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University of Nebraska - Lincoln, craigadams17@gmail.com

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The Impact of Land Use on Nitrate-N Movement and Storage in the Vadose Zone of the Hastings' WHPA

by

Craig J. Adams

A THESIS

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The Impact of Land Use on Nitrate-N Movement and Storage in the Vadose Zone of the Hastings' WHPA

Craig J. Adams, M.S.

University of Nebraska, 2018

Advisor: Daniel Snow

Nebraska has one of the largest agricultural economies in the United States and relies heavily on irrigation and fertilizer application to maintain crop yields. Over-irrigation and continuous application of nitrogen (N) in many areas has led to accumulation of nitrate-N in soils and sediments throughout the state's vadose zone. Because nitrate-N is both persistent and mobile, groundwater concentrations in many areas of Nebraska and other agriculturally intensive states are increasing. Nitrate-N contamination of public and private drinking water supplies that utilize groundwater are of particular concern. Vadose zone sampling is an important method for rapidly assessing the effect of changing land use on potential groundwater contamination. In the current project, the occurrence and movement of nitrate-N was investigated using deep vadose zone soil cores collected from urban and irrigated farmland in the Hastings, NE Well Head Protection Area (WHPA) and compared to a previous study done at the same locations (R. Spalding & Toavs, 2011). Sampling previously collected sites allows for direct comparisons of current and historical nitrate-N profiles, potential movement, and

can provide a method for evaluating effects of changing land use at the surface. Cumulative nitrate-N in the top 65 ft for urban irrigated lawns, pivot irrigated farmland, and gravity irrigated farmland had an average of 320, 540, and 700 total lbs-N/acre respectively. In farmland where irrigation changed from gravity to pivot application there was an average reduction of 170 lbs-N/acre in the top 55 ft of the profile over a five-year time span. This observation supports the use of sprinkler irrigation for more uniform water application, reducing potential leaching at the head and tail rows of gravity irrigated fields. While future studies are still needed, the importance of vadose zone monitoring in evaluating and protecting groundwater is beneficial in determining connections between surface activities and the underlying groundwater.

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List of Abbreviations

Abbreviation	Description
ANOVA	Analysis of Variance
AOI	Area of Interest
ASTM	American Society for Testing
BMP	Better Management Practices
CME	Central Mine Equipment
COHYST	Cooperative Hydrology Study
DDI	Distilled Deionized
GIS	Geographic Information System
GWMA	Ground Water Management Area
K_d	Soil-partitioning Coefficient
KCL	Potassium Chloride
LIDAR	Light Detection and Ranging
MCL	Maximum Contamination Limit
M	Molar
N	Nitrogen
NRD	Natural Resource District
SOP	Standard Operating Procedure
SSURGO	USDA Web Soil Survey Soil Spatial Dataset
UNL	University of Nebraska-Lincoln
US	United States
USDA	United States Department of Agriculture
USCS	Unified Soil Classification System
WHPA	Well Head Protection Area
WSL	UNL Water Science Laboratory

The Impact of Land Use on Nitrate-N Movement and Storage in the Vadose Zone of the Hastings' WHPA

1.1 Introduction

The state of Nebraska consists primarily of cropland and is one of the largest contributors of agricultural goods in the United States (US) (USDA, 2018). Large demands for crop yields along with a lack of farmers' best management practices (BMPs) have allowed agriculture to become a major cause of groundwater contamination (Adelman et al., 1985). The impact of nitrate-N on groundwater beneath agricultural land in Nebraska has been well documented (Adelman et al., 1985). Nitrate-N is the most common contaminant in groundwater worldwide (Exner et al., 2014). In the US, it is also the most prevalent cause for impairment of public water supplies (Burow et al., 2010). The US Environmental Protection Agency established a maximum contaminant limit (MCL) of 10 mg/L for nitrate-N in drinking water (US Environmental Protection Agency, 1995). Blue baby syndrome, methemoglobinemia, and an increased risk of non-Hodgkin's lymphoma have been linked to continued ingestion of nitrate-N contaminated water (Adelman et al., 1985).

Nitrate-N and ammonium-N are the only two forms of nitrogen (N) that crops can absorb from the soil (Adelman et al., 1985). Nitrate-N is a highly soluble and mobile anion with a low soil-partitioning coefficient (K_d), making it highly susceptible to dissolve into water. Most nitrate-N contamination in Nebraska is related to long-term excessive fertilizing of irrigated cropland (Adelman et al., 1985). Large deposits of natural nitrate-N stored within deep loess layers in Southwestern and Central Nebraska can also be a source of contamination (Boyce et al., 1976). However, these geologic accumulations of mineral nitrogen have not been documented in Adams County, NE where the current study takes place.

A 2014 study linked increasing nitrate-N concentrations in Nebraska's groundwater to fluctuations of nitrate-N in the unsaturated zone (Exner et al., 2014). The study found that sediment samples taken from the unsaturated zone within the Upper Big Blue Natural Resource District (NRD) showed 60 mg/L pulses of nitrate-N had moved 65 ft (20 m) over a 30-year period. As these pulses approach the groundwater they pose a risk to those who consume the water. In Nebraska, 85% of the drinking water comes from municipal groundwater wells (Department of Environmental Quality, 2013). An improved understanding of the occurrence and rate of transport of nitrate-N in the unsaturated zone is important for these municipalities, especially for those without water treatment facilities.

There are many factors controlling the occurrence and movement of nitrate-N in the unsaturated zone. Potential factors include sediment characteristics, land use, fertilizer application, and water input (Adelman et al., 1985). Water input in agricultural areas is controlled by precipitation and irrigation. In 2011, Nebraska received 29 in. (74 cm) of rain, around the average amount of annual rainfall for the state. It is possible that farmers managing pivot or gravity irrigated fields aren't taking the additional water input from precipitation events into account. This excess water creates the potential for high nitrate-N loss beyond the root zone (Adelman et al., 1985). Other factors influencing the amount of nitrate-N impacting the groundwater include unsaturated zone thickness, soil organic matter content, and preferential flow pathways. Light detection and ranging (LIDAR) can provide high-resolution topographic maps displaying the occurrence and duration of water ponding (Amos et al., 2011). Areas with large amounts of ponded water have a greater chance for preferential flow, a rapid movement of water that would flush solutes through the root zone. Nitrate-N can also rapidly leach from the root zone through cracks that develop in fine-textured soils (R. F. Spalding & Exner, 1993).

Vadose zone coring can be used to estimate the amount of nitrogen that has leached into the unsaturated zone. This approach can be used to quantify concentrations of nitrate-N and ammonium-N in agricultural and urban settings. The objectives of this study were to use vadose zone coring to: 1) estimate changes in the quantity and distribution of nitrogen in the unsaturated zone of a municipal WHPA and 2) compare the determined quantity and distribution across different types of land use and agricultural irrigation methods.

In a 2011 study done to assist Hastings Utilities, vadose zone cores were collected within the Hastings, NE WHPA (R. Spalding & Toavs, 2011). The goal was to evaluate which agricultural practices were having a significant impact on nitrate leaching in the uppermost 60 ft of the unsaturated zone and to provide a baseline of nitrogen concentrations. Vadose zone cores reached maximum depths of 45 - 60 ft, primarily due to the coring method used. Accumulations of nitrate-N were highly varied across the sampling locations. The lowest average nitrate-N accumulations (90 to 380 lbs-N/acre) occurred beneath residential lawns. The highest average accumulations (390 to 2,500 lbs-N/acre) occurred beneath gravity irrigated corn fields. The study concluded that improved management within the WHPA had likely led to lower rates of nitrate leaching compared to previous studies done beneath fields in the same locality.

For the current study, 32 of the previous 36 sampling locations were revisited to estimate changes in the quantity and distribution of nitrate-N and ammonium-N. The land use and irrigation type of the sampled locations varied from urban, pivot irrigated cropland, gravity irrigated cropland, and non-irrigated (Table 1). To determine the quantity and distribution of nitrogen across different types of land use and irrigation methods, statistical analyses were performed on categorical averages of the collected data from these groups to determine statistically significant differences.

FID	***Description***	***Land Use***	***Cored***	***Depth***
1	HC-1 Head (West)	Gravity irrigation	11/16	110’
2	HC-1 Tail (East)	Gravity irrigation	11/16	Refusal 105’
3	HC-2	Non-irrigated	11/16	Refusal 75’
4	HC-3a (Marty)	Residential	8/16	Refusal 65’
5	HC-3b (Hurst)	Residential	8/16	Refusal 55’
6	HC-4	City Park	8/16	Refusal 65’
7	HC-5	Residential	8/16	Refusal 50’
8	HC-6	Residential	8/16	Refusal 75’
9	HC-7	Barnyard	8/16	Refusal 70’
10	HC-8	Barnyard	8/16	Refusal 70’
11	HC-9A (North)	Pivot irrigation	3/17	Refusal 75’
12	HC-9B (South)	Pivot irrigation	3/17	Refusal 74’
13	HC-10 Head (North)	Pivot irrigation	3/16	89.5’
14	HC-10 Tail (South)	Pivot irrigation	3/16	83.2’
15	HC-11 Head (West)	Pivot irrigation	12/15	102.5’
16	HC-11 Tail (East)	Pivot irrigation	12/15	93.8’
17	HC-12 Head (West)	Gravity irrigation	3/17	Refusal 120’
18	HC-12 Tail (East)	Gravity irrigation	4/17	Refusal 80’
19	HC-13 SW	Pivot irrigation	3/16	Refusal 95’
20	HC-13 NE	Pivot irrigation	3/16	104.7’
21	HC-14 West	Pivot irrigation	4/16	Refusal 109’
22	HC-14 East	Pivot irrigation	4/16	Refusal 92’
23	HC-15 North	Pivot irrigation	3/17	Refusal 93.5’
24	HC-15 South	Pivot irrigation	4/17	Refusal 105’
25	HC-16 North	Pivot irrigation	3/17	Refusal 85’
26	HC-16 South	Pivot irrigation	3/17	Refusal 90’
27	HC-17 North	Pivot irrigation	11/16	95’
28	HC-17 South	Pivot irrigation	11/16	100’
29	HC-18 West	Pivot irrigation	3/17	100’
30	HC-18 East	Pivot irrigation	3/17	105’
31	HC-20 West	Pivot irrigation	11/16	113.7’
32	HC-20 East	Pivot irrigation	11/16	Refusal 105’

Table 1: CME drill and Geoprobe vadose zone location descriptions. Sites that experienced refusal were unable to reach a final depth near the groundwater table due to sediment compaction, typically in the form of cemented-sands.

Site descriptions are denoted by the letters “HC” (Hastings Core) and are followed by an identification number (1 - 20). When more than one core was taken from a single field a directional component (e.g., East, West, etc.) was added to the end of the site description. Sites HC-4 and HC-6 are located in the heart of the metropolitan area of Hastings. Sites HC-3A and HC-3B are located in a suburb west of Hastings, three miles east of the village of Juniata. HC-5 is located in the northwestern corner of a suburb five miles north of Hastings. Unsaturated zone profiles from these five sites were grouped into an urban category. After every 10 ft (~3 m) of depth a single average value of the interval was plotted to simplify data interpretation. Sites HC-1-E, HC-1-W, HC-12-E, HC-12-W are located in corn and soybean fields, their profiles were grouped into a gravity irrigated category. Sites HC-10-N, HC-10-S, HC-11-E, and HC-11-W were gravity irrigated at the time of the 2011 sampling but have since been converted into pivot irrigated cropland (Figure 1). These sites are compared in a different graph comparing averages from 2011 to 2016 profiles.

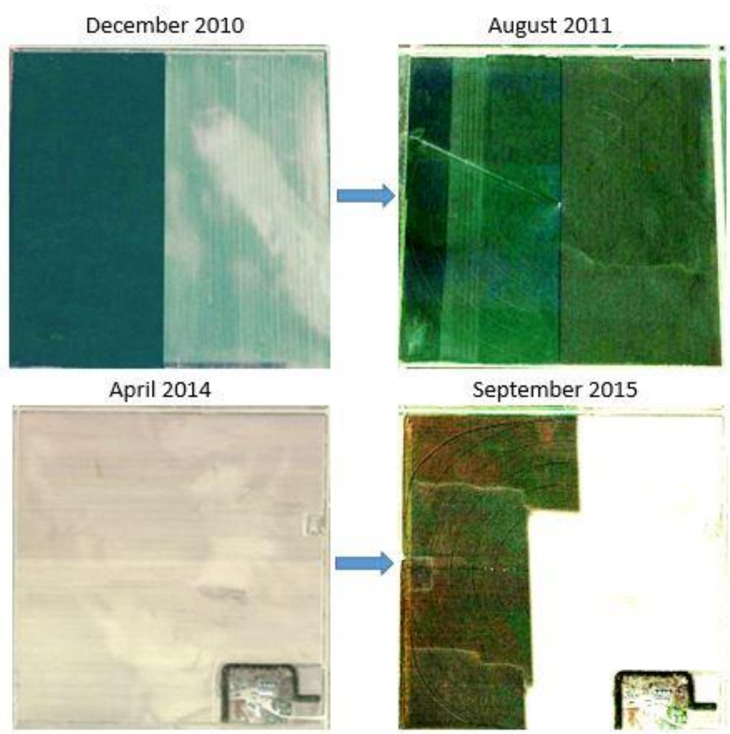

Figure 1: Conversion from gravity to pivot irrigation at sites HC-10 (top) and HC-11 (bottom).

Sites HC-14-E, HC-14-W, HC-15-N, HC-15-S, HC-16-N, HC-17-N, HC-17-S, HC-18-E, HC-18-W, HC-20-E, and HC-20-W are located in corn and soybean fields and will be grouped into a pivot irrigated category. Site HC-13 was not included in the land use comparisons due to uncharacteristically high nitrate-N in the top 30 ft. Urban sites were cored using a Geoprobe to preserve lawns. They experienced refusal (defined in Table 1) around 65 ft, preventing comparisons beyond this depth. For this reason, comparisons of the urban category to cropland will be made using only the top 65 ft. Continued sampling of these sites will allow for better estimations of changes in nitrogen storage over time and help further determine how different types of land use and irrigation methods influence nitrogen movement.

2.1 Literature Review

2.1.1 Trends in Nebraska's agricultural nitrogen use

The importance of fertilizer monitoring has been more widely implemented with the increased awareness of nonpoint source environmental impacts (Nielsen & Lee, 1987). A lack of consistent data in the past has made it more challenging to quantify the relationship between fertilizer application and groundwater contamination. However, over the years many agricultural practices have changed, putting highly-vulnerable regions such as those getting their drinking water from unconfined alluvial aquifers at risk for higher rates of groundwater contamination (Nielsen & Lee, 1987). A 1987 study found that per-acre use of inorganic nitrogen fertilizer in the United States doubled from 1965 to 1984 (Nielsen & Lee, 1987). In the Central Platte Valley (Figure 1), application rates in 2012 were 170 lbs-N/acre, roughly 30 lbs-N/acre higher than Central Platte NRD recommendations (Hard & Ferguson, 2015).

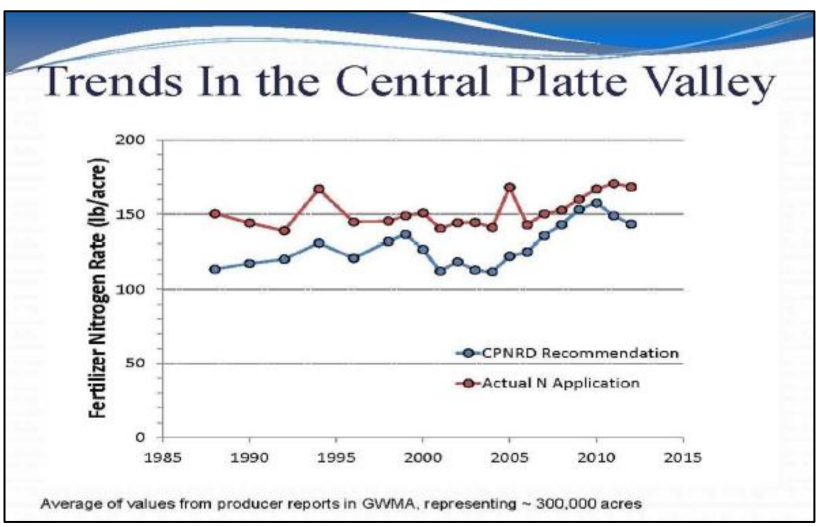

Figure 2: Trends in nitrogen fertilizer application rates in the Central Platte Valley (Hard & Ferguson, 2015).

A study done in 1979 used isotopes to trace the primary source of nitrogen contamination in groundwater wells in this area (Gormly & Spalding, 1979). Groundwater samples from 183 wells were collected over a two-year period and concentrations of $\delta^{15}N$ were traced back to their parent source (Figure 3). The primary source of contamination in most wells was from commercial applications of anhydrous ammonia (NH_3) and urea (CH_4N_2O). Areas with high clay content were more impermeable to leaching and more impacted by animal wastes. Because fertilizers are a source of nitrate-N in groundwater, their management is crucial to protect public supply wells.

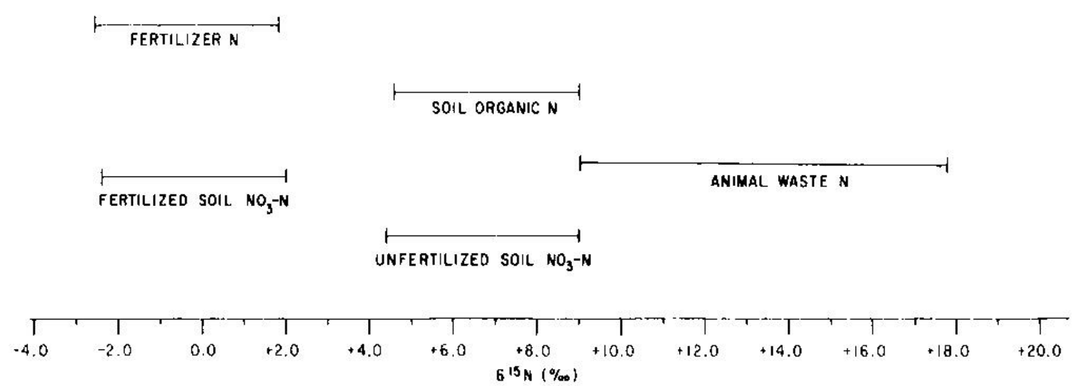

Figure 3: Isotopic ranges of potential nitrate-N sources in the Central Platte Valley. The largest fraction of $\delta^{15}N$ found in most groundwater samples was traced back to commercial fertilizers (Gormly & Spalding, 1979).

2.1.2 Agriculture and groundwater quality

A past study found that 74% of Nebraska's counties are impacted by contaminated groundwater pumped from public supply wells (Nielsen & Lee, 1987). In the Central Platte Valley, groundwater nitrate-N concentrations decreased 3 mg/L between 2005 and 2015 (Hard & Ferguson, 2015). However, average concentrations in 2012 were still above the MCL for drinking water regulations at 15 mg/L.

Cropland in Nebraska often requires large inputs of fertilizer because of the repeatedly excessive production of corn and soybeans (Hard & Ferguson, 2015). This trend in mass production leaves the soil less productive, requiring more nitrogen-based fertilizer be applied to maintain yields. Applied nitrogen leaches past the root zone most commonly in the spring seasons, when the majority of farmers apply the bulk of their fertilizer (M. R. Burkart & Stoner, 2007).

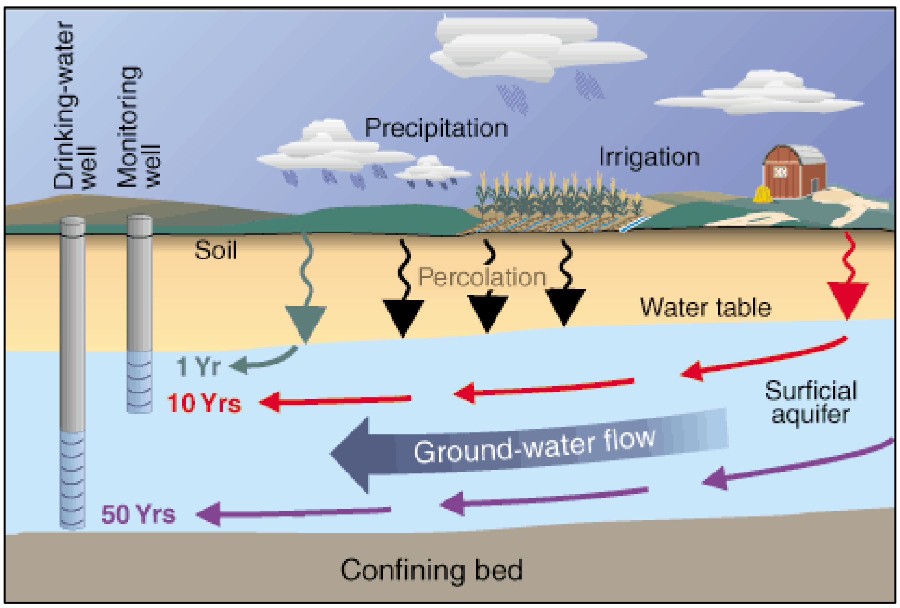

Figure 4: Irrigation increases the recharge rate of aquifers underlying the vadose zone and can influence groundwater quality (USGS, 2016).

Groundwater under highly-permeable sediment can be more vulnerable to leached agrichemicals (Adelman et al., 1985). If the groundwater is surrounded by large areas of agricultural land they become even more influenced by leached fertilizers (M. Burkart & Kolpin, 1993). A 1993 study found that groundwater sampled from wells surrounded by more than 25% corn and soybean fields had nitrate-N values 30% greater than less intensive agricultural regions (M. Burkart & Kolpin, 1993). The study also found that the frequency of groundwater contamination is greater when irrigation is used within 1.9 miles (3.2 km) of a well. Irrigation inputs increase aquifer recharge (Figure 4) and over-irrigated agricultural land is one of the largest contributors to nitrate in groundwater (Adelman et al., 1985).

2.1.3 The impact of land use on nitrogen leaching

Irrigation usage and efficiency can influence leaching in both rural and urban settings. In Nebraska, most groundwater nitrate-N comes from intensely irrigated cornfields (Hergert & Shapiro, 2015). As mentioned in Section 2.1.2, leaching of fertilizers in agricultural fields becomes greater with excessive irrigation (Adelman et al., 1985). Leaching can also occur in urban irrigated lawns, golf courses, and gardens making urban areas another source of groundwater nitrate-N (Hergert & Shapiro, 2015). Residential and agricultural irrigation technologies vary by location, management, and available resources. Two commonly used methods of agricultural irrigation are gravity (e.g., drip irrigation) and pivot (e.g., sprinkler irrigation). Human water use and management practices have large influences on nitrate-N and pesticide leaching from the root zone (Anderson Jr., 1993). For this reason, understanding irrigation management can help provide insights as to why high concentrations of nitrate-N in groundwater are common in certain agricultural and residential regions.

Throughout the years, both agricultural and residential irrigation systems have changed. Overall, irrigation management and irrigation systems in Nebraska have improved with the expansion of irrigated land in the Great Plains (Howell, 2001). The quantity of irrigation systems being used has also changed, with a 13% increase in pivot irrigation from 1979 to 1994 (Figure 5). Within this time period, the use of drip irrigation also increased from 0.6 - 4% (Howell, 2001). Large increases in the overall use of irrigation systems can be attributed to higher crop demands and improvements in technology. Subsurface drip irrigation involves installing drip lines 6 - 12 in. below the surface, allowing for a rapid uptake of water at the rooting zone (Wortmann et al., 2004). Soil type, density, and water content often vary throughout an irrigated field, creating uncertainty when it comes to application rates (Hanson et al., 2008).

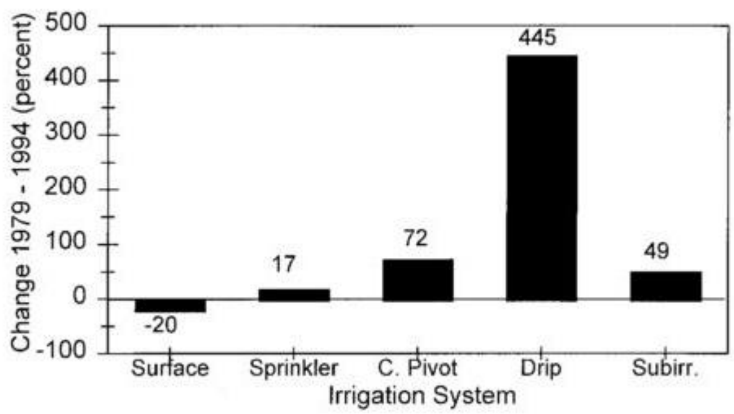

Figure 5: Percentage change in irrigation system usage in the USA from 1979 to 1994 (Howell, 2001).

Pivot irrigation makes up 67% of the irrigation systems in South Central Nebraska (Hergert & Shapiro, 2015). Pivots provide water through an overhanging sprinkler system spanning a width of 155 - 180 ft. A single pivot can cover an area of 124 acres and is preferred when it comes to meeting crop water use demands while limiting ponding and runoff. Variable rate pivots use additional technology to do this in a more precise way by adjusting the water output at each sprinkler head or by adjusting the movement rate of the pivot. This can help account for varying water demand throughout the field where soil types, low elevation areas, and areas with overlapping pivots may have different demands.

Properly managing irrigation is key to avoiding nitrate-N and other contaminants from leaching past the root zone. Pivots should be operated at a greater system capacity in certain conditions. Sandy soils hold less water and require a greater system capacity than fine-textured soils (Hergert & Shapiro, 2015). Efficient pivot usage also depends on water application uniformity, which can be achieved through proper spacing and height of the sprinkler heads. Reducing runoff during application periods can be avoided by applying at a rate below the soil-water infiltration rate. Drip irrigation systems can also be more efficiently managed to reduce nutrient leaching (Hergert & Shapiro, 2015). The integration of furrows that flow into reuse pits can keep contaminated runoff from infiltrating past the root zone and allow the water to be reapplied to the field. However, a lack of variable rate developments and other issues make drip irrigation more challenging to manage than pivot systems. Water from driplines is applied below ground, resulting in increased deep percolation loss and nitrate-N leaching. Leaks and clogs in the driplines can decrease efficiency. A 2008 study found that spatially varying subsurface soil wetting patterns under driplines are often the primary cause of leaching (Hanson et al., 2008). Properly maintained equipment and an understanding of soil infiltration rates is key to reducing leaching from drip and pivot irrigation.

Due to urban population growth and increases in lawn irrigation, nitrate-N leaching in residential areas is a concern. Landscape irrigation makes up 40 - 70% of household water use (St. Hilaire et al., 2008). Automatic in-ground irrigation is the predominant method used by residential homeowners (Haley et al., 2007). As residential water demand is expected to continue increasing with urbanization, properly managing residential irrigation systems plays an important role in protecting groundwater. In a 2007 study, average monthly water use was compared across three different residential irrigation treatments (Haley et al., 2007). A treatment that used irrigation controllers to control water input according to general seasonal demands resulted in less water being over-applied. A 2008 study found that providing real-time information to consumers on their usage via digital readers helped motivate customers to reach more efficient water use targets (Kenney et al., 2008). Application efficiencies for both hand-move and in-ground systems were researched in a 1984 study (Jafari & Willardson, 1984). The different applications had efficiencies of 30% and 37% respectively. Homeowners in the study were generally unaware of specific water input requirements of their lawns and did not measure the quantity of water they were applying. In a 2002 study, information made available to consumers regarding hourly water consumption and improved communication from utility providers helped prevent over-irrigating (Zhou et al., 2002). These strategies are particularly useful in times of drought and when social and economic stress is heightened.

Certain geographic regions are more vulnerable to nitrate-N leaching than others. For instance, areas west of the Missouri River with well-drained soils are often heavily irrigated (R. F. Spalding & Exner, 1993). The previous study found that more than half of the wells exceeding the 10 mg/L MCL for nitrate-N in Nebraska were characterized by irrigated corn and well-drained sandy soils. Variability and intensity of rainfall make irrigating in most parts of this region a necessity (Gilley et al., 1982). It also makes it more difficult for the farmer to control the proper timing and amount of water being used to irrigate. A 1993 study found groundwater nitrate-N concentrations in Minnesota's Anoka Sand Plain Aquifer (Figure 6) were significantly higher at irrigated sites than non-irrigated (Anderson Jr., 1993). This emphasizes the importance of coordinating the timing of irrigation along with fertilizer applications.

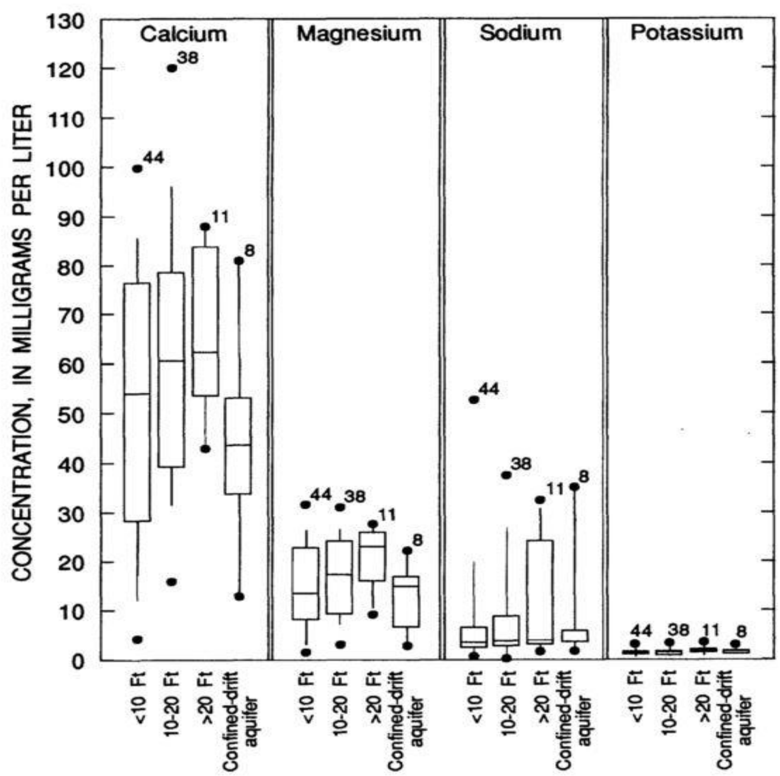

Figure 6: Concentrations of groundwater nitrate-N by land use in the Anoka Sand Plain Aquifer (Anderson Jr., 1993).

Contrary to popular belief, the difference between urban and rural groundwater nitrate-N concentrations tend to be small (Wakida & Lerner, 2005). Groundwater contamination in urban areas typically come from wastewater, solid waste disposal, and fertilizer applications. Fertilizers used in urban horticulture can be a significant source of groundwater nitrate-N in urbanized areas (Wakida & Lerner, 2005). A 2017 study found that rapid growth of residential land had increased pools of reactive nitrogen in lawns (Raciti et al., 2017). Housing density and the availability of nitrate-N in residential soils can be useful indicators of groundwater quality at a landscape scale. The amount of leaching in residential locations depends on factors similar to those of agricultural regions. Management practices, water input, and land use within an urban environment are all factors impacting leaching potential.

2.1.4 Chemical transport and fate of nitrate-N in the vadose zone

Nitrate-N follows a complex process of transformations during its journey through the vadose zone. The process starts with an application of a nitrogen fertilizer such as urea (CH_4N_2O), ammonium nitrate (NH_4NO_3), or more commonly anhydrous ammonia (NH_3) (Adelman et al., 1985). Anhydrous ammonia is applied as a gas and can be lost to the atmosphere during the application process. The process of hydrolysis converts the fertilizer to ammonium-N. Ammonium-N can be converted back to ammonia and lost to the atmosphere through the process of volatilization. Remaining ammonium-N in the soil gets converted to different forms of nitrogen. Ammonium-N can be immobilized through its transformation into organic nitrogen by soil bacteria.

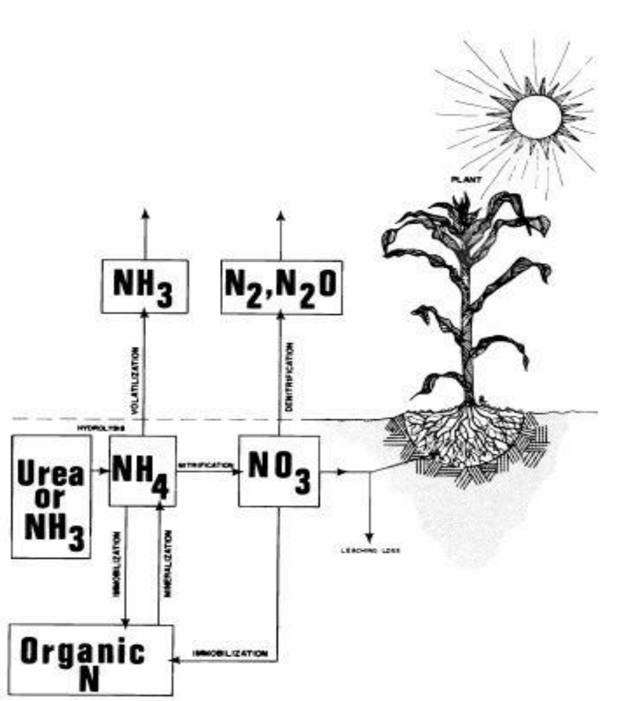

Figure 7: A portion of the nitrogen cycle as it occurs in an agricultural region (Watts & Martin, 1982).

Nitrogen that sorbs to soil organic matter is not likely to leach past the root zone (Adelman et al., 1985). Over time, this organic matter can decay and soil microbes can convert the tied-up nitrogen back into ammonium-N through mineralization (Figure 7). Excess nitrate-N ideally remains in the soil as residual nitrate-N where it can be taken up by crops or converted into the gaseous phases N_2 and N_2O through microbial denitrification. Denitrification is favored in anaerobic conditions when in the presence of organic matter (Adelman et al., 1985). Fine-textured soils in large unsaturated zones prohibit oxygen diffusion, leading to more denitrification. The likelihood and rate of these processes are dependent upon variables such as time, application rate, moisture, and temperature. The reality is that most excess nitrate-N becomes lost to the plant and leaches through the soil to the groundwater table (Hoover & Oscar, 1982).

Nitrate-N that leach past the root zone commonly travel in slugs known as pulses. This is because nitrate-N that accumulates in the root zone rapidly leach with heavy irrigation or rainfall inputs, creating a wetting front that mobilizes the previously immobilized concentrations of nitrate-N and moves it further through the vadose zone. The UNL Sandhill's Agricultural Laboratory found that up to 89 lbs-N/Acre/yr (100 kg-N/ha/yr) leached beyond the root zone in cropland receiving excessive inputs of nitrogen fertilizer (Hergert, 1982). A 1988 study done near Clay Center, NE found that vadose zone nitrate-N accumulations approximately doubled at plots with each 100 lbs-N/Acre/yr increase in N-fertilizer (R. F. Spalding & Kitchen, 1988). Groundwater nitrate-N concentrations in capture zones will continue to increase if recharge water contains high concentrations (R. Spalding & Toavs, 2011). It often takes numerous large water inputs over multiple years for nitrogen pulses in the unsaturated zone to reach the groundwater table. In a 1993 study, movement rates of nitrate-N in fine-textured sediments were determined to be 30 in./yr (Bobier et al., 1993). Once the nitrate-N reaches the groundwater they tend to stratify in the upper portion of the saturated zone before mixing with deeper groundwater (Adelman et al., 1985). Denitrification in this region can also occur under similar conditions to those mentioned in the vadose zone. Soil characteristics relating to nitrate-N concentrations are directly related to water flux (M. Burkart & Kolpin, 1993). For this reason, understanding fluid transport rates is necessary to understand chemical transport in the vadose zone.

2.1.5 Farmers' best management practices (BMPs)

Improper and excessive fertilizer use is the main driver of groundwater contamination in agricultural areas. To reduce leaching past the root zone, farmers can account for crop nitrogen needs by setting realistic yield goals, applying the appropriate form/amount of fertilizer and making applications when the crop can most effectively uptake the nutrients (Waskom & Bauder, 2011). Proper timing of fertilizers will increase yields while reducing nutrient loss. Timing can be tricky due to varying plant nutrient uptake rates throughout the season and fluctuating soil moisture conditions. Fertilizers applied in the Midwest during fall are dormant longer, making them more susceptible to leaching in areas with high fall and winter precipitation. Applying nitrogen in smaller increments immediately before and during the crop season improves uptake efficiency and reduces potential for nutrient loss.

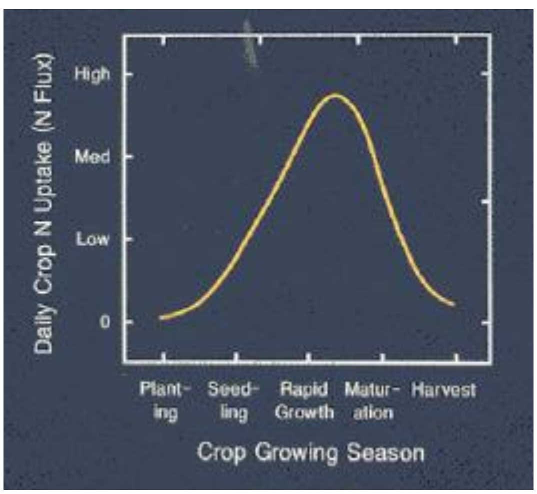

Figure 8: Generalized pattern of nitrogen uptake for annual crops (Doerge et al., 1991).

Annual crops, such as corn (Figure 8) have the highest nitrogen demand during the middle of the growing seasons when fruiting structures are developing (Doerge et al., 1991). Proper timing of applications must also account for the lag between the time of application and the time it takes the nitrogen to become chemically and physically available to the plant roots. Nitrogen applied as urea and other mobile forms are available for root uptake within 1 - 2 days after irrigation (Doerge et al., 1991). Immobile ammonium-N and slow release nitrogen fertilizers can take 7 - 20 days to become available to the crops depending on soil characteristics. Fertilizers applied to the surface can be incorporated into the subsurface to reduce the likelihood of volatilization or surface runoff (Waskom & Bauder, 2011). The time it takes the fertilizer to become available to the crops also depends heavily on the irrigation and incorporation method. For this reason, proper application timing and dosing will vary on an operation-to-operation basis.

Determining the amount of nitrogen a crop needs is a challenging process due to the constant fluctuations in annual yields and weather patterns (Looker, 1991). Farmers tend to err on the side of over-fertilization to avoid a potential decrease in crop yield. Soil testing for residual nutrients can provide producers with season-end information regarding remaining nitrate-N for next year’s crop and help minimize over-fertilization (Waskom & Bauder, 2011). Changes in cultivation practices can contribute to lowering total fertilizer needs. A corn-soybean crop rotation can lower nitrogen application rates while allowing deep rooted crops to uptake leftover nitrate-N in the subsoil (Huang & Uri, 1993). Rotating a legume crop (soybeans) that can fix nitrogen with a non-legume crop (corn) allows fixed nitrogen to substitute for a portion of the nitrogen being applied. Cover crops planted after the primary growing seasons also have the ability to use up residual nitrate-N in the soil. They can help build organic matter in the soil and lower future fertilizer input requirements by protecting bare topsoil, thereby preventing wind and water from eroding nutrient-rich soil (Waskom & Bauder, 2011).

3.1 Methods and Research Design

3.1.1 Retrieval of vadose zone cores

Collected cores were used to help determine the impact of nitrate-N loading from potential nonpoint and point sources. The current investigation used locations previously sampled to evaluate changes in stored nitrate-N over time and, wherever possible, penetrated the entire vadose zone to better estimate accumulated nitrate-N. Sampling sites are reflected in Figure 9 and have been selected on the basis of availability for sampling, management, land use, cropping history, and location. Soil cores were collected in 2.5 ft intervals during drilling with either a CME hollow stem auger or Geoprobe Model 66DT direct push coring system. An ASTM standard guide for soil sampling from the vadose zone was utilized to ensure proper quality assurance practices (American Society for Testing and Materials, 1991). These drilling guidelines contributed to the proper capture of undisturbed cores and the avoidance of preventable sample loss.

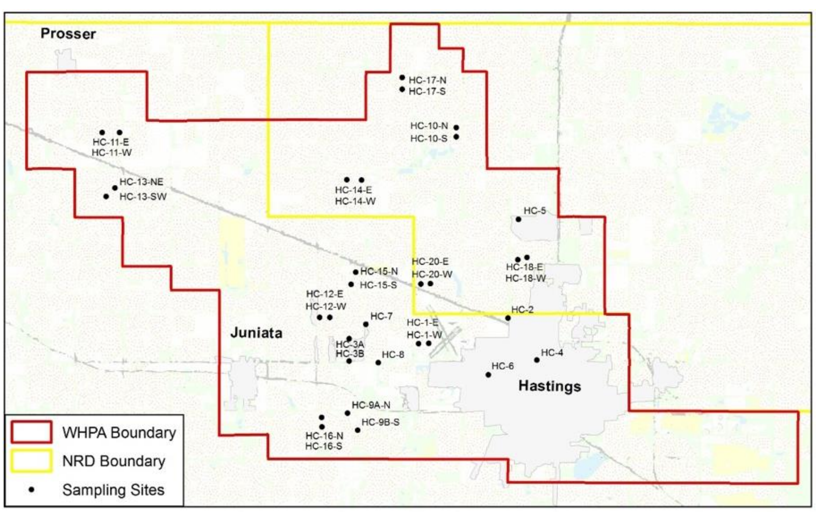

Figure 9: CME drill and Geoprobe vadose zone core locations.

Any changes in observed lithology during core collection were documented in a field notebook. Samples were collected throughout 2015 - 2017 before planting or after crop harvest. Vadose zone drilling operations were performed under the supervision of UNL's Field Service Coordinator Mathew Marxsen. All assisting staff followed a standard operating procedure (SOP) for more detailed methodology (Appendix 3).

The sampling depth in the previous 2011 study reached maximum depths of 60 ft. This was taken into consideration when comparing data from 2011 to 2016, as samples gathered in 2011 do not represent the complete vadose zone profile. In 2016 coring at residential sites required a Geoprobe for sampling, which was unable to reach the groundwater table. The maximum coring depth at these sites was 60 - 70 ft. Fourteen agricultural sites experienced refusal during the coring process (Table 1). Refusal occurs when the boring auger is unable to penetrate into deeper depths due to sediment compaction, typically in the form of cemented-sands. Since initial coring in 2011, sites HC-10 and HC-11 have changed from gravity irrigation to pivot irrigation and these locations provide an ideal opportunity to evaluate the effect of pivot irrigation on nitrate-N leaching beneath these fields.

Figure 10: Extruding a core liner from a CME drill's hollow stem auger at HC-11-W.

3.1.2 Core processing

Core processing was completed at UNL’s Water Science Lab following a SOP (Appendix 4). Soil moisture content and bulk density were determined by weighing a 0.98 in. (2.5 cm) aliquot of sample before and after drying at 221º F (105º C). Gravimetric water content was determined by taking the difference between the weights of the oven-dried soil from the initial soil and dividing by the weight of the oven-dried soil. A 0.17 oz (5 g) aliquot was mixed with 0.17 fluid oz (5 mL) of DDI water. After 10 minutes the mixture was analyzed for pH using a pH electrode.

Values for bulk density and nitrate-N are used to calculate lbs-N/Acre-ft. The calculation used is documented in Table 5. In the 2011 study, bulk density was not measured and assumed to be 1.33 g/mL for each sample (R. Spalding & Toavs, 2011). The lbs-N/Acre in each interval was calculated using the 1.33 g/mL bulk density and then summed to calculate total lbs-N/acre. This bulk density value is ideal for a silt loam soil, however the lithology of the sediment in the WHPA varies throughout the unsaturated zone. In the 2016 study, bulk density was calculated for each individual sample to more accurately represent storage potential across different lithologies. The lbs-N/Acre in each interval was calculated using the specific bulk density of that sample, along with the determined nitrate-N concentration. To calculate total lbs-N/Acre a Sigmaplot function was used to total the area of a plot generated from lbs-N/Acre and depth (Systat Software, 2015). For the 2016 study, the 2011 total lbs-N/Acre were recalculated using this same method.

Figure 11: Segments of core aliquots after being dried overnight for bulk density and moisture content analysis.

Particle size analysis was completed on half of the site locations to evaluate changes in hydraulic conductivity using an abbreviated method (Kettler et al., 2001). Determining soil particle size variation at different depths can contribute to the understanding of contaminant transport rates in the vadose zone. Using the Beaker Method, soil samples were analyzed for percent sand, silt, and clay. An ASTM standard test method for particle size distribution of soils using sieve analysis was utilized to ensure proper quality assurance practices (American Society for Testing and Materials, 2004). This method outlines sieving techniques and reagent preparation. A wide range of additional analyses were performed on select samples to allow for a better understanding of additional properties within the vadose zone.

3.1.3 Nitrate-N and ammonium-N extraction and measurement

Nitrogen content was determined using previously published methods for nitrate-N (Knepel, 2012) and ammonium-N (Hofer, 2003). Briefly, each 2.5 ft (0.76 m) interval was described and subsampled for gravimetric moisture content and divided lengthwise in half. One half was returned to the freezer for pesticide and pore water isotope measurement while the remaining half air-dried overnight. Dried intervals were homogenized in a Thomas-Wiley mill. A 0.35 oz (10 g) aliquot of homogenized sample was weighed into a flask, mixed with 3.38 fluid oz (100 mL) of 1M potassium chloride (KCl), and shaken for 60 minutes.

Figure 12: Filtering KCl extractions using a vacuum pump manifold.

Extracts were then filtered, acidified with sulfuric acid, and frozen. Thawed extracts were subsequently analyzed on a Lachat 8500 flow injection autoanalyzer for nitrate-N using QuikChem Method 12-107-04-1-B (Knepel, 2012). Ammonium-N was analyzed using QuikChem Method 12-107-06-2-A (Hofer, 2003).

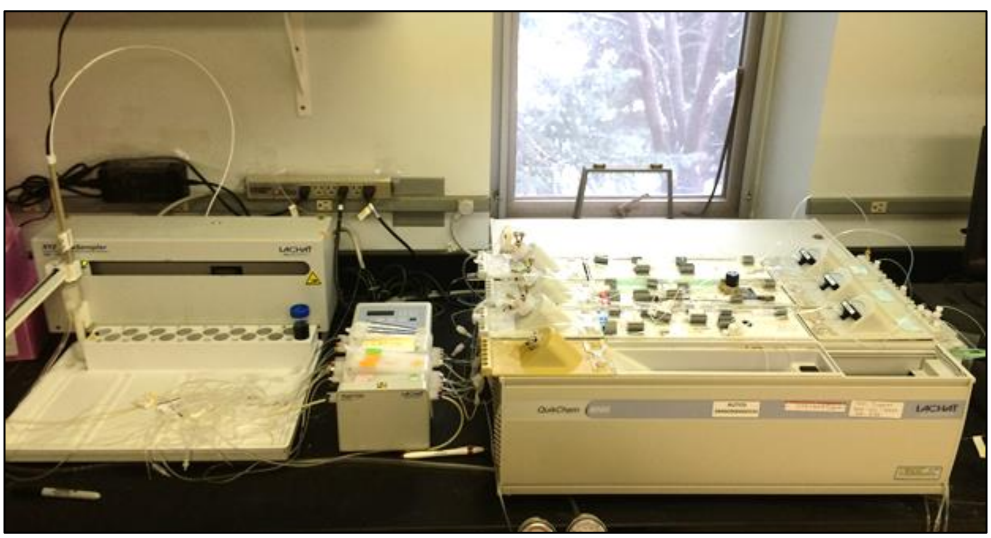

Figure 13: A QuikChem 8500 Lachat used for analyzing nitrate-N and ammonium-N.

3.1.4 Graphical analysis and interpretation of data

Graphs were created using the computer program Sigmaplot (Systat Software, 2015). Concentrations of nitrate-N, pore water nitrate-N, ammonium-N, and moisture content were graphed versus depth for each of the 32 coring locations and compared to previous profiles. Expressing nitrate-N as pore water concentration reveals where in the profile pulses of nitrate-N exceed the MCL (R. Spalding & Toavs, 2011). Textural descriptions were used to generate unsaturated zone geologic profiles to identify areas of changing hydraulic conductivity and preferential flow. Comparisons of zones of accumulated vadose zone nitrate-N may be tracked over time as they move towards and intercept the water table. Average nitrogen storage as nitrate-N was converted to lbs-N/Acre in the vadose zone to illustrate differences in accumulated nitrate-N between locations. Vadose zone profiles and accumulated nitrogen estimated in both the 2011 and 2016 study were compared and interpreted to evaluate impacts of nitrogen and water management at the surface. Land surface data was obtained and mapped for better predictions of changing land use effects, changing soil type/composition, and topography (ESRI, 2016).

Error bars reflect the standard deviation from the mean and are included for graphs representing an average value. To simplify graphs, error bars are shown only in a positive direction. However, the same error in the negative direction is present. Statistical differences between more than two groups were analyzed with a one-way ANOVA followed by Tukey's post hoc test (GraphPad Software, 2016). This test compares the mean of each group (e.g., pivot irrigated cropland, gravity irrigated cropland, and urban irrigated lawns) to one-another. This test is ideal in this scenario because there are multiple comparisons being made with no control group. A post hoc Tukey analysis was performed when ANOVA comparisons concluded there was evidence that the group means differed. This compared the differences between each pair of means using the appropriate adjustment for multiple testing (Olleveant, 1995). Statistical differences between two groups were analyzed with an unpaired t-test using Welch's correction (GraphPad Software, 2016). An unpaired test was used because two different groups were being compared. An unpaired t-test without a correction assumes that both groups have the same variances and "n" size. The Welch's correction was utilized because it would be incorrect to assume that the groups have equal variances. The denoted statistical significance on the graphs indicate a p-value ≤ 0.05, representing a 95% confidence interval. Statistics performed on the gravity irrigated category have lower statistical power due to a small sample size, relative to pivot irrigated farmland and urban lawns. This may explain the lack of statistically significant data from this category. To increase statistical power of these categories for future samplings a larger sample size of gravity irrigated sites is recommended.

4.1 Study Site

Capture zones for municipal wells northwest of Hastings, NE in Adams County were previously delineated (Hastings Utilities, 1997). The WHPA includes portions of the Little Blue and Big Upper Blue NRDs and is just south of the Central Platte NRD. Alluvial aquifers, intensive irrigation, and fertilizer demand of corn production make the groundwater in this region highly vulnerable to contamination (Nebraska Water Center, 2016). Applications of nitrogen in this area are commonly in the form of anhydrous ammonium-N. In the spring, the absorbed ammonium-N is microbially converted to nitrite/nitrate-N, highly soluble forms of nitrogen.

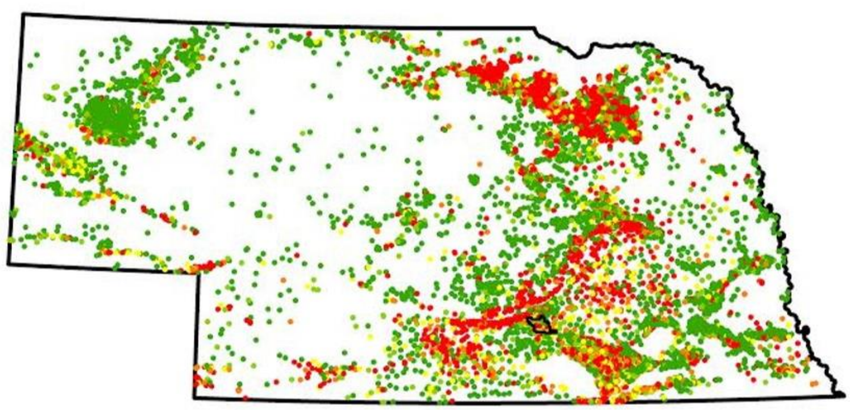

Figure 14: Groundwater nitrate-N concentrations in Nebraska and the area surrounding the WHPA using 2015 data from the Nebraska Agrichemical Clearinghouse database (University of Nebraska-Lincoln, 2000). Dark points indicate values above 10 mg/L.

Locations for vadose zone core collection and municipal supply wells within the WHPA can be seen in Figure 15. This map, along with all other ArcGIS maps, are displayed using a Lambert Conformal Conic projection. The coordinate system used is NAD_1983_StatePlane_Nebraska_FIPS_2600_Feet (ESRI, 2016). Characterization of soil characteristics, land use, and low-lying land can help municipalities detect areas that are vulnerable to nitrate-N and other contaminant leaching. Hastings, NE implemented the WHPA to protect the city's municipal supply wells. The boundary was established to represent the entire surface area where an introduced contaminant could reach a municipal well within twenty years assuming no degradation (Hastings Utilities, 1997).

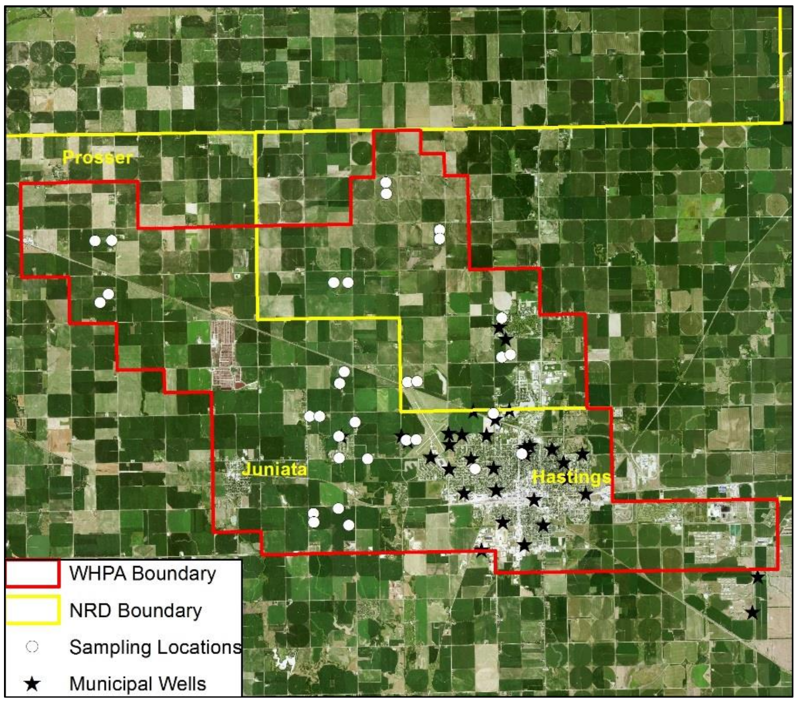

Figure 15: Natural Resource District and WHPA surrounding Hastings, NE.

4.1.1 Topography

The topography in the area of study is a mix of flat valleys running parallel to the Platte River and neighboring plains consisting of glacial, wind, and alluvial deposited sediments. An elevation map was created using a two-meter LIDAR digital elevation model from the Department of Natural Resources. Because elevation data at the sampling locations is useful, a map was created to look at elevation changes at a field-scale to acquire a more detailed resolution, identifying potential ponding locations. Elevation data from Figure 16 shows the lowest-lying areas in the southeastern portion of the map. The land surfaces gently slope south to southeast, except in the areas where streams sharply dissect the uplands (Hastings Utilities, 1997). Increasing the resolution on a site-by-site scale indicates areas where ponding may occur, activating preferential pathways and drastically expediting contaminant transport rates.

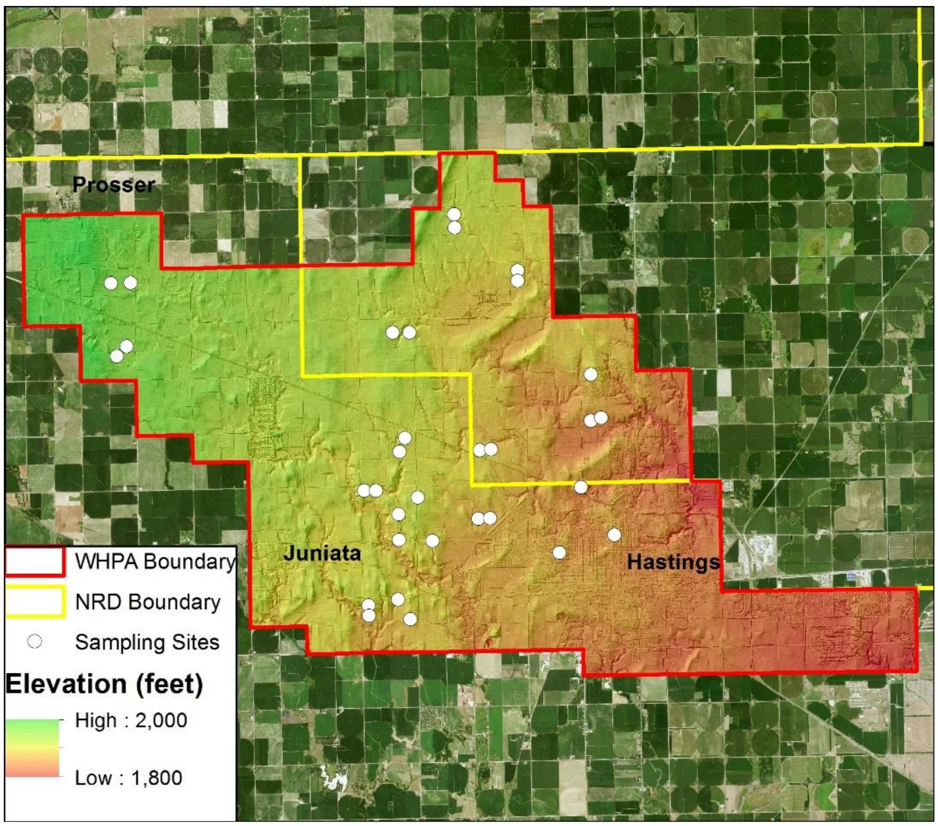

Figure 16: Elevation of the Hastings' WHPA and its surroundings.

4.1.2 Land Use

The primary land use in the study area is cropland, consisting of irrigated hybrid corn with some soybean rotation. Land use in the area consists of 61% irrigated agriculture, totaling 283 mi^2. Dryland makes up only 16%, totaling 73 mi^2. Corn makes up 56% of the irrigated and dryland agriculture in Figure 17, with soybeans being the next most widely-planted crop. Sampling locations on irrigated cropland have higher water inputs than dryland. Dryland agricultural typically only receives water from rainfall. To simplify land use depicted in Figure 17, the data was reclassified to reduce the number of categories. All dryland crops and irrigated crops were grouped together. These included alfalfa, corn, soybeans, grains, sorghum, and sunflower. Other agricultural land was combined with summer fallow. Grassland includes all ranges, pastures, and grassland. Water includes both open water and wetlands. Percentages of each land use type are displayed in Figure 18.

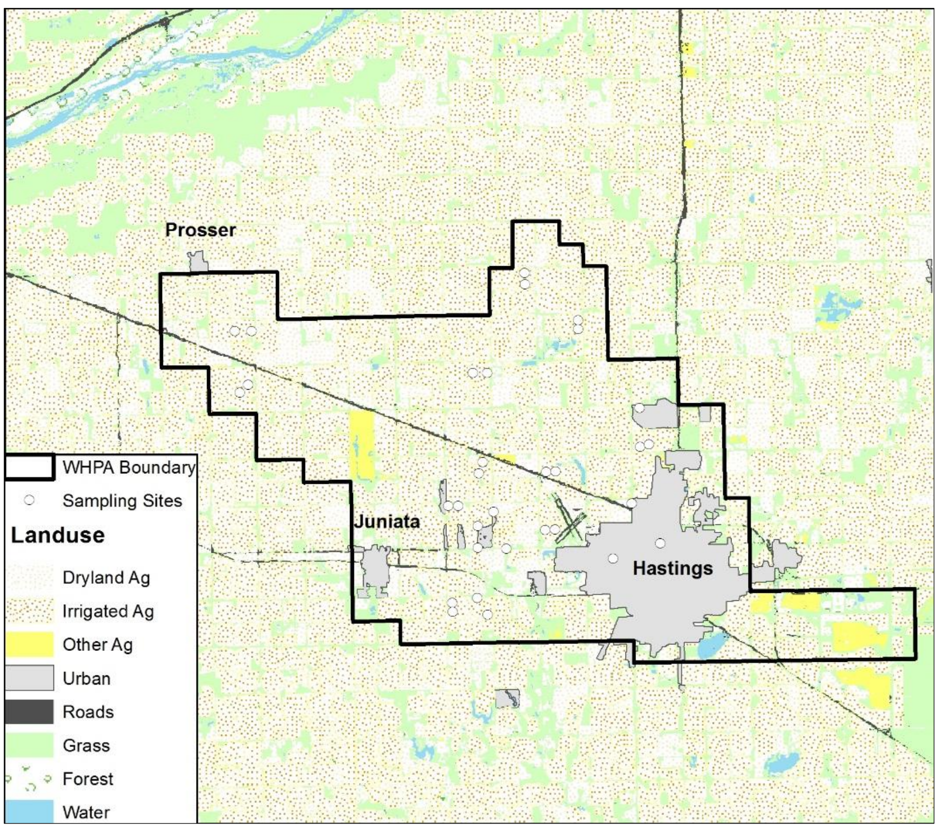

Figure 17: Land use type in the Hastings' WHPA and its surroundings.

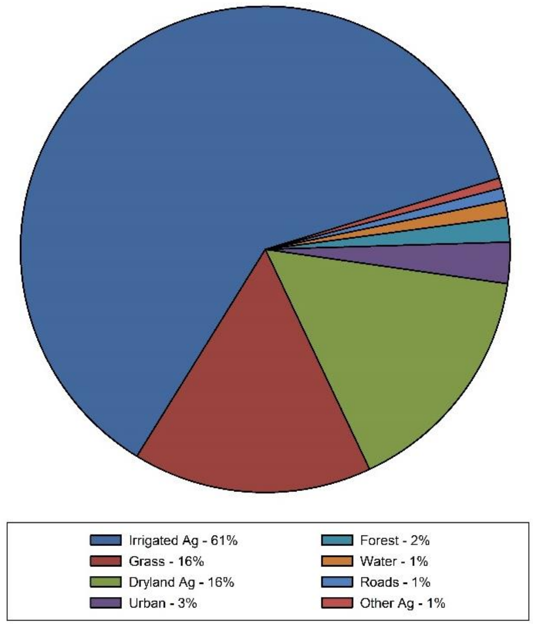

Figure 18: Proportions of land use for the Hastings' WHPA and its surroundings.

4.1.3 Geology

Soil classifications at the different sampling locations were collected using the USDA web soil survey (USDA, 2014). Residential sites are predominantly made up of Hastings silt loam. Gravity and pivot irrigated sites are made up of a wider variety, including Holder loam, Holder silt loam, Holder silty clay loam, and Crete silt loam. Hastings, Crete, and Holder series soils are all moderately well to well-drained soils formed in loess. Hastings and Crete soils have slopes ranging from 0 - 17%, while Holder soils are typically less than 4%. Mean annual precipitation to these soils is 20 - 28 in. Hastings and Holder soils are commonly found on interfluves and hillslopes of loess uplands in the Central Loess Plains. Crete soils are found in upland and stream terraces in river valleys in the Central Loess Plains. Hastings soils are fine, smectitic, mesic Udic Argiustolls. Crete soils are fine, smectitic, mesic Pachic Udertic Argiustolls.

Holder soils are fine-silty, mixed, superactive, mesic Udic Argiustolls. These soils are frequently moist October - April, intermittently moist May - July, and driest July - September.

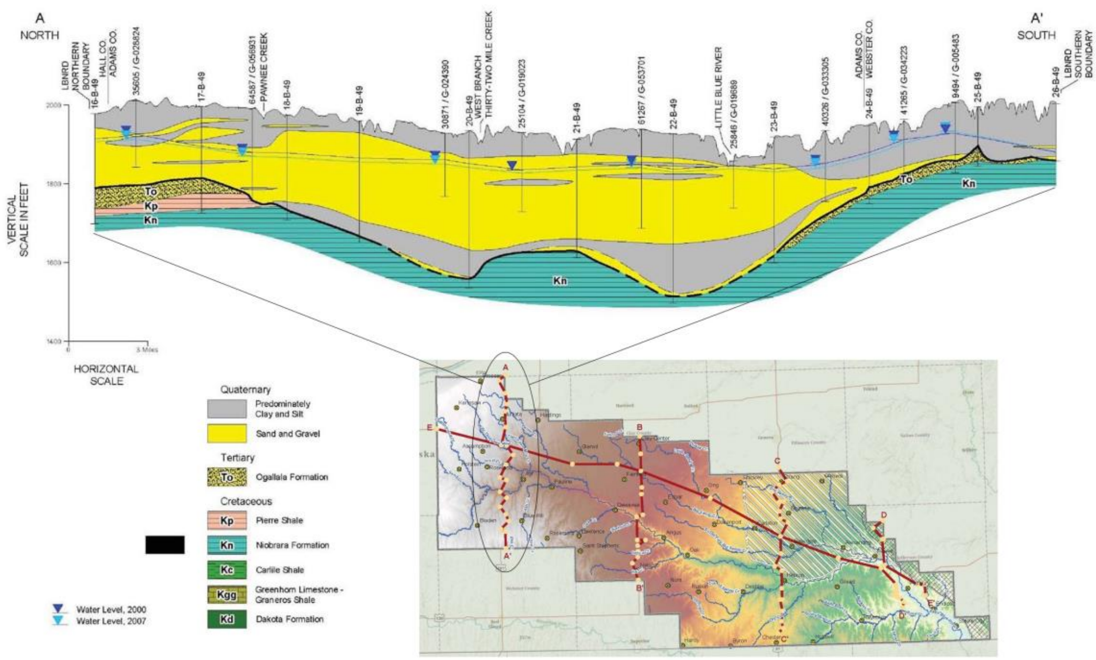

Figure 19: Location of Adams County within a Little Blue Natural Resource District cross-section constructed by JEO consulting (Little Blue NRD, 2011).

The geology of the underlying area consists of early Cretaceous-age to Tertiary-age bedrock overlain by Pliocene-age to Quaternary-age sediments (Little Blue NRD, 2011). The layering of these units is reflected in Figure 19, along with unconsolidated geology and groundwater levels. The primary materials making up the unconsolidated material that covers the bedrock consist of sand, silt, loess, and gravel. Glacial deposits are present in the eastern portion of the Little Blue NRD but may not be present in Adams County.

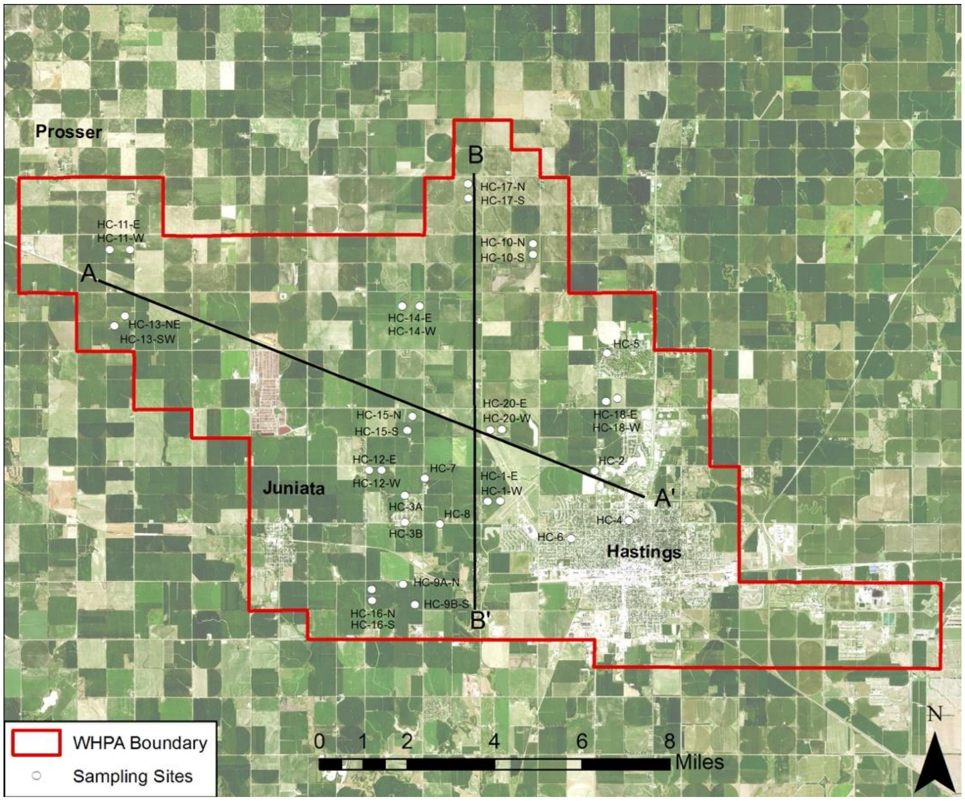

Figure 20: Map of the study site with locations of coring locations used to develop two cross-sections that display the geology of the WHPA.

In Figure 20, two additional cross-sections were generated from 16 coring locations within the WHPA. All lithologic properties used to generate the cross-sections were observed and documented during core breakdown in the lab. The A – A' cross-section generated in Figure 21 was drawn from northwest to southeast. It is ~10 miles in length, has an elevation gradient of ~100 ft, and generally follows the groundwater flow of the underlying aquifer. A number of sand lenses can be observed throughout the cross-section, but primarily in the southeastern end at sites HC-2, HC-4, and HC-20-W. The sand lenses in this area are present 70 and 90 ft below the surface. The shallowest portion of the groundwater intersects a sand layer roughly 100 ft below the surface. To the northwest, the groundwater intersects with layers of silts and clays, with alternating sand and clay layers overlying this area. The B – B` cross-section generated in Figure 22 was drawn north to south, just east of the Hastings city limit. The elevation of the ~ten-mile section increases and decreases, but generally stays at ~1,970 ft. Sand lenses can be observed primarily in the southern end at sites HC-1-W, HC-7, HC-8, HC-15-N, and HC-20-W. Similar to Figure 21, these lenses are present at 70 and 90 ft below the surface. This region along with the far northern section containing HC-17 has an additional sand lens present 30 ft below the surface. The shallowest portion of the groundwater intersects a sand layer 100 ft below the surface, extending the length of the cross-section. Throughout the unsaturated zone alternating clay and silt layers are present, with an average thickness of roughly 10 ft. Numerous deposits of alluvial clay and eolian silt and sand were too thin to be represented in Figure 21 and Figure 22.

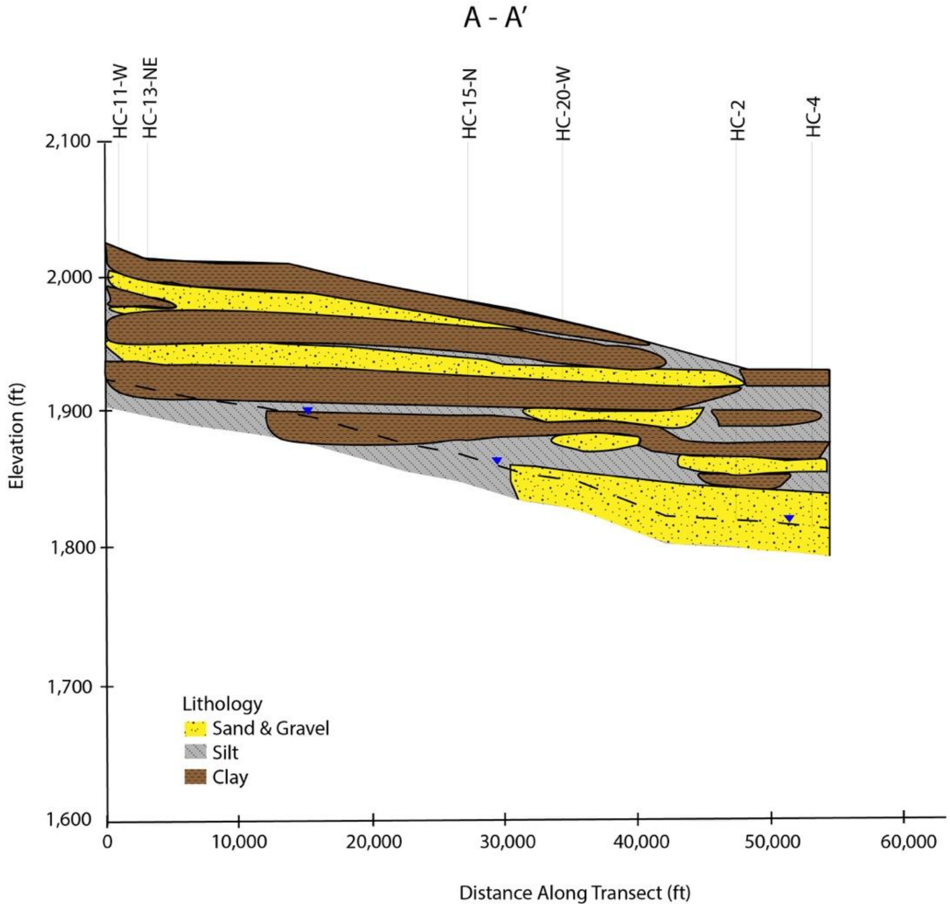

Figure 21: Lithologic cross-section of A – A'.

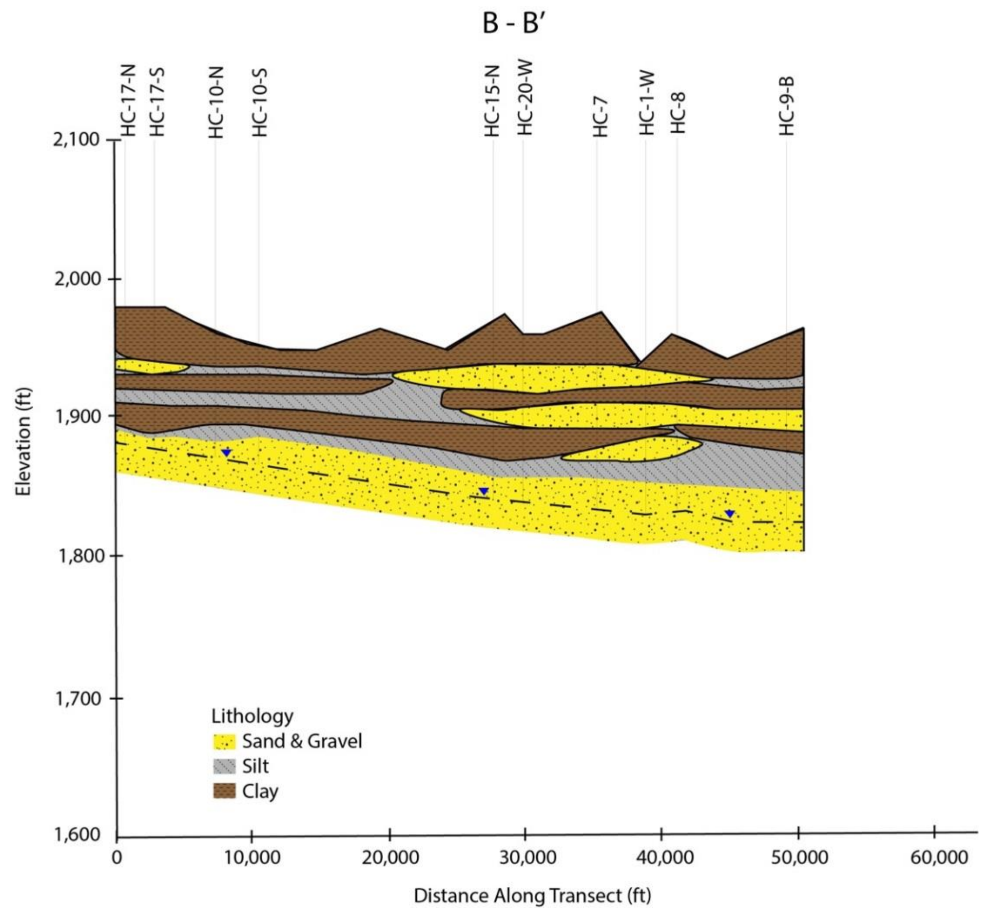

Figure 22: Lithologic cross-section of B – B'.

Sediment type and soil organic matter content for Adams and Hall County were made available by the USDA Soil Survey (Soil Survey Staff, 2017). Spatial and tabular datasets from this website were combined and projected in ArcGIS using a USDA soil data viewer extension. Soil organic matter is the plant and animal residue that is left in the soil after decomposition. The estimated content of organic matter in Figure 25 is expressed as a weighted average of organic matter in soil that is less than 0.04 in. (2 mm) in diameter. All layers were included in the depth range. The values are expressed as a weighted average throughout the entire map unit.

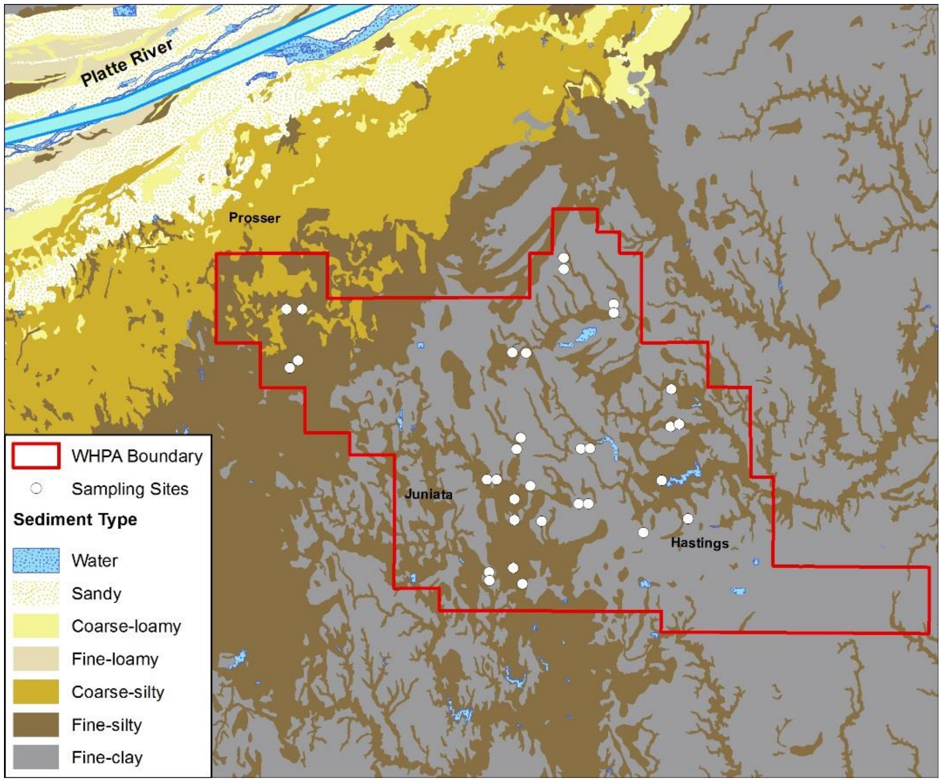

Figure 23: Sediment texture classifications in the Hastings' WHPA and its surroundings.

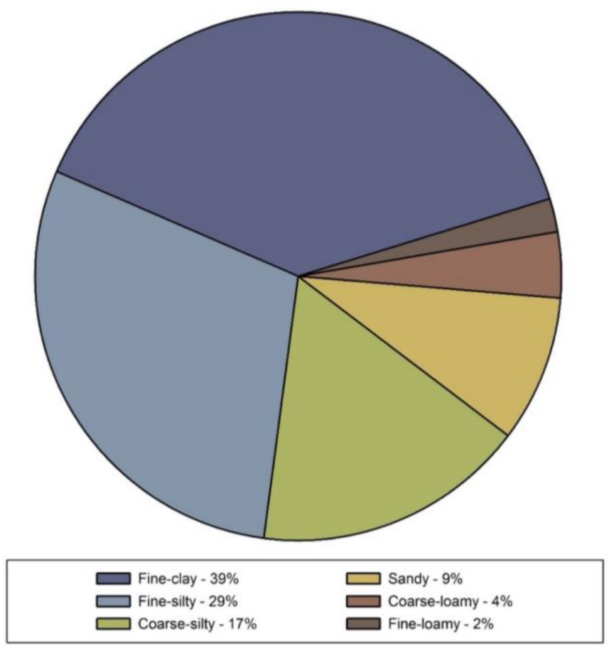

Figure 24: Proportions of sediment texture classifications for the Hastings' WHPA and its surroundings.

Sediment texture was mapped using a "Soil Taxonomy Classification" tool provided by the USDA soil data viewer extension. The classification is based on soil properties observed in the field and from laboratory measurements (Natural Resources Conservation Service, 1999). The original data contained an order, suborder, great group, subgroup, family, and series. To simplify the map, the data was reclassified using sediment family (e.g., silty, fine clay, etc.). Texture in the WHPA is highly variable, making fluid transport predictions challenging. The sediment is generally sandier closer to the Platte River, visible in the northwestern corner of Figure 23. Moving southeast, the sediment is siltier before giving way to fine clay. The profile in this area is complex, often containing lenses of sand, silty, and clay throughout. As shown in Figure 24, clay sediments make up 51 mi^2 of the area, 39% of the area of interest. These areas have smaller pore spaces, making the sediment less hydraulically conductive and slowing fluid transport. Sandy sediments make up only 40 mi^2, 9% of the total area.

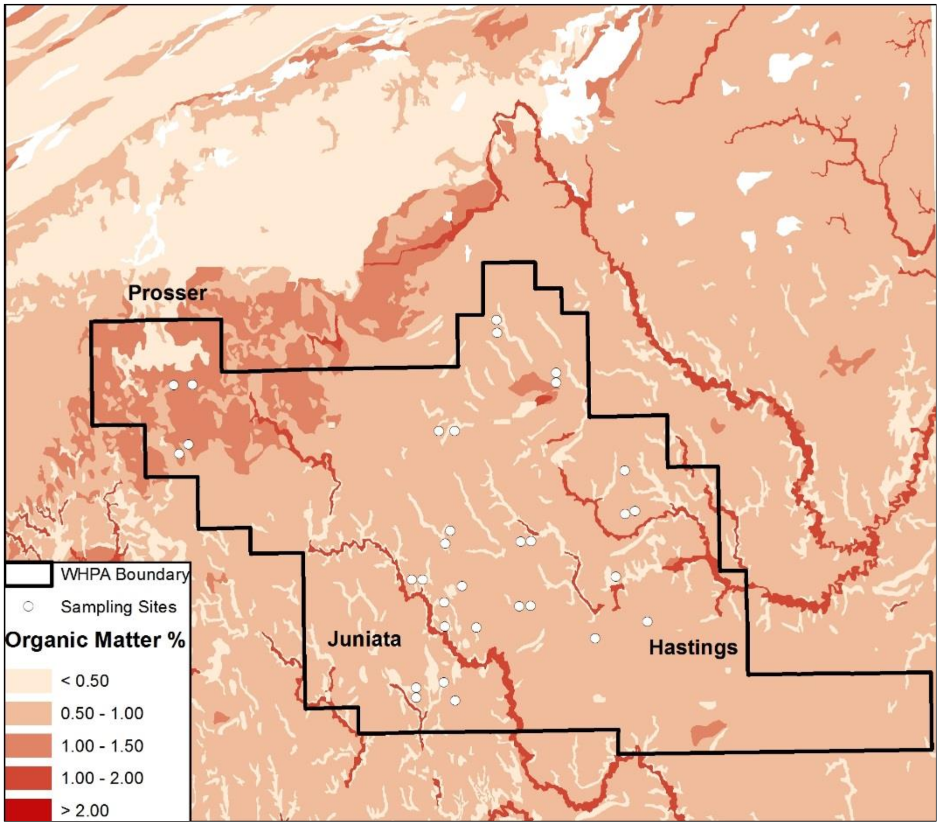

Figure 25: Soil organic matter expressed as a weighted average for all soil layers in the Hastings' WHPA.

Areas with higher amounts of soil organic matter could increase potential for denitrification at the surface. Ammonium-N can sorb to organic matter, preventing its downward movement. Areas in the northwestern section of the WHPA in Figure 25 have higher percentages of organic matter, around 1 - 2%. This may be due to alluvial deposition from the Platte River, which can be seen in Figure 26. Alluvial deposition would also explain the higher amounts of organic matter in the small streams and rivers that flow in the southeastern portion of the map. Sites HC-14 and HC-16 are located in areas containing <0.5% organic matter.

4.1.4 Hydrogeology

The city of Hastings, NE utilizes municipal wells, which pump directly from the High Plains Aquifer. Beneath the WHPA, the thickness of the unconsolidated aquifer is roughly 100 ft. Below the aquifer lies the Ogallala bedrock formation, containing unconsolidated deposits of Pleistocene-age and semi-consolidated deposits of Tertiary-age sand, silt, and clay (Little Blue NRD, 2011). This formation covers one-fifth of Adams County (Keech & Dreeszen, 1968). Originally, these sediments most likely covered the entire area, but erosion from streams removed a large portion of deposits in Central Nebraska. The bedrock primarily contains lenticular deposits of sandstone, shale, chalk, and limestone (Hastings Utilities, 1997). No major faults exist in the study area that would impact the hydrogeology.

Groundwater travels into Adams County from adjoining areas to the north, west, and south (Keech & Dreeszen, 1968). Groundwater movement is augmented by precipitation, irrigation water, and well-withdrawals. Water pumped from the aquifer would otherwise move toward the Little Blue River valley and be discharged through evapotranspiration, seepage into the Little Blue River, or movement east as sub-surface outflow. The amount of groundwater being pumped from the aquifer reflects heavily on changes in irrigation rates due to seasonal differences in climate. A 1968 study sampled wells in Adams County for dissolved solids (Keech & Dreeszen, 1968). Dissolved solids ranged from 100 - 300 ppm, water in sandy soils had much lower concentrations than in areas with fine-textured soils. The groundwater composition was characterized as calcium bicarbonate type, some with increased hardness due to calcium and magnesium.

Unsaturated thickness maps were created using water table contours from a 2012 Cooperative Hydrology Study (COHYST) dataset and a two-meter LIDAR digital elevation model from the Department of Natural Resources. It is noted that groundwater levels fluctuate over time, so the present-day unsaturated thickness may vary. The thickness in the alluvial valleys of the Platte River and the Little Blue rivers can be less than 10 ft thick. Thicker unsaturated zones can lengthen fluid transport rates, making the groundwater less vulnerable to certain contaminants. A previously drilled well three miles west of Juniata had an unsaturated zone as deep as 150 ft (Keech & Dreeszen, 1968). Of the 32 sites cored, residential sampling sites HC-3A and HC-7 have the deepest unsaturated zones, at 130 ft. Pivot irrigated sites HC-10-N and HC-10-S have a thickness of only ~80 ft.

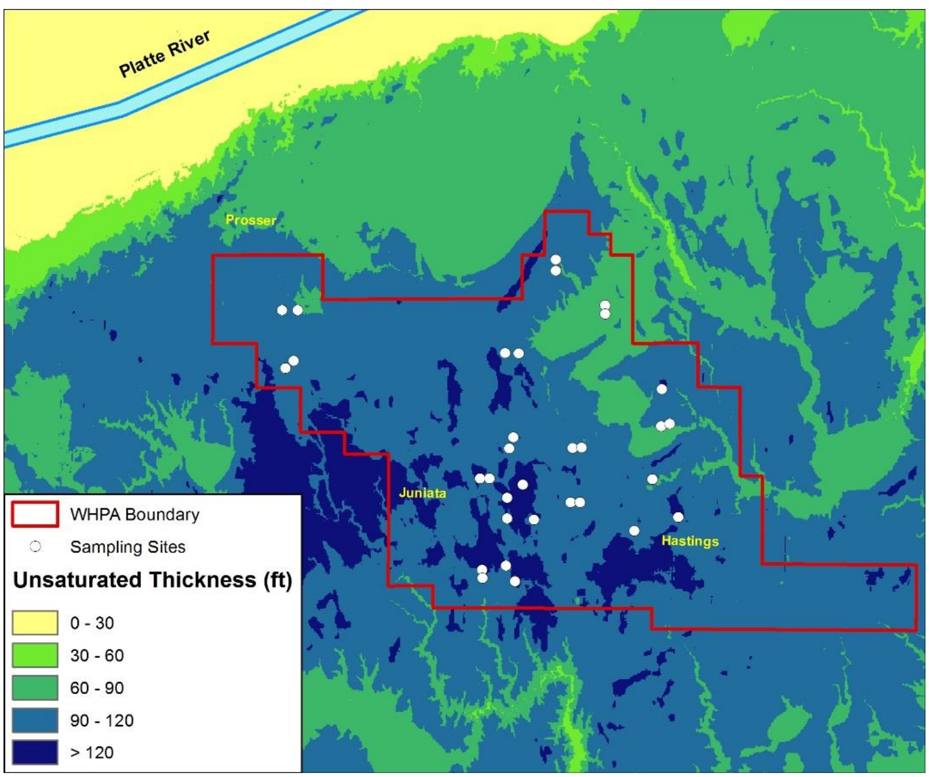

Figure 26: Unsaturated thickness in the Hastings' WHPA and its surroundings.

The average rate of horizontal groundwater flow in Adams County ranges from 0.5 - 1 ft/day (Keech & Dreeszen, 1968). Water levels of some monitoring wells within the city of Hastings, NE fluctuate greatly due to large pumping from the Hastings Utilities wellfield (Hastings Utilities, 1997). Spatial changes in groundwater nitrate-N concentrations from this area were evaluated in Figure 27 using data from the Nebraska Agrichemical Clearinghouse database and were used to examine spatial changes in nitrate-N over the last 25 years (University of Nebraska-Lincoln, 2000). Between 1990 and 2000, concentrations exceeding the MCL are visible under a portion of the Platte River Valley and averaged 5.18±1.95 throughout the entire visible region. Between 2011 and 2015, the contaminated region along the Platte River Valley appears to have spread, consuming the town of Prosser. Groundwater within the WHPA starts to show high nitrate-N, with concentrations over the MCL present within the city limits of Hastings and its municipal supply wells, averaging 7.34±3.57 throughout the entire visible region.

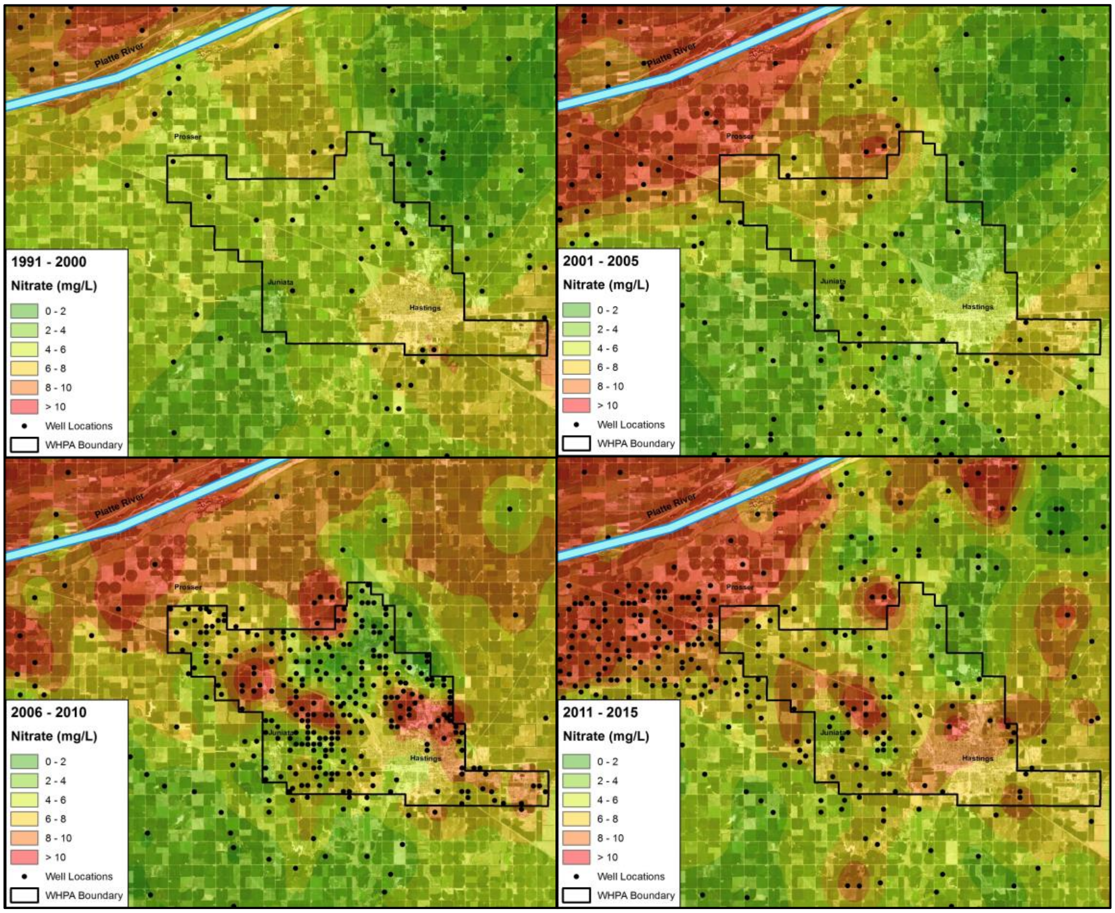

Figure 27: Changes in groundwater nitrate-N concentrations over a 25-year period in the Hastings' WHPA using interpolated data from the Nebraska Agrichemical Clearinghouse database (University of Nebraska-Lincoln, 2000).

Precipitation changes can affect nitrate-N accumulation and transport rates in the vadose zone. Average annual precipitation within the study area from 1941 to 1970 was found to be 25 in. (Hastings Utilities, 1997). During early 2012 through summer 2013, much of Western and Central Nebraska experienced drought. Precipitation totals in Hastings presented in Table 2 reflect the last eight years, with only 20 inches of rain in 2012. The average for this time period was 26 inches.

A 1997 study conducted a 50-year groundwater travel assessment in the area of study (Hastings Utilities, 1997). It is estimated that it takes groundwater 50 - 75 years to travel from the Platte River to the municipal wells in Hastings. Using a modeling approach, source of groundwater within the WHPA was estimated to be 50% from the Platte River, 25% from irrigation recharge, and 25% from participation recharge.

Year	***Rainfall (in.)***
2010	26.79
2011	27.12
2012	20.49
2013	25.25
2014	29.20
2015	29.89
2016	20.66
2017	30.28

Table 2: Annual rainfall precipitation for Hastings, NE over the last eight years.

5.1 Results and Discussion

Changes in the stored nitrate-N between the 2011 and 2016 vadose zone cores are summarized in Table 3. The totals were calculated by summing the total nitrogen stored beneath each profile as total lbs-N/Acre-ft. Because of the incomplete vadose zone coring depths, sites HC-13 and HC-17 were calculated and compared using the top 45 ft, HC-3B and HC-5 using the top 50 ft, and all other sites using the top 60 ft. Nitrate-N accumulations are arranged by land use in Table 4, with calculated averages reported for each group. All single site profiles are accompanied by a lithologic profile indicated sediment type. All lithologic changes were determined in the lab and symbolized using the USCS standards represented in Figure 28.

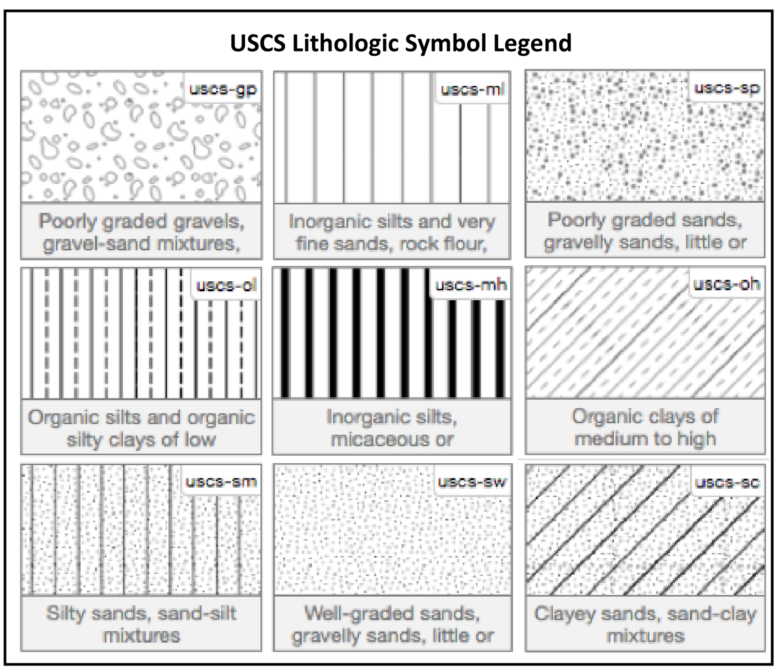

Figure 28: USCS graphics used to visualize sediment categories for lithologic profiles.

Location	*Land Use*	*2011 Total lbs-NO_3-N/Acre*	*2016 Total lbs-NO_3-N/Acre*	*Change in Total lbs-NO_3-N/acre*	*Percent Difference*
HC-1-E	Gravity irrigation	314	487	+173	+55.0
HC-1-W	Gravity irrigation	496	295	-201	-40.5
HC-2	Non-irrigated	178	172	-5.53	-3.11
HC-3A	Residential	286	562	+275	+96.2
HC-3B	Residential	124	323	+198	+160
HC-4	City Park	98.6	386	+288	+292
HC-5	Residential	255	145	-110	-43.2
HC-6	Residential	1240	36.0	-1200	-96.8
HC-7	Barnyard	292	588	+296	+101
HC-8	Barnyard	378	692	+315	+83.3
HC-9A	Pivot irrigation	270	650	+380	+141
HC-9B	Pivot irrigation	413	434	+20.4	+4.93
HC-10-N	Pivot irrigation	421	297	-141	-33.6
HC-10-S	Pivot irrigation	442	396	-45	-10.3
HC-11-E	Pivot irrigation	506	229	-277	-54.8
HC-11-W	Pivot irrigation	505	324	-181	-35.8
HC-12-E	Gravity irrigation	585	586	+1.47	+0.25
HC-12-W	Gravity irrigation	421	1380	+958	+228
HC-13-N	Pivot irrigation	306	561	+255	+83.5
HC-13-S	Pivot irrigation	829	798	-31.3	-3.77
HC-14-E	Pivot irrigation	293	236	-56.9	-19.4
HC-14-W	Pivot irrigation	411	317	-94.5	-23.0
HC-15-N	Pivot irrigation	427	801	+374	+87.6
HC-15-S	Pivot irrigation	261	539	+278	+106
HC-16-N	Pivot irrigation	249	743	+494	+198
HC-16-S	Pivot irrigation	276	437	+161	+58.6
HC-17-N	Pivot irrigation	534	228	-307	-57.4
HC-17-S	Pivot irrigation	259	331	+72.8	+28.1
HC-18-E	Pivot irrigation	404	760	+357	+88.3
HC-18-W	Pivot irrigation	483	910	+427	+88.5
HC-20-E	Pivot irrigation	357	785	+428	+120
HC-20-W	Pivot irrigation	315	472	+157	+50.0
Average	Average	395	497	+102	+51.5

Table 3: Comparisons of 2011 and 2016 total estimated stored nitrate-N (lbs-N/Acre).

Location	*Land Use*	*2011 Total lbs-NO_3-N/Acre*	*2016 Total lbs-NO_3-N/Acre*	*Change in Total lbs-NO_3-N/acre*	*Percent Difference*
HC-3A	Residential	286	562	+275	+96.2
HC-3B	Residential	124	323	+198	+160
HC-5	Residential	255	145	-110	-43.2
HC-6	Residential	1240	36.0	-1200	-96.8
Average		476	266	-209	-28.9
HC-4	City Park	98.6	386	+288	+292
HC-7	Barnyard	292	588	+296	+101
HC-8	Barnyard	378	692	+315	+83.3
Average		256	556	+300	+159
HC-2	Non-irrigated	178	172	-5.53	-3.11
Average		178	172	-5.53	-3.11
HC-9A	Pivot irrigation	270	650	+380	+141
HC-9B	Pivot irrigation	413	434	+20.4	+4.93
HC-10-N	Pivot irrigation	421	297	-141	-33.6
HC-10-S	Pivot irrigation	442	396	-45	-10.3
HC-11-E	Pivot irrigation	506	229	-277	-54.8
HC-11-W	Pivot irrigation	505	324	-181	-35.8
HC-13-N	Pivot irrigation	306	561	+255	83.5
HC-13-S	Pivot irrigation	829	798	-31.3	-3.77
HC-14-E	Pivot irrigation	293	236	-56.9	-19.4
HC-14-W	Pivot irrigation	411	317	-94.5	-23.0
HC-15-N	Pivot irrigation	427	801	+374	+87.6
HC-15-S	Pivot irrigation	261	539	+278	+106
HC-16-N	Pivot irrigation	249	743	+494	+198
HC-16-S	Pivot irrigation	276	437	+161	+58.6
HC-17-N	Pivot irrigation	534	228	-307	-57.4
HC-17-S	Pivot irrigation	259	331	+72.8	+28.1
HC-18-E	Pivot irrigation	404	760	+357	+88.3
HC-18-W	Pivot irrigation	483	910	+427	+88.5
HC-20-E	Pivot irrigation	357	785	+428	+120
HC-20-W	Pivot irrigation	315	472	+157	+50.0
Average		398	512	+114	+40.8
HC-1-E	Gravity irrigation	314	487	+173	+55.0
HC-1-W	Gravity irrigation	496	295	-201	-40.5
HC-12-E	Gravity irrigation	585	586	+1.47	+0.25
HC-12-W	Gravity irrigation	421	1380	+958	+228
Average		454	687	+233	+60.6

Table 4: Average estimated stored nitrate-N (lbs-N/Acre) of different land use types from 2011 and 2016.

5.1.1 Nitrate-N accumulations in vadose zones beneath corn and soybean fields

Nitrate-N accumulations in the vadose zone beneath corn and soybean fields ranged from 230 to 1,400 lbs-N/Acre. These sites made up the largest majority of sampled sites; 23 of the 32 cores were collected beneath cropland. These sites consisted of both gravity and pivot irrigated fields, as well as one non-irrigated field (HC-2). Nitrate-N stored within the top 6 ft of still has the potential to still be utilized by corn roots (R. Spalding & Toavs, 2011). Nitrate-N that has leached past 6 ft is not considered accessible to the crop and may travel further downward towards the water table.

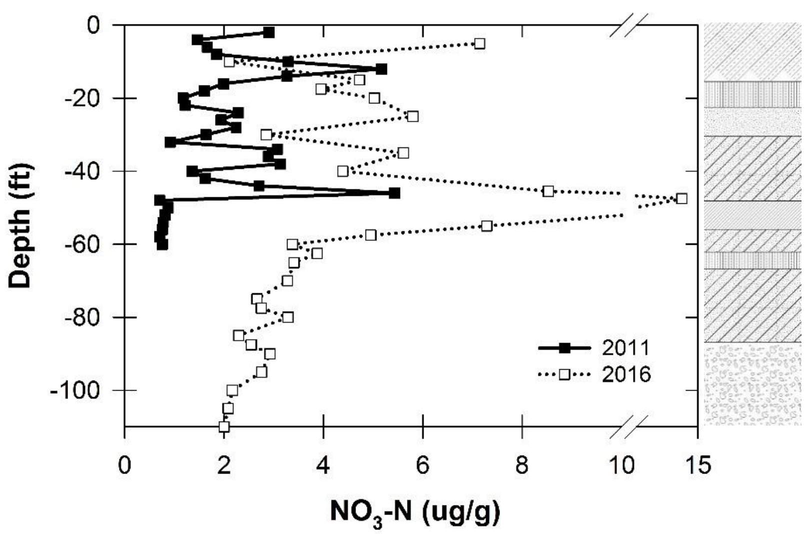

Figure 29: Nitrate-N in the vadose zone beneath gravity irrigated site HC-12-W.

Some agricultural sites showed increases in nitrate-N over the five-year sampling span, while others showed reductions. Overall, fluctuations of stored nitrate-N in producers' fields increased by 2,800 lbs-N/Acre. The average amount in 2011 and 2016 was 400±140 and 520±280 lbs-N/Acre, respectively, an increase of roughly 30%. Although totals increased, the stored amount in 2016 is similar to accumulations of nitrate-N at Clay Center, NE research plots taken in the mid-1990's underneath tilled cropland which totaled ~530 and ~620 lbs-N/Acre (Katupitiya, 1995). The largest difference was found beneath the gravity irrigated site HC-12-W seen in Figure 29, which went from 420 to 1,400 lbs-N/Acre in the top 60 ft. This site is located at the head of the field, while HC-12-E is located at the tail-end of the field. HC-12-W contained 590 lbs-N/Acre in 2016. Furrow irrigation systems present at sites like HC-12 typically have greater deep percolation of water loss at the upstream head of the field (Katupitiya, 1995). Water percolation at gravity irrigated locations like HC-12-W may be responsible for larger amounts of leached nitrate-N present in the underlying sediment. More sufficient information on irrigation rates is needed to determine with more certainty the cause for changes in stored nitrate-N at the sampling locations.

Higher rates of nitrate-N leaching at gravity irrigated sites is common due to less uniformity in irrigation water applications. This lack of uniformity can lead to furrows being over-irrigated, causing ponding of water (Hergert & Shapiro, 2015). Rapid preferential flow of nitrate-N in low-lying regions can result in excess leaching along with overall reductions in crop yields. In contrast, pivot irrigated fields apply water more uniformly. Another potential cause of increases in leached nitrate-N may be from changes in N-fertilizer application. A 1988 study done near Clay Center found that vadose zone nitrate-N accumulations approximately doubled at plots with each 100 lbs-N/Acre/yr increase in N-fertilizer (R. F. Spalding & Kitchen, 1988).

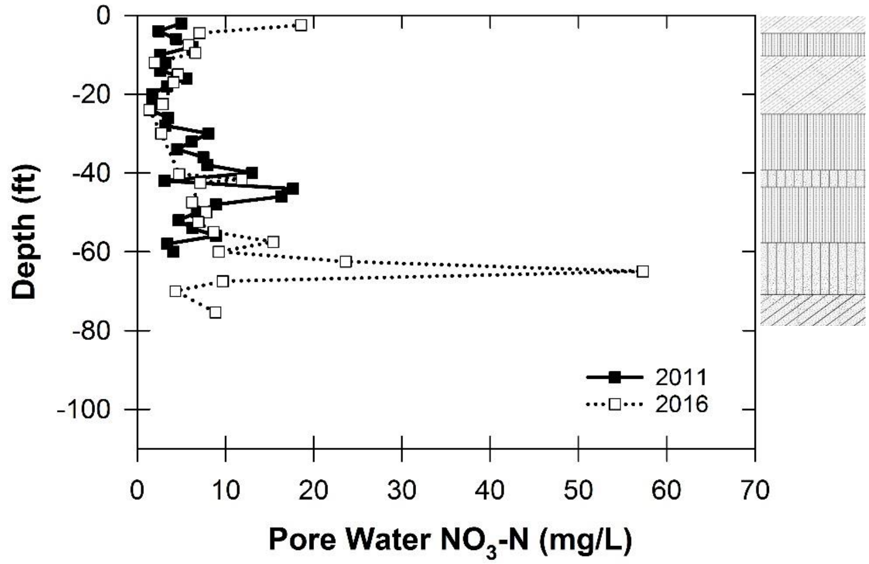

Figure 30: Pore water nitrate-N at dryland corn site HC-2.

Dryland site HC-2 showed a reduction in nitrate-N over the five-year span, although it was the smallest measured variation among all of the cored locations. The site contains an estimated 170 lbs-N/Acre in the top 60 ft, which was the lowest accumulation of comparable nitrate-N from the 2016 sampling. Maximum pore water nitrate-N was observed at 65 ft below the surface (Figure 30), otherwise concentrations were below 10 mg/L. When summing the entire 75 ft profile from 2016, the total amount of nitrate-N is still relatively low at 250 total lbs-N/Acre. A zone of elevated nitrate-N was observed in a 15 ft deep layer of silty sand. In contrast to pivot and gravity irrigated locations, HC-2 would reflect nitrate occurrence and transport beneath dryland corn. A study done in Minnesota found groundwater nitrate-N concentrations in the Anoka Sand Plain Aquifer were significantly higher at irrigated sites than non-irrigated (Anderson Jr., 1993). Based on the low totals of nitrate-N stored in the vadose zone beneath site HC-2, one could expect lower nitrate-N leaching rates from this and other dryland fields than irrigated fields.

Significant leaching from irrigated fields may be avoided if irrigation water is properly scheduled and managed (Bobier et al., 1993). Inefficient irrigation or other management practices can be responsible for higher amounts of leached nitrate-N from certain irrigated cropland locations. In a 1993 study, transport rates of nitrate-N in similar fine-textured sediments were determined to be approximately 30 in./yr (Bobier et al., 1993). If this nitrate-N transport rate were applied to the vadose zone in Hastings' WHPA we should expect to find 12 - 14 ft of vertical movement over the 5-year period between 2011 and 2016.

5.1.2 Stored Nitrate-N beneath fields converted from gravity to pivot irrigation

Irrigated agricultural sites HC-10-N, HC-10-S, HC-11-E, and HC-11-W were gravity irrigated at the time of the 2011 sampling, as discussed in Section 1.1. Between the past and recent samplings, they have been converted to pivot irrigated cropland. Ariel imagery in Figure 1 shows the irrigation change occurring sometime between winter 2010 and fall 2011. Site HC-11 appears to have converted to pivot irrigation between spring 2014 and fall 2015. Before being converted to pivot irrigation, these fields may have experienced greater instances of mid-field ponding of irrigation water, which can result from furrows blocked by stalks and stover (R. Spalding & Toavs, 2011).

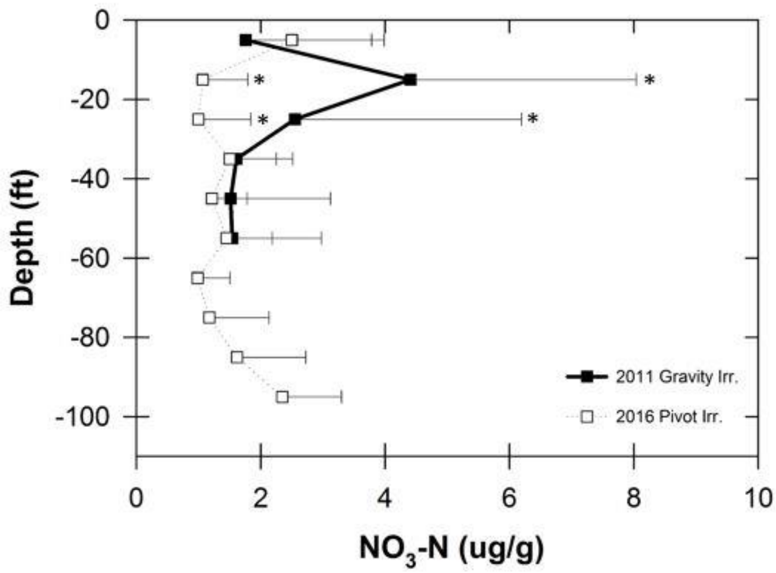

Figure 31: Average nitrate-N of gravity irrigated sites in 2011 that have since converted to pivot irrigation. Asterisks indicate a statistical significance (p-value $\leq$0.05) between the two groups at a particular depth.

In Figure 31, differences in average nitrate-N are evident. There is an average reduction of approximately 170 lbs-N/acre in the top 55 ft of the profile over a five-year time span. Ammonium-N findings weren't discussed in the 2011 Hastings vadose zone study report and methods of analysis were not reported, making comparisons of ammonium-N between the two sampling periods challenging. Differences in ammonium-N between the two sampling periods weren't compared due to consistently lower 2011 concentrations, potentially due to improper sample storage. A statistically significant difference in nitrate-N was present at a depth of 15 and 25 ft. This reduction may be due to differences in how water applications were applied. Current pivot irrigation methods could apply water more uniformly and at times when crops can more readily absorb both the water and the nutrients. A 1990 study deemed effective irrigation management as a highly effective BMP to protect groundwater quality (Logan, 1990). If irrigation water wasn't properly scheduled or over-applied during gravity irrigated seasons, excessive leaching may have led to the higher amount of nitrate-N stored in the unsaturated zones of these sites. Efforts to convert from gravity to pivot irrigation should be encouraged, especially in agricultural land within capture zones of municipal wells, such as those within the Hastings' WHPA.

5.1.3 Nitrate-N accumulations in sites beneath urban irrigated lawns

Unsaturated zones beneath residential homes also showed both positive and negative fluctuations of nitrate-N between the five-year sampling span. Urban sites HC-3A and HC-3B are located in a newly-developed suburb west of Hastings, three miles east of the village of Juniata. It is possible that nitrate-N stored at deeper depths under these sites was impacted by previous land use practices. Sites HC-3A and HC-3B showed increases of 280 and 200 lbs-N/Acre, respectively. The larger increase of nitrate-N at HC-3A is speculated to be from nutrient rich runoff coming from a chemigated agricultural field located a ½ mile east of HC-3A. Since 2010, the pivot irrigated NE ¼ and drip irrigated NW ¼ of this field has been permitted to chemigate, a process which utilizes fertilizer injected water to simultaneously irrigate and fertilize crops. Chemigation can improve yields but also lead to water quality issues (Hergert & Shapiro, 2015). Excess water coupled with applications of liquid nitrogen can lead to more leaching within crop rows of agricultural land. Additionally, surface runoff to down-gradient areas and windblown spray to up-wind areas have the ability to deposit unwanted nitrate-N at neighboring areas (Anderson Jr., 1993).

Overall, the estimated amount of nitrate-N stored in lawns decreased by 840 lbs-N/Acre. The average amount in 2011 and 2016 was 480±440 and 270±200 lbs-N/Acre, respectively. However, the overall decrease beneath urban locations can largely be attributed to a dramatic reduction in stored nitrate-N at site HC-6, an urban lawn located within the city of Hastings. This site contained the largest amount of stored nitrate-N (1,200 lbs-N/Acre) under all 32 sites in 2011. In 2016, this site was estimated to contain only 36 lbs-N/Acre, a decrease of 1,200 lbs over the five-year span. The 2011 plot in Figure 32 shows a large peak extending from 6 - 20 ft beneath the lawns surface. This peak was expected to have been introduced five to ten years prior to the 2011 sampling from non-uniform fertilizer application, given the relatively low values of nitrate-N throughout the rest of the profile (R. Spalding & Toavs, 2011). The 2016 plot in Figure 32 shows both nitrate-N and pore water nitrate-N have decreased significantly throughout the profile and the large peak present in 2011 is no longer visible.

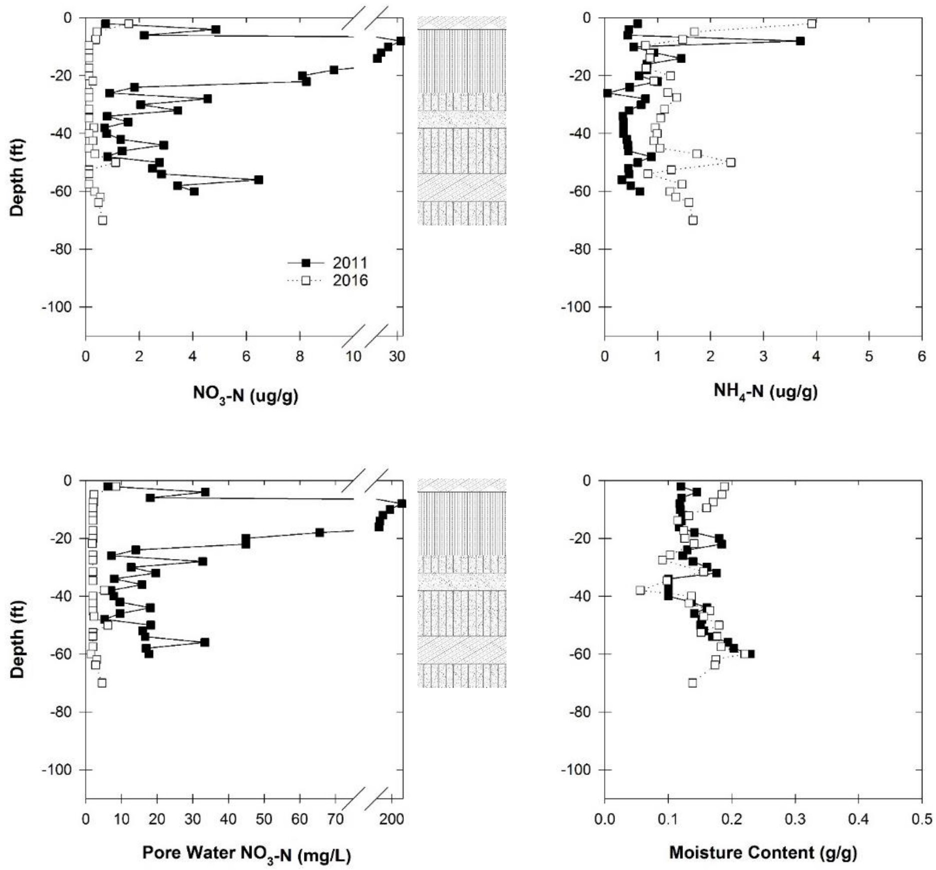

Figure 32: Profile characteristics beneath urban lawn site HC-6.

Although it is not certain what may have caused this drastic decrease, there are several possibilities that may have individually or in tandem contributed to the decrease in stored nitrate-N. For instance, fine-textured sediments underneath this site or others can prohibit the oxygen diffusion through the soil (Adelman et al., 1985). Anoxic conditions along with the presence of organic matter may have increased microbial denitrification, converting portions of the stored nitrate-N to nitrous oxide and nitrogen gas. Soil microbes could have also converted the tied-up nitrogen back into ammonium-N through mineralization, although 2016 concentrations of ammonium-N at HC-6 averaged only 1.3±0.63 μg/g. Concentrations of ammonium-N in 2011 were lower

(0.67±0.62 µg/g) but as mentioned previously, this increase in ammonium-N between sampling periods was common across nearly all of the sampling locations.

Historical application of fertilizer at site HC-6 was not made available, but given estimated transport rates of nitrate-N we would expect changes in landowner management practices to only be reflected within the top 12.5 ft. This may explain decreases in nitrate-N content in the upper 12.5 ft, but not below. Wetting fronts in the thick, lithologically varied WHPA unsaturated zone often travel from coarse sandy sediments into clay layers, such as those present 5 - 25 ft and 55 - 65 ft below the surface of HC-6. The small pores within the clay layers hold the water more tightly and can halt vertical movement (UNL Plant & Soil Sciences, 1999). The slowing of the wetting front causes water to move laterally in the overlying coarse sediment, which can lead to perched water tables. Drainage of water in coarse-grained sediments such as those present in HC-6 can be impeded by fine-grained sediment, increasing the chances of lateral movement between the two different layers (McMahon et al., 2003). Nitrate-N in the pore water of the sandy loam may have been prevented from vertical movement when it reached a barrier of fine-textured sediment. Horizontal flow may have caused stored nitrate-N at HC-6 to travel away from the small cored area (0.034 ft^2) into adjacent sediment. However, matric-potential measurements along these contacts would be needed to verify the occurrence of horizontal flow.

Unsaturated zones beneath barns and parks all showed increases in nitrate-N over the five-year span. Sites HC-7 and HC-8 are located in barnyards but are surrounded by irrigated agricultural land. In 2016 these sites contained 590 and 690 lbs-N/Acre in the top 60 ft, respectively. These totals are higher than 2016 accumulations at urban irrigated lawn sites. However, accumulations are lower than those at abandoned barnyard sites sampled in 2010 in Edgar, which contained 100 μg/g pulses of nitrate-N and exceeded 2,000 lbs-N/Acre in the top 45 ft (Olsson Associates, 2011). In contrast, spikes of nitrate-N under barnyard sites in Hastings didn't exceed 9 μg/g, with the largest spike located ~50 ft below the surface, as shown in Figure 33. Overall, the amount of nitrate-N stored under barnyard and residential park sites increased by 300 lbs-N/Acre. The average amount in 2011 and 2016 was 260±120 and 560±130 lbs-N/Acre, respectively. Portions of the nitrate-N in these regions may have accumulated from manure leachates, fertilizer applications at surrounding properties, and/or sub-surface horizontal flow of nitrate-N-rich water fronts from neighboring agricultural fields.

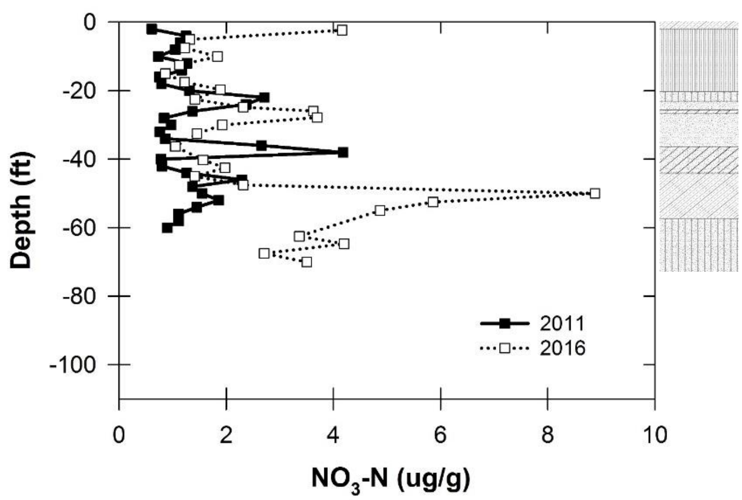

Figure 33: Nitrate-N in the vadose zone of barnyard site HC-7.

Differences between urban and rural groundwater nitrate-N concentrations can be both significant or negligible (Wakida & Lerner, 2005). Groundwater contamination by nitrate-N in urban areas typically comes from fertilizer application, as well as wastewater and solid waste disposal. A 2017 study found that rapid growth of residential land increased pools of reactive nitrogen in lawns (Raciti et al., 2017). Housing density and the availability of nitrate-N in residential soils were both determined to be useful indicators of groundwater quality on a landscape-scale. The amount of leaching in residential locations, such as site HC-6 depends on factors similar to agricultural regions. These include management practices such as water input, fertilizer usage, and land use within the urban environment.

5.1.4 Comparisons of stored nitrate-N and ammonium-N among different land uses

Unsaturated zones beneath urban irrigated lawns, gravity irrigated cropland, and pivot irrigated cropland collected in 2016 were grouped together as mentioned in Section 1.1 and compared to show differences in average nitrate-N and ammonium-N among different types of land use. In Nebraska, most groundwater nitrate-N comes from intensely irrigated cornfields (Hergert & Shapiro, 2015). The primary irrigation types within the Hastings' WHPA are made through gravity and pivot technologies. Pivot irrigation makes up 67% of the irrigation systems in South Central Nebraska (Hergert & Shapiro, 2015). As discussed in Section 5.1.2, there has been a movement to convert from primitive forms of irrigation (i.e., drip irrigation) to pivot irrigation. A 1998 study found that crop yields in large pivot irrigated fields (>160 acres) were typically higher than similar-sized drip irrigated fields (O'Brien et al., 1998). This is because pivots can make more uniform, properly timed applications. Even with increased yields, the amount of fertilizer applied to pivot irrigated fields typically remains the same due to improved timeliness of water applications.

In Hastings and the surrounding area an average annual water application of 2.15±0.78 in./acre was applied to all irrigated land between 2012 and 2017 (Hastings Utilities, personal communication, March, 28, 2017). The largest annual amount (3.58 in./acre) was applied in 2012, which coincides with drought-like conditions and the lowest amount of annual rainfall during the five-year period. Although water applications of gravity and pivot irrigation weren't reported seperatly, it is likely that the water efficiency of the pivot irrigated fields was greater than fields utilizing gravity/flood irrigation systems, especially if the pivots were low pressure (<30 psi) (Johnson et al., 2011). Irrigation rates for four urban irrigated lawns were reported between 2012 and 2016. Average urban application rates at these sites was higher and more variable than the irrigated cropland annual average, at 5.78±5.07 in./acre. Similar to the total irrigated land, the largest annual average application at the urban sites was in 2012 at 9.53 in./acre. These homeowners apply their water using a mixture of manual sprinklers, underground sprinklers, and hoses. In the U.S., landscape irrigation makes up 40 - 70% of household water use and automated underground irrigation is the predominant method used to irrigate (Haley et al., 2007).

Soil in the WHPA is primarily a silt loam, which relative to other types of soil has a high available water capacity of 2.00 - 2.50 in./ft of depth (UNL Plant & Soil Sciences, 1999). Since the soil only has the ability to hold this much water, water applied in excess of this can leach past the crop's root zone into the unsaturated zone. Water use and management practices have large influences on the ability of nitrate-N to leach past the root zone (Anderson Jr., 1993). Differences in irrigation rate and type may impact the amount of water diffusing into the vadose zone. Unsaturated zones beneath the top 65 ft of urban irrigated lawns, pivot irrigated farmland, and gravity irrigated farmland had an average gravimetric water content of 0.14±0.02, 0.17±0.04, and 0.17±0.04 g/g respectively.

Although urban lawns contained a lower amount of average water stored in the unsaturated zone than irrigated cropland, there was no difference between the water content of the pivot and gravity sites. The water content among both of these irrigation types generally decreased with depth, decreasing from ~0.22±0.03 g/g in the root zone to ~0.05±0.05 g/g at 105 ft deep. Depth to groundwater varied but averaged ~100±8.50 ft when sites were collected without experiencing refusal. It is possible that sites other than those outlined in Section 5.1.2 have been converted from gravity to pivot irrigation in the last >five years. This may explain the similarities in average moisture content between the two irrigation types. Additionally, the proper timing and amount of water applied at gravity irrigated fields may have prevented runoff, ponding, or leaching from occurring during application periods.

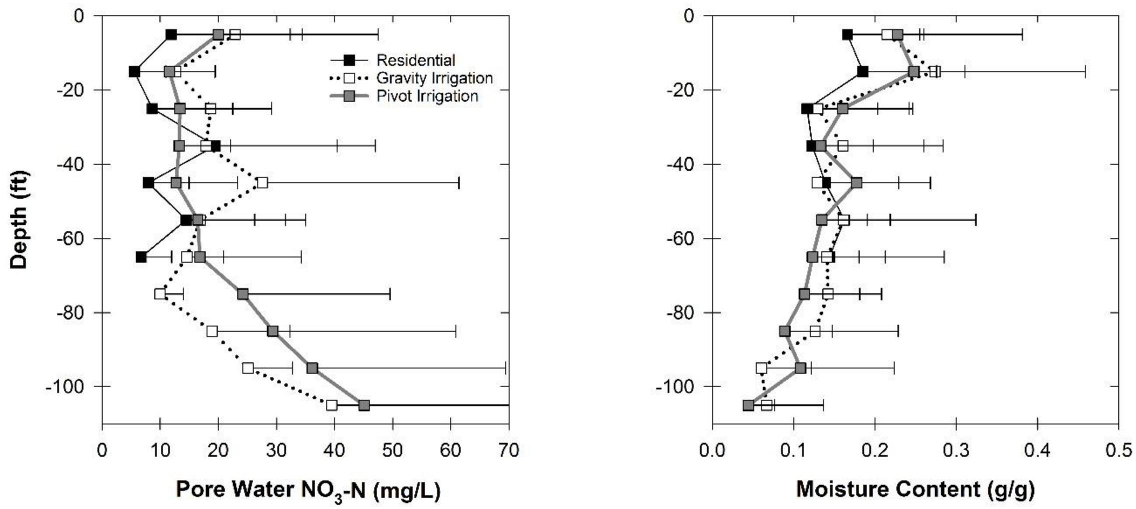

Figure 34: Average pore water nitrate-N and moisture content of three different land use groups collected in 2016.

Land owner surveys indicated that on an average, 175 lbs-N/Acre is being applied to irrigated cropland fields within the WHPA. The reccomended fertilizer application rate set by the UNL Irrigation and Nitrogen Management User Education/Certification Program for South Central Nebraska is 201 lbs-N/acre (Hergert & Shapiro, 2015). Recommended fertilizer rates with a corn and soybean rotation are lower, with no form of nitrogen fertilizer required during soybean season. Most of the farmers applied anhydrous ammonia for their source of nitrate-N in the spring. Some surveys indicated split applications were performed in more recent years. The WHPA is classified by the NRD as a GWMA, which regulates scheduling of fertilizer and irrigation applications (The Little Blue NRD, 2013). For instance, anhydrous ammonia may not be applied prior to November 1st and nitrification inhibitors must be used with fertilizers applied between November 1st and March 1st.

GWMA regulations are less strict for urban home owners. Most restrictions are directed towards lawn care services and those who fertilize >one acres of lawn. Survey responses from urban home owners indicated that most followed the reccomendations set by their lawn fertilizers. A common brand of fertilizer (Scotts Lawn Food) reccomends four split-applications of nitrogen fertilizer totaling 151 lbs-N/Acre. The typical application amount for urban lawns is lower than that of agricultural fields, but still plays a significant role in groundwater nitrate-N contamination due to large housing densities in Hastings and Juanita. The amount of leaching in these urban locations depends on factors similar to those of agricultural regions (Raciti et al., 2017). Management practices such as irrigation type and amount within an urban environment can impact leaching potential. Not enough land use data for urban and agricultural information was received to make site-specific statements about how fertilizer applications were impacting nitrate-N leaching. However, based on a previous study it is expected that vadose zone nitrate-N accumulations would approximately double at sites with each 100 lbs-N/Acre/Yr increase in N-fertilizer (R. F. Spalding & Kitchen, 1988).

Cumulative nitrate-N beneath the top 65 ft in 2016 for urban irrigated lawns, pivot irrigated farmland, and gravity irrigated farmland had an average of 320, 540, and 700 total lbs-N/acre respectively. Allthough no significant differences in nitrate-N were present at the different depths, trends of higher average nitrate-N under farmland vadose zones shown in Figure 35 were present. On average, farmland had nearly double the nitrate-N of urban irrigated lawns. Between irrigation methods, gravity sites had the largest amount of stored nitrate-N on average, 30% more than pivot irrigated sites.

Nitrate-N is typically stored as pore water in sediments and can move with excess irrigation water.

The average pore water nitrate-N for urban irrigated lawns, pivot irrigated farmland, and gravity irrigated farmland was 10.66±4.58, 14.88±2.75, and 18.73±4.71 mg/L respectively. Pore water nitrate-N was 25% higher in gravity irrigated profiles than pivot irrigated fields. Average pore water nitrate-N at each depth shown in Figure 34 for urban irrigated lawns was lower except at 35 ft, which contained an average of 19.47±27.51 for urban sites. The high variation at this depth can be attributed to site HC-3A, which contained >100 mg/L pore water nitrate-N 32 ft below the surface. Average pore water concentrations for both pivot and gravity irrigated farmland was at or above the MCL at each measured depth. Once a depth of 65 ft was reached, average concentrations showed steady increases with each 10 ft, increasing from 14.59±6.29 to 39.48±35.40 mg/L at gravity irrigated sites and 16.80±17.42 to 45.09±61.67 mg/L at pivot irrigated sites. As depth increases, sediments in the WHPA typically become sandier and hold less moisture. This is made apparent in Figure 34. Average moisture content from 65 to 105 ft decreased in gravity and pivot sites from 0.14±0.07 to 0.06±0.07 and 0.12±0.05 to 0.04±0.03 g/g, respectively. Even with low moisture content, there are still large amounts of nitrate-N presence at deeper depths. High average concentrations of pore water nitrate-N (>40 mg/L) at depths within 5 - 10 ft of the groundwater table will lead to further nitrate-N accumulation in the aquifer in the next few years.

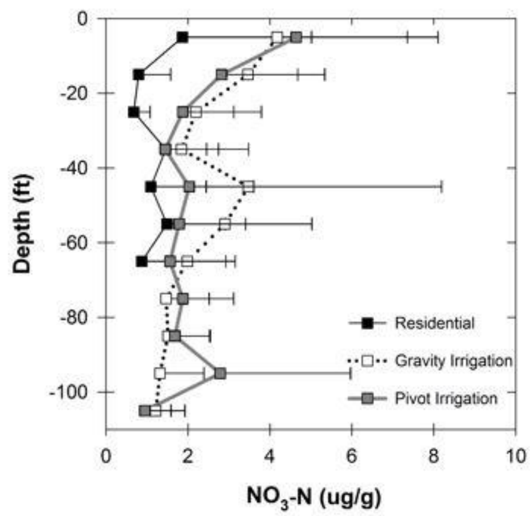

Figure 35: Average nitrate-N and ammonium-N of three different land use groups collected in 2016. Asterisks indicate a statistical significance (p-value ≤ 0.05) between different groups at a particular depth.

Transport of ammonium-N diffuses through sediments more slowly and can be oxidized into nitrate-N through biological nitrification. Cumulative ammonium-N beneath the top 65 ft in 2016 for urban irrigated lawns, pivot irrigated farmland, and gravity irrigated farmland had an average of 200, 500, and 380 total lbs-NH_4-N/acre respectively. A statistically significant difference in ammonium-N was present between urban and pivot groups at depths of 25 and 35 ft. Ammonium-N can sorb to organic matter, preventing potential downward movement. In both 2011 and 2016 samplings, ammonium-N was present throughout the profile, indicating that given its chemical properties it is still leaching past the root zone into deep subsurface layers. It is also possible that nitrogen sorbed to organic matter decayed, allowing microbes to convert the tied-up nitrogen into ammonium-N through mineralization (Adelman et al., 1985).

Similar to average nitrate-N accumulations, average ammonium-N in urban sites was lower at each depth than the irrigated farmland. Average ammonium-N beneath the top 65 ft for urban irrigated lawns was 0.89±0.36 μg/g, compared to 2.07±0.23 μg/g for pivot and 1.54±0.32 μg/g for gravity irrigated sites. In contrast to total nitrogen loads from nitrate-N, the average loads from ammonium-N was greater under pivot irrigated fields than gravity. This may be due to the nitrification process being more inhibited at pivot irrigated sites than gravity. Both water and oxygen content within the pore space can influence nitrification by aerobic microbes (Linn & Doran, 1984). Further information on microbe population densities and historic management practices such as the utilization of nitrification inhibitors at these sites could assist in determining the cause of this trend. When combining average nitrate-N and ammonium-N accumulations in the top 65 ft, pivot and gravity irrigated sites had 1,040 and 1,080 total lbs-N/acre. Similarities in total stored nitrogen between the two irrigation practices may be due to shifting irrigation practices that impacted previous amounts of leached nitrate-N and ammonium-N. Previous research suggests that when irrigation water is applied at proper rates it does not increase leaching (Bobier et al., 1993). Proper water application timing and quantity at gravity irrigated fields may have prevented substantial leaching and significant differences in total nitrogen compared to pivot irrigated fields. Nearly $^{2}/_{3}$ of the stored nitrogen under pivot sites was in the form of ammonium-N. In contrast, only $^{1}/_{2}$ of the stored nitrogen under gravity irrigated sites was in the form of ammonium-N.

6.1 Summary and Conclusion

An improved understanding of the occurrence, rate of transport, and breakdown of agrichemicals in the vadose zone allows municipalities to better anticipate and predict groundwater contamination. By sampling previously collected sites, it is possible to determine if changing practices and the use of BMPs such as improvements in water and fertilizer application input have a measurable effect on nitrate-N loading to the vadose zone and the underlying groundwater. Quantifying the contaminant mass in the entire vadose zone allows for a more complete representation of stored agrichemicals. It also more effectively reveals nitrate-N concentrations in recharge water close to the groundwater table. Recharge water that is approaching or exceeding the 10 mg/L MCL for nitrate-N has implications towards water quality within the capture zones of municipal wells. Concentrations of ammonium-N should also be taken into consideration, as it also has been observed accumulating in the vadose zone and can be biologically converted to nitrate-N under certain conditions.

This investigation quantified the mass of agrichemicals in Hastings' WHPA and compared them to estimations made five years previously in a 2011 study (R. Spalding & Toavs, 2011). Land use among the sampled locations varied from urban land, pivot/gravity irrigated cropland, and non-irrigated cropland. Certain lithologic properties seemed to correlate with concentrations of agrichemicals. High nitrate-N concentrations were commonly found in sediments consisting of clay and silt loams. Overall, fluctuations of stored nitrate-N varied site by site over the five-year span. Potential nitrogen sources at these sites varied from nonpoint sources in row-cropped farmland to suspected point source releases (R. Spalding & Toavs, 2011).

Producer fields increased by 2,800 lbs-N/Acre of stored nitrate-N in the top 60 ft. Sites that were converted from gravity to pivot irrigation showed a reduction of approximately 170 lbs-N/acre in the top 55 ft of the profile over a five-year time span. This reinforces the idea that irrigation management can be an effective BMP to protect groundwater quality. Overall, amount of nitrate-N stored under urban lawns decreased by 840 lbs-N/Acre. The amount of vadose zone contamination from urban locations depends on factors similar to agricultural regions, such as water input, fertilizer usage, and land use within the urban environment. Cumulative nitrate-N beneath the top 65 ft for urban irrigated lawns, pivot irrigated farmland, and gravity irrigated farmland had an average of 320, 540, and 700 total lbs-N/acre respectively. Although no significant differences between their nitrate-N were present at the different depths, trends of higher nitrate-N under cropland vadose zones were present.

A better understanding of urban and rural BMPs would allow for more definitive statements to be made about how the adoption of new practices are influencing agrichemical leaching. Additionally, understanding irrigation management can help provide insights as to why high concentrations of nitrate-N in groundwater are common in certain agricultural and residential regions. It is likely that improved management practices have positively reduced the amount of nitrate-N being leached in certain locations. Continuing the transition from gravity to pivot irrigation can allow for more uniform water applications, eliminating potential leaching at the head and tail rows of gravity irrigated fields. The importance of vadose zone monitoring in evaluating and protecting groundwater is beneficial in determining connections between surface activities and the underlying groundwater.

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Appendix

Please note, all digital files can be requested from (craigadams17@gmail.com) or Daniel Snow (dsnow1@unl.edu). The appendix contains vadose zone profile data from the 2016 sampling for each of the 32 sampling locations and relevant SOPs. Table 5 shows the calculations used for the different parameters.

Parameter	*Calculation*
Depth	Start Depth - Stop Depth
Gravimetric Water Content	Water (g) / Dry Sample (g)
Bulk Density	Dry Sample (g) / Sample Volume (mL)
pH	Scale of 1 - 14
NO3-N (µg/g)	(NO3-N (mg/L) * L of Extract * 1000 µg) / sample weight (g)
NH4-N (µg/g)	(NH4-N (mg/L) * L of Extract * 1000 µg) / sample weight (g)
Pore Water NO3-N (mg/L)	NO3-N (µg/g) / Gravimetric Water Content
lbs-N/Acre-ft	(NO3-N (µg/g) * 2.2×10^{-9} (lb/µg) * Bulk Density (g/mL)) / 8.11×10^{-10} (Acre-ft/mL)
lbs-N/Acre-ft in Cored Interval	lbs-N/Acre-ft * Total Feet in Interval
Lithologic Description	Sediment Type, Iron (Chemical or Physical), Organic Matter, Color
Sand %	(Sand (g) / Sample (g)) * 100
Silt %	(Silt (g) / Sample (g)) * 100
Clay %	(Clay (g) / Sample (g)) * 100

Table 5: Definitions and calculations of parameters listed in vadose zone profile data. Methods used to obtain data can be found in Section 3.1.3.

Appendix 1 Vadose zone profile data by site

Site ID: HC-1-E, Gravity Irrigated Corn - Cored November '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
2.5-5	0.132	1.13	5.83	10.91	2.27	82.79	33.62	84.06	clay loam - black
7.5-10	0.260	1.55	6.86	1.19	1.37	4.57	5.01	12.52	silty clay - Fe C - light brown
10-12.5	0.269	1.06	7.16	1.39	1.32	5.17	4.03	10.07	silty clay - Fe C - light brown
12.5-15	0.324	1.27	7.14	1.15	0.88	3.55	3.98	9.95	clay - Fe C - OM - light brown
18.1-20	0.208	1.57	7.16	0.88	0.79	4.24	3.77	7.17	sandy clay loam - Fe C - tan
22.5-25	0.079	1.74	6.99	0.85	0.70	10.74	4.02	10.06	sand - light tan
25.9-27.1	0.129	1.65	7.16	1.01	1.32	7.80	4.53	5.44	loamy sand - Fe C -tan
27.1-30	0.205	1.57	7.16	1.40	1.04	6.84	6.01	17.42	clay loam - brown
31.7-32.5	0.135	1.30	7.17	1.33	1.19	9.82	4.69	3.75	loam - Fe C - OM - light brown
32.5-35	0.369	1.15	7.05	1.16	1.00	3.16	3.64	9.11	loamy sand - tan
37.5-40	0.081	1.47	7.02	1.48	1.07	18.26	5.91	14.77	loamy sand - tan
42.5-45	0.092	1.84	7.05	1.42	1.26	15.48	7.13	17.82	sand - Fe C - Fe P - tan
47.5-50	0.145	1.58	7.14	1.99	0.78	13.79	8.56	21.39	sand - Fe C - Fe P - light tan
50.6-51.4	0.153	1.41	7.03	2.16	0.77	14.12	8.31	6.65	sand - Fe C - Fe P - light tan
51.4-52.5	0.193	1.79	6.55	4.16	1.99	21.53	20.29	22.32	clay - Fe P - light brown
57.8-60	0.167	1.81	6.70	4.47	1.69	26.80	21.98	48.35	sandy clay - Fe P - OM - light brown
61.4-62.5	0.077	1.50	6.73	2.09	0.76	27.10	8.54	9.40	sandy clay - Fe C - light brown
62.5-65	0.127	1.81	5.97	2.24	0.05	17.64	11.05	27.61	sandy clay - Fe P - OM - brown
65-67.5	0.155	1.61	6.76	2.37	1.03	15.25	10.36	25.89	sandy clay - Fe C - light brown
67.5-70	0.055	1.30	6.64	1.18	0.05	21.49	4.18	10.44	loamy sand - light brown
77.5-78.7	0.185	1.89	6.62	1.23	0.05	6.64	6.32	7.58	sandy clay - Fe C - OM - light brown
78.7-80	0.046	2.24	6.86	0.50	0.05	10.87	3.06	3.98	sand - tan
82.5-85	0.021	1.83	6.92	0.76	0.05	36.17	3.75	9.39	rocky sand - Fe C - tan
85-87.5	0.090	1.44	6.87	0.57	0.05	6.33	2.22	5.54	rocky sand - Fe C - tan
92.5-94.3	0.021	1.51	6.77	0.77	0.05	37.17	3.18	5.72	rocky sand - tan
101-102.5	0.011	1.53	6.72	0.60	0.21	55.67	2.51	3.76	rocky sand - tan
102.9-105	0.068	2.06	6.86	1.05	0.05	15.41	5.87	12.33	rocky sand - Fe C - dark tan

Total lbs-N/Acre = 722.46

Site ID: HC-1-W, Gravity Irrigated Corn - Cored November '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
3.7-5	0.167	1.18	5.93	3.93	2.26	23.52	12.64	16.43	clay loam - OM - black
7.8-10	0.214	1.54	7.35	0.73	0.51	3.40	3.04	6.69	silty clay loam - light brown
12.5-15	0.248	1.50	7.58	1.03	0.52	4.16	4.20	10.51	clay - light brown
15-17.5	0.282	1.05	7.46	2.45	0.86	8.67	7.02	17.54	clay - Fe P - OM - light brown
17.5-20	0.270	1.30	7.57	3.59	1.04	13.31	12.72	31.80	clay - Fe P - OM - light brown
22.9-25	0.061	1.40	7.72	1.37	0.29	22.42	5.24	11.00	loamy sand - dark tan
25-27.5	0.069	1.63	7.77	1.01	0.24	14.58	4.45	11.12	sand - tan
27.5-30	0.058	1.46	7.68	1.22	0.34	20.99	4.85	12.12	clay - Fe P - OM - brown
30-32.5	0.079	1.55	7.64	1.99	0.57	25.27	8.43	21.08	clay loam - Fe P - OM - brown
32.5-34.7	0.314	1.39	7.59	1.39	0.83	4.42	5.23	11.50	clay loam - Fe P - OM - brown
37.5-38.9	0.084	1.85	6.89	0.48	0.14	5.69	2.39	3.35	loamy sand - light brown
38.9-40.1	0.176	1.88	7.16	0.88	0.80	5.00	4.50	5.40	sandy clay loam - Fe C - brown
40.1-42.5	0.106	1.65	7.29	0.91	0.42	8.59	4.07	9.76	sandy loam - Fe C - light brown
45.9-49.3	0.169	1.64	7.25	1.05	0.35	6.18	4.67	15.87	clay loam - Fe C - light brown
49.4-51.9	0.157	1.34	7.22	0.95	0.95	6.02	3.44	8.60	loam - Fe C - OM - brown
51.9-55	0.144	1.30	7.31	0.93	0.80	6.42	3.29	10.19	sandy clay loam - grey
57.5-60	0.073	1.98	7.39	0.71	0.91	9.75	3.83	9.58	sand - tan
62.5-65	0.068	1.52	7.37	0.72	0.86	10.66	2.99	7.48	loamy sand - tan
67.5-70	0.049	2.01	7.50	0.44	0.65	8.95	2.41	6.03	sand - tan
71.4-72.5	0.195	1.72	6.89	1.35	2.89	6.91	6.32	6.96	clay loam - grey
72.5-74.1	0.043	1.66	7.54	0.29	0.32	6.74	1.32	2.11	sand - tan
77.7-80	0.059	1.70	6.81	0.63	0.68	10.65	2.93	6.73	sand - Fe C - tan
82.5-85	0.183	1.81	7.40	0.99	1.23	5.39	4.85	12.13	clay loam - dark brown
87.5-90	0.016	1.64	7.15	0.51	0.35	31.08	2.27	5.67	rocky sand - Fe C - dark tan
92.5-95	0.018	2.25	7.33	0.43	0.19	24.50	2.66	6.64	rocky sand - dark tan
95-97.5	0.023	1.54	7.38	0.45	0.20	19.91	1.89	4.73	rocky sand - dark tan
103.3-105	0.067	1.76	7.17	0.34	0.70	5.09	1.63	2.78	sand - tan
107.5-110	0.202	1.84	6.79	1.20	2.09	5.93	6.00	14.99	sandy clay - grey

Total lbs-N/Acre = 442.80

Site ID: HC-2, Dryland Corn - Cored November '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-2.5	0.282	0.57	5.80	5.24	12.90	18.56	8.08	20.20	clay loam - dark black
2.5-4.5	0.264	0.64	6.33	1.85	2.40	7.04	3.25	6.49	silty clay loam - Fe P - dark brown
5-7.5	0.227	0.54	6.95	1.32	3.26	5.82	1.95	4.88	silt loam - Fe P - brown
7.5-9.5	0.205	0.59	7.46	1.34	1.28	6.57	2.16	4.31	silt loam - light brown
10.0-12.0	0.242	0.69	7.64	0.13	0.71	2.00	0.23	0.47	clay - Fe P - brown
12.5-15	0.250	0.69	7.62	1.15	1.33	4.58	2.15	5.37	clay - Fe P - brown
15.0-17.0	0.272	0.69	7.78	1.12	1.64	4.10	2.10	4.21	clay - Fe P - brown
20.6-22.5	0.265	0.72	7.69	0.76	1.37	2.88	1.50	2.84	clay - brown
22.5-24	0.275	0.85	7.81	0.37	1.40	1.36	0.86	1.30	clay - OM - Fe P - brown
27.6-30	0.140	0.88	7.73	0.38	1.30	2.71	0.91	2.18	sandy loam - dark brown
37.5-40.3	0.230	1.80	6.78	1.10	0.43	4.76	5.36	15.01	clay - Fe C - Fe P - brown
40.3-41.6	0.115	2.26	7.17	1.36	1.09	11.82	8.34	10.85	loam - Fe P - grey
41.6-42.5	0.116	2.01	7.32	0.83	1.19	7.14	4.51	4.06	sandy loam - grey
45-47.5	0.161	1.66	7.29	1.00	0.10	6.20	4.51	11.28	loam - Fe C - Fe P - grey
47.5-50	0.110	1.48	7.28	0.86	0.05	7.81	3.44	8.59	sandy loam - Fe P - OM - light brown
51.5-52.5	0.107	1.78	7.30	0.74	0.05	6.92	3.57	3.57	loamy sand - Fe P - light brown
52.5-55	0.101	1.87	7.36	0.87	0.18	8.66	4.45	11.12	loamy sand - Fe P - light brown
55-57.5	0.054	2.18	7.32	0.83	0.19	15.41	4.91	12.28	sand - Fe C - Fe P - brown
57.5-60	0.087	1.89	7.17	0.80	0.05	9.21	4.13	10.31	sand - Fe P - tan
60-62.5	0.040	1.92	7.20	0.93	0.05	23.61	4.89	12.23	sand - Fe P - tan
62.5-65	0.019	1.56	6.09	1.07	0.05	57.30	4.53	11.32	sand - Fe C - tan
65-67.5	0.105	1.69	6.43	1.02	0.18	9.68	4.68	11.71	sand - light tan
67.5-70	0.226	1.88	6.62	0.98	0.05	4.32	4.99	12.48	loam - light brown
72.5-75.4	0.109	2.05	6.81	0.96	0.05	8.86	5.37	15.59	loam - light brown

Total lbs-N/Acre = 246.94

Site ID: HC-3A, Residential - Cored August '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-2.2	0.120	0.70	6.71	0.40	0.57	3.34	0.76	1.67	clay - black
2.2-5	0.106	0.57	7.53	0.19	0.10	1.77	0.29	0.82	silty clay - light tan
5.8-7.5	0.118	0.59	7.74	0.73	0.46	6.19	1.17	1.98	silt loam - light tan
7.5-9.2	0.171	0.60	7.88	0.49	0.27	2.90	0.81	1.37	loam - tan
9.2-10	0.176	0.65	7.95	0.39	0.31	2.22	0.69	0.55	sandy clay loam - dark tan
10-12.5	0.235	1.35	7.67	0.33	0.05	1.41	1.21	3.02	silty clay - light brown
13.5-17.5	0.222	0.68	8.03	0.36	0.05	1.61	0.66	2.63	loamy sand - tan
17.5-20	0.037	0.86	8.03	0.60	0.38	16.41	1.41	3.52	sand - OM - tan
20-22	0.114	1.96	7.96	0.40	0.05	3.50	2.13	4.26	sand - light brown
22-24.1	0.041	1.97	8.08	0.60	0.05	14.50	3.21	6.75	sand - OM - brown
24.1-25.3	0.155	1.87	7.68	1.46	0.13	9.42	7.43	8.92	sandy clay loam - dark brown
25.3-27.5	0.040	1.98	8.02	1.85	0.14	45.82	9.96	21.91	sand - brown
27.5-30	0.069	1.97	7.87	0.57	0.24	8.29	3.04	7.61	loamy sand - brown
30-32.5	0.050	2.01	7.77	2.00	0.31	40.01	10.92	27.31	loamy sand - brown
32.8-34.5	0.038	1.74	8.02	4.35	0.25	114.68	20.54	34.92	sandy loam - dark brown
34.5-36.5	0.035	2.07	8.11	2.29	0.32	65.51	12.88	25.77	sand - brown
37.5-40	0.044	1.97	7.83	2.50	0.09	57.01	13.42	33.54	sand - brown
40-42.8	0.117	1.74	8.18	1.59	1.35	13.59	7.53	21.08	loamy sand - dark brown
42.8-45	0.191	1.77	7.46	5.59	0.09	29.31	26.97	59.33	sand - brown
48.1-50.1	0.112	2.15	7.52	4.01	0.06	35.68	23.44	46.87	sand - brown
50.1-53.5	0.188	1.83	7.47	3.77	0.07	20.08	18.76	63.78	sandy loam - brown
53.5-55	0.166	1.93	7.55	3.64	0.05	21.84	19.06	28.59	clay - brown
55-57.5	0.070	2.09	7.76	2.62	0.12	37.52	14.89	37.22	clay loam - brown
57.5-60	0.026	2.08	7.73	1.43	0.05	54.72	8.07	20.18	clay - OM - brown
61.2-63.5	0.131	1.75	6.35	1.91	0.05	14.61	9.06	20.83	sand - Fe P - light brown
63.5-65.0	0.174	1.92	6.59	0.40	0.05	2.30	2.10	3.14	sandy clay loam - OM - brown

Total lbs-N/Acre = 599.87

Site ID: HC-3B, Residential - Cored August '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-1.9	0.146	1.17	6.60	2.71	5.35	18.48	8.63	16.40	clay - black
1.9-5	0.146	1.16	6.80	0.48	1.07	3.25	1.50	4.64	silt - light brown
6.7-8.7	0.183	1.24	7.67	0.78	1.07	4.25	2.62	5.25	silt loam - Fe C - light brown
8.7-10	0.230	1.32	7.74	0.54	0.50	2.35	1.94	2.52	silty clay loam - Fe C - light brown
10-12.5	0.257	1.53	7.65	0.94	1.41	3.65	3.91	9.77	clay loam - dark brown
12.5-14.1	0.295	1.42	7.82	0.86	0.63	2.92	3.32	5.31	clay - dark brown
14.1-15	0.050	1.85	7.84	0.99	0.05	19.86	5.01	4.50	sand - tan
15-16.4	0.232	1.86	7.69	1.09	1.23	4.70	5.50	7.70	clay - dark brown
16.4-19.7	0.062	2.08	7.94	0.57	0.05	9.19	3.24	10.68	sand - tan
20-22.5	0.052	1.97	7.40	0.65	0.21	12.52	3.49	8.74	sandy clay - dark tan
22.5-25	0.073	1.99	7.75	0.61	0.05	8.35	3.32	8.30	sand - dark tan
28.9-31.7	0.116	2.27	7.55	0.40	0.86	3.41	2.44	6.83	loamy sand - dark tan
31.7-34.8	0.199	1.88	7.50	3.08	0.48	15.46	15.76	48.86	clay loam - Fe P - OM - dark tan
34.8-35.3	0.152	1.93	7.62	1.09	1.06	7.13	5.70	2.85	sandy clay - dark tan
35.3-36.4	0.163	2.13	7.54	3.26	0.77	19.96	18.86	20.74	clay - OM - brown
37.3-40	0.221	2.20	7.20	4.07	0.36	18.47	24.42	65.93	clay - OM - dark grey
45-46	0.181	1.59	7.28	0.59	2.20	3.26	2.56	2.56	clay - brown
46-49.7	0.197	1.76	6.90	1.11	0.16	5.65	5.32	19.69	sandy clay loam - OM - dark tan

Total lbs-N/Acre = 322.61

Site ID: HC-4, City Park - Cored August '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-1.7	0.162	1.37	7.03	11.72	2.51	72.52	43.68	74.26	clay - black
2.5-5	0.145	1.44	6.46	9.91	5.18	68.41	38.80	97.01	clay loam - brown
5-7.5	0.169	1.30	7.00	2.48	0.13	14.63	8.76	21.91	silty clay - Fe C - tan
7.5-10	0.166	1.15	7.14	0.78	0.05	4.68	2.44	6.10	silty clay - Fe C - tan
10-12.5	0.158	1.06	7.16	2.15	0.23	13.59	6.18	15.46	silty clay - Fe C - OM - tan
12.5-15	0.168	1.10	7.45	1.08	0.27	6.41	3.22	8.05	silt - Fe C - tan
15-17.5	0.181	1.16	7.59	0.56	0.05	3.07	1.75	4.38	silt - tan
17.5-20	0.185	1.27	7.43	0.62	0.05	3.36	2.14	5.34	silt - tan
20-22.2	0.226	1.27	7.36	0.51	0.05	2.25	1.76	3.87	silty clay - light brown
22.5-25	0.194	1.33	7.35	0.59	0.05	3.03	2.13	5.33	clay loam - black
25-27.5	0.119	1.41	7.30	0.66	0.05	5.59	2.54	6.35	loam - light brown
27.5-28.7	0.111	1.57	7.31	0.67	0.05	6.10	2.89	3.46	loam - brown
28.7-30	0.092	1.56	7.27	0.93	0.05	10.03	3.95	5.13	sandy loam - dark tan
30-32.9	0.161	1.34	6.56	0.96	1.37	5.99	3.51	10.18	clay loam - brown
32.9-35.9	0.191	1.81	6.70	0.72	1.33	3.77	3.54	10.63	clay - brown
35.9-37.5	0.119	1.53	6.63	0.77	1.21	6.43	3.18	5.09	loamy sand - light brown
37.5-40	0.031	2.08	6.76	0.58	0.85	18.40	3.26	8.16	sand - tan
40-42.5	0.146	2.00	6.76	1.00	1.56	6.88	5.45	13.62	sandy clay - OM - brown
42.5-45	0.050	2.05	6.76	0.48	1.03	9.47	2.65	6.63	sand - tan
45-47.5	0.088	1.79	6.72	0.87	1.56	9.89	4.23	10.58	sandy clay - brown
47.5-49	0.085	1.94	6.62	0.69	1.09	8.15	3.66	5.48	loamy sand - OM - tan
49-52.1	0.175	2.03	6.59	1.18	1.63	6.76	6.54	20.26	sandy clay - OM- brown
52.1-55.3	0.149	2.15	6.76	0.97	2.14	6.53	5.68	18.19	clay loam OM - brown
55.3-57.9	0.353	1.60	6.83	1.21	1.82	3.43	5.28	13.74	loam - dark tan
57.8-60.6	0.129	2.28	6.29	0.72	1.87	5.57	4.44	12.44	clay loam - OM - brown
60.6-64.3	0.103	2.17	6.53	0.97	1.56	9.39	5.69	21.06	loam - brown

Total lbs-N/Acre = 418.29

Site ID: HC-5, Residential - Cored August '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-2.3	0.164	1.24	6.66	1.40	2.16	8.50	4.70	10.82	clay loam - OM - black
2.5-5	0.212	1.31	6.42	0.83	1.85	3.93	2.95	7.38	clay loam - OM - dark brown
5-7.5	0.217	1.53	6.28	0.84	1.03	3.89	3.51	8.76	clay - brown
7.5-10	0.218	1.19	6.17	0.69	1.08	3.14	2.22	5.55	loam - OM - brown
10-12.5	0.237	1.58	6.10	0.67	0.49	2.83	2.88	7.21	clay loam - OM - brown
12.5-15	0.258	1.29	6.10	0.76	0.46	2.95	2.67	6.68	clay - OM - light brown
15-17.5	0.293	0.80	6.48	0.54	1.37	1.86	1.19	2.97	clay - OM - brown
17.5-20	0.294	1.37	6.26	3.55	0.45	12.07	13.21	33.02	clay - brown
20-22.9	0.267	1.32	6.30	0.74	0.79	2.79	2.67	7.74	clay - light brown
22.5-23.2	0.227	1.65	6.72	0.79	0.22	3.46	3.52	2.47	clay loam - brown
23.2-25	0.117	1.79	6.30	0.66	0.65	5.63	3.22	5.79	sandy clay -brown
25.8-27.5	0.054	2.19	6.30	0.63	0.35	11.63	3.75	6.37	sand - dark brown
27.5-30	0.049	2.01	6.26	0.68	0.05	14.04	3.75	9.37	sand - tan
30-32.5	0.103	2.17	6.25	0.90	0.31	8.71	5.28	13.20	sand - tan
32.5-35	0.164	2.12	7.56	0.83	0.18	5.06	4.76	11.90	loam - Fe P - light brown
35-36.2	0.116	1.95	6.48	1.87	1.63	16.07	9.88	11.86	sand - light brown
36.2-37.5	0.123	2.43	7.52	0.95	0.85	7.68	6.27	8.15	sandy clay - Fe P - light brown
37.5-40	0.235	1.94	6.53	0.83	0.05	3.53	4.39	10.97	clay loam - light brown
45-46.7	0.118	1.67	6.79	0.85	0.17	7.20	3.85	6.55	sandy loam - light brown
46.7-50	0.141	1.99	6.70	0.74	0.14	5.26	4.03	13.29	sandy clay loam - light brown

Total lbs-N/Acre = 144.90

Site ID: HC-6, Residential - Cored August '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-2	0.189	0.92	7.31	1.60	3.91	8.50	4.00	8.00	clay - black
2.7-4.8	0.185	0.73	6.60	0.42	1.69	2.28	0.72	1.15	clay loam - light brown
5.9-7.5	0.171	0.58	7.25	0.36	1.47	2.13	0.66	1.40	silt loam - light tan
7.5-9.5	0.160	0.65	6.97	0.13	0.77	2.00	0.22	0.44	silt loam - light brown
10-12.2	0.132	0.67	7.18	0.13	0.86	2.00	0.23	0.50	silt - Fe C - light brown
12.2-13.8	0.115	0.62	7.22	0.13	0.86	2.00	0.21	0.34	silt - light brown
15-17.3	0.125	0.55	7.26	0.13	0.78	2.00	0.19	0.43	silt loam - light brown
17.3-20	0.126	0.62	7.22	0.13	1.24	2.00	0.21	0.57	silt - light brown
20-21.8	0.141	0.64	7.33	0.26	0.93	1.81	0.45	0.80	silty clay - brown
21.8-25.8	0.103	0.71	7.30	0.13	1.19	2.00	0.24	0.96	loam - dark brown
26.2-27.5	0.091	0.74	7.26	0.13	1.36	2.00	0.25	0.33	sandy loam - brown
30.3-31.6	0.156	0.94	7.34	0.13	1.13	2.00	0.32	0.42	sandy loam - light brown
32.2-34.6	0.098	1.20	7.47	0.13	1.06	2.00	0.41	0.98	sand - light tan
35-37.5	0.056	0.86	7.59	0.29	0.95	5.25	0.69	2.07	sand - tan
37.5-40	0.136	0.75	6.71	0.13	0.99	2.00	0.25	0.63	sandy loam - tan
40.6-42.5	0.133	0.89	7.56	0.26	0.93	1.98	0.64	1.21	loamy sand - brown
42.9-45	0.166	1.07	7.55	0.13	1.04	2.00	0.36	0.76	loam - brown
45-47	0.155	1.09	7.57	0.35	1.74	2.24	1.04	2.07	loamy sand - brown
47.9-50	0.180	0.99	7.23	1.11	2.38	6.18	2.99	6.28	loam - OM - brown
50.6-52.5	0.152	0.89	7.50	0.13	1.26	2.00	0.30	0.58	loamy sand - brown
52.5-53.9	0.177	1.01	7.31	0.13	0.81	2.00	0.34	0.48	clay - brown
55.5-57.5	0.183	1.02	7.45	0.13	1.46	2.00	0.35	0.69	clay loam - brown
57.5-60	0.221	0.93	7.48	0.32	1.23	1.44	0.81	2.02	clay loam - brown
60-61.9	0.175	0.93	7.64	0.54	1.35	3.11	1.37	2.61	clay loam - brown
62.5-63.8	0.174	1.24	7.72	0.47	1.59	2.73	1.60	2.08	sandy clay loam - brown
67.5-70	0.139	1.04	7.69	0.63	1.67	4.54	1.77	4.43	sandy loam - brown

Total lbs-N/Acre = 51.36

Site ID: HC-7, Barnyard - Cored August '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-2.3	0.104	1.38	7.00	4.16	5.33	40.01	15.67	36.03	clay - black
2.3-5	0.131	1.18	7.36	1.32	0.14	10.06	4.21	11.38	silty clay - light brown
5.-7.5	0.155	1.09	7.42	1.23	0.05	7.90	3.64	9.09	silt loam - Fe C - light brown
7.5-10	0.154	1.15	7.32	1.83	0.29	11.93	5.74	14.35	silt - Fe C - light tan
10-12.5	0.169	1.07	7.27	1.12	0.26	6.64	3.28	8.19	silty clay - Fe C - light tan
12.5-15	0.164	1.29	7.31	0.86	0.05	5.26	3.03	7.58	silty clay - light tan
15-17.5	0.175	1.30	7.35	1.22	0.05	6.98	4.33	10.83	silty clay - light tan
17.5-19.7	0.178	1.35	7.32	1.89	0.19	10.61	6.93	15.25	silty clay - light tan
19.7-22.5	0.193	1.28	7.27	1.41	0.05	7.32	4.93	13.81	loam - light brown
22.5-24.8	0.051	1.68	7.24	2.32	0.05	45.11	10.58	24.32	sand - light brown
24.8-25.9	0.184	1.42	7.17	3.63	0.39	19.71	13.98	15.38	sandy clay - brown
25.9-27.8	0.045	1.47	7.14	3.70	0.05	82.01	14.76	28.05	sand - light brown
27.8-30	0.097	1.61	7.46	1.92	0.05	19.77	8.42	18.52	sand - Fe C - light tan
30-32.5	0.077	1.99	7.53	1.45	0.07	18.84	7.86	19.65	sand Fe C - light tan
35-36.3	0.076	2.22	6.79	1.05	1.81	13.85	6.32	8.22	loamy sand - tan
36.3-40.2	0.177	2.00	7.02	1.57	1.60	8.86	8.51	33.17	loam - Fe C - OM - brown
40.2-42.5	0.092	1.83	7.00	1.98	0.63	21.56	9.86	22.68	sandy clay - brown
42.5-45	0.198	1.80	6.98	1.41	2.58	7.13	6.90	17.24	clay - OM - brown
45-47.5	0.234	2.01	7.06	2.32	1.17	9.92	12.69	31.72	clay - OM - brown
47.5-50	0.184	2.17	7.11	8.88	1.22	48.28	52.44	131.10	clay loam - brown
50-52.5	0.215	2.02	7.12	5.86	1.50	27.26	32.27	80.67	clay - OM - brown
52.5-55	0.217	1.70	7.11	4.87	1.58	22.42	22.54	56.34	clay - brown
60-62.5	0.099	1.91	7.86	3.36	0.16	33.94	17.46	43.65	sand - tan
62.5-64.7	0.077	2.11	7.58	4.20	0.05	54.89	24.05	52.91	loamy sand - dark tan
64.7-67.5	0.090	2.02	7.64	2.71	1.38	29.96	14.86	41.62	loamy sand - dark tan
67.5-70	0.047	2.36	7.50	3.50	0.05	75.21	22.52	56.29	sand - tan

Total lbs-N/Acre = 885.30

Site ID: HC-8, Barnyard - Cored August '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-1.9	0.146	1.48	5.86	2.12	1.86	14.54	8.56	16.27	clay loam - OM - black
1.9-5	0.116	1.25	7.06	0.86	0.70	7.42	2.94	9.10	silty clay loam - tan
5-7.5	0.134	1.15	7.40	0.90	0.44	6.74	2.84	7.09	silty clay loam - Fe C - tan
7.5-10	0.120	1.27	7.77	1.34	0.37	11.18	4.62	11.56	silty clay loam - Fe C - tan
10-12.5	0.188	1.20	7.80	0.81	0.37	4.33	2.66	6.66	silty clay - Fe C - OM - tan
12.5-15	0.195	1.23	7.86	1.10	0.16	5.66	3.69	9.23	silty clay - Fe C - tan
15-17.5	0.198	1.20	7.80	1.42	0.38	7.21	4.63	11.58	silty clay - OM - tan
17.5-20	0.224	1.35	7.88	2.09	0.28	9.35	7.66	19.16	silty clay - OM - tan
20-22.5	0.235	1.47	7.74	4.44	0.41	18.93	17.70	44.25	clay - Fe - brown
22.5-25	0.193	1.83	7.56	7.04	0.05	36.53	34.99	87.48	clay loam - dark brown
25-26.1	0.221	1.78	7.68	2.44	3.13	11.05	11.80	12.98	clay - OM - brown
26.1-27.5	0.119	1.81	7.73	3.15	0.54	26.54	15.52	21.73	sandy clay loam - dark brown
27.5-30	0.085	1.79	7.43	2.85	0.91	33.65	13.92	34.79	sandy clay loam - dark brown
30-32.5	0.186	1.93	7.53	2.76	0.81	14.78	14.43	36.08	sandy clay - OM - dark brown
32.5-35	0.150	2.04	7.61	3.41	0.51	22.69	18.95	47.37	sandy clay - OM - dark brown
35-36.8	0.171	1.92	7.73	1.72	2.20	10.04	8.99	16.18	clay loam - dark brown
36.8-40	0.142	1.76	7.78	2.89	1.11	20.37	13.81	44.19	sandy clay - OM - dark brown
45-47.5	0.124	1.69	7.77	2.69	1.21	21.72	12.34	30.85	sandy clay - OM - dark brown
47.5-50	0.152	1.99	7.73	3.41	0.43	22.45	18.47	46.18	sandy loam - OM - dark tan
50-52.5	0.142	2.09	7.77	2.40	0.99	16.91	13.63	34.07	loamy sand - OM - dark tan
52.5-55	0.057	0.98	7.73	2.65	1.25	46.58	7.11	17.77	sand - OM - tan
55-56.5	0.191	1.68	7.48	4.70	0.52	24.58	21.52	32.27	loamy sand - OM - brown
57.5-60	0.145	1.90	7.44	3.91	0.85	27.03	20.20	50.49	sandy clay loam - OM - light brown
60-62.4	0.065	0.96	7.45	0.92	0.05	14.22	2.39	5.75	sandy loam - OM - brown
62.5-64.5	0.140	2.21	7.24	3.12	0.14	22.24	18.75	37.50	sandy clay - Fe P - OM - brown
64.5-67.5	0.148	2.00	7.30	2.65	1.66	17.89	14.41	43.22	sandy clay - Fe P - OM - brown
67.5-70	0.044	0.99	7.36	2.34	9.57	53.74	6.32	15.80	sand - tan
70-72.5	0.120	2.36	7.25	1.57	0.81	13.15	10.09	25.22	loamy sand - light brown
72.5-75	0.033	2.29	7.13	1.46	0.49	44.77	9.12	22.80	sand - Fe C - OM - tan

Total lbs-N/Acre = 861.77

Site ID: HC-9A, Pivot Irrigated Soybeans - Cored March '17

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-0.8	0.207	1.26	5.70	9.14	3.94	44.27	31.36	25.09	clay loam - OM - black
0.8-3.3	0.180	1.84	6.04	2.50	4.55	13.94	12.50	31.25	clay loam - OM - black
5-6.5	0.218	1.77	6.54	1.59	3.22	7.29	7.67	11.50	silty clay - OM - dark brown
10-11.5	0.176	1.80	7.28	1.97	2.39	11.21	9.64	14.45	clay loam- Fe C - light brown
15-17.5	0.263	1.27	7.58	3.15	2.10	11.99	10.92	27.29	silt loam - OM - brown
20-22	0.097	2.10	7.57	2.48	2.42	25.51	14.17	28.33	sandy loam - brown
25-27	0.057	1.76	7.63	3.61	2.18	63.57	17.28	34.56	sand - dark tan
30-31.2	0.136	1.22	7.85	2.39	2.04	17.62	7.94	9.53	sandy clay loam - dark brown
31.2-32.9	0.054	1.95	7.88	2.18	2.06	40.29	11.59	19.70	loamy sand - dark brown
35-36.8	0.099	2.08	7.90	1.94	1.96	19.63	10.97	19.74	sandy loam - dark tan
40.2-42.7	0.164	1.66	7.56	4.11	2.19	25.13	18.61	46.52	loam - OM - Fe P - light brown
45.4-47.5	0.174	1.83	7.32	1.82	2.35	10.45	9.06	19.03	silty clay - OM - Fe P - light brown
50-52.5	0.176	1.44	6.96	0.87	1.51	4.91	3.39	8.49	sandy clay - OM - Fe C - dark brown
52.5-55	0.172	1.41	6.90	1.10	2.81	6.39	4.22	10.54	silt loam - OM - light brown
55-56	0.116	1.76	6.78	1.14	1.43	9.85	5.47	5.47	sandy clay loam - dark brown
56-58.2	0.105	1.35	6.78	1.08	1.18	10.27	3.96	8.72	sandy loam - light brown
60-62.3	0.052	1.90	6.80	0.95	0.88	18.29	4.87	11.21	loamy sand - light brown
65-67.5	0.049	2.05	7.07	0.93	1.95	19.02	5.19	12.96	loamy sand - tan
70-72.5	0.045	2.03	7.14	1.42	1.13	31.63	7.86	19.65	sandy loam - tan

Total lbs-N/Acre = 727.00

Site ID: HC-9B, Pivot Irrigated Soybeans - Cored March '17

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-2.5	0.138	1.18	5.74	10.60	3.53	76.76	34.08	85.21	clay loam - OM - black
0.5-2.7	0.151	1.42	7.44	0.95	3.32	6.28	3.66	8.05	silt loam - OM - brown
5.0-7	0.176	1.57	6.94	1.81	2.93	10.28	7.74	15.47	silty clay - Fe C - light brown
10.0-12	0.155	1.49	7.60	1.12	2.27	7.27	4.55	9.11	clay loam - OM - Fe C - brown
15-16.7	0.189	1.71	7.58	1.76	2.29	9.31	8.19	13.92	silty clay - OM - brown
17.5-20	0.172	1.59	7.64	4.28	1.72	24.91	18.56	46.40	loam - OM - brown
20-22	0.164	1.51	7.45	3.17	2.26	19.33	12.96	25.92	sandy clay loam - dark brown
25-27	0.066	1.93	7.37	1.88	2.35	28.41	9.88	19.76	sandy loam - brown
30-30.5	0.106	1.44	7.24	1.38	2.61	12.93	5.39	2.70	loamy sand - dark tan
30.5-33	0.101	1.72	7.13	1.37	2.27	13.62	6.42	16.04	loamy sand - dark tan
35-37	0.157	1.93	6.95	1.48	1.83	9.40	7.74	15.48	sandy clay - brown
40.3-42.8	0.102	1.86	7.00	1.66	2.03	16.20	8.39	20.97	sandy loam - brown
45-47	0.049	1.46	7.10	1.39	2.10	28.50	5.54	11.08	loamy sand - OM - dark tan
50-51	0.120	1.58	6.96	1.84	2.21	15.40	7.91	7.91	sandy clay loam - dark tan
51-53.5	0.058	1.26	6.90	1.50	1.99	25.88	5.15	12.87	sandy loam - OM - dark tan
55-57	0.145	1.74	6.83	1.72	2.37	11.82	8.11	16.22	sandy clay - OM - brown
60-62	0.112	1.93	6.98	1.30	2.11	11.65	6.84	13.68	sandy clay loam - brown
65-67.5	0.077	1.82	7.02	1.12	2.11	14.51	5.54	13.85	sandy clay loam - brown
70-72	0.088	1.82	7.09	1.28	3.26	14.65	6.36	12.71	loamy sand - light tan

Total lbs-N/Acre = 532.09

Site ID: HC-10-N, Pivot Irrigated Soybeans - Cored March '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-0.8	0.219	1.33	6.19	5.56	4.78	25.36	20.06	16.05	clay loam - OM - black
10-12.5	0.234	0.92	7.13	0.70	0.77	2.98	1.74	4.35	silty clay - grey
13.6-15	0.262	0.99	7.17	0.34	1.06	1.29	0.91	1.28	clay loam - grey
15.3-17.1	0.156	1.40	7.12	0.48	0.80	3.05	1.81	3.26	sandy clay - dark brown
17.1-20	0.075	1.54	7.21	0.31	0.64	4.20	1.31	3.81	loamy sand - dark brown
20.7-23.2	0.089	1.55	7.28	0.42	0.88	4.76	1.78	4.44	loamy sand - brown
23.5-25.9	0.117	1.92	7.27	1.65	0.75	14.10	8.64	20.73	sandy clay loam - light brown
32.4-36.2	0.227	1.72	7.05	0.53	0.96	2.34	2.49	9.45	clay loam - Fe C - OM - light brown
35-36.2	0.176	1.17	7.27	0.56	1.19	3.19	1.79	2.15	clay loam - Fe C - light brown
40-42.5	0.084	1.85	7.43	0.52	0.46	6.26	2.64	6.61	sandy loam - light brown
45-47.5	0.142	1.44	7.28	1.03	0.97	7.26	4.02	10.06	sandy clay - OM - dark tan
47.5-50	0.084	1.41	7.18	0.74	0.85	8.84	2.86	7.14	sandy clay - Fe P - OM - brown
50-52.5	0.097	1.46	7.35	0.61	0.81	6.27	2.41	6.03	sand - brown
57.5-59.7	0.092	1.35	7.21	0.80	1.07	8.70	2.93	6.44	sandy clay - Fe P - OM - brown
62.1-63.3	0.173	1.50	7.13	0.58	1.30	3.38	2.39	2.86	clay loam - Fe C - OM - light brown
63.3-64.6	0.079	1.35	7.10	0.57	0.87	7.19	2.10	2.72	loamy sand - light brown
65-67.5	0.468	1.19	7.00	0.47	0.97	1.00	1.52	3.79	clay loam - Fe P - brown
67.5-70	0.199	1.65	7.05	0.52	0.87	2.62	2.33	5.82	clay loam - OM - Fe C - light brown
72.5-75	0.168	1.66	7.04	0.33	1.44	1.99	1.51	3.77	clay loam - OM - Fe C - light brown
75-77.3	0.042	1.67	7.22	0.23	0.58	5.36	1.04	2.38	sand - Fe C - light tan
80-82.3	0.042	1.48	7.19	0.44	0.66	10.48	1.77	4.08	sand - Fe C - tan
85-87.5	0.154	1.73	7.19	0.69	1.54	4.48	3.25	8.13	sandy clay loam - Fe P - tan
85.8-88.8	0.282	1.21	7.02	4.00	0.50	14.22	13.21	39.64	sandy clay - grey

Total lbs-N/Acre = 325.14

Site ID: HC-10-S, Pivot Irrigated Soybeans - Cored March '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-1.7	0.211	1.28	5.64	2.66	2.73	12.64	9.27	15.76	clay loam - OM - black
1.7-5	0.245	1.17	6.02	0.62	0.49	2.53	1.97	6.51	loam - Fe C - OM - black
5-7.5	0.202	0.98	6.89	0.60	0.14	2.96	1.59	3.99	silt loam - Fe C - OM - brown
7.5-10	0.216	0.98	7.30	1.59	0.68	7.33	4.21	10.52	silt loam - Fe C - OM - brown
10-12.5	0.215	1.01	7.33	0.58	0.19	2.71	1.60	4.01	silty clay loam - Fe C - OM - brown
12.5-15	0.219	1.04	7.23	1.79	1.21	8.16	5.04	12.61	silty clay loam - Fe C - OM - brown
15-17.5	0.251	1.53	7.22	1.83	0.88	7.30	7.61	19.04	silty clay loam - Fe C - OM - brown
20-23.1	0.261	1.42	7.21	2.87	1.27	11.01	11.07	34.32	clay - Fe C - brown
25.7-28.2	0.163	1.77	7.18	1.94	0.56	11.92	9.33	23.34	sandy loam - light brown
30-32.5	0.050	1.56	7.31	2.09	0.51	42.08	8.86	22.15	sand - tan
32.5-35	0.065	1.74	7.24	1.32	0.05	20.32	6.27	15.67	sand - light tan
40-42.2	0.135	1.64	6.74	1.57	0.20	11.65	6.99	15.37	loamy sand - light brown
45-47.4	0.124	1.71	7.13	1.08	0.05	8.70	5.02	12.05	loamy sand - dark tan
50-51	0.053	2.17	7.02	0.81	0.05	15.40	4.82	4.82	loamy sand - dark tan
51-53.3	0.226	1.87	7.03	2.22	0.53	9.82	11.28	25.95	sandy clay - Fe P - light brown
53.3-56.7	0.177	1.57	6.95	2.02	0.81	11.40	8.67	29.47	sandy clay - Fe P - light brown
56.7-59.2	0.181	1.78	7.03	2.03	0.66	11.20	9.82	24.56	sandy clay - Fe C - light brown
60-62.3	0.175	1.34	6.87	1.78	0.28	10.16	6.49	14.93	sandy clay - Fe C - dark brown
62.3-64.6	0.136	1.66	6.93	1.47	0.42	10.75	6.63	15.25	sandy clay - dark brown
64.6-67.2	0.060	1.70	7.09	0.85	0.05	14.19	3.93	10.23	sand - light tan
75-77	0.141	1.90	7.14	0.66	0.05	4.71	3.43	6.87	sand - light tan
80-82.5	0.196	1.72	7.20	2.42	0.89	12.35	11.30	28.25	clay - Fe C - light brown
82.5-85.2	0.188	1.63	7.34	2.34	0.34	12.44	10.39	28.04	sandy clay - grey

Total lbs-N/Acre = 556.24

Site ID: HC-11-E, Pivot Irrigated Corn - Cored December '15

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
1.5-4	0.188	1.08	6.86	4.25	1.03	22.63	12.47	31.19	clay loam - dark brown
4.0-5.0	0.148	1.19	7.33	2.29	1.91	15.53	7.40	7.40	sandy clay loam - brown
7.5-9.5	0.228	1.47	7.61	0.56	0.65	2.44	2.22	4.44	clay loam - OM - brown
11.5-13.5	0.197	1.01	7.58	0.78	0.52	3.95	2.13	4.27	clay loam - OM - brown
13.5-15	0.267	1.15	7.60	0.35	0.55	1.33	1.11	1.67	clay loam - dark brown
15-17	0.273	0.96	6.39	0.73	0.85	2.66	1.90	3.79	silty clay - brownish grey
17-19	0.278	1.14	6.57	0.87	0.71	3.14	2.72	5.43	loam - dark brown
20.5-22.5	0.192	1.17	6.99	1.08	0.75	5.62	3.44	6.88	loam - dark brown
22.5-24	0.290	1.13	7.15	0.84	0.61	2.89	2.58	3.87	clay loam - brown
24-25	0.083	1.21	7.16	0.50	1.19	6.10	1.65	1.65	silt loam -OM - light brown
27.5-30	0.101	1.29	7.24	0.33	0.77	3.30	1.16	2.91	loamy sand - light brown
30-32.5	0.175	1.17	7.39	1.71	0.85	9.76	5.41	13.54	loam - Fe chemical - brown
32.5-35	0.223	1.24	7.36	0.91	0.57	4.07	3.07	7.67	clay - OM - brown
37.5-38.5	0.174	1.44	5.72	1.76	2.60	10.10	6.87	6.87	silty clay - OM - brown
38.5-40	0.188	1.54	5.94	2.88	2.24	15.33	12.07	18.10	clay loam - dark brown
45-47.5	0.212	1.16	7.26	1.27	0.68	6.01	3.29	8.22	clay loam - OM - Fe chemical - brown
50-51.5	0.086	1.72	6.03	0.73	5.45	8.42	3.40	5.10	sand - dark tan
54-55	0.063	1.65	6.07	0.92	2.04	14.57	4.12	4.12	loamy sand - OM - dark tan
57.5-59	0.146	1.51	6.40	0.92	1.37	6.29	3.77	5.65	loam - OM - brown
59-60	0.072	1.34	6.46	0.91	1.88	12.63	3.31	3.31	sandy loam - light brown
62.5-63.5	0.062	1.40	6.31	0.92	2.64	14.97	3.51	3.51	loamy sand - dark brown
63.5-65	0.071	1.37	6.40	0.94	1.34	13.16	3.50	5.24	sand - dark brown
67.5-70	0.039	1.21	6.41	0.67	1.59	17.09	2.21	5.52	loamy sand - dark brown
70-72.5	0.082	1.29	6.44	1.06	1.17	12.90	3.74	9.34	loamy sand - OM - dark tan
75-77	0.038	1.90	7.38	1.57	1.54	41.30	8.15	16.29	sandy clay - OM - dark brown
78-80	0.046	2.01	7.48	0.47	7.37	10.17	2.57	5.13	sand - dark tan
82.5-83.5	0.096	1.87	6.79	0.61	0.96	6.31	3.09	3.09	sand - tan
88-89	0.155	2.08	6.99	0.72	1.19	4.66	4.10	4.10	sand - OM - dark tan
90-92	0.096	1.59	7.24	1.25	0.95	13.03	5.40	10.80	sand - Fe chemical - dark tan
93.5-95	0.320	0.94	7.51	1.64	0.61	5.12	4.17	6.26	sandy loam - Fe chemical - dark tan
101-102.5	0.343	0.99	7.65	1.75	0.90	5.11	4.72	7.09	sand - dark tan

Total lbs-N/Acre = 410.34

Site ID: HC-11-W, Pivot Irrigated Corn - Cored December '15

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
1.2-2.5	0.239	1.01	7.00	1.99	1.06	8.34	5.47	7.10	clay loam - dark brown
2.5-3.5	0.433	1.09	7.09	2.70	3.30	6.23	8.01	8.01	clay - OM - brown
4.5-6.8	0.333	1.01	7.44	3.59	0.91	10.79	9.88	22.72	silty clay - Fe chemical - light brown
6.8-8	0.351	1.31	7.25	3.34	1.21	9.53	11.91	14.30	clay - Fe chemical - tan
8.0-10	0.545	1.09	7.30	2.73	0.68	5.00	8.10	16.21	clay - OM - brown
10.0-12.0	0.292	1.35	6.89	2.47	7.92	8.45	9.08	18.16	clay - Fe physical - OM - light brown
12.0-14.0	0.282	1.20	6.99	1.78	2.41	6.31	5.83	11.65	clay - Fe physical - light brown
15.5-17.5	0.320	1.03	7.13	1.20	0.93	3.74	3.34	6.69	clay loam - light brown
18.7-20	0.227	1.20	7.21	0.47	0.67	2.09	1.54	2.00	silty clay - dark brown
22-23.1	0.117	1.16	7.34	0.88	0.82	7.50	2.75	3.03	silty clay loam - dark brown
23.1-25	0.074	1.79	7.31	0.32	0.41	4.33	1.56	2.96	loamy sand - light brown
27.5-29.5	0.087	1.95	7.46	0.13	0.53	2.00	0.66	1.32	sand - OM - light brown
32-33.3	0.223	1.65	7.13	1.98	1.27	8.89	8.90	11.57	silt loam - light brown
33.3-35	0.489	1.30	6.91	0.76	0.41	1.54	2.67	4.55	sandy loam - light brown
37.5-40	0.064	1.30	6.91	2.00	0.52	31.17	7.08	17.71	loamy sand - light brown
42.5-44.5	0.039	1.51	6.27	1.34	1.19	34.05	5.50	10.99	sand - tan
45-47.5	0.058	1.36	6.04	0.89	2.03	15.31	3.29	8.22	loamy sand - tan
47.5-50	0.069	1.11	6.29	2.47	1.14	35.93	7.48	18.69	loamy sand - Fe chemical - tan
52.5-55	0.070	1.25	6.41	1.85	0.96	26.33	6.28	15.70	loamy sand - light tan
55-57.5	0.082	1.26	6.42	1.44	1.42	17.62	4.97	12.42	sandy loam - OM - brown
58.5-60	0.093	1.38	6.56	2.91	1.39	31.22	10.89	16.34	sandy clay loam - OM - brown
67.5-69.5	0.042	1.47	6.39	2.08	1.13	49.80	8.33	16.65	sand - tan
73-75	0.070	1.55	6.64	2.86	1.35	40.72	12.07	24.14	sand - brown
77.5-80	0.045	1.27	5.87	2.19	2.32	48.18	7.57	18.93	sand - tan
82.5-84.5	0.037	1.35	6.27	1.39	1.67	37.31	5.10	10.21	sand - Fe chemical - tan
86.5-88	0.066	1.70	6.47	1.60	1.88	24.28	7.39	11.08	loamy sand - dark brown
88-90	0.063	1.52	6.74	1.95	1.31	31.21	8.08	16.16	sand - dark tan
92.5-94	0.061	1.66	7.04	3.66	2.11	59.55	16.54	24.80	sand - dark tan
95-97	0.060	1.26	7.19	3.33	2.80	55.73	11.45	22.91	silt loam - Fe chemical - brown
97-99	0.047	1.79	7.26	2.16	1.29	45.49	10.53	21.05	silty clay loam - Fe chemical - dark brown
99-101	0.045	1.90	7.31	2.04	1.18	45.79	10.52	21.04	clay loam - OM - dark brown

Total lbs-N/Acre = 720.58

Site ID: HC-12-E, Gravity Irrigated Soybeans - Cored April '17

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
3.4-5	0.266	1.54	6.84	4.59	3.07	17.26	19.20	30.72	clay loam - OM - black
5-7.5	0.218	1.62	7.54	3.02	2.12	13.86	13.35	33.36	silty clay - OM - Fe P - brown
8.0-10	0.263	1.34	7.58	3.98	1.87	15.13	14.44	28.88	silty clay - Fe C - brown
10-12.5	0.306	1.02	7.31	4.83	2.45	15.80	13.41	33.53	silty clay - Fe C - OM - brown
12.5-15	0.254	1.54	7.33	6.20	2.41	24.42	26.00	65.00	clay - Fe C - brown
15.8-17.5	0.342	1.34	5.37	5.61	2.31	16.40	20.52	34.88	clay - light brown
17.5-18.9	0.234	1.57	5.60	4.21	2.91	18.02	17.92	25.09	sandy clay loam - Fe C - light brown
22.5-25	0.110	1.69	5.96	3.10	2.39	28.23	14.20	35.49	sandy loam - OM - dark gray
25-27.5	0.214	1.49	6.00	1.48	2.17	6.92	6.02	15.04	sandy clay - Fe C - OM - light brown
29-30	0.157	1.86	6.09	4.11	3.22	26.19	20.79	20.79	sandy clay loam - Fe C - OM - light brown
32.5-35	0.185	1.68	6.23	0.71	2.08	3.84	3.25	8.12	sandy clay - OM - light brown
35-37.5	0.177	1.29	6.52	1.01	2.33	5.69	3.55	8.87	sandy clay - OM - brown
38-40	0.140	1.35	6.64	0.74	1.85	5.31	2.72	5.43	sandy loam - Fe C - brown
45.6-47.5	0.149	1.86	6.64	1.19	3.80	8.01	6.03	11.46	loamy sand - brown
47.9-50	0.059	1.88	6.48	1.06	2.21	17.93	5.42	11.38	sand - Fe C - tan
53.7-55	0.073	1.71	6.32	1.19	2.40	16.35	5.54	7.20	sand - Fe C - tan
57.5-60	0.154	1.71	6.50	1.72	2.63	11.16	8.03	20.07	sandy clay - Fe C - tan
63.0-65.0	0.150	1.42	6.11	1.01	2.58	6.70	3.89	7.79	loamy sand - tan
68.2-70	0.185	1.66	6.20	1.21	2.57	6.54	5.45	9.81	sandy clay loam - OM - Fe c - light brown
72.5-75	0.171	1.76	6.46	0.86	2.45	5.00	4.09	10.22	sandy clay loam - OM - Fe C - light brown
78.1-80	0.151	1.40	6.46	1.12	2.82	7.44	4.25	8.08	loamy sand - tan

Total lbs-N/Acre = 684.04

Site ID: HC-12-W, Gravity Irrigated Soybeans - Cored March '17

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
3.3-5	0.198	1.82	6.35	7.15	3.92	36.11	35.32	60.05	clay loam - OM - black
7.9-10	0.219	1.10	6.92	2.10	2.90	9.61	6.28	13.19	silty clay - Fe C - brown
13.5-15	0.252	1.55	7.14	4.72	2.14	18.74	19.95	29.92	clay - Fe C - light brown
15.9-17.5	0.272	1.25	7.25	3.95	1.54	14.53	13.41	21.46	clay - Fe C - light brown
17.5-20	0.298	1.22	7.29	5.02	2.53	16.87	16.63	41.56	clay - Fe C - Fe P - light brown
22.5-25	0.275	1.63	7.37	5.80	2.70	21.12	25.68	64.19	loam - Fe C - Fe P - light brown
27.7-30	0.072	1.24	7.51	2.85	1.20	39.83	9.57	22.00	sand - dark tan
33.5-35	0.150	1.95	7.35	5.61	1.34	37.34	29.70	44.56	sandy clay loam - Fe C - brown
37.5-40	0.057	1.72	7.55	4.39	1.65	77.50	20.55	51.38	sand - Fe C - tan
44.2-45.5	0.095	1.84	7.48	8.53	1.41	90.17	42.71	55.52	loamy sand - Fe C - tan
46-47.5	0.171	1.58	7.47	14.23	1.55	83.19	60.94	91.42	sandy loam - light brown
52.5-55	0.192	1.59	7.11	7.29	1.15	37.88	31.50	78.74	clay - Fe P - dark brown
56.3-57.5	0.279	0.96	6.81	4.95	2.46	17.75	12.88	15.46	clay loam - Fe C - brown
57.5-60	0.191	1.42	6.92	3.37	1.95	17.61	13.07	32.66	clay - Fe C - OM - light brown
60.9-62.5	0.224	1.78	7.00	3.88	1.51	17.31	18.75	30.00	clay loam - brown
63.2-65	0.237	1.75	6.80	3.41	1.69	14.39	16.21	29.17	sandy clay - Fe C - light brown
67.5-70	0.226	1.48	6.88	3.28	1.49	14.51	13.15	32.88	clay - OM - Fe C - light brown
72.5-75	0.186	1.45	6.89	2.66	1.75	14.29	10.48	26.19	clay loam - OM - Fe C - light brown
75-77.5	0.186	1.84	6.92	2.75	1.62	14.80	13.71	34.28	sandy clay - Fe C - light brown
77.5-80	0.203	1.68	6.99	3.29	1.81	16.23	15.06	37.65	clay loam - Fe C - light brown
83.7-85	0.073	1.63	6.94	2.29	2.18	31.61	10.16	13.21	sandy clay - light brown
85-87.5	0.258	1.31	6.99	2.55	1.54	9.85	9.05	22.62	sandy clay - light brown
87.5-90	0.246	1.51	7.11	2.92	1.98	11.87	11.96	29.89	sandy clay loam - Fe C - light brown
94-95	0.159	1.56	7.03	2.75	2.66	17.32	11.69	11.69	sandy clay loam - light brown
98.5-100	0.082	1.62	7.02	2.16	1.96	26.41	9.50	14.25	sand - tan
103.5-105	0.031	1.93	7.62	2.08	1.92	66.40	10.91	16.36	gravely sand - tan
108.7-110	0.023	1.50	7.60	2.00	2.32	88.40	8.15	10.59	gravely loamy sand - tan
114-115	0.031	1.76	7.50	1.77	2.03	56.38	8.49	8.49	gravely sand - tan
118.9-120	0.024	1.53	7.48	1.42	1.27	59.84	5.91	6.50	gravely sand - tan

Total lbs-N/Acre = 2,062.50

Site ID: HC-13-N, Pivot Irrigated Corn - Cored March '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-0.9	0.323	0.89	7.19	19.22	4.08	59.43	46.73	42.06	clay loam - dark brown
0.9-1.2	0.212	1.24	6.45	5.97	1.73	28.24	20.21	6.06	clay loam - dark brown
1.2-3.4	0.229	1.58	6.08	5.59	1.86	24.45	23.98	52.75	clay loam - dark brown
5-6.3	0.330	1.33	6.15	6.95	2.26	21.03	25.22	32.78	clay loam - brown
6.3-7.5	0.267	1.46	5.83	5.19	1.96	19.42	20.60	24.72	clay loam - brown
7.5-8.4	0.242	1.69	5.83	6.05	1.78	25.03	27.87	25.08	silt loam - brown
10-11.2	0.257	1.17	5.95	4.02	2.39	15.65	12.75	15.30	silt loam - brown
12.5-14.5	0.317	0.95	6.10	7.66	1.90	24.15	19.86	39.73	silt loam - brown
17.5-20	0.302	0.99	6.14	5.84	1.33	19.35	15.69	39.22	silt loam - brown
20-22.6	0.277	1.48	5.47	3.26	1.51	11.75	13.10	34.07	sandy clay loam - light brown
25.8-26.3	0.318	1.09	5.76	1.67	1.50	5.24	4.91	2.46	sandy loam - dark brown
26.3-28.3	0.299	1.26	5.90	1.14	0.84	3.81	3.91	7.82	loamy sand - tan
30-31.8	0.145	1.48	6.06	1.03	0.90	7.07	4.13	7.43	loamy sand - tan
35-36.5	0.177	1.50	5.91	1.08	1.39	6.10	4.41	6.62	sand - light tan
40-41.6	0.323	1.21	6.36	2.33	1.27	7.22	7.63	12.21	clay loam - light brown
41.6-43.6	0.154	1.82	6.63	2.14	1.62	13.91	10.64	21.28	sandy clay loam - lighter brown
45-47.2	0.215	1.75	6.46	1.41	1.50	6.55	6.72	14.79	sand - light tan
50-51.7	0.173	1.29	6.25	0.84	1.11	4.84	2.94	5.00	sand - light tan
57.5-60.9	0.119	1.46	5.81	0.68	1.67	5.75	2.72	9.26	sandy clay loam - Fe - dark tan
60.9-61.9	0.147	1.04	6.09	0.83	1.00	5.63	2.34	2.34	sandy clay loam - Fe - light brown
61.9-63.4	0.120	1.57	5.85	0.39	0.98	3.24	1.66	2.49	sand - Fe - light brown
65-66.7	0.071	1.61	5.80	0.45	0.99	6.26	1.95	3.32	sand - Fe - dark tan
66.7-67.5	0.067	1.70	5.96	0.44	0.96	6.54	2.04	1.63	loamy sand - tan
70-71.9	0.238	1.28	5.99	0.84	0.99	3.55	2.94	5.58	silty clay - Fe - OM - brown
71.9-73.1	0.137	1.43	6.00	1.12	0.93	8.14	4.36	5.23	clay loam - brown
75-77.5	0.043	1.81	5.47	1.02	1.05	23.63	5.02	12.54	sandy loam - Fe - light brown
80.5-82.5	0.044	1.66	5.41	0.54	0.64	12.15	2.44	4.88	sand - light tan
90-92	0.034	1.54	5.94	1.01	0.45	30.03	4.22	8.44	sand - light tan
95-97	0.101	1.34	5.97	0.79	0.48	7.87	2.89	5.78	sand - tan
100-101.7	0.188	1.25	6.39	2.42	0.81	12.88	8.25	14.03	sandy clay loam - brown
103.2-104.2	0.211	1.48	7.11	1.28	0.68	6.07	5.15	5.15	sandy clay loam - brown

Total lbs-N/Acre = 831.93

Site ID: HC-13-S, Pivot Irrigated Soybeans - Cored March '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-2.7	0.194	1.27	6.47	8.26	2.87	42.63	28.53	77.03	clay loam - OM - black
2.7-4.7	0.184	1.41	6.21	9.07	2.04	49.29	34.69	69.38	loam - OM - dark brown
5-7.2	0.206	1.06	6.10	6.27	1.94	30.45	18.09	39.80	clay loam - OM - black
7.2-9.7	0.177	1.17	6.18	8.49	1.48	47.94	26.92	67.31	loam - OM - dark brown
10-12.5	0.209	1.18	6.38	3.08	2.17	14.78	9.87	24.67	silt loam - OM - brown
12.8-15	0.216	1.13	6.52	4.46	1.44	20.70	13.71	30.16	silt loam - Fe P - OM - light brown
15-17.5	0.217	1.12	6.87	4.55	1.94	20.98	13.80	34.50	silt loam - Fe C - OM - light brown
17.5-20	0.300	1.41	6.70	5.67	1.24	18.91	21.82	54.54	clay - Fe P - OM - light brown
20-22.5	0.322	1.05	7.01	5.58	2.17	17.32	16.01	40.03	clay - Fe P - OM - light brown
22.5-25	0.363	1.22	7.16	7.98	2.39	21.98	26.50	66.26	clay - Fe P - OM - light brown
25-27.5	0.360	1.25	7.15	7.14	2.06	19.86	24.27	60.66	clay - Fe P - brown
30-32.5	0.334	1.00	7.05	6.25	4.05	18.73	16.93	42.32	clay - Fe C - brown
32.5-35	0.195	1.61	6.94	5.20	2.17	26.66	22.75	56.87	sandy clay - dark brown
35-37.6	0.184	1.28	7.02	4.47	1.30	24.23	15.54	40.39	sandy clay - dark brown
37.6-40	0.157	1.59	7.13	2.83	1.11	17.98	12.20	29.28	sandy loam - tan
42-43.2	0.161	1.60	7.25	4.04	0.59	25.02	17.60	21.12	sand - tan
45-47.5	0.154	1.32	6.52	1.37	0.35	8.90	4.90	12.25	clay loam - Fe C - dark brown
47.5-50	0.151	1.60	6.70	1.96	0.91	12.95	8.54	21.35	sandy clay loam - dark brown
50-52.5	0.066	1.38	6.76	3.16	1.07	47.73	11.86	29.65	loamy sand - tan
55-57.2	0.053	1.59	6.87	3.52	1.20	66.43	15.26	33.58	sand - light tan
60-62.5	0.056	1.62	6.90	3.09	1.39	55.08	13.66	34.16	sand - light tan
65-66.4	0.083	1.98	6.58	2.17	0.45	26.10	11.71	16.40	loamy sand - tan
66.4-68.9	0.080	1.70	6.98	1.47	0.69	18.43	6.78	16.96	sandy clay loam - brown
70-72.5	0.126	1.64	6.83	3.90	0.90	30.98	17.36	43.41	sandy clay - brown
72.5-74	0.180	1.69	6.90	3.46	0.75	19.16	15.84	23.76	sandy clay - brown
75-77.5	0.221	1.30	6.81	5.34	1.22	24.22	18.94	47.36	clay - dark brown
77.5-80	0.208	1.72	6.92	5.05	1.05	24.27	23.60	59.01	clay loam - Fe C - Fe P - dark brown
80-82.2	0.167	1.43	7.00	4.19	0.73	25.14	16.29	35.83	sandy clay - Fe C - OM - brown
82.2-83.7	0.109	1.86	7.03	3.50	0.51	31.99	17.65	26.47	loamy sand - Fe C - light brown
85-88.7	0.160	1.87	7.09	5.93	0.79	37.05	30.17	111.64	clay loam - Fe C - brown
90-93.1	0.084	1.63	7.06	3.45	0.25	41.23	15.23	47.21	loamy sand - brown

Total lbs-N/Acre = 1,572.73

Site ID: HC-14-E, Pivot Irrigated Soybeans - Cored April '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-2.1	0.229	0.99	6.32	2.66	3.72	11.64	7.17	15.05	clay loam - dark brown
2.1-4.5	0.191	1.21	6.51	0.05	1.54	2.00	0.41	0.99	silt loam - brown
5-6.9	0.198	0.91	7.00	0.64	0.73	3.25	1.59	3.02	silty clay loam - Fe C - brown
7.5-10	0.214	0.95	7.00	1.81	1.14	8.43	4.69	11.72	silty clay - brown
10-11.6	0.216	1.20	7.46	2.54	1.02	11.72	8.28	13.25	clay loam - brown
12.5-15	0.267	1.12	7.71	2.75	0.84	10.32	8.36	20.90	clay - brown
17.9-20	0.134	1.93	7.61	1.92	1.16	14.40	10.09	21.18	clay loam - dark brown
23.1-25	0.060	1.71	7.73	0.67	1.14	11.23	3.14	5.96	sand - light brown
27.9-30	0.064	1.47	8.06	0.30	2.09	4.74	1.21	2.55	sand - light brown
30-32.5	0.169	1.18	7.61	0.05	0.79	2.00	0.40	1.00	sandy loam - Fe C - dark brown
32.7-34.8	0.163	1.25	7.69	0.05	0.40	2.00	0.42	0.89	sandy loam - Fe P - OM - brown
37.5-39.3	0.152	1.59	7.78	0.73	0.55	4.79	3.15	5.68	clay loam - light brown
40-42.5	0.233	1.21	7.72	1.16	0.64	4.99	3.82	9.54	clay - OM - light brown
42.5-44.4	0.223	1.66	7.13	0.99	0.84	4.45	4.48	8.52	clay - OM - light brown
46.1-47.5	0.226	1.91	7.26	0.47	0.94	2.10	2.47	3.45	clay loam - dark brown
48.1-50	0.166	1.62	7.30	0.77	0.53	4.65	3.39	6.45	loam - OM
51.7-52.5	0.090	0.97	6.90	0.48	1.04	5.31	1.26	1.01	sandy loam - light brown
52.5-55	0.117	1.98	7.10	0.63	2.21	5.43	3.41	8.54	loamy sand - OM - light brown
57.5-59	0.177	1.92	7.14	1.35	1.00	7.64	7.03	10.54	loam - OM - brown
60-62.5	0.147	1.30	7.44	0.83	2.84	5.65	2.94	7.35	sandy clay loam - OM - light brown
62.5-63.9	0.196	1.42	7.02	0.93	0.92	4.75	3.61	5.05	sandy clay loam - Fe C - light brown
63.9-65	0.147	1.73	7.24	0.68	1.24	4.64	3.22	3.54	loamy sand - Fe C - OM - light brown
67.5-70	0.107	1.46	6.57	0.67	1.13	6.24	2.67	6.67	loamy sand - OM - brown
70-71.5	0.202	1.10	7.17	1.07	1.58	5.28	3.18	4.77	clay loam - Fe C - OM - dark tan
71.5-72.5	0.170	1.38	7.98	1.55	2.21	9.08	5.82	5.82	sandy clay loam - Fe P - OM - dark tan
72.5-75	0.170	1.50	6.97	1.54	1.03	9.04	6.26	15.66	sandy loam - Fe P - OM - dark tan
77.5-80	0.085	2.09	7.36	3.14	4.41	37.17	17.82	44.55	loamy sand - Fe P - Fe C - tan
82.5-85	0.046	1.76	7.01	0.93	0.68	20.11	4.43	11.09	loamy sand - Fe P - OM - tan
85.9-87.5	0.131	1.57	7.05	0.92	1.25	7.07	3.94	6.30	sandy loam - OM - light brown
87.5-90	0.066	1.53	6.81	1.44	1.09	21.67	5.98	14.95	sand - Fe C - Fe P - dark tan
92.5-94.6	0.049	1.72	6.38	0.30	1.37	6.04	1.39	2.92	sand - tan
97.5-100	0.059	1.38	6.64	0.46	1.15	7.88	1.74	4.34	sand - tan
102.5-105	0.080	1.54	6.71	0.38	1.44	4.75	1.60	4.00	sand - tan
107.5-110	0.061	1.50	6.88	0.47	1.25	7.76	1.92	4.79	sand - light tan

Total lbs-N/Acre = 432.55

Site ID: HC-14-W, Pivot Irrigated Corn - Cored April '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-2	0.271	1.17	6.13	6.72	3.18	24.81	21.34	42.68	loam - dark brown
2.5-4.5	0.235	1.50	6.40	0.69	2.61	2.92	2.80	5.59	clay loam - dark brown
4.5-6.7	0.240	1.21	6.47	1.59	1.04	6.61	5.22	11.48	clay - OM - brown
7.5-10	0.257	1.47	6.62	3.28	1.03	12.80	13.09	32.72	clay OM - Fe P - Fe C - brown
10-12.5	0.239	1.15	6.91	2.60	2.08	10.89	8.12	20.29	clay OM - Fe P - Fe C - brown
12.5-14.5	0.231	1.15	6.98	1.55	1.00	6.69	4.82	9.64	clay OM - Fe P - brown
15-17.2	0.246	1.13	7.01	1.78	1.07	7.26	5.50	12.11	clay OM - Fe P - brown
18.1-20	0.242	1.12	7.19	2.02	2.68	8.38	6.18	11.75	clay - OM - Fe P - brown
20-22.5	0.267	1.14	7.34	2.83	1.47	10.58	8.79	21.97	silty clay - OM - Fe P - brown
22.5-24.5	0.238	1.36	7.69	1.32	1.69	5.56	4.87	15.10	silty clay - brown
26.1-28	0.133	1.29	7.60	0.90	1.36	6.77	3.17	11.74	loam - dark brown
30.5-32.5	0.056	2.12	7.30	0.60	2.04	10.74	3.43	6.87	loamy sand - tan
33-35	0.043	1.67	7.89	0.90	2.09	20.96	4.12	8.23	sand - light tan
37.5-39.5	0.093	1.79	7.72	1.70	3.33	18.42	8.31	16.62	sand - Fe C - tan
40-40.8	0.149	1.60	7.89	2.47	2.64	16.57	10.73	8.59	sandy loam - Fe P - OM - tan
40.8-42.8	0.206	1.11	7.90	2.11	1.47	10.23	6.38	12.77	clay loam - brown
42.8-45	0.204	1.38	7.78	1.46	1.75	7.17	5.48	12.05	clay - brown
45-46.1	0.158	1.03	7.87	0.69	0.78	4.38	1.93	2.12	sandy clay - OM - light brown
46.1-47.5	0.131	1.31	7.80	1.09	0.95	8.34	3.88	5.44	sandy loam - OM - light brown
47.5-50	0.154	1.95	9.96	0.38	0.80	2.45	2.01	5.03	loamy sand - OM - light brown
50-52	0.220	1.34	9.92	0.86	1.76	3.89	3.12	6.25	loamy sand - Fe P - brown
52.5-55	0.192	1.26	9.98	0.63	2.70	3.28	2.16	5.41	clay loam- Fe P - Fe C - brown
57.5-59.5	0.063	1.30	10.02	0.29	0.77	4.54	1.01	2.02	sand - Fe P - dark tan
59.5-60.8	0.074	1.73	9.99	0.37	1.03	4.96	1.73	2.25	loamy sand - dark tan
60.8-62.5	0.154	1.51	9.96	0.46	1.90	2.97	1.89	3.21	sandy loam - dark tan
62.3-65	0.221	1.37	9.91	0.13	1.01	2.00	0.47	1.26	loamy sand - OM - dark tan
66.8-68.3	0.120	1.51	10.01	0.50	0.99	4.06	2.07	3.10	loamy sand - dark tan
72.5-75	0.112	1.55	10.05	0.42	1.44	3.76	1.78	4.45	loamy sand - OM - dark tan
78.2-80	0.054	1.54	10.04	0.46	2.04	8.52	1.93	3.47	sand - dark tan

Total lbs-N/Acre = 351.05

Site ID: HC-15-N, Pivot Irrigated Soybeans - Cored March '17

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
4.0-5.0	0.244	1.42	7.66	7.02	240.09	28.81	27.03	27.03	clay loam - OM - black
7.5-10	0.227	1.62	6.73	5.55	3.41	24.45	24.51	61.27	clay loam - OM - dark brown
12.9-15	0.228	1.71	6.67	5.83	9.18	25.56	27.17	57.06	clay loam - OM - dark brown
18.3-20	0.229	1.46	6.71	8.29	1.66	36.13	32.98	56.06	silty clay - brown
23.7-25	0.243	1.39	6.84	4.57	1.85	18.81	17.27	22.46	silty clay - Fe C - light brown
27.5-30	0.267	1.14	6.95	2.28	4.25	8.54	7.06	17.66	silty clay - Fe C - light brown
33.4-35	0.179	1.70	6.89	1.76	3.12	9.82	8.14	13.02	sandy clay loam - brown
38.3-40	0.049	1.68	7.62	1.40	1.73	28.57	6.39	10.86	loamy sand - dark tan
43.1-45	0.081	1.64	7.22	1.34	1.94	16.58	6.00	11.40	sandy clay loam - tan
45-47.5	0.213	1.76	7.10	2.20	2.97	10.34	10.55	26.39	clay loam - brown
47.5-50	0.206	1.77	7.06	1.85	3.60	8.97	8.88	22.20	clay loam - OM - brown
51-52.5	0.135	1.31	6.76	1.51	2.85	11.22	5.40	8.10	sandy clay loam - OM - dark brown
52.5-55	0.143	1.79	7.18	1.64	3.17	11.43	8.00	20.01	sandy clay - OM - light brown
57.5-60	0.190	1.64	7.24	1.81	3.69	0.11	0.53	1.32	sandy clay - dark brown
63-65	0.095	1.61	7.03	3.47	2.58	36.53	15.20	30.40	sand - tan
68.1-70	0.048	1.60	6.71	3.67	3.60	76.24	15.93	30.26	sand - light tan
72.5-75	0.072	1.49	7.05	3.12	4.05	43.19	12.66	31.65	sand - Fe C - light tan
75.5-77.5	0.186	1.29	6.93	2.00	2.56	10.74	7.02	14.04	sandy loam - Fe C - light brown
77.5-80	0.175	1.14	7.13	3.33	2.98	19.02	10.30	25.76	silty clay - Fe C - light brown
82.5-85	0.172	1.97	6.85	3.05	2.99	17.74	16.36	40.89	silt loam - light brown
87.5-90	0.065	1.59	7.22	2.24	3.73	34.19	9.68	24.20	sandy loam - Fe C - tan

Total lbs-N/Acre = 1,167.69

Site ID: HC-15-S, Pivot Irrigated Corn - Cored April '17

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
3.3-5	0.264	1.33	6.11	11.30	4.21	42.86	40.75	69.27	clay loam - OM - black
5-7.5	0.253	1.18	6.30	7.33	2.43	28.93	23.58	58.96	silty clay - OM - light brown
8.0-10	0.272	1.31	6.84	7.16	2.28	26.36	25.43	50.87	silty clay - OM - light brown
12.9-15	0.287	1.12	7.00	2.65	2.56	9.23	8.08	16.97	silty clay - OM - light brown
15-17.5	0.268	1.17	7.08	1.79	2.28	6.69	5.69	14.23	clay loam - OM - light brown
17.5-20	0.282	1.15	7.10	2.23	2.34	7.90	6.96	17.41	clay loam - OM - Fe C - light brown
22.7-25	0.237	1.20	6.65	2.13	2.54	8.96	6.96	16.00	clay - Fe C - dark brown
28.1-30	0.140	1.70	7.30	1.79	2.36	12.79	8.28	15.73	sandy loam - Fe C - dark brown
32.9-35	0.146	1.43	7.19	1.21	2.13	8.27	4.69	9.85	loamy sand - tan
38-40.0	0.102	1.78	7.17	1.34	3.16	13.15	6.49	12.98	sandy loam - light brown
42.5-45	0.175	1.75	7.16	1.89	2.34	10.81	8.98	22.46	sandy clay loam - Fe C - light brown
45.7-47.5	0.279	1.38	7.15	2.27	2.88	8.16	8.51	15.32	loam - Fe C - OM - brown
47.9-50	0.283	1.38	6.85	2.19	3.09	7.74	8.21	17.23	loam - Fe C - OM - brown
53.1-55	0.212	1.22	6.98	1.83	3.27	8.62	6.08	11.55	sandy clay - OM - dark brown
57.5-60	0.186	1.40	7.28	1.58	2.76	8.47	6.01	15.03	sandy clay loam - dark brown
63.1-65	0.237	1.17	7.32	1.25	3.02	5.29	3.98	7.55	sandy clay - light brown
65.9-67.5	0.166	1.21	7.22	1.56	3.50	9.37	5.12	8.19	sandy clay - light brown
67.5-70	0.237	1.19	7.09	1.77	3.51	7.47	5.73	14.33	sandy clay - light brown
77.7-80	0.264	1.18	6.80	1.63	3.05	6.18	5.22	12.00	sandy clay - Fe C - light brown
84-85	0.104	1.84	6.87	1.84	2.83	17.73	9.19	9.19	loamy sand - Fe C - tan
87.5-90	0.168	1.92	6.87	2.74	2.67	16.30	14.31	35.78	clay loam - Fe C - brown
91-93.5	0.043	1.75	7.30	1.98	2.06	46.11	9.42	23.55	loamy sand - Fe C - tan
98-100	0.033	2.50	7.19	1.58	2.04	47.83	10.77	21.54	sand - Fe C - light ran
103.6-105	0.010	2.44	7.26	1.82	2.58	179.60	12.06	16.88	sand - light tan

Total lbs-N/Acre = 902.84

Site ID: HC-16-N, Pivot Irrigated Soybeans - Cored March '17

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
1.4-2.5	0.232	1.84	5.99	9.92	3.76	42.77	49.72	54.69	clay loam - OM - black
5.4-7.5	0.228	1.60	6.79	2.52	2.23	11.05	10.95	23.00	silty clay - OM - dark brown
11.1-12.5	0.249	1.75	7.00	1.77	1.93	7.10	8.42	11.78	silty clay - OM - dark brown
15.5-17.5	0.264	1.46	7.07	2.17	1.94	8.22	8.64	17.27	clay loam - OM - dark brown
21-22.5	0.272	1.31	7.22	3.35	1.86	12.33	11.95	17.93	clay - OM - dark brown
25.5-27.5	0.091	1.46	7.32	2.11	2.08	23.19	8.37	16.74	loamy sand - brown
28.6-30	0.107	1.93	7.31	3.06	1.92	28.47	16.05	22.47	sandy clay loam - brown
38.9-40	0.068	1.64	7.52	2.24	1.95	32.84	9.98	10.98	sand - brown
43.6-45	0.056	1.93	7.48	2.24	2.16	39.86	11.78	16.50	sand - light brown
47.5-50	0.169	1.98	7.31	2.78	2.34	16.49	14.96	37.39	sandy clay - brown
53-55	0.090	1.74	6.75	2.22	2.10	24.68	10.52	21.04	sandy loam - tan
57.8-60	0.189	1.73	6.74	2.22	2.33	11.74	10.45	23.00	sandy clay loam - dark tan
63.1-65	0.170	1.97	6.55	2.89	2.55	17.00	15.45	29.36	sandy loam - OM - light brown
67.5-70	0.116	1.92	6.50	2.64	1.93	22.74	13.75	34.37	sandy clay - light brown
72.5-75	0.132	1.61	6.76	1.40	2.92	10.65	6.17	15.41	sandy clay - light brown
77.8-80	0.098	2.19	6.64	1.25	1.91	12.76	7.42	16.33	loamy sand - tan
82.5-85	0.087	1.95	6.86	0.98	2.42	11.30	5.19	12.96	sandy loam - light brown

Total lbs-N/Acre = 996.13

Site ID: HC-16-S, Pivot Irrigated Soybeans - Cored March '17

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
10.5-12	0.215	1.72	7.19	0.96	1.76	4.47	4.52	6.77	silty clay loam - OM - Fe P - light brown
15-17.2	0.226	1.58	7.31	0.89	1.95	3.94	3.82	8.40	silty clay loam - OM - Fe P - light brown
20-22.5	0.205	2.05	7.26	1.62	1.31	7.94	9.07	22.68	clay - light brown
25-26.8	0.150	1.87	7.31	1.73	1.29	11.52	8.77	15.78	sandy clay - black
26.8-29.3	0.097	1.70	7.41	6.03	4.71	61.84	27.80	69.49	sandy loam - black
30-32.5	0.153	2.07	7.40	1.53	1.15	10.03	8.63	21.59	sandy clay - dark brown
35.5-37.5	0.180	1.13	7.22	2.54	1.66	14.08	7.79	15.57	loam - Fe C - light brown
37.5-40	0.212	1.35	7.31	2.83	1.48	13.32	10.37	25.93	sandy clay loam - Fe C - brown
40.9-43.2	0.188	1.64	7.41	2.97	1.53	15.79	13.31	30.60	silty clay loam - Fe C - brown
43.2-45	0.186	1.87	7.24	2.17	1.99	11.68	11.07	19.93	sandy clay - Fe C - OM - brown
45-47	0.183	1.50	7.26	1.88	2.35	10.27	7.64	15.29	silty clay - OM - brown
47-49.5	0.188	1.79	7.17	1.77	1.99	9.40	8.59	21.48	silty clay - OM - brown
51-53.5	0.161	1.79	6.85	1.50	2.14	9.31	7.30	18.25	clay loam - OM - brown
55-57.5	0.168	1.27	6.88	1.67	1.75	9.95	5.74	14.36	silt loam - light brown
57.5-60	0.163	1.89	6.83	1.74	1.59	10.68	8.93	22.33	sandy loam - light brown
60-61.5	0.169	1.32	6.84	1.87	2.02	11.05	6.70	10.05	sandy clay loam - brown
61.5-63.6	0.165	1.45	6.76	1.58	2.27	9.63	6.24	13.11	loamy sand - OM - light brown
63-65	0.157	1.80	6.74	1.89	2.53	12.05	9.27	18.55	loamy sand - OM - light brown
65.5-67.5	0.087	2.10	7.13	1.18	1.17	13.55	6.70	13.40	sandy loam - dark tan
67.5-69.4	0.181	1.93	7.14	1.63	1.55	8.97	8.55	16.24	sandy clay - light brown
70.9-72.5	0.172	1.17	7.17	1.61	1.12	9.35	5.13	8.21	sandy clay loam - light brown
72.5-75	0.119	1.48	7.16	1.83	1.72	15.45	7.36	18.39	loamy sand - light brown
80-81.2	0.136	1.98	7.21	1.37	1.59	10.14	7.39	8.86	sand - light brown
85.4-87.5	0.118	1.50	7.48	1.29	1.70	10.94	5.25	11.03	loamy sand - Fe P - light brown

Total lbs-N/Acre = 629.93

Site ID: HC-17-N, Pivot Irrigated Corn - Cored November '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-1.8	0.187	1.59	6.09	3.77	4.08	20.19	16.33	29.40	clay loam - OM - black
5-7.5	0.193	1.10	7.09	1.83	0.46	9.49	5.48	13.69	silt loam - Fe P - brown
10-12.5	0.239	1.26	7.58	0.27	0.92	1.12	0.92	2.29	silt loam - Fe P - brown
12.5-15	0.247	1.33	7.65	0.51	0.33	2.09	1.86	4.66	silt loam - Fe P - brown
15-17.1	0.249	1.23	6.95	5.12	0.81	20.57	17.15	36.02	silty clay - Fe C - light brown
17.1-19.6	0.259	1.14	7.34	1.00	3.33	3.86	3.11	7.77	silty clay - Fe P - light brown
19.6-22.5	0.137	1.81	7.53	1.15	5.50	8.35	5.64	16.35	sandy clay loam - OM - black
25-27.1	0.050	1.53	7.76	0.85	2.44	16.98	3.55	7.45	sandy loam - dark tan
31.6-32.5	0.110	1.77	7.83	1.19	1.42	10.77	5.70	5.13	sand - Fe C - tan
37.8-40	0.111	1.49	7.96	0.64	0.94	5.73	2.59	5.70	sand - light tan
41.3-43.2	0.228	1.42	7.43	0.14	1.57	0.63	0.55	1.04	clay - Fe C - tan
43.2-45	0.198	1.77	7.42	1.24	2.23	6.27	5.98	10.76	clay - brown
48.4-50	0.189	1.83	7.34	0.58	0.68	3.07	2.90	4.63	clay loam - Fe C - OM - dark brown
50.5-52.5	0.114	2.05	7.56	0.42	0.39	3.70	2.35	4.70	sandy clay loam - dark brown
57.5-60	0.094	1.78	7.53	1.10	1.62	11.61	5.32	13.29	sand - tan
62.5-65	0.083	1.45	7.31	2.05	2.00	24.68	8.06	20.14	sand - Fe C - light tan
65-67.5	0.121	1.29	6.54	0.77	3.79	6.37	2.70	6.75	sandy loam - Fe C - brown
67.5-70	0.101	1.68	6.82	0.84	3.15	8.33	3.84	9.59	sandy loam - Fe C - brown
72.5-74.4	0.182	1.69	6.94	2.34	2.09	12.89	10.75	20.42	clay loam - Fe C - dark tan
74.4-75	0.063	1.26	7.00	0.76	2.17	12.12	2.62	1.57	loamy sand - Fe C - dark tan
75-77.5	0.053	1.61	7.05	0.70	2.24	13.36	3.08	7.70	sand - Fe C - dark tan
80.5-82.5	0.052	1.64	7.05	0.85	2.14	16.57	3.82	7.64	loamy sand - dark tan
85-87.5	0.042	2.18	7.07	0.85	1.64	20.49	5.06	12.64	sand - light tan
93-95	0.179	1.59	7.27	0.74	1.46	4.15	3.21	6.41	sand - light tan

Total lbs-N/Acre = 453.87

Site ID: HC-17-S, Pivot Irrigated Soybeans - Cored November '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-1.5	0.235	1.31	5.70	4.52	2.40	19.25	16.07	24.11	clay loam - OM - black
5.9-7.5	0.187	1.57	7.11	2.64	1.48	14.13	11.27	18.04	silty clay - Fe C - OM - light brown
11.4-12.5	0.235	1.68	7.30	1.87	1.17	7.96	8.52	9.37	silty clay - light brown
16.1-18.6	0.261	1.03	7.36	2.04	1.27	7.79	5.69	14.22	silty clay - light brown
18.6-20	0.291	1.53	7.39	1.06	1.31	3.65	4.43	6.20	clay - Fe C - light brown
20-22.5	0.256	1.47	7.37	1.26	1.14	4.92	5.05	12.63	clay - Fe C - OM - brown
26.4-27.5	0.126	1.66	7.41	1.02	0.86	8.06	4.59	5.05	sandy clay loam - black
30-32.5	0.139	1.57	7.49	1.12	0.33	8.04	4.78	11.95	sand - Fe C - dark tan
35.6-37.5	0.130	1.53	7.64	1.63	0.57	12.58	6.80	12.92	sand - dark tan
40-42.5	0.184	1.66	7.48	3.89	1.96	21.10	17.61	44.02	sandy clay loam - dark brown
47.5-50	0.203	1.70	7.42	7.56	2.15	37.25	35.02	87.56	clay loam - dark brown
50-52.5	0.078	1.60	7.58	4.46	2.13	57.04	19.48	48.70	sandy clay loam - dark tan
56.1-57.5	0.041	1.72	7.70	3.02	1.86	74.33	14.10	19.74	sand - tan
62.9-65	0.049	1.67	7.70	2.42	1.86	49.72	10.99	23.07	sand - tan
67.5-70	0.180	1.47	7.54	7.28	1.82	40.39	29.08	72.71	sandy clay loam - Fe C - brown
72.7-75	0.054	2.00	7.25	2.32	1.46	42.56	12.58	28.93	loamy sand - light brown
77.5-80	0.054	1.57	7.40	1.76	2.36	32.34	7.48	18.71	loamy sand - light brown
80-82.5	0.174	1.45	7.06	2.78	3.93	15.98	10.94	27.35	loam - Fe C - dark grey
82.5-85	0.180	1.74	6.97	2.17	4.64	12.06	10.23	25.58	loam - Fe C - dark grey
87.5-89.4	0.190	1.85	6.94	2.24	3.11	11.83	11.29	21.46	clay - Fe C - grey
89.4-90	0.089	2.15	7.03	1.74	2.30	19.62	10.17	6.10	sandy loam- tan
93.7-95	0.030	1.92	7.23	0.91	1.11	30.26	4.73	6.15	sand - Fe C - tan
97.5-100	0.169	1.74	7.11	2.71	2.15	16.01	12.80	32.01	sandy clay - Fe C - dark grey

Total lbs-N/Acre = 1,213.68

Site ID: HC-18-E, Pivot Irrigated Soybeans - Cored March '17

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
3.0-5.0	0.184	1.46	5.83	6.35	2.77	34.52	25.22	50.43	clay loam - OM - black
9.0-10	0.201	1.78	7.20	1.89	2.31	9.39	9.16	9.16	loam - light brown
12.9-15	0.238	1.38	7.32	3.12	2.41	13.08	11.68	24.52	silty clay - light brown
18.4-20	0.260	1.45	7.42	2.66	2.45	10.26	10.53	16.84	clay - Fe C - light brown
22.9-25	0.283	1.53	7.48	2.20	2.18	7.77	9.14	19.19	silty clay - Fe C - brown
28.5-30	0.059	1.67	7.37	1.81	1.71	30.78	8.23	12.34	sandy loam - dark brown
32.5-35	0.223	1.69	7.49	4.12	2.05	18.43	18.93	47.32	silty clay - Fe C - brown
38.4-40	0.215	1.54	7.50	4.20	2.19	19.50	17.54	28.06	silty clay - Fe C - brown
42.8-45	0.170	1.68	7.46	5.18	1.95	30.45	23.63	51.98	silty clay loam - Fe C - brown
48.1-50	0.119	1.76	6.97	3.44	2.21	28.80	16.40	31.17	sandy clay - Fe C - brown
53.5-55	0.081	1.83	7.24	2.14	2.28	26.56	10.66	16.00	loamy sand - Fe C - light brown
58.3-60	0.066	1.65	7.67	1.59	3.41	24.19	7.15	12.16	sand - Fe C - tan
63.5-65	0.045	2.45	7.81	1.59	2.55	35.35	10.58	15.88	sandy loam - Fe C - tan
67.5-70	0.053	1.44	7.98	1.82	3.47	34.53	7.11	17.78	loamy sand - tan
72.5-73.9	0.047	1.68	7.94	1.48	5.02	31.14	6.76	9.47	loamy sand - tan
73.9-75	0.130	1.41	7.74	5.43	2.29	41.79	20.82	22.90	loamy sand - brown
77.5-80	0.040	2.47	7.87	2.34	1.85	58.85	15.70	39.26	gravely sand - tan
82.5-85	0.019	2.46	7.80	1.84	1.96	98.64	12.30	30.74	gravely sand - tan
88.1-90	0.027	2.57	7.92	2.01	1.71	73.15	14.03	26.66	gravely sand - tan
92.5-95	0.107	1.84	7.59	3.57	2.96	33.46	17.93	44.82	sandy loam - brown
96.2-97.5	0.322	1.44	6.58	7.81	1.81	24.30	30.65	39.84	silty clay - light brown
98.3-100	0.298	1.43	6.74	10.59	2.49	35.51	41.25	70.13	sandy clay - light brown
102.5-105	0.087	2.26	7.10	1.83	2.36	21.18	11.28	28.19	loamy sand - dark tan

Total lbs-N/Acre = 1,480.12

Site ID: HC-18-W, Pivot Irrigated Corn - Cored March '17

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
0-2.5	0.232	1.31	6.32	9.73	3.64	41.94	34.73	86.83	clay loam - black
10-12.5	0.256	1.06	7.11	4.02	2.82	15.75	11.57	28.92	silty clay - Fe C - dark brown
15-17	0.304	1.51	7.19	2.71	2.65	8.92	11.18	22.36	clay - OM - Fe C - dark brown
20-22	0.045	2.35	6.66	1.35	1.70	30.05	8.66	17.32	sand - dark tan
25-27	0.146	2.03	6.95	2.43	2.03	16.61	13.39	26.79	loamy sand - dark tan
30-32.5	0.119	1.76	7.21	2.76	2.16	23.19	13.20	32.99	loamy sand - tan
35-37	0.092	1.91	7.21	2.90	2.02	31.49	15.07	30.14	loamy sand - tan
40-42.5	0.194	1.70	7.39	3.24	2.49	16.72	14.97	37.43	silty clay loam - Fe C - OM - light brown
42.5-45	0.126	1.88	7.23	3.76	2.59	29.79	19.23	48.07	silty clay - Fe C - OM
45.8-47.5	0.109	1.72	7.30	3.78	2.35	34.85	17.71	30.11	sandy loam - Fe C - OM - light brown
47.5-50	0.279	1.80	7.18	5.06	2.74	18.17	24.73	61.82	clay - Fe C - OM - light brown
50-52.5	0.190	1.20	7.22	5.21	2.58	27.46	17.06	42.64	silty clay - Fe C - OM - light brown
52.5-54.2	0.187	1.75	7.11	5.89	2.47	31.41	28.08	47.73	silty clay - Fe C - OM - light brown
55-57	0.111	2.17	7.27	3.78	2.21	33.90	22.28	44.56	sandy clay loam - Fe C - OM - dark tan
60.5-62	0.058	1.88	7.32	3.23	1.99	56.14	16.53	24.79	sand - Fe C - dark tan
65-67.5	0.092	1.87	6.83	3.89	1.88	42.29	19.78	49.46	loamy sand - Fe C - dark tan
70-72.5	0.032	2.40	7.13	3.17	2.05	98.01	20.72	51.80	loamy sand - Fe C - dark tan
75-77.5	0.029	2.86	7.37	2.81	1.75	96.63	21.88	54.69	sand - Fe C - dark tan
81-82.5	0.023	3.28	7.42	2.48	1.79	107.55	22.15	33.23	gravely sand - Fe C - tan
85-87	0.024	3.46	7.58	2.30	1.87	96.60	21.63	43.26	gravely sand - tan
90.8-92	0.028	3.43	7.62	2.37	1.85	84.37	22.09	26.51	sandy clay - Fe C - brown
97.5-100	0.333	1.25	7.27	8.04	1.94	24.17	27.33	68.33	sandy clay loam - OM - brown

Total lbs-N/Acre = 1,830.04

Site ID: HC-20-E, Pivot Irrigated Soybeans - Cored November '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
3.4-5	0.241	1.44	6.50	6.30	3.68	26.15	24.67	39.47	clay loam - OM - black
7.1-9.1	0.176	1.43	7.26	1.48	2.11	8.38	5.77	11.54	silty clay loam - OM - dark brown
9.1-10	0.223	1.41	7.34	3.10	1.68	13.91	11.88	10.69	clay loam - Fe C - OM - dark brown
12.9-15	0.249	1.55	7.31	6.65	1.89	26.73	28.02	58.84	clay loam - Fe C - dark brown
17.5-20	0.247	1.63	7.36	7.94	2.02	32.08	35.09	87.72	silty clay - Fe C - OM - dark brown
23.7-25	0.153	1.92	7.04	5.62	1.65	36.76	29.38	38.19	sandy clay loam - dark brown
31.5-33.4	0.269	1.44	7.33	1.22	1.95	4.55	4.81	9.13	sandy loam - light brown
33.4-35	0.255	1.45	7.34	1.06	1.79	4.14	4.16	6.66	sandy clay - Fe C - OM - light brown
35-37.5	0.089	2.15	7.43	1.35	1.92	15.29	7.92	19.81	clay loam - Fe C - OM - light brown
37.5-40	0.184	1.66	7.53	1.27	1.80	6.87	5.74	14.34	clay - Fe C - OM - light brown
42.5-45	0.089	2.15	7.73	1.28	1.88	14.44	7.49	18.71	sandy loam - Fe C - tan
47.8-50	0.184	1.66	7.81	0.72	1.74	3.89	3.24	7.14	loamy sand - light brown
53-55	0.153	1.92	7.62	1.07	1.77	6.99	5.59	11.18	sandy clay loam - OM - brown
57.5-58.4	0.078	1.78	7.71	1.12	1.73	14.26	5.41	4.87	loamy sand - tan
58.4-60	0.084	2.15	7.60	1.62	2.33	19.22	9.49	15.18	loam - dark tan
62.5-65	0.061	2.18	7.60	1.80	4.40	29.50	10.69	26.72	silty clay loam - Fe C - grey
66.5-67.5	0.089	2.15	7.18	1.75	4.09	19.73	10.22	10.22	silty clay loam - Fe C - OM - grey
67.5-70	0.089	2.15	7.34	1.40	1.99	15.82	8.20	20.50	sandy loam - Fe C - grey
72.5-74.4	0.193	1.10	7.16	1.56	2.43	8.06	4.65	8.84	silt loam - Fe C - OM - light brown
74.4-77.5	0.261	1.03	7.12	3.29	2.80	12.60	9.20	28.51	silty clay - Fe C - OM - light brown
77.5-79.6	0.089	2.15	7.19	3.72	2.35	42.04	21.79	45.76	sandy loam - Fe P - OM - light brown
82.5-85	0.078	1.78	7.42	1.90	1.36	24.24	9.20	22.99	loamy sand - Fe C - tan
88.1-90	0.161	1.45	7.47	2.43	1.40	15.06	9.60	18.25	sand - Fe C - tan
92.5-95	0.014	2.23	7.28	1.73	1.21	127.61	10.48	26.20	gravely sand - Fe C - Fe P - tan
97.5-100	0.015	2.26	7.63	1.00	1.42	67.14	6.16	15.40	gravely sand - light tan
103.7-105	0.045	2.18	7.63	0.99	1.75	22.07	5.85	7.61	gravely sand - Fe C - light tan

Total lbs-N/Acre = 1,218.90

Site ID: HC-20-W, Pivot Irrigated Soybeans - Cored November '16

Depth	Gravimetric Water Content	Bulk Density	pH	NO3-N (ug/g)	NH4-N (ug/g)	Pore Water NO3-N (mg/L)	lbs-N/Acre-ft	lbs-N/Acre-ft in Cored Interval	Lithologic Description
1-2.5	0.224	1.23	6.03	12.95	8.56	57.86	43.37	65.06	clay loam- OM - dark brown
2.5-5	0.223	1.22	6.73	8.83	2.28	39.63	29.33	73.33	clay loam - Fe C - dark brown
8.6-10.7	0.269	1.44	7.03	2.94	1.49	10.93	11.55	24.26	silty clay loam - OM - Fe C - dark brown
10.7-13.1	0.231	1.69	7.20	3.15	1.77	13.59	14.46	34.70	clay loam - Fe C - dark brown
13.1-15	0.240	1.16	7.25	3.30	1.57	13.72	10.43	19.82	clay loam - Fe C - dark brown
18.1-20	0.264	1.49	7.13	2.46	1.69	9.31	9.99	18.99	clay - OM - light brown
20.9-22.5	0.132	1.31	7.26	0.75	2.03	5.65	2.65	4.24	sandy clay - dark brown
22.5-25	0.078	1.78	7.23	1.24	3.33	15.82	6.00	15.01	loamy sand - brown
27.9-30	0.107	1.74	7.15	0.51	2.21	4.77	2.41	5.06	sand - Fe P - tan
32.5-35	0.177	1.59	7.15	0.77	2.05	4.35	3.33	8.32	clay loam - light brown
38.4-40	0.208	1.66	7.14	1.04	2.86	5.02	4.71	7.54	clay loam - OM - light brown
43.6-45	0.169	1.89	7.24	0.70	2.00	4.14	3.60	5.03	sandy clay - light brown
52.8-55	0.153	1.92	7.68	0.76	2.03	4.99	3.99	8.77	sandy clay loam - light brown
58.2-60	0.041	1.58	7.73	0.73	1.48	17.76	3.13	5.64	sand - dark tan
63.9-65	0.161	1.45	7.72	0.23	1.82	1.43	0.91	1.00	sand - dark tan
67.9-70	0.099	1.79	7.66	0.13	1.49	1.26	0.61	1.28	sandy clay - tan
72.5-75	0.118	1.87	7.60	0.45	1.86	3.80	2.27	5.68	sandy clay loam - tan
77.5-80	0.061	1.30	7.59	0.50	1.95	8.15	1.75	4.38	sand - light tan
83.6-85	0.057	1.80	7.25	0.13	1.01	2.18	0.61	0.86	sand - dark tan
87.5-90	0.032	1.49	7.53	0.26	1.37	8.02	1.05	2.62	sand - dark tan
92.5-95	0.019	1.57	7.56	0.13	1.70	6.58	0.53	1.34	sand - Fe C - tan
97.5-100	0.038	1.54	7.74	0.64	1.26	16.95	2.70	6.75	gravely loamy sand - Fe C - tan
102.5-105	0.016	1.69	7.73	0.37	1.43	23.54	1.69	4.22	gravely sand - tan
107.5-110	0.014	2.23	7.87	0.77	1.47	56.77	4.66	11.66	gravely sand - tan
112.9-115	0.030	2.06	7.51	0.52	1.69	17.27	2.92	6.14	gravely sand -Fe C - tan

Total lbs-N/Acre = 570.94

Appendix 2 Vadose zone particle size data by site

Site ID: HC-1-E, Gravity Irrigated Corn

Depth	Sand %	Silt %	Clay %
2.5-5	41.8	12.3	45.9
7.5-10	32.1	11.3	56.6
10-12.5	27.1	35.4	37.5
12.5-15	21.9	15.9	62.2
18.1-20	21.9	9.9	68.2
22.5-25	89.6	6.4	3.9
25.9-27.1	37.5	9.0	53.5
27.1-30	24.5	5.5	70.0
31.7-32.5	25.4	6.4	68.2
32.5-35	82.3	7.9	9.8
37.5-40	81.6	14.9	3.5
42.5-45	86.5	6.5	7.0
47.5-50	85.9	5.7	8.3
50.6-51.4	86.7	6.8	6.5
51.4-52.5	45.1	32.6	22.3
57.8-60	59.4	25.6	15.0
61.4-62.5	80.8	10.8	8.4
62.5-65	54.5	27.8	17.7
65-67.5	66.3	21.7	12.0
65-67.5	49.3	34.5	16.2
67.5-70	81.2	12.0	6.8
77.5-78.7	60.2	23.4	16.3
78.7-80	94.6	3.9	1.5
82.5-85	98.4	1.0	0.6
85-87.5	97.7	1.3	1.0
92.5-94.3	95.1	3.7	1.2
101-102.5	92.6	5.9	1.6
102.9-105	91.0	5.9	3.1

Site ID: HC-2, Dryland Corn

Depth	Sand %	Silt %	Clay %
0-2.5	20.3	47.8	31.8
2.5-4.5	14.8	56.7	28.4
5-7.5	26.0	60.5	13.5
7.5-9.5	22.8	56.8	20.4
10.0-12.0	25.5	53.7	20.8
12.5-15	21.6	57.1	21.3
15.0-17.0	20.9	56.5	22.6
20.6-22.5	27.9	49.6	22.5
22.5-24	25.1	51.0	23.9
27.6-30	58.8	24.1	17.1
37.5-40.3	48.3	27.8	23.9
40.3-41.6	46.4	30.3	23.3
41.6-42.5	91.4	2.8	5.8
45-47.5	58.1	22.1	19.8
47.5-50	66.7	15.4	17.9
51.5-52.5	75.9	11.1	13.0
52.5-55	81.3	9.0	9.7
55-57.5	68.1	16.3	15.6
57.5-60	91.2	3.5	5.2
60-62.5	90.4	3.7	5.9
62.5-65	92.3	2.2	5.4
65-67.5	90.9	4.4	4.6
67.5-70	82.5	10.1	7.4
72.5-75.4	84.6	10.2	5.2

Site ID: HC-3A, Residential

Depth	Sand %	Silt %	Clay %
0-2.2	9.1	19.0	71.9
2.2-5	4.4	27.4	68.2
5.8-7.5	11.7	21.5	66.8
7.5-9.2	18.7	14.4	67.0
9.2-10	18.6	13.9	67.5
10-12.5	19.5	64.1	16.4
13.5-17.5	24.8	5.9	69.3
17.5-20	30.9	1.2	67.9
20-22	86.2	7.6	6.2
22-24.1	87.0	5.8	7.2
24.1-25.3	61.9	23.1	15.1
25.3-27.5	82.6	10.0	7.4
27.5-30	84.3	8.0	7.7
30-32.5	79.6	11.6	8.8
32.8-34.5	73.5	13.5	13.0
34.5-36.5	90.5	3.5	6.0
37.5-40	76.4	11.2	12.4
40-42.8	47.8	27.1	25.0
42.8-45	90.9	5.2	4.0
48.1-50.1	64.9	16.7	18.5
50.1-53.5	23.2	41.3	35.5
53.5-55	42.0	32.0	26.0
55-57.5	63.6	20.6	15.8
57.5-60	88.4	4.2	7.3
61.2-63.5	76.4	13.9	9.7
63.5-65.0	47.7	31.1	21.2

Site ID: HC-4, City Park

Depth	Sand %	Silt %	Clay %
0-1.7	17.4	56.7	25.9
2.5-5	25.6	45.3	29.1
5-7.5	38.7	44.4	16.9
7.5-10	31.3	51.8	17.0
10-12.5	32.2	51.5	16.4
12.5-15	29.4	54.3	16.3
15-17.5	30.6	54.5	14.9
17.5-20	29.7	57.0	13.3
20-22.2	19.7	59.4	20.9
22.5-25	36.1	39.3	24.6
25-27.5	52.9	27.8	19.3
27.5-28.7	72.5	11.9	15.6
28.7-30	70.0	18.0	12.0
30-32.9	47.8	32.8	19.4
32.9-35.9	50.5	28.6	20.9
35.9-37.5	67.9	18.0	14.1
37.5-40	87.9	3.9	8.2
40-42.5	67.6	7.3	25.1
42.5-45	83.6	6.5	9.9
45-47.5	51.9	32.9	15.2
47.5-49	71.9	17.1	11.0
49-52.1	44.0	35.8	20.2
52.1-55.3	47.2	36.9	15.9
55.3-57.9	44.5	33.5	21.9
57.8-60.6	59.9	21.2	18.9
60.6-64.3	59.2	24.3	16.5

Site ID: HC-5, Residential

Depth	Sand %	Silt %	Clay %
0-2.3	21.3	58.7	20.0
2.5-5	16.5	55.7	27.8
5-7.5	23.8	48.0	28.3
7.5-10	24.2	61.8	14.0
10-12.5	22.5	61.5	16.0
12.5-15	23.4	50.2	26.4
15-17.5	28.9	56.3	14.8
17.5-20	22.2	64.7	13.1
20-22.5	30.0	63.9	6.0
22.5-23.2	48.0	38.9	13.1
23.2-25	69.2	20.7	10.1
25.8-27.5	27.3	10.2	62.5
27.5-30	91.6	5.1	3.2
30-32.5	92.1	3.9	4.0
31.3-32.5	52.5	26.8	20.7
32.5-35	58.2	21.4	20.4
35-36.2	84.0	9.4	6.5
36.2-37.5	69.9	15.9	14.2
37.5-40	46.8	30.1	23.0
45-46.7	76.8	13.0	10.2
46.7-50	67.1	17.2	15.7

Site ID: HC-6, Residential

Depth	Sand %	Silt %	Clay %
0-2	8.0	31.1	60.8
2.7-4.8	13.4	37.7	48.8
5.9-7.5	11.2	39.7	49.1
7.5-9.5	11.0	27.3	61.6
10-12.2	10.7	33.5	55.8
12.2-13.8	16.0	27.8	56.2
15-17.3	9.3	32.6	58.1
17.3-20	8.4	32.9	58.7
20-21.8	9.1	26.0	64.9
21.8-25.8	17.9	15.9	66.1
26.2-27.5	23.8	10.7	65.4
30.3-31.6	31.1	39.6	29.4
32.2-34.6	65.6	20.3	14.1
35-37.5	74.6	13.4	12.0
37.5-40	67.4	19.8	12.8
40.6-42.5	36.9	45.9	17.3
42.9-45	33.9	41.8	24.2
45-47	34.6	39.8	25.5
47.9-50	38.1	35.0	26.8
50.6-52.5	40.3	37.1	22.6
52.5-53.9	19.3	46.6	34.1
55.5-57.5	21.8	40.5	37.7
57.5-60	24.7	34.3	41.0
60-61.9	26.7	28.5	44.8
62.5-63.8	40.5	16.4	43.1
67.5-70	33.3	19.2	47.5

Site ID: HC-9A, Pivot Irrigated Soybeans

Depth	Sand %	Silt %	Clay %
0-0.8	26.8	46.9	26.3
0.8-3.3	24.5	45.4	30.1
5-6.5	24.6	48.0	27.4
10-11.5	28.0	49.1	22.8
15-17.5	58.0	28.0	14.0
20-22	77.3	12.5	10.2
25-27	13.6	66.7	19.7
30-31.2	89.9	4.3	5.8
31.2-32.9	80.8	11.2	8.0
35-36.8	84.3	9.9	5.8
40.2-42.7	60.0	20.1	19.9
45.4-47.5	51.6	29.5	18.9
50-52.5	45.3	31.2	23.4
52.5-55	48.0	26.7	25.3
55-56	57.4	27.9	14.7
56-58.2	73.5	16.4	10.2
60-62.3	72.6	5.6	21.8
65-67.5	67.9	18.0	14.2
70-72.5	76.7	12.7	10.6

Site ID: HC-10-N, Pivot Irrigated Soybeans

Depth	Sand %	Silt %	Clay %
0-0.8	22.6	52.8	24.6
10-12.5	30.8	52.5	16.7
13.6-15	31.1	48.3	20.5
15.3-17.1	58.6	25.2	16.2
17.1-20	79.6	12.0	8.4
20.7-23.2	73.7	16.3	9.9
23.5-25.9	73.0	16.8	10.3
32.4-36.2	47.4	28.3	24.2
35-36.2	47.7	32.5	19.8
40-42.5	86.1	6.5	7.4
45-47.5	70.0	16.3	13.7
47.5-50	78.8	10.6	10.6
50-52.5	83.3	6.5	10.2
57.5-59.7	49.1	37.2	13.7
57.5-60	39.2	41.5	19.3
62.1-63.3	64.6	29.1	6.3
63.3-64.6	78.8	10.8	10.4
65-67.5	59.8	26.2	14.1
67.5-70	60.6	20.5	18.9
72.5-75	68.5	15.3	16.2
75-77.3	95.5	1.7	2.8
80-82.3	93.0	2.4	4.6
85-87.5	80.4	10.4	9.2
85.8-88.8	77.2	11.5	11.3

Site ID: HC-11-E, Pivot Irrigated Corn

Depth	Sand %	Silt %	Clay %
1.5-4	54.2	26.4	19.5
4.0-5.0	24.0	58.9	17.1
7.5-9.5	21.2	65.7	13.1
11.5-13.5	18.2	72.3	9.6
13.5-15	17.1	71.5	11.4
15-17	19.0	59.8	21.3
17-19	27.8	55.8	16.3
20.5-22.5	42.4	38.3	19.3
22.5-24	50.0	29.9	20.0
24-25	55.8	28.1	16.1
27.5-30	85.5	6.9	7.7
30-32.5	57.7	24.3	18.0
32.5-35	64.2	20.6	15.2
37.5-38.5	24.3	52.0	23.7
38.5-40	35.7	43.8	20.6
45-47.5	47.2	30.6	22.2
50-51.5	86.8	6.6	6.6
54-55	86.6	6.3	7.2
57.5-59	65.9	20.2	13.9
59-60	84.2	9.4	6.4
60.5-62.5	84.2	8.2	7.6
62.5-63.5	75.4	15.8	8.9
63.5-65	83.9	8.9	7.2
67.5-70	85.1	8.9	6.0
70-72.5	80.9	9.8	9.3
75-77	69.4	18.0	12.6
78-80	89.4	5.6	5.0
82.5-83.5	94.9	2.5	2.6
88-89	95.5	2.1	2.4
90-92	87.6	6.5	5.9
93.5-95	74.6	9.7	15.7
101-102.5	88.4	5.7	5.9

Site ID: HC-12-E, Gravity Irrigated Soybeans

Depth	Sand %	Silt %	Clay %
3.4-5	30.3	39.9	29.8
5-7.5	27.6	51.6	20.8
8.0-10	24.0	52.7	23.4
10-12.5	23.9	54.9	21.2
12.5-15	20.0	57.9	22.1
15.8-17.5	17.7	52.7	29.5
17.5-18.9	43.2	37.4	19.4
22.5-25	72.9	17.2	9.9
25-27.5	44.4	30.7	24.9
29-30	60.8	21.3	17.9
32.5-35	68.3	17.0	14.7
35-37.5	86.6	7.9	5.5
38-40	87.2	7.2	5.6
45.6-47.5	63.0	21.8	15.2
47.9-50	57.6	23.3	19.1
53.7-55	71.0	14.0	15.0
57.5-60	76.2	12.0	11.8
63.0-65.0	70.8	15.5	13.6
68.2-70	58.4	21.0	20.6
72.5-75	66.0	20.7	13.3
78.1-80	73.9	14.1	11.9

Site ID: HC-13-N, Pivot Irrigated Corn

Depth	Sand %	Silt %	Clay %
0-0.9	23.7	53.1	23.3
0.9-1.2	29.7	44.4	25.9
1.2-3.4	42.3	38.5	19.2
5-6.3	22.6	58.1	19.2
6.3-7.5	29.0	49.6	21.4
7.5-8.4	21.8	54.8	23.4
10-11.2	12.4	57.0	30.6
11.2-12.5	14.5	48.9	36.6
12.5-14.5	11.1	63.0	25.9
14.5-17.5	14.2	60.3	25.5
17.5-20	15.2	66.3	18.5
20-22.6	44.6	34.6	20.8
22.6-24.3	57.0	26.9	16.2
25.8-26.3	72.9	7.0	20.2
26.3-28.3	82.3	9.7	8.0
30-31.8	90.8	4.7	4.4
35-36.5	95.0	2.0	3.0
40-41.6	26.1	42.9	31.1
41.6-43.6	49.7	31.2	19.1
45-47.2	89.1	5.2	5.7
50-51.7	88.7	6.1	5.3
55-57	90.4	3.6	6.0
57.5-60.9	81.5	10.0	8.5
60.9-61.9	62.0	25.2	12.8
61.9-63.4	73.9	15.6	10.5
65-66.7	81.2	9.4	9.4
66.7-67.5	85.9	6.6	7.5
70-71.9	47.5	34.8	17.6
71.9-73.1	60.8	24.0	15.2
73.1-74.4	75.6	15.0	9.4
75-77.5	86.8	7.2	6.0
80.5-82.5	93.0	4.7	2.4
90-92	89.1	6.4	4.5
95-97	92.1	5.6	2.4
100-101.7	58.3	8.9	32.8
101.7-103.2	27.6	58.7	13.7
103.2-104.2	78.3	12.4	9.4

Site ID: HC-14-W, Pivot Irrigated Corn

Depth	Sand %	Silt %	Clay %
0-2	22.6	51.1	26.3
2.5-4.5	13.8	53.8	32.3
4.5-6.7	21.1	51.8	27.1
7.5-10	25.6	57.2	17.3
10-12.5	24.0	50.3	25.7
12.5-14.5	20.9	54.4	24.6
15-17.2	21.7	51.9	26.4
18.1-20	25.6	52.6	21.7
20-22.5	24.0	52.4	23.6
22.5-24.5	36.2	36.6	27.2
26.1-28	63.1	21.1	15.8
30.5-32.5	81.8	10.1	8.2
33-35	90.8	6.5	2.7
37.5-39.5	83.3	5.6	11.1
40-40.8	65.3	17.0	17.7
40.8-42.8	46.0	27.8	26.2
42.8-45	47.5	27.5	25.0
45-46.1	67.5	16.1	16.4
46.1-47.5	55.8	23.0	21.2
47.5-50	73.7	11.3	15.0
50-52	62.2	17.8	20.0
52.5-55	44.8	30.7	24.5
57.5-59.5	43.5	3.7	52.8
59.5-60.8	77.0	11.5	11.5
60.8-62.5	59.0	24.0	17.1

Site ID: HC-15-N, Pivot Irrigated Soybeans

Depth	Sand %	Silt %	Clay %
4.0-5.0	19.5	46.3	34.2
7.5-10	21.2	43.6	35.2
12.9-15	16.8	49.5	33.7
18.3-20	33.4	48.0	18.6
23.7-25	27.9	49.2	22.9
27.5-30	48.9	30.4	20.7
33.4-35	56.4	25.6	17.9
38.3-40	88.4	4.9	6.7
43.1-45	91.2	2.0	6.8
45-47.5	47.1	28.3	24.6
47.5-50	38.1	32.7	29.2
51-52.5	85.8	7.2	6.9
52.5-55	55.3	23.9	20.8
57.5-60	67.7	18.8	13.5
63-65	59.0	22.2	18.8
68.1-70	49.1	29.8	21.1
72.5-75	50.3	23.6	26.1
75.5-77.5	89.3	2.9	7.8
77.5-80	59.7	21.5	18.9
82.5-85	64.2	20.8	15.1
87.5-90	73.3	14.3	12.4

Site ID: HC-17-S, Pivot Irrigated Soybeans

Depth	Sand %	Silt %	Clay %
0-1.5	22.8	46.2	31.0
5.9-7.5	23.4	56.7	19.9
11.4-12.5	22.2	56.4	21.4
16.1-18.6	24.1	58.3	17.6
18.6-20	33.3	48.3	18.5
20-22.5	28.3	47.9	23.8
26.4-27.5	56.2	25.7	18.0
30-32.5	86.9	3.2	10.0
35.6-37.5	90.0	1.8	8.2
40-42.5	68.1	18.3	13.6
47.5-50	54.3	26.0	19.7
50-52.5	83.0	7.7	9.3
56.1-57.5	91.6	2.5	5.9
62.9-65	92.1	3.4	4.5
67.5-70	62.1	24.8	13.1
72.7-75	86.7	6.2	7.1
77.5-80	85.8	6.2	8.0
80-82.5	36.2	38.9	24.8
82.5-85	34.8	38.4	26.8
87.5-89.4	57.0	22.5	20.6
89.4-90	84.2	8.1	7.7
93.7-95	94.6	2.5	2.9
97.5-100	58.3	25.8	15.9

Site ID: HC-18-W, Pivot Irrigated Corn

Depth	Sand %	Silt %	Clay %
0-2.5	24.5	42.0	33.4
10-12.5	18.8	65.3	15.9
15-17	35.8	49.5	14.7
20-22	88.0	7.6	4.4
25-27	87.6	2.9	9.6
30-32.5	76.0	13.6	10.4
35-37	82.6	6.8	10.6
40-42.5	38.6	39.9	21.5
42.5-45	43.2	37.9	18.8
45.8-47.5	50.4	27.8	21.8
47.5-50	32.0	39.2	28.7
50-52.5	60.8	23.2	16.0
52.5-54.2	49.6	29.8	20.6
55-57	68.8	17.1	14.1
60.5-62	85.0	10.1	4.9
65-67.5	83.4	10.9	5.8
70-72.5	91.3	5.7	3.0
75-77.5	93.6	4.6	1.8
81-82.5	96.1	2.9	1.0
85-87	92.8	5.6	1.6
90.8-92	93.9	4.4	1.7
97.5-100	56.1	35.3	8.6

Site ID: HC-20-W, Pivot Irrigated Soybeans

Depth	Sand %	Silt %	Clay %
1-2.5	28.2	45.7	26.1
2.5-5	30.0	48.1	21.9
8.6-10.7	30.9	50.5	18.7
10.7-13.1	26.1	54.9	19.0
13.1-15	30.0	55.9	14.1
18.1-20	26.2	57.0	16.8
20.9-22.5	69.2	17.8	12.9
22.5-25	81.2	9.7	9.1
27.9-30	89.6	3.7	6.7
32.5-35	55.7	22.9	21.4
38.4-40	59.9	22.9	17.3
43.6-45	61.1	20.8	18.1
52.8-55	82.7	9.6	7.7
58.2-60	94.6	1.3	4.1
63.9-65	92.1	2.7	5.2
67.9-70	84.9	9.3	5.9
72.5-75	81.5	8.3	10.2
77.5-80	93.2	3.5	3.3
83.6-85	96.3	1.6	2.1
87.5-90	94.4	4.3	1.3
92.5-95	93.6	3.4	3.0
97.5-100	95.6	2.2	2.2
102.5-105	96.4	2.3	1.3
107.5-110	95.8	3.0	1.1
112.9-115	96.9	1.9	1.2

Appendix 3 Water Science Laboratory protocol for field soil coring

WATER SCIENCE LABORATORY STANDARD OPERATING PROCEDURE (SOP)

Procedure for Obtaining Cores

Document File Name:	Issue:	Issue Effective Dates:
Field coring-001	001	Dec-2015 to Present

Author's Name (Print):	Author's Signature:	Date:
Craig Adams		1-5-16
Laboratory Director's Name (Print):	**Laboratory Director's Signature:**	**Date:**
Dr. Daniel D. Snow		

Revision/Review Schedule:	Training Schedule:
Annually	New Employee / New Issue / Annually

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Water Science Laboratory
University of Nebraska - Lincoln - East Campus
203 Water Science Laboratory
Lincoln, NE 68583-0844

1. **References**

2. **Scope and Application**
    a. This method describes the coring techniques used to plan, obtain, label, document, and store cores for further analyses. This procedure is used when assisting the DPT and hollow steam auger drilling operator.

3. **Basic Principles**
    a. Coring sites are selected based off of a number of criteria. Two cores are to be taken every 5 feet. Two 2.5 foot plastic coring tubes are placed inside a 5 foot core barrel each time the drilling operator drills to a new depth. Once the sample is obtained, the core barrel is opened and the cores are removed. Each core is capped, labeled, and recorded in a field notebook before being stored in a labeled Styrofoam container. Cores are stored in a freezer to preserve field conditions (e.g., moisture content, Nitrogen, and VOC's).

4. **Apparatus, Materials and Reagents**
    a. Apparatus:
        i. Computer with google earth or GIS
        ii. 2.5 foot plastic tubes
        iii. Rubber tube caps
        iv. Styrofoam coolers
        v. Water resistant field notebook
        vi. Work gloves
        vii. Thick sharpies
        viii. Tools and supplies provided by drilling operator
            1. Drill Rig
            2. Hollow-stem augers
            3. Core barrels
            4. Water level indicator
            5. Egg shell stoppers
            6. Core holding rack
            7. Pipe vice
            8. Pipe wrenches
            9. Sediment separator
            10. Brushes
            11. Water bucket
            12. Bentonite bore-hole plug
            13. GPS unit
    b. Materials
        i. None
    c. Reagents
        i. None

5. **Safety Precautions and Reagent Disposal**
    a. Use work gloves, hard hat, steel toed boots, and keep a safe distance from the drilling rig.

6. **Definitions**
    - ***Core Barrel*** – Encases core liners and prevents sample loss down the bore-hole
    - ***DPT*** – Direct Push Technology (e.g., GeoProbe)
    - ***GIS*** – Geographical Information Systems used for planning and site selection
    - ***Head Assembly***—Head of the core barrel that screws onto the hex rods for sample retrieval

- ***Refusal***—When the drill is unable to penetrate deeper into the sediment
- ***Shoe*** –End of the core barrel where the sample enters the core barrel
- ***VOC's*** – Volatile Organic Compounds

7. Procedure

a. Site Selection

  i. Sites will vary based on project goals and land-owner consent. Examples include:

    1. Areas of high contaminant concentration vs. low concentration
    2. Varied land use
    3. Previously sampled vs. newly sampled

  ii. Select sites that are:

    1. Accessible
      a. Agricultural land
      b. Lawns and parks
    2. In low-lying areas with greater leaching potential
    3. Are within the depth constraints of the drilling equipment
    4. Sampled past the rooting zone into the vadose zone, ideally reaching the water table

b. Field Book Record Keeping

  i. Start a new entry for every site and record the following:

    1. Name
    2. Site Location
      a. Record latitude/longitude or legal description
    3. Date & Time
    4. Weather
    5. GPS coordinates
    6. At what depth visible changes between any sediment horizons occur and
    7. Groundwater depth
    8. Depth of any missing core intervals

c. Coring Preparation

  i. Ensure that the two 2.5 foot plastic tubes are aligned with the top and bottom of the open steel core encasement once placed inside.

  ii. Place top shell of the steel core encasement on top of the loaded bottom shell. To avoid cross threading, ensure the two shells are properly aligned with each other before using the monkey wrenches to assist in screwing on the rear steel cap.

  iii. Screw on the core barrel head assembly and then the shoe after securing the core barrel in place with the pipe vice.

    1. **Note:** An egg shell can be placed inside the front steel cap to prevent sample loss when drilling in sandy sediment.

d. Core Collection and Labeling

  i. The core barrel will be placed on the core holding rack and secured by the pipe vice.

  ii. Unscrew the head assembly and the shoe. Clean the thread of any debris with a wet brush.

  iii. Lift and gently drop one end of the steel core encasement on the holding rack to open it.

1. **Note:** if both tubes aren't fully filled with sediment, inform the drilling operator so adjustments can be made.

iv. Insert sediment separator tool in-between the two cores to divide them.
v. Carefully remove the cores and place a rubber tube cap on each side.
vi. Label every core with their respective site location found in the coring locations pdf file. If a site has more than one drilling location, add a "-#" to the end to denote the location (i.e., HC1-1, HC1-2, and HC1-3).
vii. Label the top cap and highest part of the tube with the depth the sample was taken at. Do the same with the bottom cap and the lowest part of the tube.
viii. Place the labeled core into a Styrofoam cooler labeled with the site location, date, and range of depths.
ix. Revert back to coring preparation.

e. Sample Preservation:
   i. Styrofoam coolers should be stored in a freezer as soon as possible to preserve field conditions.

8. Calculations

9. Statistics

10. Quality Assurance

a. Use clean liners and caps to prevent cross contamination
b. Perched water tables can interfere with perceived aquifer depths. If unusually shallow saturated sediments are recovered in the core barrel, drill 5 more feet and attempt to push through the perched table. If sediments are still unsaturated, reassess the situation.
c. If refusal occurs, mark the depth of refusal and discontinue drilling operations.

11. Comments

12. Attachments

Appendix 4 Water Science Laboratory protocol for lab core processing

WATER SCIENCE LABORATORY
STANDARD OPERATING PROCEDURE (SOP)

Procedures for Processing Cores

Document File Name:	Issue:	Issue Effective Dates:
Analyte-Processing soil core-001	001	May-2009 to Present

Author's Name (Print):	Author's Signature:	Date:
Craig Adams		5-18-09
Laboratory Director's Name (Print):	**Laboratory Director's Signature:**	**Date:**
Dr. Daniel D. Snow		

Revision/Review Schedule:	Training Schedule:
Annually	New Employee / New Issue / Annually

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Water Science Laboratory
University of Nebraska - Lincoln - East Campus
203 Water Science Laboratory
Lincoln, NE 68583-0844

1. References

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2. Scope and Application

2.1. The method describes the process of sediment separation and extraction for determining moisture content, bulk density, pH, and NO_3/NH_4 analysis.

3. Basic Principles

3.1. Sediment is thawed then separated into smaller intervals. A 1 inch segment of the cylinder is removed for moister analysis and bulk density, the rest of the raw sample is is stored or used for other analyses. The other half is ground in the Thomas-Wiley Mill and 10 grams of every section are sub-sampled for KCl extraction. 5 grams are sub-sampled for pH analysis and other analyses. 100ml of 1M KCl is added to 10 grams of sediment and shaken, then vacuum filtered so the eluent can be analyzed for NO_3 and NH_4. 5ml of DDI H_2O is added to the 5 grams of sediment and the ph is measured.

4. Apparatus, Materials and Reagents

4.1. Apparatus:

4.1.1. Aluminum foil
4.1.2. Knife
4.1.3. Beakers 250mL
4.1.4. Scale (Top loader)
4.1.5. Drying oven
4.1.6. 20-liter carboy
4.1.7. Graduated cylinder
4.1.8. Thomas-Wiley Mill
4.1.9. Kimwipes
4.1.10. Whirl-Pak bag
4.1.11. Top-loader balance
4.1.12. 250 ml Erlenmeyer flask
4.1.13. 7 dram vial
4.1.14. Stopper
4.1.15. Wrist action shaker
4.1.16. Buchner filter

4.1.17. 7 cm Whatman #42 filter paper
4.1.18. Erlenmeyer vacuum flasks
4.1.19. 150 ml polyethylene bottle
4.1.20. Pipette
4.1.21. pH electrode
4.1.22. EC electrode

4.2. Reagents:

4.2.1. reagent grade 1 N KCl

4.2.1.1. This method uses 1 N KC, which is preferred. If necessary, prepare the 1 N KCl solution be weighing 1491.2 grams of reagent grade KCl and transferring to 20-liter carboy. Add 4 liters of deionized distilled water, measured with a 1-liter graduated cylinder, to KCl and shake vigorously to dissolve KCl. Add 16 liters more of deionized distilled water with graduated cylinder and swirl carboy to mix thoroughly before using.

4.2.2. DDI water
4.2.3. buffer solutions of pH=4.00 and pH 8.00

5. Safety Precautions and Reagent Disposal

6. Definitions

- ***DDI*** – Double distilled water
- ***EC*** – Electrical Conductivity
- ***IDL*** – Instrument Detection Limit
- ***KCl*** – Potassium Chloride
- ***LFB*** - Lab Fortified Blank
- ***LRB*** – Lab Reagent Blank
- ***MDL*** – Method Detection limit
- ***NH_4*** – Ammonium
- ***NO_3*** – Nitrate
- ***Pb*** – Bulk density
- ***Processed Sample*** – A dried and ground sample stored in the freezer or at ambient temperatures
- ***QAQC*** – Quality Assurance and Quality Control
- ***Raw Sample*** – An unprocessed sample stored in the freezer to preserve moisture and analytes
- ***SPS*** – Soil particle size
- ***TOC*** – Total organic carbon
- ***WSL*** – University of Nebraska at Lincoln’s Water Science Laboratory
- ***θg*** – gravimetric water content

7. Procedure

7.1. Preparation of Core Extrusion:

7.1.1. Remove 10 to 20 feet of core from freezer 1 ½ hours before extruding the sediment to allow sufficient thawing. Lay out clean aluminum foil on table (Jones, 2001).

7.2. Core Extrusion:

7.2.1. Measure distance from top of core (0.0-2.5’interval) to the end of the liner and record in lab notebook. Carefully slide the sediment out of the liner onto the foil. Be careful not to break up the core sample any more than necessary. Lay successive cores end to end, matching the depths, and cut into intervals, ideally where a lithologic change has been identified. Extrude and process no more than 5 feet of core at one time for moisture content. Use a clean knife for working each interval to minimize cross-contamination.

Record observations of color, texture, and evidence of organic carbon and iron. A sediment texture pyramid along with visual and physical observations should be used to classify sediment texture. Cut the core length-wise and store a raw section in a labeled Whirl-Pak bag in the freezer. The other half will be dried overnight, ground, and processed.

7.2.1.1. Raw sample used for the following:

- Moisture content, bulk density, chlorides/TOC (WSL Protocol: IC Chloride in Dried Solids - Hot Water Extraction), pesticides, deterium, porewater isotopes, ions

7.2.1.2. Processed sample used for the following:

- NO_3/NH_4, pH, soil particle size (WSL Protocol: Soil particle size-001), non-volatile metals, ions, electrical conductivity

7.3. Preparation of Moisture Content and Bulk Density:

7.3.1. Label and weigh beakers before the samples are added. Preheat oven to 98^{O} C.

7.4. Moisture Content and Bulk Density:

7.4.1. Using a knife, cut a section of known volume (typically from 2.1 in. diameter liners cut 1" thick which = 65.22 cm^3) out of the core and place it in preweighed and labeled beaker. Weigh the beaker and wet sample before placing into the drying oven at 105 ºC to determine wet weight and bulk density (Blake & Hartge, 1986). See section 8 for calculations. Allow the samples to dry for 24 hours, remove and cool to room temperature and reweigh the dry sample and beaker to determine moisture content (Jones, 2001). Record all weights in the laboratory notebook. Discard the dried sample and clean the beaker before using again.

7.5. NO_3/NH_4 & pH Processing:

7.5.1. Preparation of NO_3/NH_4, pH Processing, and Electrical Conductivity

7.5.1.1. Grind each processed interval sample in a Thomas-Wiley Mill being sure to clean out the mill between foot intervals using Kimwipes, flat-headed screwdrivers, and a brush. Place the composite in a labeled bag. Using the top-loader balance, weigh out 10.00 grams ($\pm$ 0.01) into a labeled 250 ml Erlenmeyer flask. Weigh out 5.00 grams ($\pm$ 0.01) into a 7 dram vial for pH, which may be labeled or placed in a consecutive order to coincide with core intervals.

7.5.1.2. For QAQC purposes, every 20 samples process a replicate sample, a soil standard (known soil), LRB, and LFB.

- Replicate – Use the same sediment as the 20^{th} sample.
- Soil Standard – Use the same homogenized sample for every soil standard
- LRB – A blank sample consisting of 100 ml of 1 N KCl
- LFB – A blank sample consisting of 100 ml of 1 N KCl spiked with a known amount of NO_3/NH_4 (preferably 500 ul of a 100 mg/L solution of both NO_3 and NH_4).

7.5.1.3. Store the remaining processed sample in a labeled Whirl-Pak bag in the freezer.

7.5.2. NO_3/NH_4 Processing

7.5.2.1. Mix 100 ml of 1 N KCl solution into each 10.00 gram sample, stopper the solution and shake by hand for 1 minute, then place on the wrist action shaker and shake for 1 hour at a low speed.

7.5.2.2. Set up the Buchner filtering assemblies using 7 cm Whatman #42 filter paper. Wash the filter before using with 10 ml of 1 N KCl into a separate flask and discard the filtrate.

7.5.2.3. Remove the samples from the shaker after 1 hour and filter into clean Erlenmeyer vacuum flasks.

7.5.2.4. Transfer the filtrate into a clean labeled 150 ml polyethylene bottle, acidify with 5 drops of Sulfuric Acid, and store in the freezer (samples can be stored for 2-3 months). Use labeling tape and include project name, core #, foot interval, and date on the bottle.

7.5.3. pH and EC Processing

7.5.3.1. Calibrate pH meter before each use with fresh buffer solutions of pH=4.00 and pH=8.00 using a two-point calibration method. EC meter should be calibrated with a 0.01 N KCL solution (Doran and Smith, 1996). Check calibration buffer every 20 samples.

7.5.3.2. Measure 5 ml of deionized distilled water using a pipette into the 7 dram vial containing the 5.00 gram sample and shake thoroughly to mix.

7.5.3.3. Let the mixture stand for 10 minutes before inserting the pH electrode. Stir the solution by swirling the vial or the electrode gently, read and record the pH immediately. It is important to be consistent in the time interval between reading the pH and placement of pH electrode in the vial. The pH should be read as soon as the readings have stabilized, usually within a few seconds.

7.5.3.4. Rinse pH electrode thoroughly with deionized distilled water before measuring the pH of the next sample. When finished, clean electrode thoroughly, using care to remove any sediment from the reference junction, and put cap back on or soak in electrode soaking solution.

7.5.3.5. Electrical Conductivity will be taken using the EC probe and the same procedure as above.

7.6. NO_3/NH_4 Analysis:

7.6.1. The NO_3/NH_4 extract will be analyzed on a Lachat auto-analyzer for nitrate using QuikChem Method 12-107-04-1-B (Knepel, 2012). Ammonia will be analyzed using QuikChem Method 12-107-06-2-A (Hofer, 2003). These methods will also be used to ensure the implementation of proper quality assurance practices through sample preservation, calibration procedures, and method performance. Nutrient analysis will allow us to quantify the amount and spatial variation of contaminants throughout soil depth and compare their profiles to lithology, moisture content, and other soil characteristics.

7.6.2. Include a QAQC summary for every instrument run. Summary should contain replicate ranges, standard deviation and running averages for all LFB, LRB, and soil standards.

8. Calculations

8.1. Subtract the distance from the top of the first core to the end of the liner to account for the displacement during coring.

8.2. Dry Sample = (dry sample weight) – (beaker weight)

8.3. Wet Sample = (wet sample weight) – (beaker weight)

8.4. Water (g) = (wet sample) – (dry sample)

8.5. Ɵg = Dry Sample / Water (g)

8.6. Pb = (dry sample weight) / (65.22 cm^3)

9. Statistics

10. Quality Assurance

Ran 2/27/17	NO3-N IDL Test
Known (ppm)	**Measured (ppm)**
0.025	0.0245
0.025	0.0261
0.025	0.0201
0.025	0.0247
0.025	0.02
0.025	0.029
0.025	0.0246
0.025	0.0241
Average of measured	0.0241
Recovery	96.6

std	0.0030
idl	0.0089

Ran 2/27/17	NO3-N MDL Test				
Known (ppm)	**Measured (ppm)**	**L of extract**	**ug in a mg**	**Soil weight (g)**	**Calculated (ug/g)**
Unknown	0.5107	0.1000	1000	10.1000	5.8210
Unknown	0.5327	0.1000	1000	10.0400	5.3062
Unknown	0.5430	0.1000	1000	10.1000	5.3762
Unknown	0.5190	0.1000	1000	9.9300	5.2266
Unknown	0.5123	0.1000	1000	10.0100	5.6820
Unknown	0.5234	0.1000	1000	9.9300	5.6933
Unknown	0.5247	0.1000	1000	9.9000	5.3000
Unknown	0.5508	0.1000	1000	10.0000	5.7390
		std	0.0142	Average of calculated (ug/g):	*5.5180*
		mdl	0.0427	Measured/Known:	Unknown

	Recovery Test	1 ug NO3-N/g			
Known **(ppm)**	Measured (ppm**)**	L of extract	ug **in a mg**	Soil **weight (g)**	Calculated **(ug/g)**
Unknown	**0.6760**	**0.1000**	**1000**	**9.9300**	**6.8077**
Unknown	0.6860	0.1000	1000	9.9600	6.8876
Unknown	0.6601	0.1000	1000	10.0400	6.5747
Unknown	0.6496	0.1000	1000	9.9700	6.5155
		std	0.0162	Average of calculated (ug/g):	6.6964
		mdl	0.0736	Measured/Known:	*Unknown*

Spiking MDL Recovery

1 ug NO3-N/**g of soil spike**			Not **Spiked**
Average of calculated (ug/g):	**Average of** calculated (ug/g):	**Recovery** of spike LFM	
6.6964	5.5180	1.1783	
	(**recovery of spike LFM/1)*100**	117.83	

Ran 2/27/17	NH4-N IDL Test
Known (ppm)	**Measured (ppm)**
0.01	0.0117
0.01	0.0116
0.01	0.0112
0.01	0.0115
0.01	0.0111
0.01	0.011
0.01	0.012
0.01	0.0115
Average of measured	0.0115
Recovery	114.5

std	0.0003
idl	0.0010

Ran 2/27/17	NH4-N MDL Test				
Known (ppm)	**Measured (ppm)**	**L of extract**	**ug in a mg**	**Soil weight (g)**	**Calculated (ug/g)**
Unknown	0.3740	0.1000	1000	10.0000	3.7400
Unknown	0.3140	0.1000	1000	10.0200	3.1337
Unknown	0.3612	0.1000	1000	10.0000	3.6120
Unknown	0.3190	0.1000	1000	9.9800	3.1964
Unknown	0.3240	0.1000	1000	9.9700	3.2497
Unknown	0.3507	0.1000	1000	10.0600	3.4861
Unknown	0.3970	0.1000	1000	9.9500	3.9899
		std	0.0312	Average of calculated (ug/g):	*3.4868*
		mdl	0.0980	Measured/Known:	Unknown

	Recovery Test	1 ug NH4-N/g			
Known (ppm)	**Measured (ppm)**	**L of extract**	**ug in a mg**	**Soil weight (g)**	**Calculated (ug/g)**
Unknown	0.4438	0.1000	1000	10.0000	4.4380
Unknown	0.4401	0.1000	1000	10.0200	4.3922
Unknown	0.4463	0.1000	1000	9.9500	4.4854
Unknown	0.4450	0.1000	1000	9.9900	4.4545
		std	0.0027	Average of calculated (ug/g):	*4.4425*
		mdl	0.0121	Measured/Known:	Unknown

Spiking MDL Recovery		
1 ug NH4-N/g of soil spike	**Not Spiked**	
Average of calculated (ug/g):	Average of calculated (ug/g):	Recovery of spike LFM
4.4425	3.4868	0.9557

(recovery of spike LFM/1)*100 95.57

11. Comments