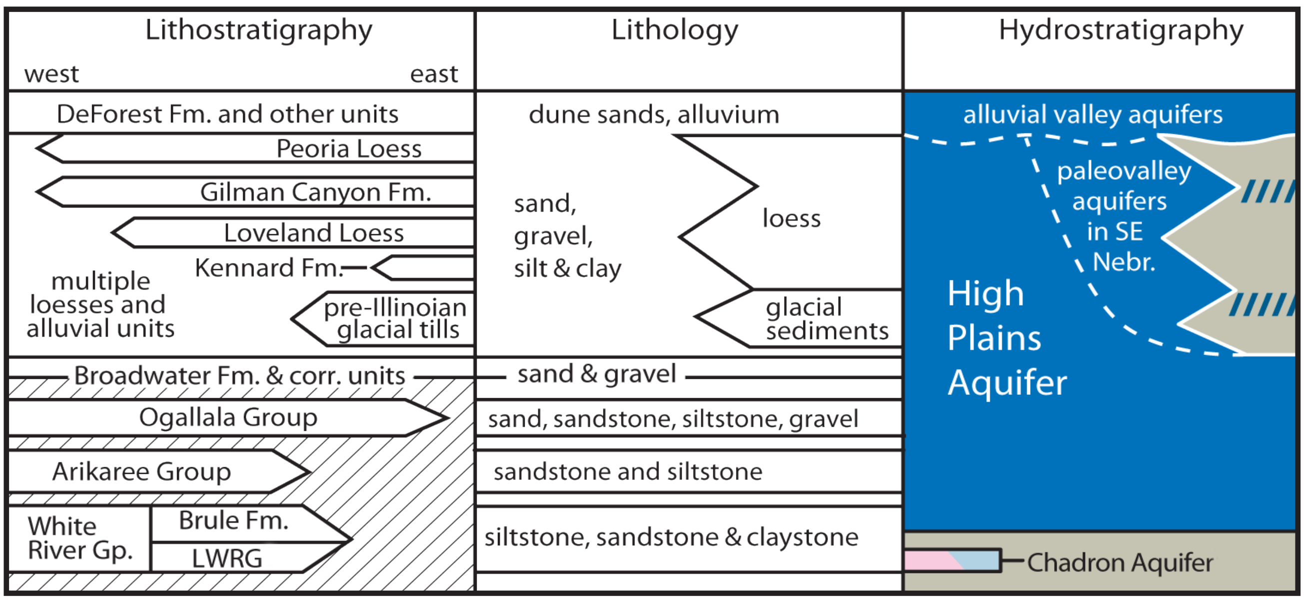


Figure 5. Excerpts from the generalized geologic and hydrostratigraphic framework of Nebraska.
(Source: University of Nebraska, Conservation and Survey Division, 2013)

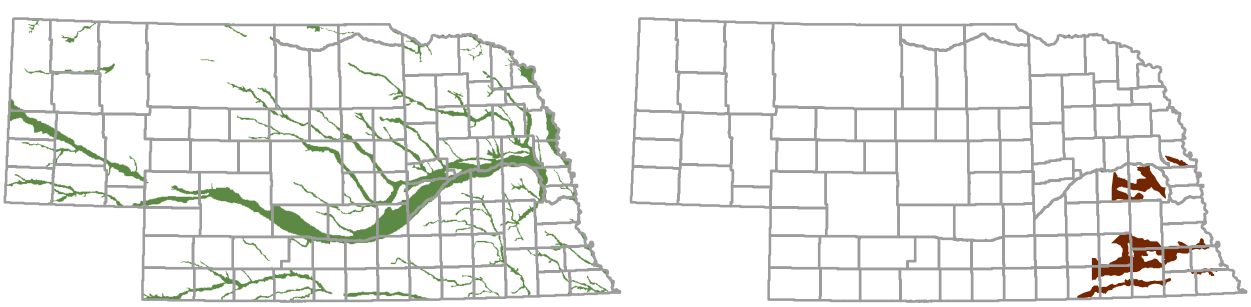


Figure 6. Map of the valleys topographic region (left) and paleovalley aquifers (right).
(Source: University of Nebraska, Conservation and Survey Division, 2013)

Importance of Groundwater

Nebraska is one of the most groundwater-rich states in the United States. Approximately 88% of the state's residents rely on groundwater as their source of drinking water. If the public water supply for the Omaha metropolitan area (which gets about a third of its water supply from the Missouri River) isn't counted, this rises to nearly 99%. Essentially all of the rural residents of the state use groundwater for their domestic supply. Not only does Nebraska depend on groundwater for its drinking water supply, but also the state's agricultural industry utilizes vast amounts of groundwater to irrigate crops and water livestock. Nebraska experiences variable amounts of precipitation throughout the year, so irrigation is used, where possible, to ensure adequate amounts of moisture for raising such crops as corn, soybeans, alfalfa, and edible beans. As of November 2022, the Nebraska Department of Natural Resources (NDNR) listed over 96,000 active irrigation wells and over 33,500 active domestic wells registered in the state. Domestic wells were not required to be registered with the state prior to September 1993, therefore thousands of domestic wells exist that are not registered with the NDNR. Figure 7 and information shown in Table 1 help illustrate this.

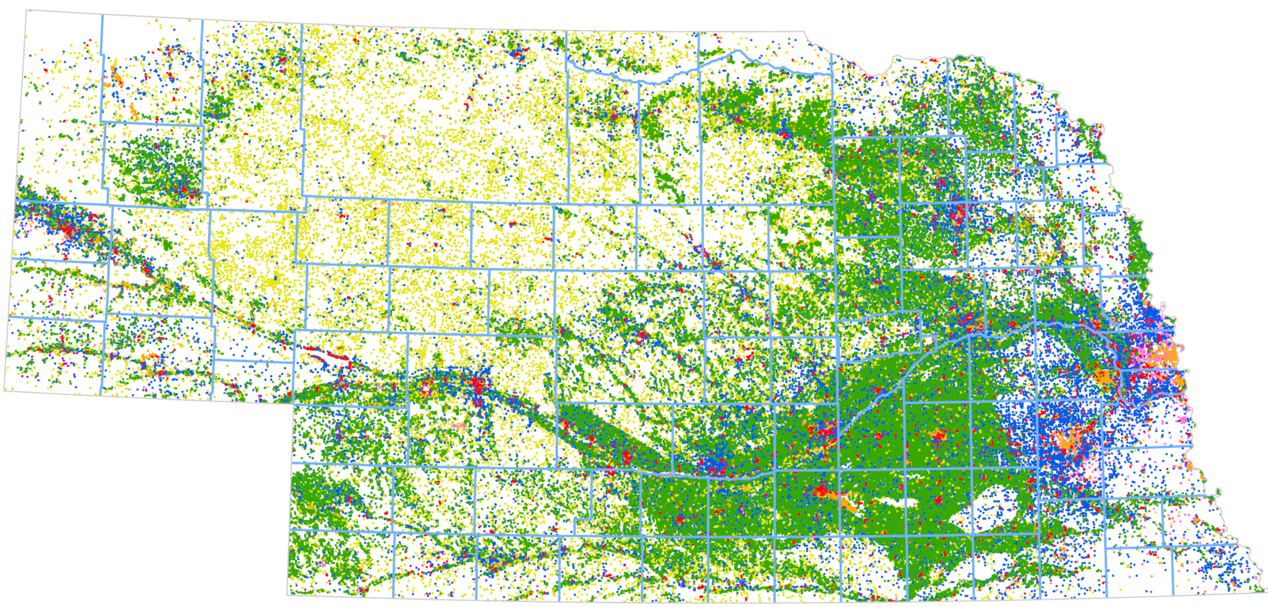


Figure 7. Active registered water wells as of November 2022. (Source: Nebraska Department of Natural Resources Registered Well Database, 2022)

Table 1. Active registered water wells and use as of November 2022. (Source: Nebraska Department of Natural Resources Registered Well Database, 2022)

	Water Use	Active
● (green)	Irrigation	96,439
● (blue)	Domestic	33,754
● (yellow)	Livestock	24,012
● (orange)	Monitoring (groundwater quality)	16,202
● (red)	Public Water Supply	3,043
● (purple)	Commercial/Industrial	1,826
● (brown)	Other	14,600
	Total	189,876

Groundwater Quality Data

Groundwater quality data (1974 to 2019) presented in the remainder of this report reflect the data present in the Clearinghouse as of January 1, 2020. The Clearinghouse also contains data collected after this date, but it is still under review by the NDEE and therefore is not used to complete statistics for this report. The NDEE is confident that the information presented in this report represents the majority of sample results available.

Types of Wells Sampled

The data summarized in Table 2 represent the quantity of water samples analyzed from a variety of well types. Historically, most wells that have been sampled are irrigation or domestic supply wells. Irrigation and domestic wells are constructed to yield adequate supplies of water, not to provide water quality samples (longer screens across large portions of the aquifer). However, in recent years, monitoring agencies have been installing increasing numbers of dedicated groundwater monitoring wells designed and located specifically to produce samples (shorter screens in distinct portions of the aquifer). By utilizing such varied sources, groundwater data from a range of geologic conditions can be obtained.

Well Type	Number of Analyses	Number of Wells
Irrigation	127,558	18,875
Domestic	77,760	6,240
Public Water Supply	1,260,952	4,680
Monitoring	259,955	2,907
Commercial/Industrial	2,592	83
Heat Pump (GW source)	8	5
Total	1,728,825	32,790

Table 2. Total number of groundwater analyses by well type.
(Source: Nebraska Groundwater Quality Clearinghouse, 2022)

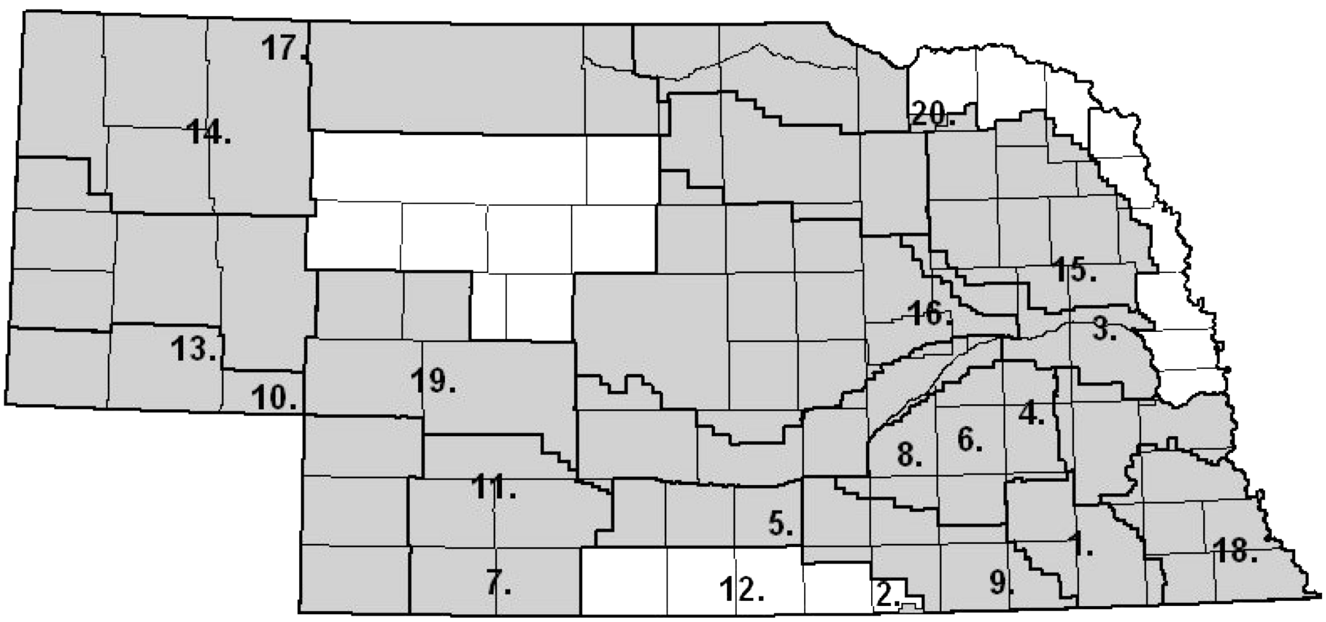
Monitoring Parameters

As already mentioned, numerous entities across Nebraska have been monitoring groundwater quality for many years, for a wide variety of possible contaminants. However, much of this monitoring has been for area-specific (part of an NRD), or at most, regional purposes (entire NRDs), and it has been difficult to assess data on a statewide basis for more than a short period of time. Creation of the Clearinghouse has provided an important tool for such analysis. Appendix A lists the compounds for which groundwater has been sampled and analyzed since 1974.

The table in Appendix A shows a wide variety of compounds for which groundwater samples have been analyzed, the majority of which are used in agricultural production. Since the creation of the Clearinghouse, analytes which Public Water Systems test for have also been added (approximately 30) to the list. The Clearinghouse has been set up so that new analytes may be added in the future.

Discussion and Analysis

This report highlights the presence of elevated levels of nitrate and herbicides in groundwater and the occurrence is associated with the practice of irrigated agriculture, especially corn production (Exner and Spalding 1990). In response, the Natural Resources Districts have instituted Groundwater Management Areas (GWMAs) in nearly all of the 23 districts based on the results of this data. The implementation of Groundwater Management Areas indicates a concern and recognition of nonpoint source groundwater contamination and a need to protect this State's most valuable natural resource. Additionally, NDEQ's (currently NDEE) Groundwater Management Area Program has completed 20 studies across the state since 1988, identifying areas of nonpoint source contamination mainly from the widespread application of commercial fertilizer and animal waste (Figure 8).



1. Beatrice/DeWitt, 1988
2. Superior, 1988
3. Fremont, 1988
4. E. Upper Big Blue, 1989
5. Wilcox/Hildreth, 1989
6. York/Polk Co., 1990
7. Red Willow/Hitchcock Co., 1990
8. W. Upper Big Blue, 1991
9. E. Little Blue, 1992 - 1994
10. Deuel Co., 1992
11. N. Middle Republican, 1995
12. Lower Republican, 1996 - 97
13. E. Cheyenne Co., 1996
14. Box Butte Co./Mirage Flats, 1998
15. S. Lower Elkhorn, 1999
16. E. Lower Loup, 2000
17. E. Sheridan Co., 2001
18. Humboldt, 2001
19. Keith-Lincoln Co., 2002 - 2003
20. Bazile Triangle, 2004

Figure 8. Location of Groundwater Management Area studies completed by NDEE.

While irrigated agriculture has been documented as a source of nitrate in groundwater, there are many other sources that can contribute. The application of commercial fertilizer on green spaces such as yards or golf courses, septic systems, waste lagoons (municipal, private or livestock) or the application of livestock waste are some examples (Appendix B, Nitrogen Cycle).

The State of Nebraska has a geographic area of over 77,000 square miles. Accurately characterizing the quality of Nebraska's groundwater in a complex aquifer system has always been challenging. Collaboration and taking a statewide view of all the groundwater data collected provides for robust trend analysis. The goal is to ascertain areas in Nebraska where groundwater contaminant levels are decreasing through better management and farming practices so that these positive trends can be spread across the State.

Though we have groundwater data, there are over 189,000 active registered wells in Nebraska and only enough resources to collect samples from less than 17% of them annually (since 2000). Samples are also not collected evenly throughout the State. Additional resources and logistics are needed to obtain a more complete picture of Nebraska's groundwater quality. Even the process for nitrate impacting groundwater can get complicated (Appendix B, Nitrogen Cycle).

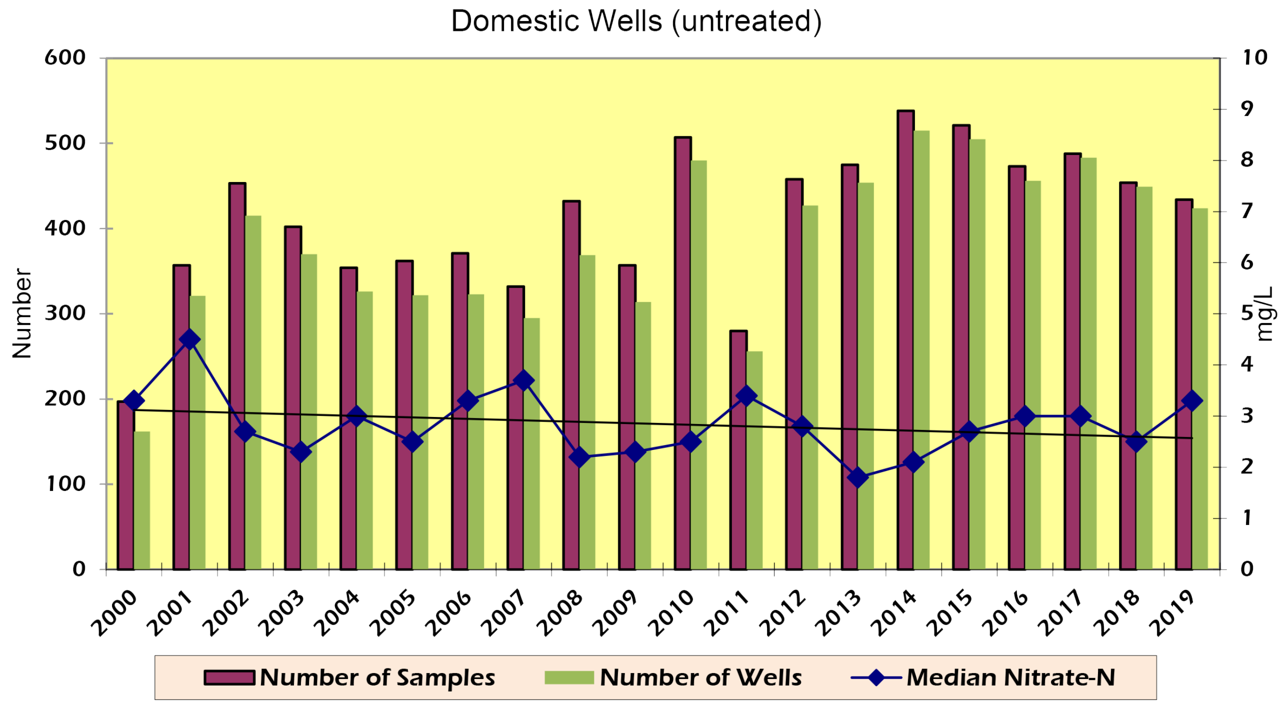
Nitrate Trends Utilizing the Database

Nitrate monitoring data have been collected from wells for many years, and the purpose of collection has varied by the agency or organization performing the work. For instance, public water system operators sample their drinking water wells to ensure they are in compliance with the Safe Drinking Water Act while the NRDs have been collecting data to make groundwater management decisions.

The Clearinghouse now makes accessing and reviewing groundwater data relatively straightforward but users need to be aware that differences in wells may result in incorrect assumptions. Data may be collected from:

- deep wells (bottom of the aquifer) vs. shallow wells (top of the aquifer) or
- irrigation wells (potentially screened across multiple aquifers) vs. dedicated monitoring wells (with perhaps only 10 feet of screen) or
- wells located near potential sources of contamination such as septic tanks or past chemical spills vs. wells located in pristine rangeland or
- wells used for measuring water levels (observation) vs. wells used for water quality.

Several different methods have been used to present and interpret the nitrate data collected since the early 1970's. Reviewing the entire Clearinghouse shows that consistent sampling events and locations have occurred since about 2000. Charts and maps are used to help "visualize" the data and were generated using the Clearinghouse. Figures 9, 10, 11, 12, and 13 present the median (center of the data) nitrate concentration and simple trends during that time period. Figure 9 is nitrate data collected from domestic wells, while figure 10 is nitrate data collected from domestic wells and public water supply wells (untreated). Figure 11 is nitrate data collected from irrigation wells. Figure 12 is nitrate data collected from monitoring wells utilized by the NRDs to assess groundwater quality in their Districts, and figure 13 is nitrate data collected from all well types.



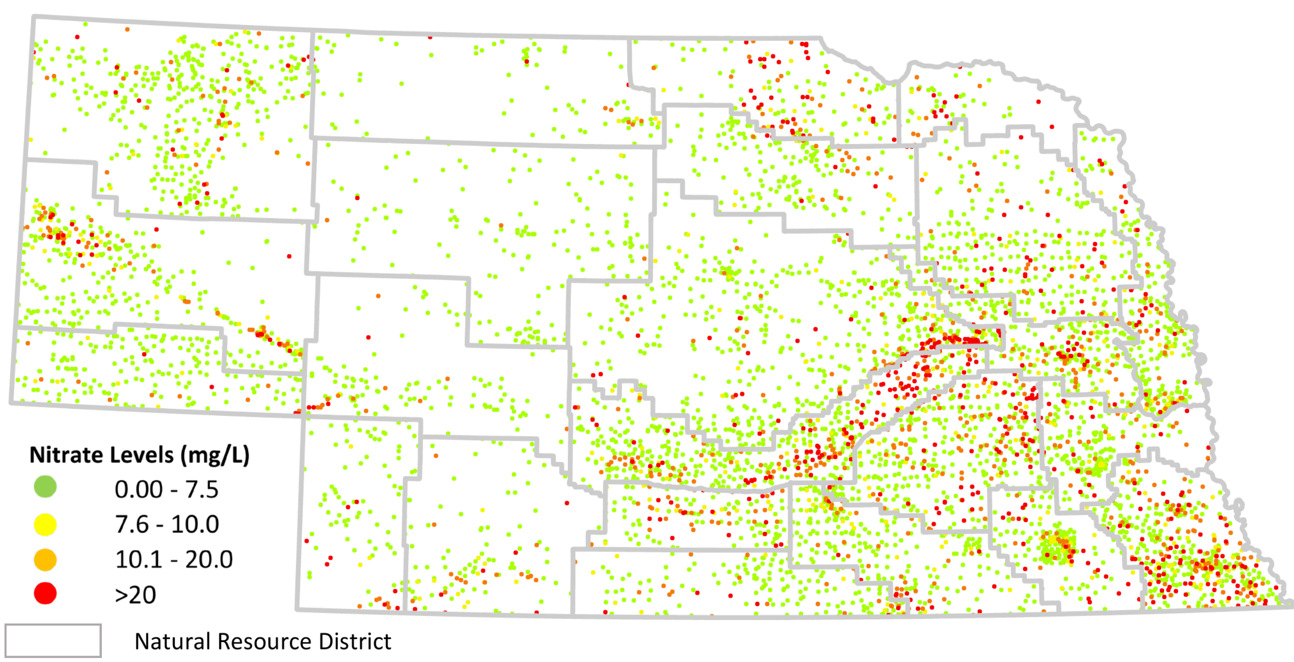


Figure 9. Graph and map of Nitrate-N concentration of 8,245 samples from an average of 383 domestic wells during 2000-2019. (Source: Nebraska Groundwater Quality Clearinghouse, 2022). *Empty areas indicate no data reported, not the absense of nitrate in groundwater.*

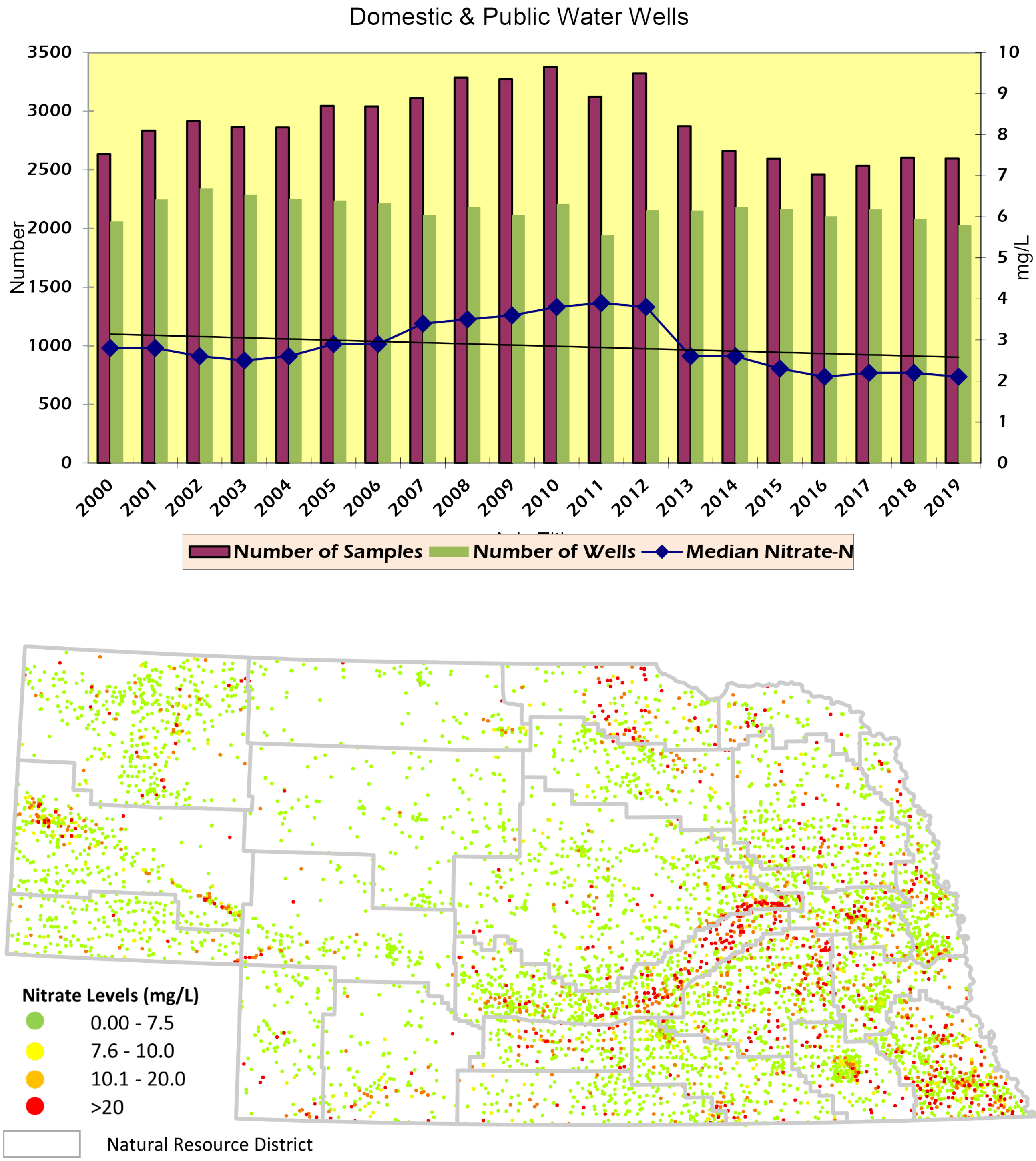
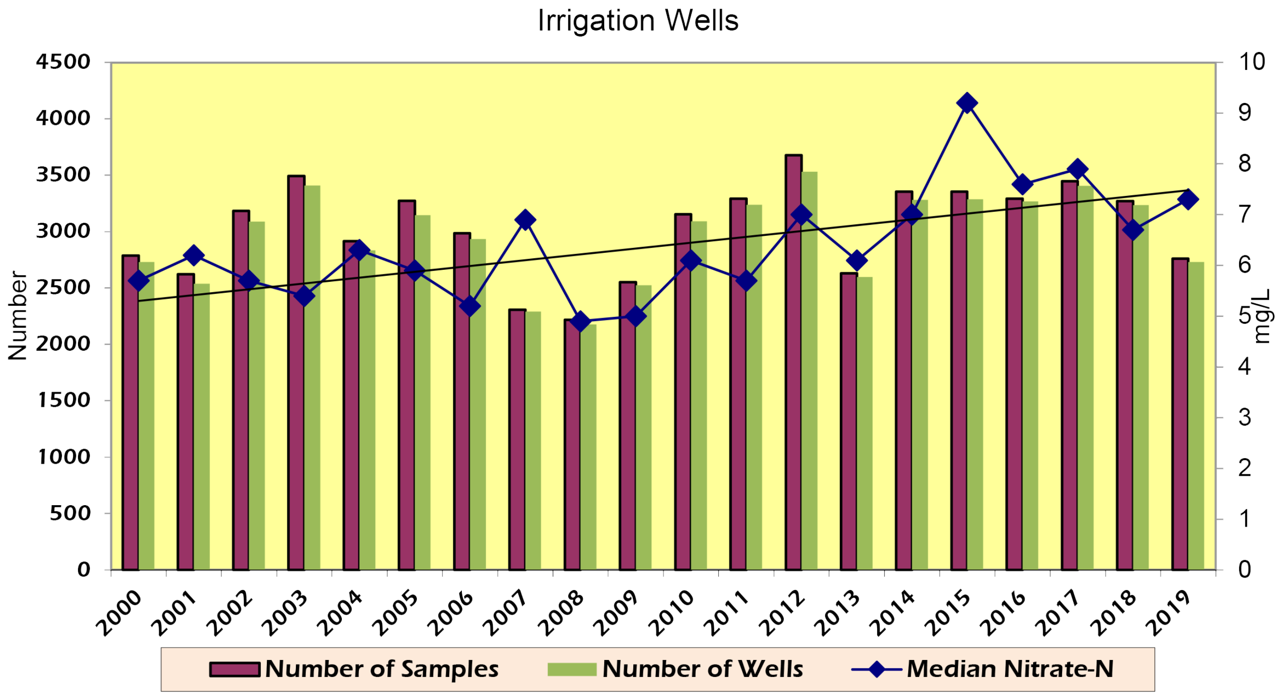


Figure 10. Graph and map of Nitrate-N concentration of 57,992 samples from an average of 2,162 domestic and public water wells during 2000-2019. (Source: Nebraska Groundwater Quality Clearinghouse, 2022). *Empty areas indicate no data reported, not the absense of nitrate in groundwater.*



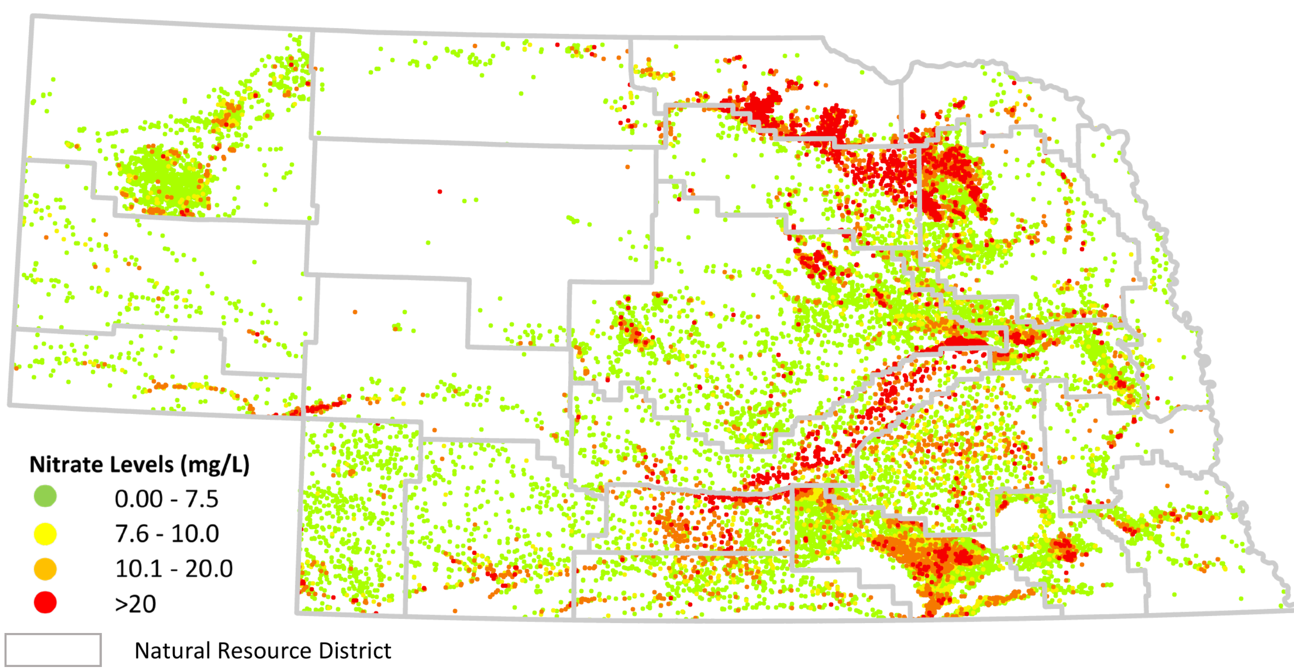
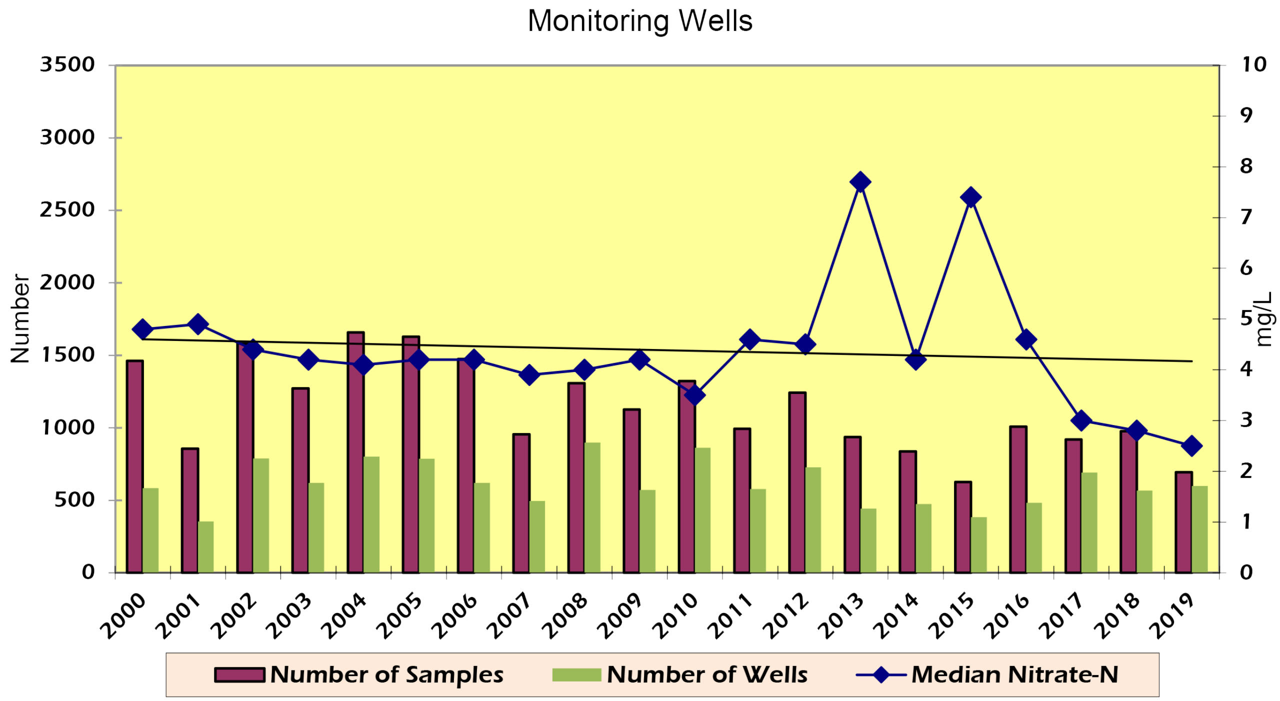


Figure 11. Graph and map of Nitrate-N concentration of 60,562 samples from an average of 2,966 irrigation wells during 2000-2019. (Source: Nebraska Groundwater Quality Clearinghouse, 2022). *Empty areas indicate no data reported, not the absense of nitrate in groundwater.*



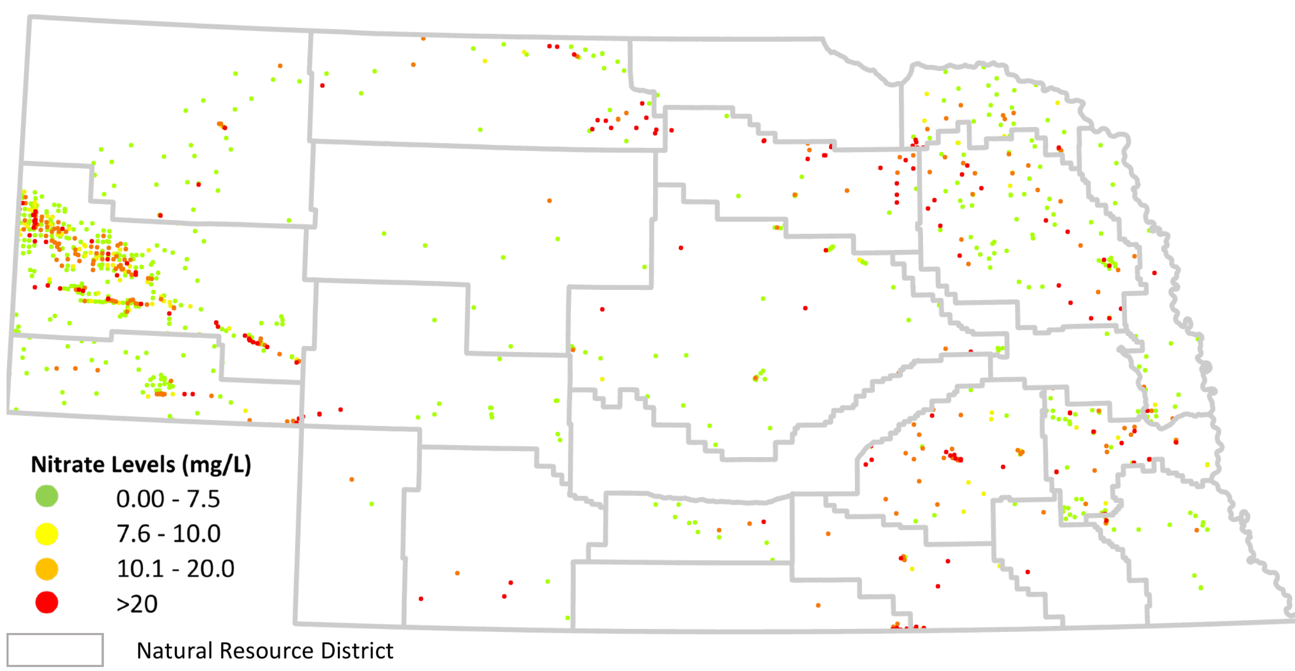
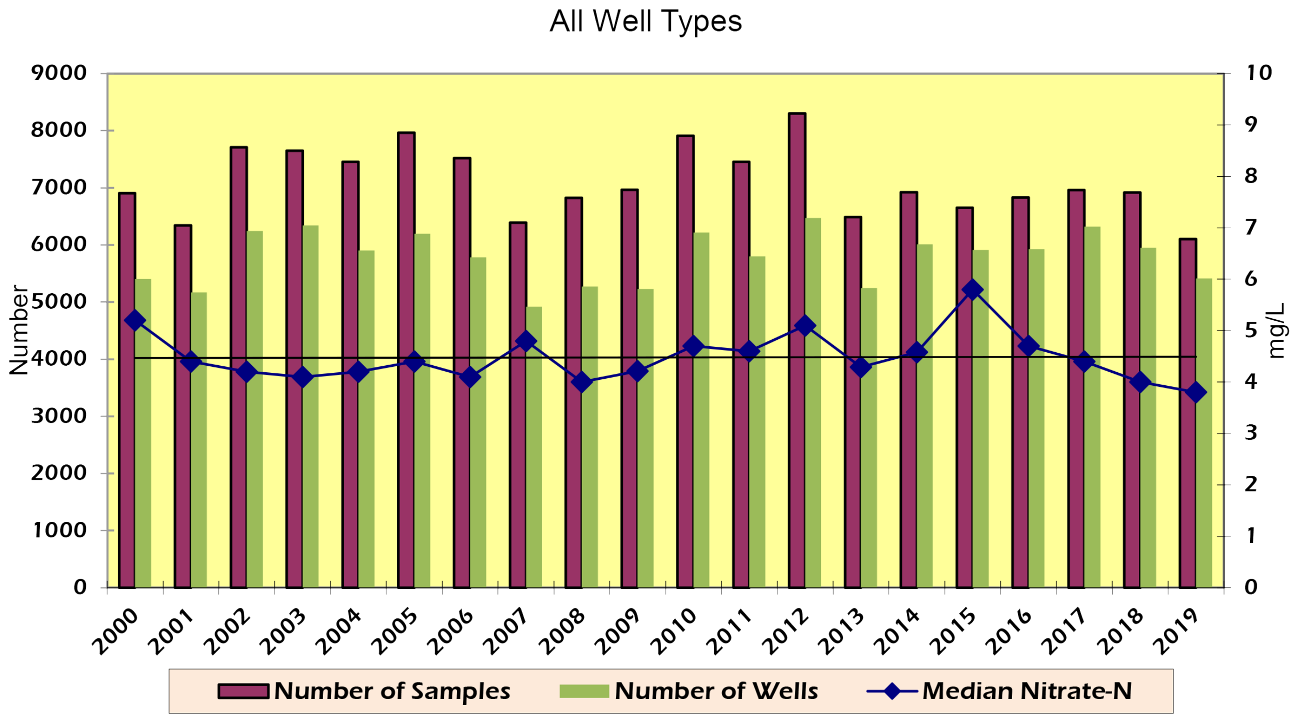


Figure 12. Graph and map of Nitrate-N concentration of 22,878 samples from an average of 616 monitoring wells during 2000-2019. (Source: Nebraska Groundwater Quality Clearinghouse, 2022). *Empty areas indicate no data reported, not the absense of nitrate in groundwater.*



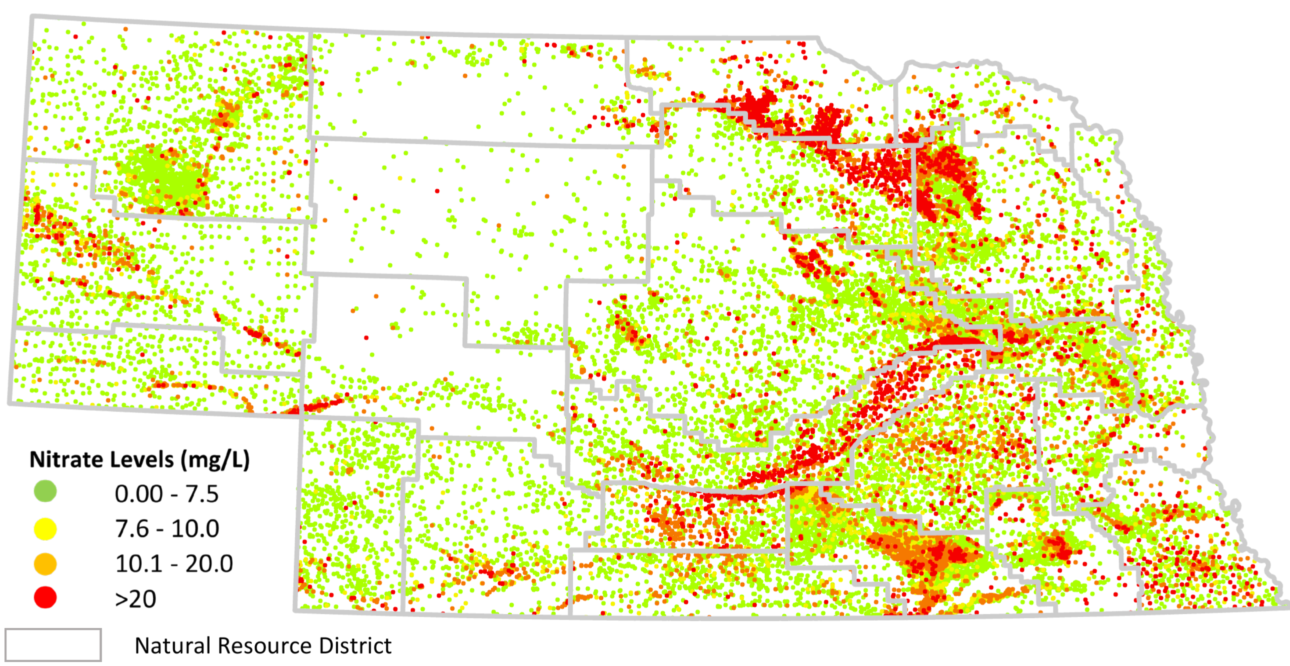


Figure 13. Graph and map of Nitrate-N concentration of 142,259 samples from an average of 5,786 water wells (all types) during 2000-2019. (Source: Nebraska Groundwater Quality Clearinghouse, 2022). *Empty areas indicate no data reported, not the absense of nitrate in groundwater.*

Maps are used in an attempt to show "current" statewide groundwater quality from the most recent time the well had been sampled (aiming to show the most current water quality at that location). A township (36 square miles) map was developed using the same data set from Figure 13. The most recent sample for each well analyzed since 2000 was used to calculate the median value of nitrate for each township (Figure 14).

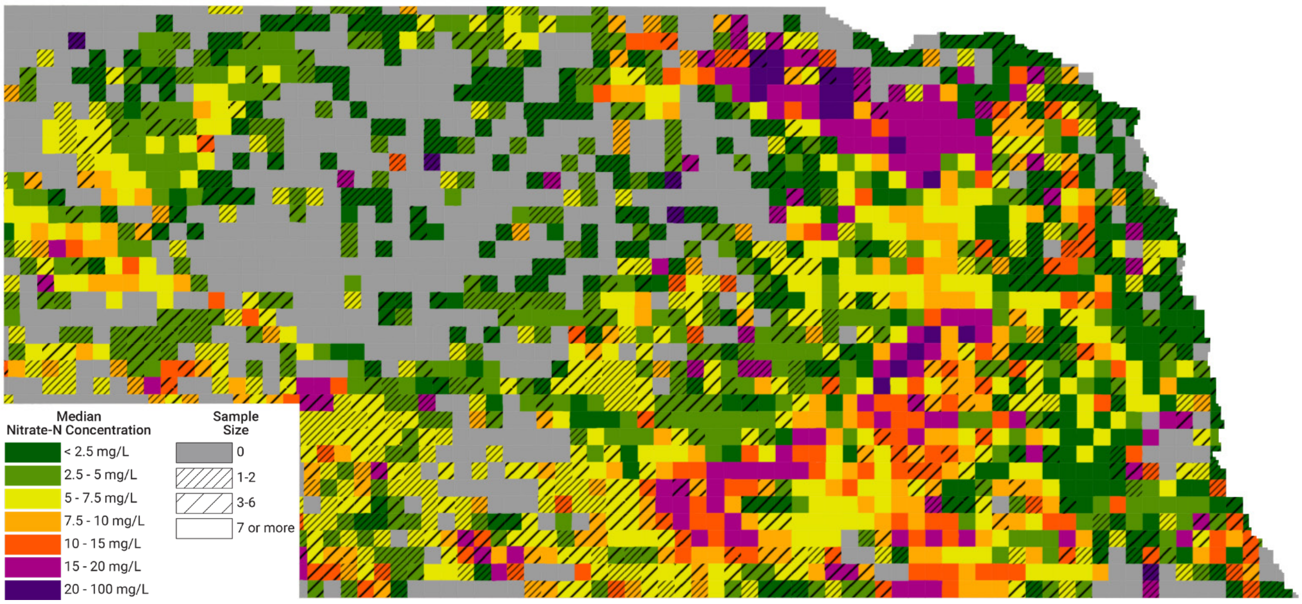


Figure 14. Median of the most recent Nitrate-N concentration by township of 34,007 water wells (all types) during 2000-2019. (Source: Nebraska Groundwater Quality Clearinghouse, 2022). *Empty areas indicate no data reported, not the absense of nitrate in groundwater.*

This is the second year Nebraska has participated in the USGS National Groundwater Monitoring Network. This network has over 500 wells that have known aquifer parameters and consistent sampling. The USGS network takes the place of the Statewide Monitoring Network.

Nitrate in Public Water Supplies

In an effort to protect the drinking water quality of America's public water systems, the federal Safe Drinking Water Act authorizes the EPA to set national drinking water standards. These standards include maximum contaminant levels based on health effects due to exposure of both naturally occurring and man-made contaminants. When a Public Water System (PWS) exceeds the Maximum Contaminant Level (MCL) for a regulated contaminant, Public Notification to the customers of the system is mandatory. If exceedances continue, an Administrative Order (AO) will be issued. This AO will mandate that the PWS make changes to their water system to bring the contaminant results consistently below the MCL for that contaminant.

The MCL for nitrate-nitrogen is 10 mg/L, but PWS systems with wells or intakes testing over 5 mg/L may be required to perform quarterly sampling. Of the nearly 550 groundwater based community PWS systems in Nebraska that supply their own water, 157 of those must perform quarterly sampling for nitrate. If a PWS exceeds the nitrate-nitrogen MCL two times in a rolling 9 month period, an AO will be issued. A nitrate AO will mandate that the PWS take steps to bring their nitrate results consistently below the MCL such as drilling a new or deeper well, hooking on to a neighboring water system, blending, or building a water treatment plant. Figures 15 and 16 show the location of active community PWS systems that have their own source of water. The maps indicate if there is an administrative order for nitrate, systems required to perform quarterly sampling, and systems treating water because of high levels of nitrate. AOs due to high levels of nitrate do not necessarily fall in the areas of highest nitrate problems, as indicated in Figures 12 and 13.

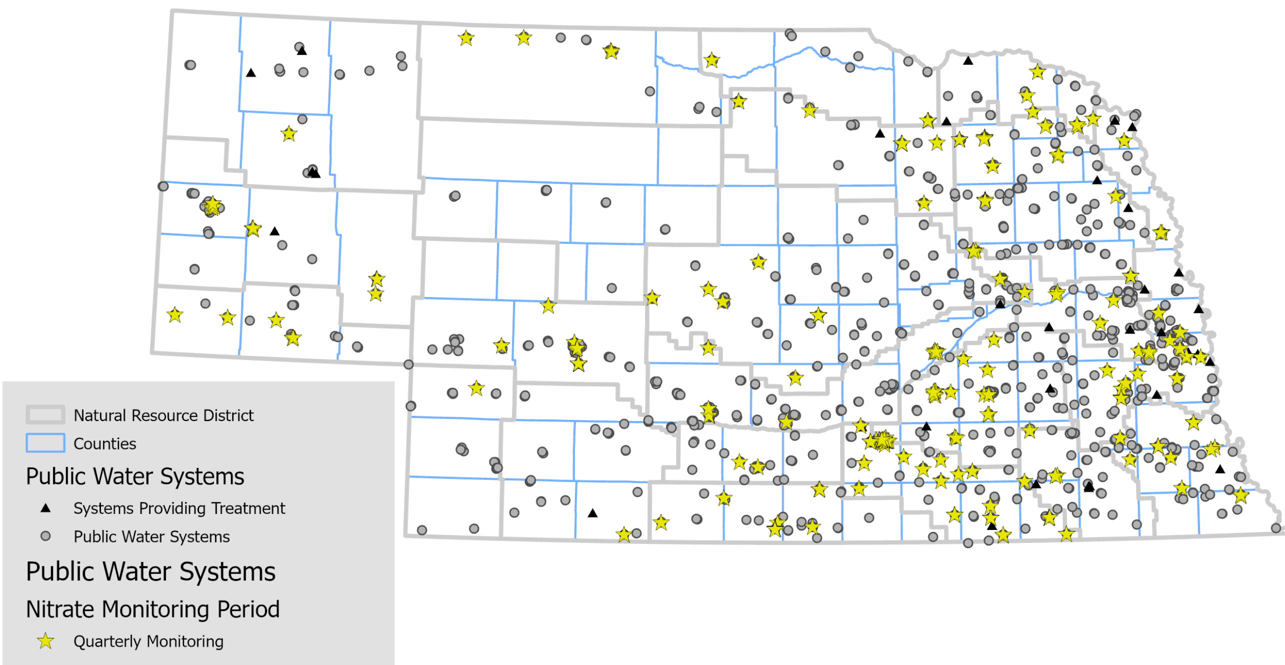


Figure 15. Community public water supply systems with requirements for nitrate. (Source: NDEE Drinking Water and Groundwater Division, 2022).

Several recent studies considered the relationship of nitrate leaching into the subsurface and uranium concentrations found in groundwater. Research indicates that natural uranium in the subsurface may be oxidized and mobilized as the nitrate (in many forms) moves through the root zone and eventually to groundwater. Uranium is found naturally in sediment deposited mainly by streams and rivers.

Some public water supply systems treat not only nitrate, but also arsenic and uranium. The MCL for arsenic is 0.010 mg/L amd uranium is 0.030 mg/L. Figure 16 shows the location of active community public water systems with arsenic, nitrate, and uranium requirements.

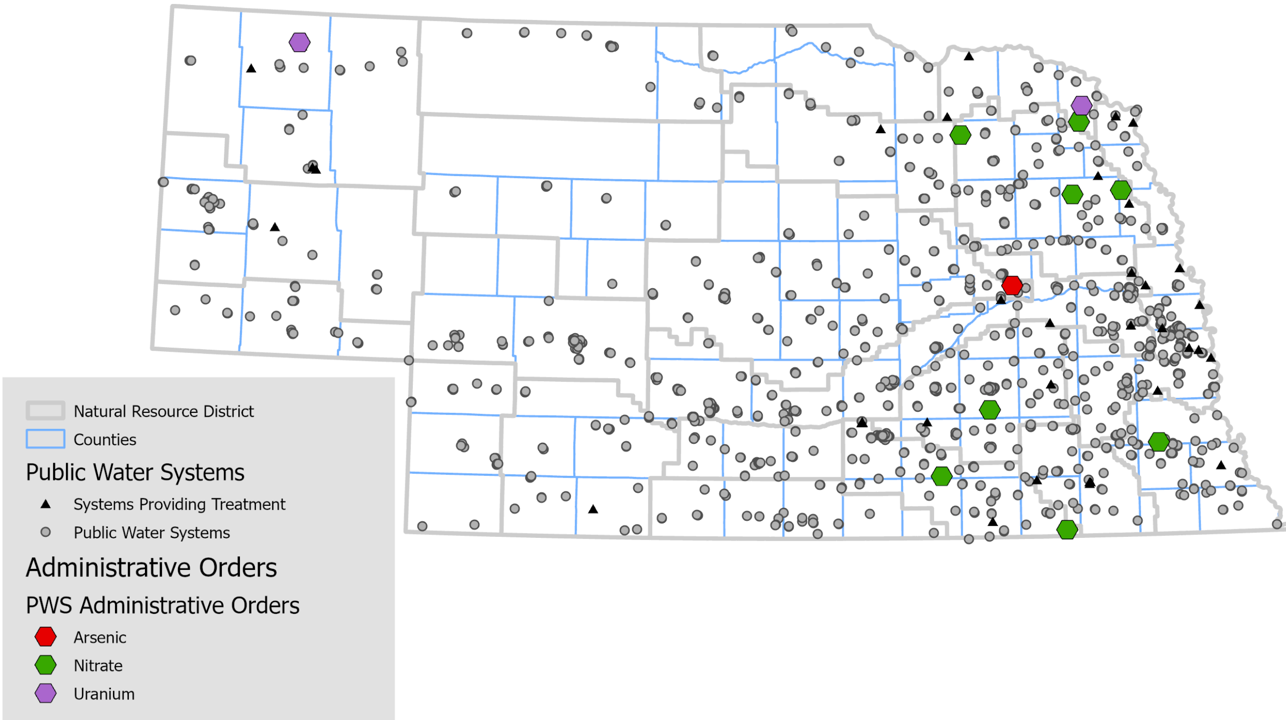


Figure 16. Community public water supply systems with requirements for arsenic, nitrate, and uranium. (Source: NDEE Drinking Water and Groundwater Division, 2022).

HERBICIDES

Atrazine, alachlor, and metolachlor are herbicides used for weed control in crops such as corn and sorghum. In addition, the Nebraska Department of Agriculture identified alachlor and simazine as priority compounds for development of pesticide State Management Plans, following guidance produced by the U.S. Environmental Protection Agency.

Atrazine

Atrazine is used as an herbicide to eradicate broad leaf weeds. There have been 11,529 groundwater samples collected and analyzed for atrazine in the last 20 years. The mean atrazine concentration is 0.10 micrograms per liter or µg/L, compared to the USEPA's Maximum Contaminant Level of 3 µg/L, as established in the Safe Drinking Water Act.

Alachlor

Alachlor is used as an herbicide to eradicate broad leaf weeds and grasses. There have been 8,652 groundwater samples collected and analyzed for alachlor in the last 20 years. The mean alachlor concentration is 0.01 µg/L, compared to the USEPA's MCL of 6 µg/L.

Metolachlor

Metolachlor is used as an herbicide to eradicate broad leaf weeds. There have been 9,285 groundwater samples collected and for metolachlor in the last 20 years. The mean metolachlor concentration is 0.17 µg/L. There is not USEPA MCL for metolachlor, however Minnesota developed a guidance value of 300 µg/L for metolachlor in drinking water.

Simazine

Simazine is used as an herbicide to eradicate broad leaf weeds. There have been 8,554 groundwater samples collected and analyzed for simazine in the last 20 years. The mean simazine concentration is 0.08 µg/L. The USEPA's MCL for simazine is 4 µg/L.

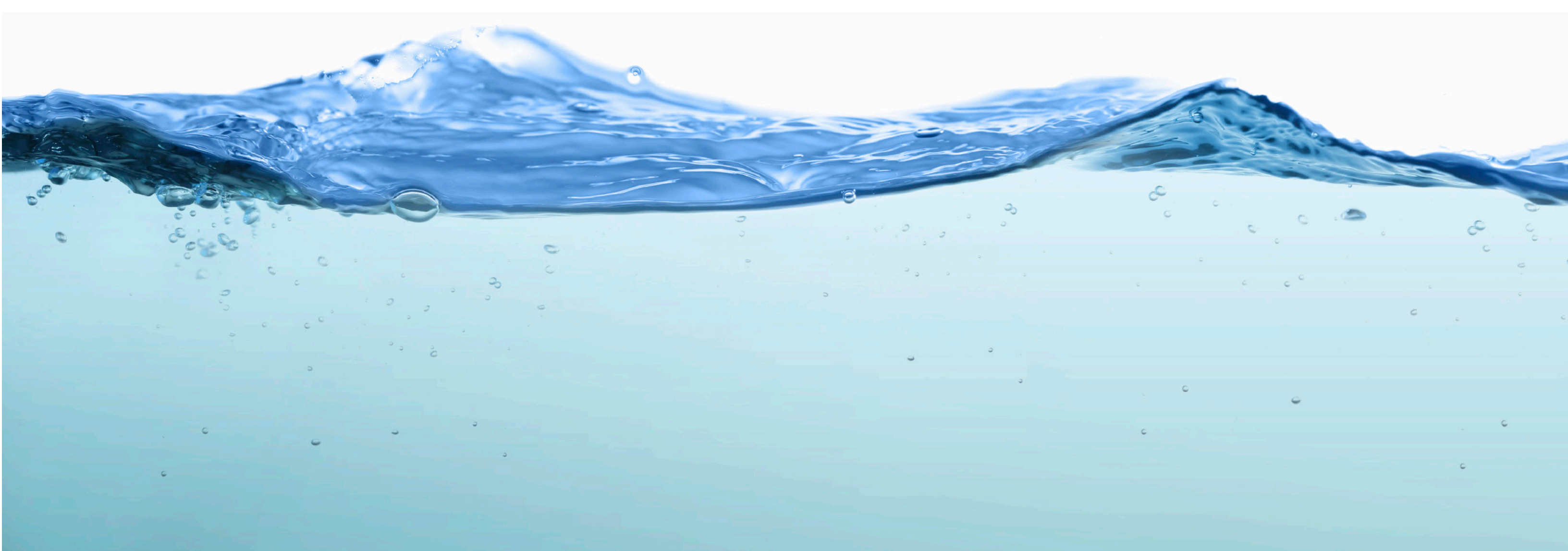
Conclusions

Groundwater is Nebraska's most valuable natural resource. 93% of Nebraska's ~1,300 public water systems serve populations under 3,300 and 95% of those systems rely solely on groundwater. Agriculture and industry in Nebraska rely on heavily on groundwater for production. Most public water supplies that utilize groundwater in Nebraska, do not require any form of treatment. The State's reliance on groundwater highlights the important of maintaining the quantity and quality of this resource Monitoring groundwater contaminant trends statewide helps to ensure this.

The Clearinghouse is available to aid in managing Nebraska's valuable groundwater resource. The report authorized by Neb. Rev. Stat. § 46-1304 (LB 329, 2001) lead the way to the development of the Clearinghouse. Now both recent and historic groundwater quality data can be easily viewed in one location for analysis, mapping, or other uses.

Concentrations and trends of contaminants. Figure 13, page 15 presents the median nitrate concentration in groundwater for each year, and this data was utilized in a simple trend analysis, which indicated that there was no clear trend after year 2000. This figure also shows that there are still areas in Nebraska where the median nitrate concentration in groundwater is approaching the drinking water MCL of 10 mg/L. Once the USGS network can be utilized along with the Clearinghouse, more detailed trend analyses for nitrate will be conducted. There is not enough recent data statewide for atrazine, alachlor, metolachlor, or simazine to conduct any trend analyses.

The Future. Continued attention and resources directed toward groundwater monitoring data for the Clearinghouse and implementation of the USGS National Groundwater Monitoring Network will be crucial for the successful management of Nebraska's groundwater. Best-Management practices, such as adjusting fertilizer application rates and timing must continue to see improvements in Nebraska's groundwater quality.



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Appendix A. Compounds for which groundwater samples have been analyzed

Compound			
1,1,1-Trichloroethane	Acetochlor sulfynilace- tic acid	Cadmium	Dechloroalachlor
1,1,2-Trichloroethane	Acifluorfen	Carbaryl	Dechlorodimethenamid
1,1-Dichloroethene	Acrylonitrile	Carbofuran	Dechlorometolachlor
1,2,4-Trichlorobenzene	Alachlor	Carbon disulfide	Deethylatrazine
1,2-Dibromo-3-chloropropane	Alachlor ethane sul- fonic acid	Carbon tetrachloride	Deethylcyanazine
1,2-Dibromoethane (Ethylene dibromide)	Alachlor oxanilic acid	Carboxin	Deethylcyanazine acid
1,2-Dichlorobenzene	Alachlor sulfynilacetic acid	Chloramben methyl ester	Deethylcyanazine amide
1,2-Dichloroethane	Aldicarb	Chlordane	Deethylhydroxyatrazine
1,2-Dichloropropane	Aldicarb sulfone	Chlorimuron-ethyl	Deisopropylatrazine
1,3-Dichloropropane	Aldicarb sulfoxide	Chlorobenzene	Deisopropylhydroxyatrazine
1,4-Dichlorobenzene	Aldrin	Chloroform	Delta-HCH
1-Naphthol	Alpha-HCH	Chlorothalonil	Demethylfluometuron
2,3,7,8-TCDD	Ametryn	Chlorpyrifos	Desulfinylfipronil
2,4,5-T	Antimony	Chlorpyrifos Oxon	Desulfinylfipronil amide
2,4,6-Trichlorophenol	Arsenic	Chromium	Di(2-ethylhexyl)adipate
2,4-D	Asbestos	Cis-1,2-dichloroethene	Di(2-ethylhexyl)phthalate
2,4-D Methyl ester	Atrazine	Cis-1,3-dichloropro- pene	Diazinon
2,4-DB	Azinphos-methyl	Cis-permethrin	Diazoxon
2,4-Dinitrophenol	Azinphos-methyl oxon	Clopyralid	Dicamba
2,6-Diethylaniline	Barium	Copper	Dichlobenil
226 Radium	Bendiocarb	Cyanazine	Dichlorprop
228 Radium	Benfluralin	Cyanazine acid	Dichlorvos
2-Ethyl-6-methylaniline	Benomyl	Cyanazine amide	Dicrotophos
3,4-Dichloroaniline	Bensulfuron-methyl	Cyanide	Didealkylatrazine
3,5-Dichloroaniline	Bentazon	Cycloate	Dieldrin
3-Hydroxycarbofuran	Benzene	Cyfluthrin	Dimethenamid
4,6-Dinitro-o-cresol	Benzo(A)pyrene	Cypermethrin	Dimethenamid ethane sulfonic acid
4-Chloro-2-methylphenol	Beryllium	Cyprazine	Dimethenamid oxalic acid
4-Chloro-3-methylphenol	Beta-HCH	Dalapon	Dimethoate
4-Nitrophenol	Bromacil	DCPA	Dinoseb
Acenaphthene	Bromomethane	DCPA Monoacid	Diphenamid
Acetochlor	Bromoxynil	DDD	Diquat
Acetochlor ethane sulfonic acid	Butachlor	DDT	Disulfoton
Acetochlor oxanilic acid	Butylate	Dechloroacetochlor	Disulfoton sulfone

Compound			
Diuron	Hexachlorocyclopentadiene	Metribuzin	Propyzamide
Endosulfan I	Hexazinone	Metsulfuron-methyl	Combined Radium (-226 & -228)
Endosulfan Ii	Hydroxyacetochlor	Molinate	Selenium
Endosulfan sulfate	Hydroxyalachlor	Myclobutanil	Siduron
Endothal	Hydroxyatrazine	Naphthalene	Silvex
Endrin	Hydroxydimethenamid	Napropamide	Simazine
Endrin aldehyde	Hydroxymetolachlor	Neburon	Simetryn
Eptc	Hydroxysimazine	Nicosulfuron	Styrene
Esfenvalerate	Imazaquin	Nitrate-N	Sulfometuron-methyl
Ethalfluralin	Imazethapyr	Nitrite as NO2	Tebuthiuron
Ethion	Imidacloprid	Norflurazon	Terbacil
Ethion monoxon	Iodomethane	Oryzalin	Terbufos
Ethoprop	Iprodione	Oxadiazon	Terbufos oxon sulfone
Ethyl parathion	Isofenphos	Oxamyl	Terbuthylazine
Ethylbenzene	Isoxaflutole	Oxyfluorfen	Terbutryn
Fenamiphos	Isoxaflutole diketonitrile	Pebulate	Tetrachloroethene
Fenamiphos sulfone	Lead	Pendimethalin	Thallium
Fenamiphos sulfoxide	Lindane	Pentachlorophenol	Thiobencarb
Fenuron	Linuron	Permethrin	Toluene
Fipronil	Malathion	Phorate	Total Xylenes
Fipronil sulfide	Malathion oxon	Phorate oxon	Toxaphene
Fipronil sulfone	MCPA	Phosmet	Trans-1,2-dichloroeth- ene
Flufenacet	MCPB	Phosmet oxon	Trans-1,3-dichloropro- pene
Flufenacet ethane sulfonic acid	Mercury	Picloram	Triallate
Flufenacet oxanilic acid	Metalaxyl	Prometon	Trichloroethene
Flumetsulam	Methidathion	Prometryn	Triclopyr
Fluometuron	Methiocarb	Propachlor	Trifluralin
Fluoride	Methomyl	Propachlor ethane sulfonic acid	Uranium
Fonofos	Methoxychlor	Propachlor oxanilic acid	Vernolate
Fonofos oxon	Methyl paraoxon	Propanil	Vinyl chloride
Glyphosate	Methyl parathion	Propargite	
Gross beta	Methylene chloride	Propazine	
Heptachlor	Metolachlor	Propham	
Heptachlor epoxide	Metolachlor ethane sulfonic acid	Propiconazole	
Hexachlorobenzene	Metolachlor oxanilic acid	Propoxur	

Appendix B. Diagram of the Nitrogen Cycle