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GLOSSARY
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Chapter I
Introduction

The Nebraska Legislature in 1984 required Natural Resources Districts to prepare a groundwater management plan by January 1986. A plan was prepared in 1985 for the Upper Loup Natural Resources District (ULNRD) by John H. Sautter. That plan presents an excellent and comprehensive overview of the technical information relative to groundwater management as required by Section 46-673.01 of the Nebraska Groundwater Management and Protection Act. However, it was judged to be lacking in some respects and was not approved by the Department of Water Resources.

A 1991 revision of the 1985 plan drew upon the technical data, tables, and figures included in the 1985 plan. New and additional data were compiled and analyzed and are presented in map, chart and tabular format. It was approved in 1991. In 1994 additions to the quality portions of this plan were made according to Section 46-673.14 of the Nebraska Groundwater Management and Protection Act, along with the addition of a glossary.

Valuable sources for information relative to groundwater management and planning include Resource Atlas No. 5, An Atlas of the Sand Hills published in 1989 (revised in 1990) by the Conservation and Survey Division, UNL (CSD), and the Policy Issues Studies published by the Nebraska Natural Resources Commission in the early to mid 1980s. A number of illustrations from these reports are included herein.

Considerable information on the soils, geology, hydrology and biology has been developed in the last two decades through test drilling, research, field investigations and data collection. What has emerged is an understanding that the land is geologically very young and the youthful sandy soils show almost no evidence of soil profile development. The land surface, although dune mantled and sloping, is relatively flat. Very little runoff from precipitation occurs due to the high infiltration rates of the sandy soils. Consequently, the network of surface drains is poorly developed and much of the land is subjected only to internal drainage.

Even though the precipitation is relatively low (averaging about 19 inches annually), the character of the landscape and soils has contributed to the filling of the groundwater reservoir to the level of the low points on the land surface in much of the area. Wetlands are common and the uniform flow of the streams draining the area is attributable to steady groundwater discharge. The natural discharge of groundwater from the area by evaporation from water surfaces and wetlands, by transpiration of wetland plants and grassland vegetation, and by streams approximately equals recharge and far exceeds the amount of water discharged by wells.

The area within the ULNRD is underlain by a considerable thickness of Quaternary sands and gravels and the sand, sandstones and gravels of the Ogallala Formation. Together they comprise the groundwater reservoir or the High Plains Aquifer. The total thickness averages more than 500 feet and the range in thickness is from about 350 feet to almost 1,000 feet. The amount of groundwater in storage is large -- as large or larger than in any of the other Natural Resources Districts. The potential for large capacity wells also is as great or greater within the ULNRD as in any other NRD. The present use of groundwater by withdrawal from wells is minimal. The groundwater supply is plentiful and evidence to date suggests that the water supply has not been measurably reduced by withdrawals.

Groundwater quality data collection, analysis and evaluation in the ULNRD has only systematically been undertaken by the ULNRD and others in the last few years. That information has been compiled in the preparation of this plan. Evidence at this time indicates that water quality, in general, has not significantly been impacted by human activities. A few scattered records suggest that water from some domestic wells has Nitrate-Nitrogen levels near or above 10 ppm (Figure 10-11). This contamination appears to be related to point sources and/or well siting and construction.

The groundwater supply in the ULNRD is plentiful and of good quality. The present day use of groundwater by withdrawal for municipal, industrial, and irrigation use is minimal. The potential for a significantly greater use over time is high based upon there being a large available supply. That potential, however, is greatly reduced due to several factors including economics, low population base, present technology to irrigate much of the land for row crops and the tradition of a ranching-based economy.

The Upper Loup Natural Resources District (ULNRD) is comprised of 6,697 square miles and includes all of Grant, Hooker, Thomas, Blaine, and Logan Counties and parts of McPherson, Brown, and Cherry Counties (Figure 1-1). About one-third of the 6,697 square miles in the ULNRD is in Cherry County. Most of the 4,275,000 acres lies within the Nebraska Sand Hills and the Sand Hills Groundwater Region. Small portions of the total area, "hard land" areas in the southeast corner of Logan County and two small areas in eastern Blaine County, lie in the Dissected Plains Topographic Region. Figure 1-2, a mosaic of Landsat satellite images from An Atlas of the Sand Hills, vividly illustrates the Sand Hills topography and boundaries compared to "hard land" areas. The several different types of dunes are illustrated on Figure 1-3.

The Upper Loup NRD is one of the largest in the state. The entire area is agricultural in character, and reflecting the sparse population, the main agricultural activity is cattle raising and hay production. An estimate of total population based on April 1, 1990 preliminary data from the Bureau of the Census is about 6,005 persons. The census data for the Upper Loup NRD is available only by county and cities or villages. Because only a part of Brown, Cherry, and McPherson counties are within the ULNRD, estimates of population within these counties were made. Population of the cities in these three counties were subtracted from the total county population and the remainder was prorated by area of the county within the NRD. Using the same procedure, the population of the ULNRD based on the April 1, 1980 census was estimated at about 6,985. That figure may be high as the Nebraska Natural Resources Commission estimated 6,223 for the same census. The population within the five counties wholly within the district declined by about 15.5 percent. If that percent of decline also occurred throughout the NRD and if applied to the 1980 estimate by the Natural Resources Commission, the 1990 population of the NRD could be as low as 5,260.

The population of the incorporated towns and villages for the 1980 and 1990 census is given in Table 1-1. All showed substantial declines with the exception of Gandy. The largest community in the district is Mullen with a population (preliminary) of 552.

TABLE 1-1

UPPER LOUP NRD POPULATION

U.S. CENSUS

County (Wholly within ULNRD)	April 1, 1980	Preliminary April 1, 1990	Percent Change 1980-1990
Blaine	867	673	-22.4
Grant	877	769	-12.3
Hooker	990	788	-20.4
Logan	983	878	-10.7
Thomas	973	851	-12.5
(Partly in ULNRD)	April 1, 1980	April 1, 1990	1980-1990
Brown	795	728	- 8.4
Cherry	1,302	1,136	-12.7
McPherson	198	182	- 8.0
Estimated Total	6,985	6,005	-14.0

INCORPORATED TOWNS AND VILLAGES

U.S. CENSUS

County	April 1, 1980	Preliminary April 1, 1990	Percent Change 1980-1990
Brewster	46	22	-52.2
Dunning	182	131	-28.0
Gandy	53	91	+71.7
Halsey	144	110	-23.6
Hyannis	336	210	-37.5
Mullen	720	552	-23.3
Seneca	90	78	-13.3
Stapleton	340	301	-11.5
Thedford	313	232	-25.9
Total	2,224	1,727	-22.3

The source for much of what is known about the groundwater resources of the ULNRD is from test holes drilled as part of the programs of the Conservation and Survey Division-UNL, the U.S. Geological Survey and the Nebraska Natural Resources Commission. The test hole logs are available from the agencies and the samples are maintained in the Conservation and Survey Division sample library. Locations of 128 test holes, most of which were drilled to shale, are shown on Figure 1-4. Logs and records of irrigation wells and tests drilled for oil and gas have

provided additional useful information to characterize the groundwater reservoir.

The U.S. Geological Survey 7.5 minute topographic quadrangle maps are another source of basic information invaluable for groundwater and other resource investigation and interpretation. Besides serving as excellent base maps with various grid systems, roads, trails and other cultural features, the maps display contours of the topography and water features such as streams, springs, lakes, and other wetlands. Complete coverage of the ULNRD has only recently been completed. The maps proved to be of much help in the preparation of this groundwater management plan and was of particular help in verifying and correcting the location of irrigation wells. Wells constructed prior to the air photos used in the making of the maps are displayed on the map. The ULNRD plans to obtain one or more complete sets of the quadrangle maps as funds permit. Figure 1-5 is an index map showing the names and location of the topographic maps covering the ULNRD.

The Upper Loup NRD groundwater management plan addresses and stresses education and a continuation and expansion of data collection programs to detect trends of water supply depletion and/or groundwater contamination. Prevention rather than remediation is a key element of the plan. The plan recognizes that because the ULNRD is one of the largest districts and has the smallest population, funding is limited and the district must enlist the help and cooperation of the state and federal agencies with expertise and interest in groundwater and related natural resources in the area.

CHAPTER II
GROUNDWATER RESERVOIR LIFE GOAL

The Nebraska Groundwater Management and Protection Act states "Groundwater reservoir life goal shall mean the finite or infinite period of time which a district establishes as its goal for maintenance of the supply of water in a groundwater reservoir at the time a groundwater management plan is adopted."

A basic principle of this plan is that the groundwater supply is currently of sufficient quantity to meet all needs and of appropriate quality to generally meet existing standards of regulatory agencies.

Based on current data and knowledge of the quantity and quality of water in the ULNRD, there does not appear to be basis for establishing management, control or special protection areas at this time.

The following goal is established in representation of an infinite period of time: THE GROUNDWATER RESERVOIR LIFE GOAL FOR THE ULNRD IS TO MAINTAIN, IN PERPETUITY, GROUNDWATER OF A QUALITY TO MEET STANDARDS APPROPRIATE TO ITS USE, IN AN ADEQUATE SUPPLY FOR DOMESTIC, LIVESTOCK, PUBLIC, IRRIGATION, AGRICULTURE, WILDLIFE, AND INDUSTRIAL USES. THE GOAL INCLUDES MINIMIZING, AS MUCH AS POSSIBLE, THE ADVERSE IMPACT OF THESE USES ON THE QUANTITY AND QUALITY OF GROUNDWATER THAT SUPPORTS LAKES, SUBIRRIGATED LANDS, AND STREAMS.

It is the intention of the ULNRD to fulfill its Groundwater Reservoir Life Goal through nonregulatory proactive measures, keeping in mind that an infinite goal may be challenged by unforeseeable circumstances. These measures are chosen on the basis that, to date, there has been no demonstrated need for regulatory action and that prevention of problems is much easier than remediation. The citizens of the ULNRD have shown good stewardship of their natural resources and strong resistance to the prospect of regulatory controls. Therefore, the most effective management strategy would include increased voluntary informational and educational programs and increased water quality monitoring. In the event that significant problems develop or are detected, other

management practices that are within the statutory authority of the ULNRD will be used.

CHAPTER III
GROUNDWATER MANAGEMENT POLICY

A. GROUNDWATER QUANTITY

Although state groundwater statutes, policy issue studies, and policy options are oriented toward

areas of the state where groundwater depletion problems are occurring or are likely to occur, depletion in the ULNRD is not considered to be a current problem. Restrictions on water use or development by means of management areas or control areas are not under consideration at this time.

In the event that a trend of annual declines in water levels related to groundwater withdrawal is detected, data collection will be intensified to determine the size of area effected.

Seasonal and possibly permanent water level declines or increases affecting Sandhill wetlands, wet meadows and shallow stock and domestic wells will be monitored. It is recognized that there may be natural physical reasons for water level fluctuations.

The current water level observation program (see Figure 10-5) will be continued and expanded as necessary. Location of specific additional wells will be affected by accessibility and cost in addition to need for the data collected.

The public will be informed about the opportunities to use and/or manage existing water supplies for wildlife habitat enhancement.

Evapotranspiration (ET) salvage potential in areas where water levels decline below the root zone of vegetation in wetlands or marshy areas will be investigated because of possible decreased production of hay or adverse impacts on wildlife habitat. This is a topic requiring research and data collection. Concepts for salvaging evapotranspiration losses in order to utilize groundwater recharge from precipitation events will be investigated. Potential adverse impacts on the supply related to various uses will also be identified and evaluated.

Four water level observation wells in the district installed 40 to 60 years ago have shown very little, if any, long-term changes in groundwater levels. See Figure 10-4. The fluctuations shown do not appear to be related to groundwater withdrawal. Future problems of supply may develop as a result of groundwater withdrawal or other

activity. NRD action to minimize or reduce adverse impacts on the groundwater supply will be based upon a triggering mechanism related to water level declines.

As wetlands and lake management practices for wildlife habitat are developed, they will be incorporated in district plans and coordinated with the Game and Parks Commission. There is a need for additional data collection before adopting specific practices.

In spite of large supplies, it is extremely important that water resources be used wisely and efficiently in conservation programs, such as minimizing ET losses. Supply augmentation is defined as "the direct use from outside sources." Given the supply available to the NRD area, no program of this nature would appear to be necessary or feasible.

As stated in the Water Transfer Study Report of the Water Management Board, Nov. 1988, "Under current law, groundwater can only be transferred off the overlying land if the Legislature has explicitly authorized it. This authority has been granted for only four types of transfers: (1) municipal and rural domestic water supply systems, (2) large-scale industrial uses, (3) exchanges of intentionally stored groundwater for surface water, and (4) interstate transfers. Agricultural uses within Nebraska are not included in the types of authorized transfers."

The same report notes that the Nebraska Supreme Court has ruled that groundwater, like surface water, belongs to the public, but landowners have a right to use it.

B. GROUNDWATER QUALITY

There are increasing public concerns regarding water quality. In spite of a large supply of presently good quality water, current monitoring and sampling programs will be continued and expanded. Present and foreseeable potential land and water use along with the distribution of population minimizes the likelihood of water quality degradation. Records of groundwater sample analyses (Chapter X Section B) indicate contaminant levels well below any health threat levels. However, because of the possibility of accidental contamination and the highly permeable nature of most of the soils within the ULNRD, it is necessary to have programs to protect groundwater from the occurrence, increase or spread of contamination.

As stated in "Nebraska Groundwater Protection Strategy Final Report, 1985", "In order to protect the valuable groundwater resources for the future, greater reliance will have to be placed on preventing contamination from occurring in the first place. To accomplish this goal, emphasis must be placed on quantifying, to the degree possible, the potential sources of contamination and understanding the complex processes by which these contaminants reach the groundwater." An assessment of known potential groundwater contamination sources within the ULNRD is provided in Chapter XIII.

"Nebraska Groundwater Protection Strategy Final Report, 1985" also states "The public policy of the State and that of DEQ as the State's principal environmental protection agency is the prevention of groundwater contamination and the maintenance of the State's high quality groundwater for beneficial uses wherever attainable." Prevention rather than remediation of pollution activities, that could result in unsafe drinking water, is a priority policy of the ULNRD; first through voluntary programs, and second, if necessary, by using existing regulatory authority.

Long-Term Solutions

The ULNRD's long-term solutions to prevent the levels of groundwater contaminants from becoming too high and to reduce high levels sufficiently to eliminate health hazards are the following: 1) Cooperation with other NRDs, agencies, and organizations for identification and control of groundwater contamination and the factors affecting them. 2) Work with district residents, and fertilizer and pesticide users individually and in groups. Provide them with needed Information and Education Programs and resources to help protect groundwater quality and its users. 3) Provide and administer as needed, cost-share programs and other services that will help protect groundwater quality and its users. 4) Establish and maintain groundwater quality monitoring programs that effectively quantify groundwater quality within the ULNRD to determine trends that will help identify the need for particular groundwater quality management programs and/or regulatory action. 5) Use regulatory authority as needed, to protect groundwater quality and its users by preventing and reducing groundwater contamination sufficiently to eliminate potential health hazards. By applying these long-term solutions, the ULNRD expects to maintain groundwater of a quality to meet standards appropriate to its use.

Cooperation:

Coordination with Nebraska Department of Environmental Quality (NDEQ) and other

agencies is essential. Provisions of NDEQ's "Nebraska Groundwater Protection Strategy" will be used wherever possible as a basic information source. That strategy addresses such potential sources of groundwater pollution as chemical and fuel storage, agricultural chemicals, waste treatment and disposal areas, water wells and unregulated test holes, industrial facilities, and spills and leaks during transport of hazardous or contaminating material.

To effectively monitor groundwater quality, the ULNRD emphasizes the need for continued information and data exchange, and joint projects with other agencies and NRDs. Gudmundsen Sandhills Research Laboratory is currently involved in hydrological research to assess water quality and seasonal variations at various depths. Regular progress reports will be provided. To better quantify the extent of NPS contamination within the ULNRD, it will continue to support and fund studies such as the U.S. Geological Survey's "Hydrologic Data for the Southern Sand Hills Area, Nebraska." To effectively manage groundwater quality, efforts must be made to better understand the factors that affect its quality. The ULNRD will continue to encourage and support research focused on doing so, particularly when it directly relates to the ULNRD.

The ULNRD is concerned about the quality of the water that its residents drink. Sample test results indicate that there are some cases of well-site localized contamination, likely the result of improper well siting or well construction. In response to this, the ULNRD will cooperate with local well drillers and the Cooperative Extension Service to disseminate information on well siting and well construction. The ULNRD will also cooperate with NDEQ, NDOH, and communities to establish wellhead protection programs for endangered public water supplies.

Information and Education Programs:

The ULNRD's Information and Education Program is the most effective Groundwater Management Program for protecting groundwater quality and its users. To remedy any undetected or developing problems, and to prevent future problems from developing; the ULNRD will continue existing Information and Education Programs and expand them to other parts of the district with similar needs. Information and Education Programs including demonstration sites, group meetings, one-on-one contacts and mailings are provided as needed. This helps to prevent and reduce groundwater contamination and its effects on groundwater users. Evaluation of the success of these programs is based on short and long term participant reactions to the programs, and measurable improvements in groundwater quality over time.

The ULNRD has and will continue to invest in various long and short range educational programs. As a result of the ULNRD's commitment to expanding its Information and Educational Programs, an Information and Education Specialist was hired in the summer of 1992. Many programs focusing on informing youth about groundwater and maintenance of its quality have been supported by the ULNRD. Likewise, the ULNRD supports more specific programs that focus on informing fertilizer and pesticide users about practices that reduce the risk of groundwater contamination.

In particular, since 1989 the ULNRD has been actively supporting the North Central Nebraska Residual Nitrate Management Project, coordinated by the University of Nebraska Cooperative Extension in partnership with the Soil Conservation Service, and other NRDs. The project is designed to promote water quality through field testing, and educational programs on appropriate use of nitrogen fertilizer. The ULNRD plans to extend the progress and benefits of this project to other areas within the district with similar needs, that are not within the project's current boundary. Additional research and technology developments including "best management practices" could be incorporated into the project that will limit water, fertilizer, and pesticide applications to times and rates that they will be completely utilized, thus reducing leaching into the groundwater. A similar project that includes the southern portion of the ULNRD is expected to be under way by March of 1994.

The ULNRD believes that the application of horticultural chemicals such as lawn fertilizers and pesticides is probably a relatively significant source of NPS contamination in the ULNRD. It will accumulate and help distribute information on preventing such

contamination through programs such as Cooperative Extension's Family Community Education spring of 1994 program "Using Water Wisely in the Landscape". Small communities with shallow individual wells are of particular concern.

Cost-Share Programs and Services:

Cost-share programs and other services are an important part of the ULNRD's solutions to prevent groundwater contamination and its effects on groundwater users. In Cooperation with UNL's Cooperative Extension, the ULNRD conducted sampling of 246 domestic wells across its eight county area in 1989. These samples were tested by the Grand Island-Hall County Health Department for nitrates and coliforms. The ULNRD cost shared 65% of the $10 per sample fee, and the homeowner/tenant paid the remainder. The ULNRD will continue this program to help assure that its residents have safe drinking water, and expand it to include pesticide testing where needed. Sampling of additional wells and selected previously sampled wells will be planned in cooperation with other agencies again in 1995-1996 and approximately every 5-7 years thereafter as needed.

In 1993, the ULNRD began a program of cost-sharing the proper abandonment of wells to help reduce well owners' costs for elimination of these direct avenues for point source contamination. Unused and abandoned wells constitute a potential threat to life and health. The ULNRD recognizes that the public may be unaware of the definition of abandoned wells and the rules and regulations relative to their proper abandonment. The ULNRD has provided information to local well drillers about the proper abandonment of wells and its cost share program for doing so. It has requested that local well drillers assist in distributing this information to their customers. The location and condition of unused wells will be noted during the pursuit of ULNRD field activities. Land owners will be notified of observations made and reminded of their legal obligations.

Since 1986, the ULNRD has been testing water samples for nitrates to help assure that families have safe drinking water. The ULNRD uses a HACH test kit to detect nitrates in water samples. Any groundwater user in the ULNRD can bring water samples from their domestic, stock or irrigation wells to the ULNRD office for nitrate testing. The ULNRD will continue to encourage this practice to help assure that groundwater users have safe drinking water. There is no charge for this service.

Monitoring Programs:

Data collection from existing cost-share and free service groundwater quality testing has been and will continue to be an essential element in the ULNRD's solutions to prevent groundwater contamination and its effects on groundwater users. A HACH test kit is carried in the field vehicle so that water samples can be checked anytime when a staff member is contacting district residents. Well location, type, available construction records, and obvious potential contamination sources are documented with the sample analysis results. The ULNRD plans to continue using test kits to analyze samples from wells and to advise well users if more precise analysis is needed.

Efforts are made to keep staff informed about the most effective water quality monitoring techniques; through participation in workshops, consultation with individual experts, and studying related resources. When collecting samples, two basic practices are always followed; letting the water to be sampled flow for at least five minutes before collecting the sample, and triple rinsing the sample bottle (unless sterilized) before collecting the sample. Particular sampling recommendations for tests of coliforms, nitrates, and pesticides are also strictly followed to assure that a representative sample is collected. If samples are collected and delivered for analysis by well users, the ULNRD will stress the need for following all recommended procedures with precision and care.

According to NDEQ's "Nebraska Non-point Source Management Program 1992 Annual NPS Report" the entire ULNRD falls into the state's lowest priority category, because NPS groundwater contamination has not been documented or is unlikely. Although the potential for NPS groundwater contamination in the ULNRD is high because of low soil fertility, high soil permeability and high water tables; the likelihood for significant groundwater contamination is low because population distribution and probable land and water uses minimize the likelihood of human induced groundwater contamination.

The ULNRD is aware that the sampling that has been done establishes only a partial, one point-in-time, baseline level of groundwater quality. In addition to existing cost-share and free-service testing for nitrates, an extensive and continuous NPS groundwater quality monitoring program is being developed. This program will be aimed at determining the extent of human induced NPS contamination within the ULNRD. It is necessary because of the potential for groundwater contamination by fertilizers and pesticides, and the need for well documented water quality data to justify management actions. Sample collection will be coordinated with other field activities when possible. The ULNRD's NPS Groundwater Quality Monitoring Program will be initiated by the

summer of 1994 and will be expanded to the level that the data collected will effectively quantify the extent of NPS contamination within areas of the ULNRD subject to human induced NPS contamination. Indications of the extent of NPS contamination and consequential risks found during the initial part of the program will dictate the rate at which the program will be expanded, and the frequency which the wells will be sampled.

To obtain the most determinative NPS groundwater quality data, selection of quality monitoring areas will be dependant upon three factors: 1) the concentration of land use practices involving nitrogen and pesticide application, particularly where supplemental water is applied; 2) the presence and proximity of domestic water wells; 3) groundwater pollution potential based on site specific data such as needs of the crops being grown and DRASTIC map parameters. A DRASTIC map is developed from GIS technology and depicts potential for groundwater contamination from various parameters. DRASTIC map parameters are Depth to water, Recharge to the aquifer (net), Aquifer media, Soil media, Topography (slope), Impact of vadose zone, and Conductivity of the aquifer. All three factors involved in determining NPS groundwater quality monitoring areas will be examined on site specific levels through the use of soils maps, well construction data, local agriculture statistics, nitrogen and pesticide use records, local crop needs, and other pertinent site specific data.

A set of specific criteria, based on these factors, will be used to determine what areas should be monitored initially. These criteria will help identify the most immediate NPS contamination health threats to groundwater users. The degree to which individual areas meet area determination criteria, and the criteria themselves will be re-examined periodically to ensure their effectiveness in prioritizing the areas in need of NPS groundwater quality monitoring.

Initial NPS monitoring areas must meet the following criteria: 1) Initial monitoring areas will be at least 3,200 acres, of which at least 20% of the acres receive nitrogen and/or pesticide applications, and supplemental water. 2) Initial monitoring area must have at least one domestic water well within its boundary or within one mile of its boundary in the direction of groundwater flow. This criterion will become less restrictive after monitoring has been established in these areas. 3) Initial monitoring areas will be those most susceptible to groundwater contamination according to available site specific pollution potential data.

The areas that meet these criteria to the greatest degree will be prioritized for monitoring. The extent of groundwater quality monitoring will initially be limited by a total of 20 sampling wells in the entire ULNRD NPS Groundwater Quality Monitoring Program. Not more than five areas will be monitored initially. At least 20 samples will be analyzed each year in the ULNRD's NPS Monitoring Program. These figures will be increased as needed. Boundaries of initial NPS monitoring areas will be drawn on quarter section lines.

When initial quality monitoring areas have been determined, particular well sites will be selected for sampling. For three reasons, center pivot irrigation wells will generally make ideal sample collection sites for determining the extent of human induced NPS groundwater contamination: 1) irrigation wells are often perforated at several depths throughout the saturated thickness of the aquifer and thus provide a good indication of groundwater quality in the aquifer; 2) groundwater below irrigated and fertilized land is most susceptible to human induced NPS contamination; 3) irrigation wells have complete and accurate well construction records of vadose media, well perforations, depth to water, and legal locations. All of this information is necessary for an accurate evaluation of the resulting water quality data. In the event that irrigation well sites are not sufficiently available to comprehensively monitor NPS groundwater quality of a selected area, domestic and stock wells will be used particularly if accurate well construction data are available and the wells are not obviously susceptible to point source contamination.

When selecting well sites for NPS monitoring, the ULNRD desires well owner's consent and cooperation. The ULNRD has shown concern about rural drinking water, and has encouraged the use of management practices that both maintain residents' drinking water quality and increase producer profits. This will help ensure that residents realize the ULNRD's sincere interest in their physical and financial well being. Acknowledging their proven stewardship will reinforce a pride that should encourage continued stewardship. Residents of the ULNRD are generally very conscientious stewards of their natural resources, and with the understanding that the ULNRD is acting with their best interests in mind, cooperation should be readily obtained.

Nitrate-nitrogen levels will be the primary indicator of NPS contamination, assuming that nitrate leaching is the most likely source of NPS contamination in that area. Pesticide testing will also be used where pesticides are known to have been used and where NPS contamination from pesticide applications appear to be likely. Pesticide testing may be

useful to confirm contamination origin because pesticides are not naturally occurring chemicals.

The evaluation of sample data from individual wells will relate perforations of that well to possible stratifications of NPS contaminants. This will be correlated with data from other NPS sampling wells within that monitoring area, and will be used to determine the groundwater quality in that monitoring area. Water quality data from any well within a monitoring area could help indicate the distribution of contaminants in the aquifer. For this reason, groundwater quality data from the ULNRD's other groundwater quality testing programs, and studies by organizations such as USGS, NDEQ, NDOH, Conservation and Survey, and UNL will be compared to the data from the NPS Groundwater Quality Monitoring Program to help determine groundwater quality and if potential health threats to groundwater users are the result of human induced NPS contamination. If the implications of the data cannot be easily interpreted; professional hydrological, biological, chemical and/or statistical assistance will be sought to help interpret the data. The primary concern will be immediate threats to groundwater users in the affected area, but any significant degradation of groundwater quality also warrants the need for groundwater management actions.

Sample data from the first year of monitoring in an area will be used to establish baselines that define existing groundwater quality conditions of that area. Analysis of baseline samples will be done at a laboratory to ensure precision. Analysis of monitoring samples from areas with an average contaminant concentration less than 50% of an MCL will be done by ULNRD staff with available test kits. Any deviation from a baseline identified with a test kit will be quantified by more precise laboratory analysis. Analysis of monitoring samples from areas with an average contaminant concentration greater than 50% of an MCL will be done at a laboratory. Established baselines will be used as reference points for determining trends of groundwater quality. Trends will trigger groundwater management action in areas where changes in groundwater quality are conclusively from NPS contamination.

NPS contamination trends approaching a level of 70% of an MCL will trigger groundwater management action. Either of the following trends will trigger groundwater management action: an average contaminant concentration increase of 5% of its MCL, in a monitoring area or portion of a monitoring area larger than 640 acres; or an average contaminant concentration increasing at a rate less than or equal to 5% of its MCL per year that will result in reaching 70% of its MCL within four years, in a monitoring area or

portion of a monitoring area larger than 640 acres. Averages must be from at least four NPS sampling wells that can provide an accurate representation of groundwater quality of the area, or the portion of an area in question. The times of year that the samples are collected will be consistent for each individual well and should provide averages that are generally representative of the water quality throughout the year. Expected seasonal fluctuations in groundwater quality will be taken into consideration.

The groundwater management actions that these trends will trigger are as follows: 1) increased Information and Education Programs in that area, 2) consideration of analyzing additional parameters in that area, 3) increased effort to work with fertilizer and pesticide users individually to reduce NPS contamination, 4) increased number of sampling wells, and frequency of sampling, in the monitoring area with a trend approaching 70% of an MCL; resulting also in an increased number of sampling wells in the entire ULNRD NPS Monitoring Program. The degree to which each of these management actions are implemented will be dependant upon area specific needs.

If average contamination levels less than 40% of MCLs are found for two consecutive years in a particular monitoring area then sampling frequency in that area will decrease, and an additional area will be monitored.

If a contaminant concentration from nitrogen or a pesticide is ever detected greater than 70% of its MCLs in a monitoring area, sampling will be increased to determine if the contamination results from point sources. If contamination does not result from point sources, then increased monitoring within that area will be used to define boundaries of the extent of NPS groundwater contamination at an average concentration of 70% of the MCL. Boundaries will be drawn along quarter-section lines and include land that is within one mile, in the direction of groundwater flow, of this contamination level. Boundary determinations will only be made from data collected in the ULNRD's NPS Quality Monitoring Program, however, data not from this monitoring program may influence what wells are monitored in this program.

Regulatory Action:

At times it is necessary for Natural Resources Districts to administer regulatory actions to prevent and reduce groundwater contamination. Currently the ULNRD administers the Chemigation Program as required by the State for all NRDs. Field inspections are made for all new permit applications, a percentage of renewals and selected unpermitted sites to

check for compliance. Regulatory action will also be necessary if NPS contamination problems develop that cannot adequately be reduced through Information and Education Programs and working with fertilizer and pesticide users individually.

NPS Management

The NPS Groundwater Quality Monitoring Program will provide data to determine the need for groundwater quality management programs and/or regulatory action. Stabilization, reduction and prevention of groundwater contamination through Information and Education programs is the primary NPS management strategy of the ULNRD. The ULNRD will continue to encourage the use of "best management practices" and will intensify its Information and Education programs where NPS contamination is evident and developing into a problem.

Depending on site specific needs, the following "best management practices" have been or may be encouraged by the ULNRD in its Information and Education programs and may be considered as possible regulatory requirements: 1) Deep soil sampling and analysis to estimate available soil nitrogen. 2) Irrigation water testing to estimate the irrigation water nitrogen contribution. 3) Selecting realistic yield goals based on field history. 4) Eliminating fall fertilizer applications to reduce leaching. 5) Using irrigation flow meters to accurately measure applied irrigation water. 6) Using an integrated pest management approach to minimize pesticide applications, and to optimize their efficiency when applied. 7) Using irrigation surge valves to more uniformly apply irrigation water. 8) Using delayed nitrogen application (sidedress or chemigation) to more efficiently use fertilizer nitrogen. 9) Using nitrification inhibitors to delay nitrification, restrict leaching, and increase nitrogen use efficiency. 10) Allowing proper nutrient credits for non-commercial fertilizer nitrogen sources. 11) Applying manures and other waste products by methods to allow efficient use of nutrients contained in the products. 12) Using crop rotations to reduce nitrogen fertilizer use and impact of pest infestations. 13) Using winter cover crops to retain residual soil nitrate between growing seasons. Other existing BMPs, or BMPs for which conclusive documentation is developed in the future, may also be encouraged or required if they meet site specific needs and are enforceable.

The ULNRD realizes that unique physical characteristics of individual areas may have varying effects on the effectiveness of "best management practices. For example, according to "Sandhills Area Study" p.29, when 135-145 pounds of nitrogen per acre

(based on crop nitrogen demand, available soil nitrogen and a desired nitrogen uptake goal) are applied, leaching of 46 pounds of nitrogen per acre can occur on Valentine soils even when BMPs are used. Conclusions of this study suggest that regulatory action other than requiring BMPs, could be necessary on sandy soils if leaching is occurring to the extent that a contamination trend reaches 70% of a MCL. However, it could be determined that such regulatory action is not necessary to reverse the trend. Such a determination could be based on the success of the ULNRD's established local Information and Education programs including one-on-one contacts with individual fertilizer and pesticide users. Success of these programs will have eliminated, to the extent possible, practices that allow nitrate leaching into the groundwater. This would eliminate any health threat risks or significant groundwater quality degradation, and reverse the contamination trend.

The ULNRD will attempt to solve potential problems on an individual basis before groundwater contamination exists to an extent that regulatory action is necessary. It will do this by encouraging individual fertilizer and pesticide users to use "best management practices" to reduce groundwater contamination. This management strategy will be most effective in many situations. However the effectiveness of this management strategy could be reduced if the size of the problem area and/or the concentration of fertilizer and pesticide users in the problem area are great; or if any individual in the problem area will not cooperate. If this is the case, regulatory action will be necessary to control NPS contamination.

Regulatory action will not be pursued until an evaluation of any available and/or necessary data for determining boundaries of the potential Groundwater Management Area is completed, and the most effective responsive actions to the problem are determined. These determinations will be made, as best as possible, within one year of the first identification of NPS contamination greater than 70% of an MCL. Technical support from organizations such as USGS and Universities may be necessary to make these determinations. The delayed responses of water quality conditions to management practices may be considered before regulatory action is taken if groundwater aging and infiltration rates indicate that producers' prior years BMPs have not yet been able to influence groundwater quality. After the date at which the BMPs could be influential; if groundwater quality improves at a rate of 5% of the MCL per year then regulatory action will not be necessary. In order to avoid regulatory action by this means, the following conditions must exist: 1) records of producers' BMPs are available for all of the irrigated

and fertilized land within a potential groundwater management area, 2) sufficient technology and data are available to determine a date at which the BMPs become influential to the groundwater being sampled, 3) determination of that date is not cost prohibitive.

Until necessary determinations are made, the response to 70% of a nitrate or pesticide MCL will be highly intensified Information and Education Programs targeted at the fertilizer and pesticide users, and residents of the problem area. The ULNRD will work closely with these groups and/or individuals to protect groundwater quality and its users. Programs will inform people of potential risks of groundwater contamination and strongly encourage the use of practices known to reduce and eliminate NPS contamination. They will continue as long as a problem exists.

Triggering of regulatory action will be based on potential health threats of various contaminants and their maximum contamination level (MCL) standards as defined in Title 118, Chapter 4, Nebraska Department of Environmental Quality's "Groundwater Quality Standards and Use Classification". Trigger levels used by the ULNRD for groundwater quality management will not be changed if Title 118 standards change after September 3, 1991 unless so stated in a later revision of the quality portion of this Groundwater Management Plan.

Regulatory action will be taken if it is determined that remediation of contamination above 70% of an MCL, resulting from human induced non-point sources, in a predetermined area will not be obtained from established local Information and Education programs including one-on-one contacts with fertilizer and pesticide users. The ULNRD will hold a public hearing to determine what regulatory courses of action will be most appropriate to remedy this level of contamination. Informational meetings and public notices will inform people in problem areas of the subject matter of the hearing and of potential risks associated with the contamination problem.

Within ninety days after the hearing the ULNRD will determine whether a management area shall be established. If determined necessary, a Groundwater Quality Management Area will be established within the predetermined boundaries of land above groundwater having an average contamination level greater than 70% of nitrate-nitrogen or a pesticide MCL if that area is larger than 640 acres. Boundaries will be drawn on quarter section lines and will include land that is within one mile, in the direction of groundwater flow,

of NPS contamination sources.

At this time it is difficult to determine what specific management actions should be applied in specific situations because the ULNRD's NPS Management Program is just beginning. No substantial baseline groundwater quality data are available from irrigation wells in the ULNRD, consequently no trends can be determined. Currently there are no known NPS contamination problems in the ULNRD and it is unlikely that any will develop or be detected in the future. Present and foreseeable potential land and water uses, and population distribution minimize the likelihood of groundwater quality degradation. It seems unreasonable to set triggers for specific regulatory management actions when there is no documentation of a problem and future problems are unlikely, particularly when a full knowledge of the factors affecting groundwater quality degradation and remediation is not available but is steadily being developed.

However, to a certain extent it is necessary to have a predetermined plan of action if regulatory action is determined necessary. Any Groundwater Quality Management Area in the ULNRD will require irrigators within that management area to analyze irrigation water and soils that receive nitrogen applications for nitrates. Before designation of the Groundwater Management Area the ULNRD will determine the quantity and distribution of pesticides in that groundwater from any necessary water quality testing. Necessary testing will be determined from a survey of pesticide sales and applications, and recommendations of a qualified hydrologist and/or a crop chemical consultant. Testing of irrigation water for pesticides, determined to be present by the ULNRD in quantities greater than 70% of their MCLs, will be required of irrigators who have used those pesticides. The ULNRD will cover the cost of any necessary pesticide contamination monitoring not required of the above irrigators. This testing is needed to provide producers and the ULNRD with information to determine what management practices to apply to minimize contaminant leaching and to monitor the effectiveness of those practices. In addition to this, the following regulatory actions may also be applied: a) restrict fall fertilizer applications; b) require the use of delayed nitrogen application techniques; c) require the use of an integrated pest management approach to minimize pesticide applications, and to optimize their efficiency when applied; d) require the use of nitrification inhibitors to delay nitrification, restrict leaching, and increase nitrogen use efficiency; e) require a reduction of, or limit on irrigated acres; f) require the use of irrigation flow meters to accurately measure applied irrigation water to help reduce leaching; g) require the use of other "best management practices" that have been proven

to be effective in a setting like that of the Groundwater Management Area.

When the average NPS contaminant concentration is maintain below 70% of its MCL for four consecutive years, a public hearing will be held to determine whether any or all of the requirements of the Groundwater Management Area should be removed.

Regulatory authority is provided to Natural Resources Districts in Nebraska's Ground Water Management and Protection Act. Compliance will be enforced if necessary, by the issuance of cease and desist orders.

CHAPTER IV
GROUNDWATER MANAGEMENT PLAN IMPLEMENTATION

Objective 1 - Continue existing formal and informal cooperative data collection and educational programs with local, state and federal agencies and develop additional programs where common interests and needs become evident.

Objective 2 - In cooperation with the Conservation and Survey Division UNL and USGS, review the existing network of wells with respect to geographical coverage, potentiometric surfaces, and existing groundwater development; eliminate some wells that may be providing duplicative information; and add some wells where existing or potential development may be concentrated.

Objective 3 - Install or convert the Hecla and Tryon wells to automatic recorder wells and install recorder wells near Stapleton and Brewster and in northeastern Brown County in cooperation with CSD and USGS and other interested agencies.

Objective 4 - Develop a lake level monitoring plan in consultation and cooperation with other interested agencies.

Objective 5 - Establish mean sea level altitude of observation well and lake reference points, by instrument survey where funding permits, or by field inspection and use of topographic maps.

Objective 6 - Develop a data base that will permit the construction of detailed water-table contour maps representing point-in-time conditions. Secure funding and cooperation to produce the maps.

Objective 7 - Repeat the NRD-wide cooperative groundwater quality sampling program of domestic wells approximately every 5-7 years. Develop and maintain an extensive sampling program of irrigation wells that will effectively quantify the extent of NPS contamination within areas of the ULNRD subject to human induced NPS groundwater contamination. Evaluate the data to determine any trends and needed groundwater management action. Increase sample collection to determine if contamination results from non-point sources in areas where contamination levels greater than 70% of Maximum Contamination Levels (MCLs) are detected. Hold a public hearing to determine what regulatory courses of action will be most appropriate if contamination greater than 70% of an MCL is determined to be from human induced NPS contamination and remediation will not be obtained from established Information and Education programs including one-on-one contacts with fertilizer and pesticide users.

Objective 8 - Continue providing the service to citizens of analyzing water samples for nitrate-nitrogen with the use of laboratory kits. Advise well user if additional, more precise analysis is desirable.

Objective 9 - Disseminate information on well siting and well construction to prevent point source contamination of domestic water supplies in cooperation with local well drillers and Cooperative Extension.

Objective 10 - Continue monitoring the use of chemigation through irrigation systems and continue periodic and area-wide inspections of the chemigation systems.

Objective 11 - Coordinate efforts with adjacent NRDs directed at groundwater reservoir management, including the exchange of data, in recognition of groundwater movement both into and out of the NRD.

Objective 12 - Continue and expand as needed, educational programs for groundwater users with Cooperative Extension and the Soil Conservation Service on "best management practices" for application of irrigation water, fertilizers and pesticides. Strongly encourage such management practices to help stabilize, reduce and prevent the occurrence, increase or spread of groundwater contamination, and to prevent groundwater level declines.

Objective 13 - Encourage development of groundwater use for beneficial purposes within

the district. Closely monitor legislation and proposals for any groundwater transfers that would result in transfer of water elsewhere. Vigorously represent the interest of district residents in protecting against adverse impacts to their well being.

Objective 14 - Encourage research directed at understanding the hydrologic, physical, chemical and biological characterization of wetlands. In cooperation with the Nebraska Game and Parks Commission, and other agencies, initiate efforts to develop plans for lake and other wetland management.

Objective 15 - Cooperate with NDEQ, NDOH and communities to establish Wellhead Protection Programs for endangered public water supplies.

Objective 16 - If data collected and studies indicate that water levels in a local or regional area are declining at apparent rates of more than one-half foot per year over a ten year period due to groundwater withdrawal, a public hearing will be held to determine what regulatory courses of action will be most appropriate.

Objective 17 - Review the groundwater management plan annually to monitor progress and the need for modification.

Objective 18 - Continue to provide a cost-share program for the proper abandonment of wells, and encourage its use.

CHAPTER V
CLIMATE

Semiarid in the western part of the ULNRD, where the average annual precipitation is about 17 inches, the climate grades to subhumid in the eastern part where the precipitation is about 22 inches (Figures 5-1 and 5-2 from An Atlas of the Sand Hills). Average annual precipitation increases from west to east about one inch per 25 miles. Ordinarily about 80 percent of the precipitation falls in the period April through September. The average growing season precipitation in the ULNRD ranges from about 14 inches in the west to nearly 17 inches in the east (Figure 5-2). About 50 percent of the precipitation falls during May, June and July. However, precipitation is highly variable and seldom average.

Wilhite and Hubbard in An Atlas of the Sand Hills illustrate the variability of precipitation at Valentine in northeast Cherry County. There the range from 1900 to 1985 was from 28.91 inches in 1929 to only 10.57 inches in 1974. Based on plot of Palmer Drought Severity Index, they state, "The large fluctuations on this graph are evidence of the variability of moisture conditions in the region; in particular, the negative indices in the 1930s and the mid-1950s show two major long-term drought episodes."

Generally the Sand Hills have been considered to be less vulnerable to impacts of drought on the vegetation and the water supply, particularly stream flow, than have other parts of Nebraska.

Heavy snowfall, with much drifting, is not uncommon in winter in the ULNRD. The number of blizzards experienced in the area from 1870-1971 ranged from about 12 in the southern part to about 14 in the northern part according to Wilhite and Hubbard. Blizzards are most common in March and April (Figures 5-3 and 5-4). They also report in An Atlas of the Sand Hills that the winter precipitation (October - March) is usually in the form of snow and that the average annual accumulation of snow ranges about 22 to 28 inches along the southeastern and southern margins of the Sand Hills to 45 inches in the north.

In the Climate Section, An Atlas of the Sand Hills, Wilhite and Hubbard suggest the importance of the right amount and kind of snowfall for vegetation and groundwater recharge. Since evaporation rates are lower in winter, snow provides a source of moisture to recharge the soil profile and groundwater. The moisture is available for the use of vegetation in the spring. Snow also helps protect the sandy soils from wind erosion.

The location of climatological data stations in the ULNRD operated by the National Oceanic and Atmospheric Administration (NOAA) is shown in Figure 5-5. The annual normal precipitation at those stations is shown where the information is available. Climatological information is available from NOAA, the Department of Agricultural Meteorology, University of Nebraska-Lincoln and from the Nebraska Natural Resources Commission data bank. In addition, the Department of Agricultural Meteorology maintains Automated Data Network stations at the Gudmundsen Sand Hills Research Laboratory near Whitman, at the Sand Hills Agricultural Field Laboratory in Arthur County, and at Halsey. Other climatological stations are located near the boundaries of the ULNRD. Data is also available at locations where collection has been discontinued or where only partial records have been maintained. Some hourly precipitation data has been collected at Thedford and near Whitman (Whitman 4E).

A station was re-established at Stapleton in July, 1989 (Stapleton 5W, Station Index No. 8133). Previously a weather station was located at Stapleton (Stapleton 5 SSE, Station Index No. 8130). The station operated from 1948 to November, 1983. The 30 year normal (1951-1980) is 20.87 inches. Because of the 6-year gap in record and change in location of the station, a new normal has not as yet been established for this station.

CHAPTER VI
GEOLOGY

A brief description of the geologic history of the Sand Hills region including a discussion of the dunes is given in the first and second editions of An Atlas of the Sand Hills, 1989 and 1990 published by the Conservation and Survey Division (pg. 29-56). A thick sequence of continental deposits i.e. those sediments deposited by wind and water overlie Cretaceous shales of marine sea origin. The total thickness of the younger Tertiary sediments (about 2 million to 37 million years in age) is as much as 2,000 feet in the southwest part of Cherry County. The Brule and the

Chadron formations of the White River Group are the oldest of the Tertiary units. They underlie the entire NRD and generally thin from west to east. Their maximum thickness of around 1,250 feet is in southwest Cherry County. These sediments are quite fine-textured and their top generally coincides with the base of the groundwater reservoir.

Underlying the dunes are discontinuous deposits of Quaternary and Pliocene sands and gravels and the sands, clays, sandstones, gravels and clay of the Ogallala Formation of Miocene Age. Probable distribution of the Ogallala paleovalleys are shown in Figure 6-1. The generalized distribution of the younger sediments of Pliocene Age are shown in Figure 6-2; the probable source of the sand and gravel, paleovalley trends and possible former extent of their occurrence are shown in Figure 6-3. Although the Ogallala Formation consists mostly of fine to medium sands, the formation is thick and constitutes a major part of the High Plains Aquifer. The Ogallala ranges up to 800 feet in thickness and is thickest beneath the western part of the NRD, where it averages more than 600 feet.

Another aquifer, the Arikaree Group, occurs in places above the White River Group as paleovalley fills. The rock unit is older than the Ogallala and the occurrence of rocks of this age (about 19 to 28 million years) is as yet poorly defined. One of the paleovalleys, up to 25 miles wide and filled with more than 200 feet of fine to medium sand, has been identified in central Hooker County.

Considerable research in recent years has been focused on the origin, age and characteristics of the Sand Hills dune fields. They are of considerable interest to the entire natural resources scientific community and they play an important role as the interface between water on and under the ground surface.

In the section, Wind-blown Deposits, An Atlas of the Sand Hills, 1990, pp 43-56, James B. Swinehart discusses the classification, distribution, formation, origin and age of the dunes. He presents evidence based on radiocarbon dating of organic material under dune sand for a landscape that is young in the geologic sense. Swinehart and others have suggested that the larger dunes formed during a warm-and-dry period about 8,000 to 5,000 years ago. Another period of activity was noted between about 3,500 to 1,500 years ago.

Widespread sand movement probably has not occurred in the last several centuries, however, some modification of the dunes is known to have taken place during the drought years of the 1930's. Overgrazing was a contributing factor. The Sand Hills region now is considered to be one of the largest areas of stabilized dunes in the world. James Stubbendick discusses range management in the Sand Hills in An Atlas of the Sand Hills and suggests, "The Nebraska Sand Hills are recognized as one of the best managed large tracts of rangeland in the world (Bose, 1977)."

CHAPTER VII
SOILS

Figure 7-1 is a generalized soil map of the ULNRD. A state-wide map in color at a scale of 1:1,000,000 showing the same information with a description of the soil associations has been published recently by the Conservation and Survey Division-UNL. Maps showing more detail are available also at a scale of 1:250,000 and detailed county surveys are available for each of the counties. However, modern soil surveys have been published for Grant, Hooker, Logan, McPherson and Thomas Counties. The mapping of Blaine and Brown Counties has been completed and is awaiting publication. The soil survey in Cherry County is in progress.

Sand, principally quartz and feldspars, is the parent source of virtually all the soils in the Sand Hills region. A description of the origin of properties of Sand Hills soils and the soil associations and series are included in chapters in An Atlas of the Sand Hills, 1990. David T. Lewis, page 57 in the atlas, summarizes some of the soil characteristics, "Soil on the dunes in the Sand Hills have thin A horizons that contain very little organic matter. These topsoils are somewhat darkened, but only slightly. The lack of organic matter may be because of the droughty nature of these soils (Valentine Series), or it may be because the dunes have not been stable long enough for well-darkened soils to form. Soils with well-darkened topsoils containing one percent or more organic matter can be found on gently sloping, well-drained sand sheets. More moisture may be available because of minimal runoff from them and because more water has run in and more groundwater has flowed in from higher land." He also states, "Subsoil development, on the other hand, appears to be lacking in the Sand Hills. Even the soils in the subirrigated meadows with thick A horizons have unstructured subsoils and show no signs of the accumulation of clay that marks a soil's development," and "All factors considered, it appears

that Sand Hills soils are in the early stage of their development."

The areal extent of the Valentine Association, an upland soil formed on eolian sand, is greater than the combined area of all the other soils. The soils are formed on gentle to steep slopes and are considered to be

excessively drained. Because the water-holding capacity of the Valentine is low (about 0.5 inch per one-foot thickness), grass roots extend to depths greater than 40 inches and in most years the dry-weight yield of grass is less than one ton per acre. Some irrigation wells have been developed in valleys and swales amongst the Sand Hills (See Figure 7-2 for location of irrigation wells).

The Coly-Uly-Holdrege Association soils are the "hard lands" of southern Logan County. They are described as well to excessively drained silty soils on uplands. They occur on gentle to steep slopes. Although they occupy only a small portion of the NRD area, these soils are the most intensively irrigated in the district.

The Valentine-Elsmere-Tryon Association is the second largest soils association in the district occurring mostly in Grant, western and northern parts of Cherry, and in parts of Brown Counties. The Valentine soils occur on the uplands and the Elsmere and Tryon soils occur in association with the Valentine on nearly level alluvium and eolian sands in valleys. They are poorly to somewhat poorly drained. Irrigation from wells is quite sparse in the areas occupied by these soils.

The Hersh-Valentine Association occurs in and around the area of the "hard land" soils in Logan County, a small adjacent area in McPherson County, and in another small area in southeast Blaine County. The Hersh soils in association with the Valentine are deep, well to excessively drained loamy soils on nearly level to steep slopes formed in eolian materials on uplands. A relatively large percent of these soils are irrigated.

The Els-Valentine-Ipage Associaton occurs in parts of four townships northeast of Brewster in Blaine County and a small area in extreme southeast Brown County. The Els and Ipage soils are

somewhat poorly to moderately well drained sandy soils formed in eolian sands and alluvium in valleys. They occupy nearly level to very gentle slopes. Some irrigation wells have been developed in parts of the area occupied by this association.

The Hobbs-Hord Association occurs on bottomland and terraces of the South Loup River in southeastern Logan County. They are well-drained silty soils formed on alluvium and loess.

The Hord-Cozad-Boel Association occurs on terraces and bottomland along the Middle Loup River near the Blaine-Custer County line. They are formed mostly on well drained silty alluvium bottomland and terraces.

The Almeria-Bolent-Calamus Association occurs in the valleys of the Calamus, North Loup, Middle Loup and South Loup Rivers. They are sandy soils formed on alluvium and range from very poorly drained to moderately well drained. Clusters of irrigation wells have been concentrated in some areas to irrigate these soils.

CHAPTER VIII
LAND USE

Land use practices can adversely affect both water quantity and quality. Large withdrawals of groundwater for irrigation, municipal, and industrial use can reduce the amount of groundwater in storage. Groundwater contamination can occur from either point or non-point sources. Point sources of groundwater contamination are many and include; private or community and industrial type waste disposal systems; the improper use, storage and disposal of chemical, other industrial and petroleum products; improperly operated or abandoned livestock feed yards; and improperly sited, constructed and abandoned wells. Non-point sources in Nebraska are generally considered

to be those associated with poorly managed agricultural practices such as improper timing and application of fertilizer (either commercial or manure) and farm chemicals in amounts greater than those generally recommended as best management practices. Elsewhere in the state, evidence clearly indicates that poor timing and over irrigation contributes significantly to the contamination of groundwater from agricultural chemicals.

There is no evidence to date that the groundwater supply has been reduced by withdrawals in the ULNRD nor is there evidence that the groundwater has been contaminated from non-point sources. The population is not concentrated, land use for industry does not exist and intensive cultivation and irrigation is minimal. However, the ULNRD plans to add additional wells for the monitoring of water levels in isolated areas of concentrated irrigation well development and to include the sampling of irrigation wells for water quality analyses along with their cooperative program of periodically sampling domestic wells.

The practice of draining lands to improve their capability for cultivation or hay production has been widespread in the state. In general, this practice has probably not affected groundwater quality and has not measurably reduced the quantity of groundwater in storage. The practice has been viewed by some as adversely affecting wildlife habitat. The ULNRD plans to work with interested agencies and to strongly encourage objective

research directed toward a balance between wildlife habitat enhancement and the use of land for hay production or other purposes. The district will also encourage and help sponsor education efforts in this regard. To this end, the district has purchased a large number of the first and second editions of An Atlas of the Sand Hills for distribution in the district.

By far the largest land use in the ULNRD is for grazing and hay production. A General Land Use Map in Nebraska - Summer 1973, Conservation and Survey Division identified only a small mappable area of currently cropped agricultural lands in southern Logan County and southeastern McPherson County. Large areas of wetlands and lakes were shown in Grant and Cherry Counties and an area less than a township in size was identified as forest in the Nebraska National Forest at Halsey. However, the legend suggests that somewhat isolated parcels of land along stream valleys and interspersed between large dunes were also cultivated.

Susan M. Miller, in the Chapter, Land Development and Use, An Atlas of the Sand Hills, also discussed cropping patterns in all of the Sand Hills. She states, "Native pasture and wild hay have always been and remain the predominant land use of the Sand Hills. Only five percent of the land is planted to crops, which include tame hay and alfalfa...." "The small amount of cultivated acreage has been used to supplement ranching enterprises and the area has never been a major grain producing area."

Changes in land use in the Sand Hills have occurred and probably will continue. As an example, Susan Miller in the same chapter reports, "Cropping patterns in the Sand Hills have not followed the trends in the rest of Nebraska.... However, corn was a popular crop with the early settlers. In 1915 (10 years after the Kinkaid Act) with only about six percent of the land in the Sand Hills cultivated, more than 60 percent of the cultivated acres was in corn. But this corn acreage began to decline rather quickly, and tame hay acreage increased." She indicates that potatoes and small grains continued to be grown until about 1950 and, "Gradually, these crops gave way to cultivated hays, particularly alfalfa."

Because of limited rainfall and recurring periodic droughts, successful cultivation of crops without supplemental water is difficult in most years in the western part of the state. The practice of irrigation from wells started to develop in the late 1940s and grew at a slow rate through the late 1960s. Many of the estimated 564 [(1)] irrigation wells in 1989 (Figure 7-2) in the ULNRD were drilled since 1973 and most of the land irrigated from wells is for crop production.

No precise figure is available either for the number of irrigation wells drilled or the number in use in any given year. The ULNRD Board believes that possibly as many as 10 to 15 percent of the irrigation wells are (and have been) inactive for a number of years. If 500 irrigation wells were active in 1989 and it is further assumed that each irrigated 135 acres, the land under irrigation, then, was about 67,500 acres or about 1.5 percent of the total land area. The 1988 Nebraska Agricultural Statistics, pg. 122, reports that according to the U.S. Census of Agriculture, 1987, the irrigated land in the counties included in the ULNRD was about 63,700 acres. (The numbers for Cherry, Brown, and McPherson counties have been prorated by percent of area within the NRD.)

The total number of irrigated acres harvested in 1988 in the ULNRD was only about 60,000 acres as estimated from preliminary information provided in 1988 Nebraska Agricultural Statistics. Corn was harvested for grain from 38,400 acres and for silage from another 3,500 acres, a total of 41,900 acres. Alfalfa was the second largest irrigated crop with 22,000 acres being harvested. Another 17,400 acres of non-irrigated alfalfa was harvested. Presumably some or much of the acreage was subirrigated. About 1,300 acres of irrigated soybeans and 500 acres of irrigated wheat were also harvested. Dryland crops in addition to alfalfa grown in the area include corn, wheat, sorghum, oats, and barley. The total number of acres of cultivated cropland (small grain and alfalfa) planted in 1988 (1988 Nebraska Agricultural Statistics is estimated to be about 104,000 acres (Table 8-1). Approximately 60 percent of this cropland was irrigated.

(1) In the preparation of this plan, considerable effort was made to correct inaccuracies related to well registration information using county plat books, soil surveys, topographic maps and field checking by NRD staff. Other errors almost surely exist. The ULNRD plans to continue efforts in cooperation with the Nebraska Department of Water Resources to obtain accurate irrigated well information.

TABLE 8-1

ACRES OF CROPLAND PLANTED IN 1988

From Agricultural Statistics

Nebraska Ag. Statistics Service, NE Department of Agriculture

Corn		48,800
Alfalfa Hay		39,400
Wheat	7,700	
Oats		3,300
Sorghum		2,900
Soybeans		1,400
Barley	300	
	Total	103,800 acres

A summary of land use for the counties in the ULNRD is given in Table 8-2. The information is

from the U.S. Census of Agriculture, 1987. The total acres of cropland reported is about 500,000 and the number of acres harvested is about 341,000. If the number of acres of small grain and alfalfa is about 104,000 acres (1988), then the remainder of cropland 237,000 acres presumably was mostly harvested native hay. Much of the native hay probably is sustained by subirrigation in the wetland areas. The total acres of wetland soils and subirrigated soils in the ULNRD was estimated to be about 244,000 acres by John H. Sautter in 1985 (Table 8-3). The information was based upon soil survey data.

Statistical information concerning wild or native hay was not reported in the 1988 Agricultural Statistics. However, the number of acres of wild hay harvested in the counties located in the ULNRD was compiled later (personal communication, Jack Aschwege, State Statistician, 1991). The number of acres of wild hay harvested in 1988 was 269,000 (the acres in the three counties partly in the NRD have been estimated based on percent of area).

The total harvested cropland of 341,000 acres in 1988 represents about eight percent of the total land area, 4,275,000 acres; and the cultivated crops of small grain and alfalfa (104,000 acres) represent only about 2.4 percent. Irrigated cropland accounts for about 1.5 percent of the total land area.

TABLE 8-2

US CENSUS OF AGRICULTURE, 1987
NRD LAND USE IN ACRES

From 1988 Agricultural Statistics
Nebraska Ag. Statistics Service, NE Department of Agriculture

Types	Total Cropland	Harvested Cropland	Irrigated Land	Pasture Land All
Blaine	54,561	34,562	7,669	375,991

Brown[2]	68,603	44,014	19,464	213,479
Cherry[2]	162,464	140,092	11,983	
	1,416,958			
Grant	114,216	45,741	3,329	630,005
Hooker	13,625	10,541	1,980	320,405
Logan	62,103	43,510	13,024	303,120
McPherson[2]	(1)	12,852	3,207	126,889
Thomas	14,264	9,551	3,074	350,842
Total	489,836+	340,863	63,730	
	3,737,695			

(1) Withheld to avoid disclosing data for individual farms

(2) Brown County - 50% of total acres reported in County.
Cherry County - 40% of total acres reported in County.
McPherson County - 33% of total acres reported in County.
(Based on percent of County in the NRD).

Conservation Reserve Program acres in the NRD total approximately 16,000 acres or about 0.4% of the total land areas.

TABLE 8-3

WETLAND SOILS AND SUBIRRIGATED SOILS

County	Wetland Soils	Subirrigated Soils
South Brown	3,425	30,599
Blaine	7,445	8,215
South Cherry	95,516	28,641
Grant	6,090	38,030
Hooker	1,681	2,037

East McPherson	0	0
Logan	5,575	13,987
Thomas	1,653	1,290
TOTALS	121,385	122,799

TABLE 8-4

CONSERVATION RESERVE PROGRAM ACRES
UPPER LOUP NRD
1990

County		Acres
Blaine	1,850.2	
South Brown	4,251.8	
South Cherry	3,208.5	
Grant	159.3	
Hooker		764.6
Logan	3,197.1	
East McPherson		1,998.8
Thomas		822.8
	Totals	16,253.1

CHAPTER IX
WATER SUPPLY

The abundance of water, groundwater, streams and lakes in the Upper Loup NRD is closely related to geology of the area and the mantle of dune sand over most of the area. The relatively low amount of precipitation belies the water abundance. The factors that contribute to the large

supply of water are: high infiltration rates of precipitation on the sandy soils; very little surface runoff due to generally very poorly integrated surface drainage; groundwater support of lakes, wetlands, and streams; and the thickness of relatively coarse aggregate sediments constituting a large groundwater reservoir.

Precipitation falling on the land surface is the source of water supply. That amount varies seasonally and annually as described previously. Total amount of annual precipitation in average, dry and wet years is estimated to be as follows:

Dry (12 inches)	4,275,000 acre feet
Average (19 inches)	6,750,000 acre feet
Wet (24 inches)	8,550,000 acre feet

Sautter in 1985 compiled the surface water acreage in the ULNRD as follows:

TABLE 9-1

SURFACE WATER ACREAGE

County	Acres	Type of Surface Water
Blaine	360	North Loup, South Loup, Dismal Rivers
South Brown	2,611	Lakes, Streams, Calamus River
South Cherry	14,870	Lakes, Streams, North Loup River
Grant	4,900	Lakes
Hooker	205	Lakes, Middle Loup, Dismal Rivers
Logan	245	Lakes, Intermittent Streams, South Loup River
East McPherson	0	No Lakes or Streams
Thomas	1,682	North Loup, Middle Loup, Dismal Rivers
TOTAL	24,873	

The source of the data was from Standard Soil Surveys and National Resource Inventories.

Surface water acres identified from these sources total 24,873 acres.

The location and name of streams are shown on Figure 1-1 and Figure 9-1. Figure 9-1 is a generalized map showing distribution of some Sand Hills lakes from An Atlas of the Sand Hills. Lakes and wetlands are common in Grant and southwestern Cherry counties and somewhat less common in the remainder of Cherry County, in southern Brown and in Logan Counties.

Most of the lakes and wetlands are groundwater supported as are the streams. A few lakes and streams (notably Goose Creek) are partially supported by flowing wells. Some of the lakes are playa-like in that they occur above the water table so that they contain water only during wet periods and often dry up in the summer.

In the An Atlas of the Sand Hills (pg. 121), Bleed and Ginsberg state "Perhaps the most notable characteristics of the lakes and wetlands in the Sand Hills is their variability. As manifestation of the groundwater, most lakes have water levels that fluctuate with changes in the water table." Because many lakes are relatively shallow, seasonal or periodic changes in precipitation affect groundwater levels. Slight changes in water levels can make large changes in lake sizes.

The chemical, physical and biological properties of all Sand Hills lakes were studied during the years of 1954 to 1960 by the Nebraska Game, Forestation and Parks Commission, M.O. Steen, Director; D. Bruce McCarraher, Principal Investigator. A report, Nebraska Sand Hills Lakes by D. Bruce McCarraher published by the Nebraska Game and Parks Commission, 1977 updates the earlier report. Studies from about 1954 to 1969 addressed primarily the fishing aspect of the lakes. McCarraher's studies from about 1969 - 1972 were more comprehensive and were oriented toward assessment of limnological parameters and the consequent evaluation of the lakes as a major northern prairie ecosystem.

Lakes of less than 10 acres in size were not included in either of the two studies. Both studies emphasize the shallow nature of the lakes. The average depth of all lakes in the Sand Hills was reported to be 3.2 feet in the 1961 report. Most of the lakes in the ULNRD portion of the Sand Hills were reported by McCarraher to be slightly alkaline.

An inventory of the lakes in the ULNRD as reported in the two studies is as follows: (no lakes were identified in Blaine, East McPherson or Thomas Counties).

TABLE 9-2

INVENTORY OF LAKES

	Sand Hills Lake Survey 1954-1960, D. Bruce McCarraher		Nebraska's Sand Hills Lakes D. Bruce McCarraher, 1977	
County	No. of Lakes	Size (in acres)	No. of Lakes	Size (in acres)
South Brown	17	2,584	18	2,555
Cherry	86	7,756	106	7,477
Grant	* 46	3,628	* 46	3,585
Hooker	4	266	4	266
Logan	4	148	4	153
TOTALS	157	14,382	178	14,036

*An additional 15 playa lakes were identified in 1960 and 24 in 1977.

McCarraher, 1961 reports a total of 1,640 lakes having a combined area of 68,500 surface acres for all of the Sand Hills and in 1977 he reports a total of 1,289 natural lakes that have a combined total surface area of 78,345 acres. Although neither study included lakes of less than 10 acres, Steen et. al. indicate that there were about 850 of the smaller lakes. The number of natural Sand Hill lakes in the ULNRD represents less than 15

percent of the total number of Sand Hills lakes based on McCarraher's data. Using the same data, the combined surface area of natural lakes in the ULNRD is about 18 percent of the Sand Hills total. The slight discrepancy in numbers of lakes and their combined surface area in the two reports probably represents conditions at two different periods of time.

Groundwater and surface water are perhaps more closely interrelated in the ULNRD than in any

of the NRDs. Most of the surface water, i.e. lakes marshes and streams originates as groundwater. Land surface profiles constructed west to east in the area compared to profiles of the water table show that many of the lakes and marshes occur where the land surface intersects the water table. As suggested previously the land surface is poorly drained and the surface drainage system can be considered to be poorly integrated. Lakes are present in the head waters of the streams but are less common or do not occur elsewhere.

The South Loup, Loup, North Loup, Dismal and Calamus Rivers and Goose Creek and their tributaries are incised more or less deeply into the water table. In this sense they drain groundwater in the area and their flow across the NRD boundary represents a transport of groundwater to the area downstream. Sautter, 1985 reported stream flow amounts (1983) at available gaging stations. That information from Sautter is reproduced here as Table 9-3.

TABLE 9-3

STREAM FLOW AMOUNTS
UPPER LOUP NRD

MIDDLE LOUP RIVER AT DUNNING

38 Year Average Discharge 401 cu. ft./sec = 290,500 ac. ft/yr.
Maximum Discharge 1020 cu. ft./sec on April 20, 1971
Minimum Discharge 100 cu. ft./sec on December 5 & 6, 1950

DISMAL RIVER SOUTH OF THEDFORD

17 Year Average Discharge 193 cu. ft./sec = 139,000 ac. ft/yr.
Maximum Discharge 1160 cu. ft./sec on August 23, 1983
Minimum Discharge 146 cu. ft./sec on December 26 & 30, 1982

DISMAL RIVER AT DUNNING

38 Year Average Discharge 323 cu. ft./sec = 234,000 ac. ft/yr.
Maximum Discharge 1290 cu. ft./sec on June 13, 1983
Minimum Discharge 100 cu. ft./sec on January 25, 1950 and January 9, 1962

NORTH LOUP RIVER AT TAYLOR

46 Year Average Discharge 462 cu. ft./sec = 334,700 ac. ft/yr.
Maximum Discharge 3210 cu. ft./sec on June 27, 1983
Minimum Discharge 45 cu. ft./sec on July 26, 1941

SOUTH LOUP RIVER AT EAST BOUNDARY OF LOGAN COUNTY

No Records - Flow is less than that of Dismal River South of Thedford.

SOURCE: Water Resources Data Nebraska 1982 - U.S. Geological Survey Water Data Report NE -83 - 1.

Ray Bentall, 1989, in An Atlas of the Sand Hills (pg 93-114) discussed and characterized streams in the Sand Hills. Quotes from this section of the Atlas illustrate some of these characteristics. Bentall (pg. 93) states, "Sand Hills streams differ in several respects from most streams in Nebraska, and for that matter, in the world. Not only do they appear to have had a unique origin, but they have few tributaries, flow at remarkably steady rate, and almost never flood despite their generally low banks."; and (pg. 94) "Since their flow is derived almost entirely from relatively steady groundwater seepage and very little overland runoff, Sand Hills streams are noted for their nearly constant discharge (rate of flow). Groundwater seepage to streams, wetlands, and lakes may be regarded as "overflow" from the water saturated materials underlying the region. Over the long term, such seepage approximates the average amount of precipitation that infiltrates below plant roots and is added to groundwater storage."

Bentall (pg. 94) considered the relationship between precipitation and streamflow in the Sand Hills "Of the average annual amount of 20 inches on the area as a whole, the average annual streamflow out of the Sand Hills represents about three inches, or approximately a seventh of the average annual precipitation. The average annual precipitation in the ULNRD is slightly less than the 20 inch average for the Sand Hills by about one inch. The calculation that stream flow from the Sand Hills represents one-seventh of the average annual precipitation should apply to the ULNRD also. One-seventh of 6,750,000 AF equals about 964,000 AF per year leaving the ULNRD as stream flow.

Stream flow is not gaged near the NRD border. The North Loup River and Goose Creek are gaged to the east in Loup County at Taylor. The Middle Loup and Dismal Rivers are gaged at Dunning. The South Loup and Calamus Rivers are not gaged near the border. Sautter, 1985, reported the gaged flows as follows:

TABLE 9-4

GAGED RIVER STREAM FLOWS

Middle Loup at Dunning	290,500 AF/year
Dismal River at Dunning	234,000
North Loup at Taylor	334,700
Total Flow 859,200 AF/year	

The comparison of stream flow based on percentage of precipitation and incomplete gaging records is quite close, 964,000 AF versus 859,000 AF. The average annual flow appears to be greater from 1982 to 1985 (Fig. 6-6 p. 102, An Atlas of the Sand Hills) in the ULNRD streams due to greater than normal precipitation. This may account for some of the difference in the two estimates of flow.

Although most of the yield of the Sand Hills streams in the ULNRD is from groundwater, some runoff occurs as the result of high precipitation storm or snow melt events. Bentall, 1989, pg. 100, calculated the percentage of groundwater in normal river discharge at selected sites:

TABLE 9-5

PERCENT OF GROUNDWATER IN STREAM FLOWS

Middle Loup River at Dunning	95%
Dismal River near Thedford	98%
Dismal River at Dunning	97%
North Loup River at Taylor	90%

Because of the negligible use in the NRD of stream flow originating from groundwater, any consideration of transfer of water out of the NRD should focus on surface flows as the source having the least impact on other water uses.

Annual average discharge from the groundwater reservoir into streams measured as outflow from the ULNRD is estimated to be about 900,000 AF. However, the total amount discharged is significantly greater because of evaporation from the free water surfaces. Sautter, 1985, estimated the combined surface water acreage (streams plus lakes) to be about 24,873 acres (Table 9-1). The Nebraska Game and Parks Commission's 1960 and 1977 reports show about 14,000 surface acres of natural Sand Hills lakes (not accounting for lakes under 10 acres). Thus, total water surface acres of streams might be about 10,000 to 11,000 acres.

McCarraher, 1960, (pg. 2) suggested that, "Evaporation losses from lakes are high -- from three to five feet water annually." Total annual evaporation from water surfaces in the ULNRD might average about 100,000 AF if annual evaporation averages four feet and the combined water surface of lakes and streams is assumed to be 25,000 acres.

Discharge through evaporation from the groundwater reservoir in the area from free water surfaces is conservatively estimated to be 100,000 AF annually. Also, an estimated 900,000 AF of water (primarily from groundwater) flows out of the area each year on the average. Natural groundwater discharge from free water surfaces and via streams totals about 1,000,000 AF. Discharge by evaporation from wetland soils and transpiration of plants in shallow water-table areas is also known to be a large quantity of water. The quantity is believed to be variable and is discussed later in this chapter.

McCarraher, 1977, pg. 2 suggests, "The Sand Hills' lakes aged through natural eutrophication over 4,000 to 5,000 years." Lakes probably are not all of the same age nor do they age uniformly. Sedimentation via water and wind transport plus accumulation of vegetable matter slowly fill lakes and marshes. Some marshes and other wetlands may have been shallow lakes in the past. Modification by humans has occurred either directly through drainage, dikes or weirs or indirectly through land use practices such as grazing, crop production and fire control.

Although limited documentation is available, some modification of wetlands probably occurred during the drought of the 1930s as blowouts developed and sand drifted. McCarraher, 1977, pg. 2 also suggested, "To date, there is no empirical evidence that

any significant number of lakes are undergoing notable accelerated eutrophication change, either natural or cultural, to cause ecological concern. Prevailing conditions suggest that changes in nutrient concentration occur only slightly over the years." He was probably correct in suggesting that no notable change has occurred over the short period of record. Later, p. 28, with particular reference to "playa lakes" and management for crustacean production, he states, "Development features such as internal dikes, sluice gates, basin deepening and grading would be required for many lakes." Practices to manage lakes and wetlands and maintain or improve their value for a variety of purposes may be a consideration of the future.

Crop statistics as previously noted indicate that about 200,000 acres of native cropland hay is harvested annually. Sautter, 1985 (Table 8-3 of this plan), showed that (based on soil survey data) there are 121,385 acres of wetland soils and 122,799 acres of subirrigated soils -- a total of 244,194 acres in the ULNRD. A problem of calculating or estimating the acreage of wetlands either as wetland soils or particularly as wetlands based upon definitions using biological and/or vegetation characteristics is that of time and timing.

Lakes and wetland characteristics change seasonally as well as in response to climatic changes over a several year span. Because of the size of the area, the large extent of wetlands, and lack of roads, the cost of physically monitoring wetlands is prohibitive. Remote sensing from high altitude photos or satellite imagery may be the only practical way to develop a data base. Such information on size, extent and changes in characteristics would be most meaningful if accomplished on a continuing basis. One effort to identify and provide baseline information on both locations and area extent of wetlands was done by the Omaha District, Missouri River Division, U.S. Army Corps of Engineers, May 1981. The project director was Donald C. Rundquist and a wetland atlas was compiled by the Remote Sensing Applications Laboratory, University of Nebraska at Omaha. The data set used was mostly for the summer period, June and July of 1978.

Interpretation for that wetland inventory utilized the Landsat resources satellite. The information from that inventory represents conditions only at a particular period of time and for categories of wetlands based upon objectives of the inventory. The definition of "wetlands" used was:

> "Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."

The wetlands were divided into the following categories:

Open Water: Areas of open surficial water large enough to be detected by the Landsat sensor system (1.12 acres or larger).

Marsh: Areas of emergent aquatic vegetation, often associated with open water.

Riparian: Areas of riverine vegetation where the growth of the plant communities is a result of the presence of a flowing stream.

Subirrigated Meadow: Areas not irrigated by man that occupy topographic lows where plant roots contact the water table. Those low-lying areas are typically occupied by vigorously growing grasses, sedges, and shrubs that contrast sharply with the adjacent vegetation. For purpose of the inventory, only meadows occurring in the Sand Hills of Nebraska and South Dakota were mapped as "subirrigated."

TABLE 9-6

Wetland Inventory in Acres[1] by County

(Adapted from Rundquist et. al., 1981)

County	Open Water	Marsh	Riparian	Subirrigated Meadow	Total
Blaine	993	1,039	138	6,815	8,985
[2]Brown	1,990	939	320	15,270	18,519
[2]Cherry	11,928	5,583	577	158,112	176,200
Grant	5,216	3,142	0	86,247	94,605
Hooker	192	180	0	19,940	20,312
Logan	132	109	0	8,927	9,168
[2]McPherson	228	217	0	8,458	8,903
Thomas	126	491	0	11,858	12,475
	20,805	11,700	1,035	315,627	349,167

Note: [1]Figures rounded to nearest whole number.

[2]Brown County - 50% of total acres reported in County

Cherry County - 40% of total acres reported in County

McPherson County - 33% of total acres in County

(Based on percent of County in the ULNRD.)

A number of other attempts to inventory and/or quantify the extent of wetlands in the Sand Hills has been made. A discussion and comparison of those attempts including the 1981 effort is contained in Wetland Inventories of Nebraska Sand Hills, Resource Report No. 9, CSD-UNL by

Donald C. Rundquist, 1983. Rundquist, 1983 (pg. 25) suggests, "Meaningful comparisons of the results of the six wetland inventories described in previous paragraphs and in Table 1 are somewhat difficult for several reasons:

(1) The definition of wetlands varies and the surveys were conducted for different reasons;
(2) The time frames and thus the precipitation regimes associated with the data collection were quite different;
(3) The data-collection techniques were dissimilar; and
(4) Some of the mapping categories (for example, marsh) were grouped in some studies but not for others...."

Another inventory of the Sand Hills has recently been completed as a part of the National Wetland Inventory by the U.S. Fish and Wildlife Service. The classification system has about 30 categories.

Resource Report No. 9 of CSD, also states "wetlands are an important part of the Sandhills ecosystem for a variety of reasons. They provide essential resting and nesting grounds for migratory waterfowl as well as habitat for fish and other wildlife. Nebraska's subirrigated meadows are also economically important since grasses in many of the large meadows are harvested as hay on a regular basis. In addition, considerable controversy today surrounds the questions of whether the pumping of groundwater for irrigation may cause a decline in area of the subirrigated meadows (Whitesides, 1982). For at least these reasons, several attempts have been made to gather data concerning the wetlands in the Nebraska Sandhills."

The same report concludes "wetland surveys conducted thus far generally have resulted in nearly the same acreage totals for open water and marsh. Where not the same, the differences are explainable. However, a major discrepancy exists in the statistics on total areal extent of subirrigated meadows in the Sandhills, indicating a need for additional research."

Clearly the extent of selected categories of wetlands can at best be only estimated at a single point in time. For example, Rundquist, 1983 (pg. 29), illustrates the wide range in acreage of three categories of wetlands -- marsh, subirrigated meadow, and open water at the Valentine National Wildlife Refuge and the Crescent Lake National Wildlife Refuge as detected by

Landsat 1973 to 1978. The areal extent of subirrigated meadow ranged from as much as 5,000 to as little as 3,000 acres at both of the refuges. Donald W. Buckwalter, 1983, Monitoring Nebraska's Sand Hills' Lakes, Resource Report No. 10, CSD-UNL, also shows the wide range in acreage of some Sand Hills' lakes in Sheridan and Holt-Rock Counties using Landsat imagery. For most lakes, the largest area of water cover usually occurred in the spring with successively decreasing water areas during midsummer and fall.

As previously discussed, natural groundwater discharge occurs as outflow through streams, as evaporation from free water surfaces and as evapotranspiration from shallow water-table areas. The amount of groundwater discharged annually obviously will vary depending primarily on groundwater levels which in turn are dependent upon climatic conditions. Some approximation of the quantity of natural groundwater discharge is important in understanding the hydrologic system and how that system and water supply is affected naturally and how it might be affected by human activity. Precise quantification, particularly in the predictive sense is not possible because of the great dependency of the water supply on climate and our inability to predict climate or climatic trends. It is extremely important to note that generalizations about the hydrologic system in the ULNRD are dangerous if applied to specific areas. Hydrologic conditions vary widely across the area as does the climate seasonally and over periods of years. Water use and management practices and their impacts in most of the area might be very localized. As an example, large withdrawal of water from a concentration of high capacity wells may lower water levels and reduce storage in the area where the wells are located either seasonally or over several years. However, that effect may not be significant or measurable one to several miles distant.

Groundwater discharged through outflow of streams was estimated to be about 900,000 AF annually. Discharge from evaporation from 24,873 acres of free water surface (Table 9-1) was estimated to be about 100,000 AF annually. Sautter estimated as previously noted, the total acres of wetland and subirrigated soils to be about 244,000 acres. Dr. Blaine Blad, Chairman, Department of Agricultural Meterology, Personal Communication, 1990, advises that the daily use of vegetation in wetland environments in the Sand Hills might range from 0.2 to 0.5 inches per day during the seven month period from April to October. That use from November through March is considered to be relatively insignificant. The range is broad and actual use is dependent upon several climatic factors including solar radiation. If it is assumed that the

average daily use of vegetation is 0.3 inches per day, the average use in a 30-day month is 9 inches and for the seven month period is about 63 inches. Discharge, primarily of groundwater from the 244,000 acres of wetland soils, on this basis might average slightly more than 1,280,000 AF annually. If these assumptions are

correct, total annual average natural discharge from the groundwater reservoir is about 2,280,000 AF less precipitation on the total wetland area and free water surface (19" x 269,000 = 426,000 AF) equals about 1,850,000 AF (Table 9-7a).

TABLE 9-7a

ESTIMATED NATURAL GROUNDWATER DISCHARGE
(BASED ON SAUTTER'S WETLAND AND SUBIRRIGATED SOIL ESTIMATE)

Discharge through Streams		900,000 AF/year
Evaporation from Free Water Surfaces		100,000 AF/year
Evapo-Transpiration from Wetlands and Subirrigated Soils	1,280,000 AF/year	
Subtotal		2,280,000 AF/year
Less: Precipitation on Free Water Surface and Wetlands area (269,000 acres)	426,000 AF/year	
TOTAL		1,854,000 AF/year

If 63 inches is considered as a typical discharge rate for all wetlands and using Rundquist, 1983 (including free water surfaces) total wetland area, then 63 inches times 350,000 acres equals about 1,830,000 AF. Adding stream flow of 900,000 AF to that figure gives a total natural groundwater discharge of about 2,730,000 AF less precipitation of 19 inches on 350,000 acres (554,000 AF) equals 2,176,000 AF (Table 9-7b).

TABLE 9-7b

ESTIMATED NATURAL GROUNDWATER DISCHARGE
(BASED ON RUNDQUIST'S WETLAND INVENTORY)

Discharge through Streams		900,000 AF/year
Evapo-Transpiration from Wetlands plus Free Water Surfaces	1,830,000 AF/year	
Subtotal		2,280,000 AF/year
Less: Precipitation on Wetlands and Free Water Surface area (350,000 acres)		554,000 AF/year
TOTAL		2,176,000 AF/year

The average for the two figures, 1,850,000 and 2,176,000 (from Tables 9-7a and 9-7b) is about two million AF. Most of the remainder of the precipitation (about 6,750,000 AF), is used by native vegetation and cultivated crops or is withdrawn from the groundwater for human and stock use.

CHAPTER X
GROUNDWATER

A. PHYSICAL CHARACTERISTICS

The thickest section of water-saturated sediments in the state occurs within the ULNRD and adjacent area. The saturated thickness of the principal groundwater reservoir is illustrated in Figure 10-1. The thickness of water-saturated fine to coarse sediments is more than 500 feet in nearly all of the district. Depth to water from the ground surface

is shown in Figure 10-2.

The principal groundwater reservoir consists of; young (Holocene or Recent), and older (Pleistocene or Ice Age) Quaternary deposits of sands and gravelly sands; Pliocene sands and gravels; Miocene (Ogallala Group) deposits of sands, sandstones and gravelly sands; and Miocene-Oligocene (Arikaree Formation) sands. The Pliocene, Miocene and Oligocene are Tertiary in age. The base of the principal groundwater reservoir is the base of the Ogallala and/or Arikaree. The base of the principal groundwater reservoir is equivalent to the upper surface of the older Tertiary beds of the White River Group. The configuration of that surface has been mapped using information from well logs. The White River Group, consisting of thick fine-grained sediments primarily of silt, siltstones and clays, is considered a secondary aquifer with limited potential or need to yield water to wells.

The upper surface of the groundwater reservoir is defined by the regional water table. Figure 10-3 shows the configuration of the regional water table of the ULNRD and surrounding areas. Each contour line joins points of equal elevation above mean sea level and was constructed based on water levels in wells and from elevations of lakes and streams shown on topographic maps. The regional water table roughly mirrors both the configuration of the land surface and the base of the groundwater reservoir. West to east across the ULNRD, regional water table elevations vary 1450 feet from an elevation of approximately 3850 feet in northwestern Grant and southwestern Cherry Counties to 2400 feet in eastern Blaine County.

10-2

Accordingly, groundwater moves slowly from higher elevations to lower elevations or generally from west to east across the ULNRD. The drop of about 1450 feet across the district takes place in a horizontal distance of 120 miles which is equivalent to about 12 feet per mile. However, the slope or gradient of the water table is not uniform. It is flatter in places as in Grant, southwestern Cherry and in much of Thomas Counties. The slope is steep in much of Hooker and north into Cherry County. Lakes and wetlands occur most frequently in the areas where the slope of the water table is least.

Streams head in the western part of the district initiating drainage of the groundwater reservoir. Groundwater moves at right angles to the groundwater contours so in any

specific area the direction of groundwater movement can be determined by constructing a right-angle to the nearest contour line. Groundwater contours "V" and point upstream along the "live" streams that are groundwater supported.

The regional water table map (Figure 10-3) is adequate to give a generalized understanding of the upper surface of the groundwater reservoir. The map is not in sufficient detail to permit interpretations of groundwater - surface water relationships relative to changes that might occur or to provide information useful in making decisions relative to groundwater management. The district will seek funding, encourage and cooperate with other agencies in developing a data base that will permit construction of more detailed water-table contour maps.

The saturated thickness map (Figure 10-1) was prepared by subtracting the elevation at coincident points of the base of the groundwater reservoir from the elevation of the water table. As previously noted, the saturated thickness is at least 500 feet in most of the area. However, a more detailed map would show areas of greater saturated thickness. For example, at the intersection of Grant, Hooker and Cherry Counties, the saturated thickness is about 950 feet. Only in a small area of Blaine County does saturated thickness decrease into the 300-500 foot range.

Saturated thickness maps indicate how much saturated material is present but do not indicate what the saturated materials are. The estimate of groundwater in storage is made by multiplying the saturated thickness by 0.2 or 20 percent. The 20 percent figure is assumed to be an average specific yield for the saturated sediments. Specific yield is a measure of the volume of water that will drain from a given volume of saturated material under the influence of gravity. It has been estimated that groundwater in storage would be equivalent to a depth of over 100 feet based on the thickness of saturation and the specific yield.

A generalized depth to water map, Figure 10-2, was derived by superimposing topographic quadrangle maps on the regional water table map and computing and contouring the differences between the two surfaces. The depths to water in the

ULNRD vary from 0 to about 300 feet. In areas of large, steep-sided dunes with intervening lakes and wet meadows, depths to water will vary within those extreme ranges in very short distances. Areas of such radical change cannot be depicted on the scale of the map shown in Figure 10-2 and are shown by the stippled area.

The depth to water has been monitored in a few wells within the ULNRD for about 50 to 55 years by the U.S. Geological Survey in cooperation with the Conservation and Survey Division UNL. Hydrographs of four wells including a well measured by personnel at the Valentine National Wildlife Refuge are shown in Figure 10-4. Additional wells have been measured and monitored for short periods by other agencies. These wells and those currently being measured one or more times per year are located on the map in Figure 10-5.

There is no evidence to date of local or regional water level declines related to groundwater withdrawal. The Dunning, Valentine Refuge and Hecla wells are wells in areas where the depth to water is shallow. The Dunning well, measured since 1935, shows no trends and appears not to reflect changes in either short or long-term droughts or wet periods. The well is measured monthly. The Valentine Refuge well appears to be affected to some degree by

climatic conditions. The well is measured three times per year and may or may not be measured at times of high or low water levels. The drought of the 1950s appears to be reflected by declines, and recovery to pre-1955 conditions did not occur until 1982-1983. The original Hecla well was replaced in 1958 at a nearby location. Since that well is only measured annually, high and low water levels are not obtained. The well does appear to reflect local precipitation conditions; at times water has stood around the well. The estimated predevelopment water level appears to be based on the earliest observation and evidence suggests that 10 to 12 feet might be a more realistic estimate of predevelopment conditions.

The Tryon well in McPherson County has been measured almost continually and semiannually since 1935. The depth to water was about 106 feet in 1935-1939 and has

not reached that level since. The depth to water is now about 110 - 111 feet. The decline of water may reflect long-term climate. The water level in this well does not respond quickly to wet and dry periods.

The ULNRD plans to review the network of water level observation wells with the U.S. Geological Survey and the Conservation and Survey Division. The review will include location and numbers of wells with respect to geographical coverage related to existing groundwater development. Duplicative efforts, if any, will be eliminated, and wells will be added where potential use conflicts may be anticipated. Automatic recorder wells will be installed at the Hecla and Tryon well sites to replace those wells and other automatic recorder wells will be installed near Stapleton and Brewster and in northeastern Brown County as funding is available.

Perhaps the one hydrologic parameter which best describes the groundwater reservoir and its potential for use and withdrawal is transmissivity. It also helps describe the rate at which groundwater moves. Transmissivity is a measure of the volume of groundwater that will move through a given width of an aquifer under a specific slope of the water table. Transmissivity also provides a measure of the ability of the aquifer to yield water to wells. Transmissivity is dependent upon the saturated thickness and

permeability. Permeability values vary considerably for the sediments filling the groundwater reservoir in the ULNRD. In general, the coarser sediments of sand and gravel are the most permeable and the fine-grained sandstones are the least permeable.

Figure 10-6 shows the transmissivity (T) of the principal groundwater reservoir for the Sand Hills. Note that the boundaries shown on this map exclude portions of Logan County and valley lands in the southeastern portion of the ULNRD. Transmissivity values can be connected across the blank areas. The map is generalized and shows a wide range of values between 50,000 and 350,000 gallons per day per foot. In only two small areas do transmissivity values fall below 100,000. Generally, large capacity wells of 700 to more than 1000 gpm can be developed anywhere in the district. Factors that determine the drawdown of large capacity wells in addition to transmissivity

include the depth of aquifer penetrated, well construction and well development. Figure 10-7 and 10-8 are computerized geographic information system (GIS) images. Figure 10-7 is similar to Figure 10-2 and indicates depth to water. Figure 10-8 indicates the general elevational configuration of the water table.

B. GROUNDWATER QUALITY

A summary of the groundwater chemistry in the Sand Hills is given by Ann Bleed in An Atlas of the Sand Hills, 1900, pg. 78. Two figures from that atlas are included herein as Figure 10-9, total dissolved solids, and Figure 10-10, alkalinity. As suggested in that summary, water quality sampling for complete hydrochemical analysis and evaluation is sparse and patterns cannot be depicted in any detail. The available information indicates that the water from shallow wells is low in total dissolved solids and alkalinity and is of high quality for most uses.

As described previously, the source of all water in the ULNRD is from precipitation which is only slightly acidic. The pH of rain falling near North Platte south of the area has been reported by J.W. Goeke as being about 5.6 (water with a pH of 7 is neutral). The ability of precipitation to dissolve mineral salts increases

with the acidity of the precipitation. Also, the ability of water percolating through the soils to dissolve minerals is related to the acidity of that water in the soil profile. The soils in the ULNRD particularly in the Sand Hills portion are low in organic content and calcium carbonate. Total dissolved solids and calcium carbonate are relatively low because of the relatively low acidity of the precipitation and deep percolation waters. Of 72 wells sampled in the southern Sand Hills, only 15 wells had greater than 100 mg/l as calcium carbonate. The groundwater, because of the scarcity of calcium and bicarbonate ions in the groundwater, is relatively soft. Two areas where total dissolved solids are in the 200 - 500 mg/l range of total dissolved solids are near the juncture of Grant, Hooker and Cherry Counties and in the southeast corner of Logan County (Figure 10-9).

Perhaps the one area of greatest concern about groundwater quality in the state is that related to contamination from the use of agricultural chemicals and in particular the use of fertilizers. Research and investigations conducted in many parts of the state and

reported in many publications have shown that the timing and rates of fertilizer application can affect groundwater quality. Over application of fertilizer coupled with over application of irrigation water has resulted in contamination of groundwater by Nitrate-Nitrogen, in several areas of the state near to or more than 10 ppm. Because of the higher rates of percolation through sandy soils versus finer-textured soils, those areas are generally considered to have the greatest potential for contamination. Evidence also suggests that areas with shallow depths to water are also susceptible to contamination from agricultural chemicals. However, new evidence is mounting that Nitrate-Nitrogen levels are rising to near or above the 10 ppm level limit in areas of silty and clay soils and where the depth to water is 100 feet or more and the land has been irrigated for 30 to 40 years. The movement of nitrates downward may only be delayed in the "hard land" areas and where the depth to water is greatest. The natural or background level of Nitrate-Nitrogen (NO3-N) in groundwater in Nebraska or in

the ULNRD is not known with any degree of certainty. Dr. Roy Spalding, Assistant Director of the Water Research Center, UNL, has suggested (personal communication, 1990) that the native level of nitrate-nitrogen probably is in the range of one to three ppm.

The ULNRD is concerned about contamination of groundwater by nitrates. The district has been providing a service to families by sampling and analyzing water for nitrate-nitrogen since 1986. The district has also had a water sample analysis cost-sharing program with the UNL Cooperative Extension Service and individuals. Samples were analyzed by the Grand Island Hall County Health Department. The location and concentrations of nitrate-nitrogen sampled from 306 domestic wells (and 45 stock wells on the Gudmundsen Sandhills Research Laboratory) are shown on a map in Figure 10-11. The map was prepared from unpublished data provided by the ULNRD, the Center for Disease Control-Nebraska State Health Department and the Gudmundsen Sandhills Research Laboratory. The data support the conclusion that the background level of nitrate-nitrogen is less than three ppm, i.e., 307 wells out of 351 wells had levels below 2.9 ppm. Only nine of the wells had levels greater than 10 ppm. The wells were sampled from 1986-1989. Results of sampling planned by the ULNRD in Hooker County were not available for inclusion in Figure 10-11. The number of sampling points in Grant County and much of Cherry County reflects the sparsity of population and wells. There is no reason to suspect that contamination in these areas is any different than that elsewhere in the district. Samples from the few wells with nitrate-nitrogen levels more than five

ppm (20 wells) almost surely are the result of point-source contamination, i.e. improper well siting with respect to sources of pollution or well construction.

Roy F. Spalding's "Assessment of Statewide Groundwater Quality Data from Domestic Wells in Rural Nebraska" provides an accumulation of groundwater quality data from 114 wells within the ULNRD. Wells included in this statewide assessment had all been tested for coliforms, gross alpha activity, 13 different pesticides, and nitrate-nitrogen. Within the ULNRD there were only two detections of nitrate-nitrogen above safe drinking water standards. There were thirteen detections of coliforms within the ULNRD of which only two were greater than USEPA's maximum acceptable level (4 colonies per 100ml). Of the thirteen pesticides tested, none were detected within the ULNRD. "The pesticides were selected on the basis of their usage in Nebraska, as well as their toxicity, soil leachability, pesticide half-life, and ease of laboratory analysis. There were no gross alpha detections above 15 pCi/L within the ULNRD. Gross alpha concentrations above this level was the standard used to trigger further investigation of possible radioactive contamination.

No trend or evidence of NPS pollution has been clearly established. Only contamination which is well-site localized is clearly evident. There has been limited amount of water quality data collected from irrigation wells within the ULNRD. Much of the available data from irrigation wells were collected in a USGS study titled "Hydrogeologic Data for the Southern Sandhills Area, Nebraska." In this study which covered only the southern part of the ULNRD, 20 wells within the district were monitored for quality. Nitrite plus nitrate as nitrogen levels of these wells averaged 1.03 ppm, with the highest concentration being 2.7 ppm.

Data were collected from one well sampled within the ULNRD in a USGS study titled "Hydrogeologic, Water Quality, and Land-Use Data for the Reconnaissance of the Herbicides and Nitrate in Near Surface Aquifers of the Mid Continental United States, 1991". Two samples collected five months apart from one well in Blaine County were recorded as having nitrite plus nitrate as nitrogen levels of .19 ppm and .16 ppm. Analyses were also done for nine different pesticides, all of which had concentrations of less than .05 ppb.

Seven different irrigation well water samples have been tested for nitrate as nitrogen by the ULNRD using a HACH test kit; three in Logan County with results of 3.0, 4.0, and

3.0 ppm, one in Blaine County with 3.0 ppm, and one in Cherry County with 2.5 ppm.

Because of the limited NPS groundwater quality data base from irrigation wells in the ULNRD; groundwater quality data provided by the Lower Loup NRD from wells within six miles of the common border are recognized in this assessment of groundwater quality. Production practices, growing conditions and pollution potential of these adjacent sites are generally common to those of the ULNRD and are valuable at least as comparisons. Average nitrate-nitrogen levels from ten irrigation wells within 6 miles of the common border have an average concentration of 1.53 ppm with the highest site concentration being 3.8 ppm.

CHAPTER XI
WATER WITHDRAWAL AND USE

A. GROUNDWATER

The largest withdrawal of groundwater through wells in the ULNRD is for irrigation. The number of acres irrigated presently by wells was estimated previously to be about 68,000 acres in 1989. No firm figures on average groundwater withdrawal or use are available. If it is assumed that the net use (withdrawal less deep percolation loss) of groundwater for irrigation is 18 inches, groundwater use for that purpose is estimated to be about 102,000 AF annually.

Sautter, 1985, estimated the numbers of domestic and stock wells based upon random sampling. That information is reproduced here:

TABLE 11-1

ESTIMATED NUMBER OF DOMESTIC AND STOCK WELLS

County	Number of Livestock Wells	Number of Domestic Wells
Blaine	985	274
Brown	711	203
Grant	758	113
Hooker	792	101
Logan	696	150
Eastern McPherson	383	60
South Cherry	1,642	271
Thomas	957	170
TOTAL	6,924	1,342

Water withdrawal for domestic use in the villages with a public water supply system appears to be relatively large. Per capita withdrawal based upon 1984 and 1985 reported information is about 450 gpd per capita in the three of the largest incorporated Villages of Stapleton, Mullen, and Thedford. Information available about water supplies in the incorporated villages is presented in the following table.

TABLE 11-2

MUNICIPAL WATER USE

	Preliminary 1990 Census	Number of Wells	Service Connections	Annual Water Use (millions of Gallons) 1984	1985	Per Capita Use (gpd) 1984	1985
Brewster	22	Private Wells					
Dunning	131	2	92	Not Metered			
Gandy	91	Private Wells					
Halsey	110	Private Wells					
Hyannis	210	3	175	Not Metered			
Mullen	552	4	406	160.2	158.4	593	586
Seneca	78	Private Wells					
Stapleton	301	2	200	33.5	47	270	378
Thedford	232	3	160	Not Metered 1984 - 85 Estimated 1983 56		438	

The estimated number of people living in Dunning, Hyannis, Mullen, Stapleton, and Thedford (the villages with public water systems) is 1426. If the average per capita use is as much as 450 gpd, the average daily withdrawal is about 641,700 gpd and the

annual withdrawal is 234,220,500 gallons or about 720 AF. The public supply wells in the five villages also supply water to some commercial and industrial establishments.

The use of water for people living in the villages or rural areas who obtain their supply from private wells is probably considerably less than 450 gpd per capita.

If it is assumed the per capita use for the remaining estimated 4,000 residents is 250 gpd, the average daily use is 1,000,000 gal./day and annual use is 365,000,000 gallons or about 1,120 AF. The total withdrawal for human use then is at least 1,840 AF annually. There are a number of churches, schools, businesses, parks, camps, forest headquarters, etc. which also have wells. Some

are classified as public water systems. Conservatively, these wells might withdraw another 130 AF annually making total human use about 1,970 AF.

The use of water for stock purposes is very difficult to estimate. Stock water supply is from windmills, pumped wells, flowing wells, lakes and streams. Sautter estimated about 6,900 livestock wells (Table 11-1). Possibly as much as 20,000 to 30,000 AF of water is used for livestock purposes.

B. SURFACE WATER

The North Loup, Middle Loup, and South Loup rivers and their tributaries, Goose Creek and the Calamus and Dismal Rivers originate within the ULNRD. Use of the streamflow, mostly supplied from groundwater, for irrigation or storage within the NRD is minimal. The Nebraska Department of Water Resources, Forty-Seventh Biennial Report, 1987-1988 indicates that currently 32 individual rights for irrigation have been granted, 30 diversions by pumping and two by canal. The total grants for diversion for irrigation is 49.34 cfs or about 22,140 gpm. That diversion if used annually would be equivalent in quantity to the withdrawal of about 25 to 30 irrigation wells. In addition, five rights totalling 226.00 AF have been granted for storage. The information about rights to surface water use within the ULNRD is presented in Table 11-3.

TABLE 11-3

Surface Water Grants for
Use within Upper Loup Natural
Resources District

River or Stream	Grants for Irrigation (Cubic feet per sec.)		Grants for Storage (AF)
North Loup River			
Cherry County	2 pump	7.49	
	2 canal	1.80	
	1 storage		41.00
Thomas County	1 storage		2.20
Blaine County	5 pump	8.69	
		17.98	43.20
Calf Creek			
Cherry County	3 storage		180.00
Goose Creek			
Cherry County	1 pump	3.80	
Middle Loup River			
Hooker County	3 pump	3.91	
Thomas County	7 pump	4.97	
Blaine County	2 pump	2.94	
Cherry County	1 storage		2.81
		11.82	
South Loup River			
Logan County	5 pump	4.71	
Dismal River			
Thomas County	1 pump	0.47	
Calamus River			
Brown County	3 pump	3.59	
Betsey Creek			
Cherry County	1 pump	1.88	
	4 canal	5.09	
		6.97	
	Total	49.34	226.01

Most of the streamflow originating in the ULNRD flows out of the district virtually unused within the district. However, considerable quantities of water are diverted from the North Loup and Middle Loup Rivers into canals for irrigation projects downstream from the ULNRD. Most diversions from the Middle Loup

into the Sargent Canal at the Milburn diversion dam for storage in the Sherman Reservoir generally begin earlier and continue longer than the others. Surface water rights from the Middle Loup River for diversion near Milburn in the southeast corner of Blaine County total 202.40 cfs.

The flow of the Middle Loup River and its tributaries including the Dismal River is categorized at least seasonally as being entirely committed to existing senior water rights (Policy Issue Study on Instream Flows, NRC, January 1982). The same report also indicates that the flow of the North Loup including Goose Creek and the Calamus River and the South Loup River are also entirely committed to existing senior water rights, i.e, irrigation or hydroelectric power generation.

A summary of estimated water withdrawal and use within the ULNRD is given in Table 11-4. Total groundwater and surface water use for human activity is estimated to be about 139,600 AF annually. Natural discharge is estimated (Chapter IX) to be about 2 million AF or about 14 times greater than the amount used for human activity.

TABLE 11-4

WATER WITHDRAWAL AND USE, ULNRD

Estimated Annual Use in Acre Feet

		Groundwater	Surface Water
Irrigation	102,000	5,400	
Livestock		20,000	10,000
Public Supply (Municipal)		720	
Domestic (Self supplied)		1,120	

Other Domestic	130		
Grants for Storage		226	
TOTALS			123,970
	15,626		

Groundwater is the economic lifeblood of the Upper Loup NRD. If the groundwater supply were to deteriorate substantially in either quantity or quality, competition for the remaining usable supply would increase. In some states where usable water is in short supply, allocation of water is made largely on an economic basis. For example, in Colorado, water rights are bought and sold in a manner similar to mineral rights. Water rights do not necessarily transfer with ownership of real estate.

Fortunately water of suitable quality is not in short supply in the Upper Loup NRD. The economic value of water is not determined by the highest bidder. The economic value of groundwater could be estimated from the use which is made of it. It follows that good quality water which is suitable for many uses has a greater economic value than poorer quality water which has limited use. Water which is usable for some purposes may have little value for other purposes. For example, water which is high in nitrates has diminished value for domestic purposes, but may be more valuable for irrigation than water with low nitrates.

Poor quality water which has little value in a water rich area may have high economic value in other areas where water is in short supply.

In summary, all water is important, but the economic value of water at any place or time depends on many aspects and can change rapidly depending on general economic conditions in the area where it is used. Ironically, a change in quantity or quality of water supply can also rapidly change the overall economy of an area. The economic value of water is a moving target, which probably can only be accurately measured in dollars if the value is assigned in an open market.

CHAPTER XII

POTENTIAL GROUNDWATER USE

"The principal aquifer in portions of Nebraska has quantities of groundwater in storage that would appear to exceed use demands over a significant period. Thus for significant areas of Nebraska, even maximum utilization for irrigation would not cause aquifer exhaustion. Groundwater withdrawal will result in some combination of decrease in storage, increase in recharge, and decrease in natural discharge. The relative values of recharge and discharge will determine both the changes in volume of water in storage and any resulting water level change. In areas conducive to rapid recharge, salvaged evapotranspiration can sustain a high rate of use. Withdrawals in such areas could occur without obvious effect upon regional stream flow.", Policy Issue Study on Groundwater Reservoir Management, March 1982, p. VIII.
The existing use of groundwater in the ULNRD is minimal. This is particularly true compared to other NRD's in the state and is also true if compared to any other area in the nation blessed with a large reservoir of groundwater. Use, defined as natural discharge from the groundwater reservoir is very large as described in other sections of the report.

The withdrawal of groundwater is very low in the area due to a number of factors. Withdrawal for municipal and domestic use is almost negligible. Industrial use also is extremely low and is due in part to the small population base and perhaps to an inadequate transportion base. Present day irrigation use is also very low partly because of the dune topography and sandy soils but may be related to present-day row-crop choices, irrigation technology, economics, and a strong ranching tradition.

The potential for increased withdrawal of groundwater for various purposes is largely based on the fact that there is a large available supply of good quality water. One example is the potential use of groundwater for irrigation. That potential was evaluated as a part of the State Water Planning and Review Process of the Nebraska Natural Resources Commission (NRC). In the policy issue study on Groundwater Reservoir Management,

March 1982, an estimate was made of the maximum irrigation development from groundwater in the State based on land suitability. The estimate for the State is presented in Figure 18, P. 25 of that report and Figure 12-1 is a reproduction of the ULNRD portion. Calculation of the projected

number of irrigation wells per county based solely on land suitability is approximately as follows:

TABLE 12-1

PRESENT AND PROJECTED NUMBER OF IRRIGATION WELLS

County	Based on Land Suitability	Number of Irrigation Wells, 1989
Blaine	1000	102
South Brown	300	82
South Cherry	3200	95
Grant	1360	24
Hooker	900	31
Logan	830	156
East McPherson	430	36
Thomas	790	38
	8,810	564

Land suitability interpretation should also include the fact that the majority of these soils have very severe limitations, the major limitation being the soils susceptibility to wind erosion. Other limitations include shallow water tables and highly alkaline and clayey characteristics. As noted in the report "Environmental Evaluation of Sand Hills Cooperative River Basin Study," PR-100-2, June 1986, by Bio/West, Inc., "To develop soils with limitations for irrigation, special management and conservation measures are required in addition to a limited choice of crops."

Bio/West also noted that "Percent of soil that is irrigable should not be interpreted in such a way that suggests large tracts of land are available for development. For example, approximately 35 percent of the Valentine association is irrigable. According to Lewis (1986), this irrigable land is distributed within the association in relatively small discrete areas not conducive to large-scale development."

Information presented above suggests that irrigation may become a fairly significant use of groundwater in the future. The 1989 total estimated 564 wells represents only about 6.5 percent of the projected maximum number

of 8,810 wells. It is impossible to predict the rate of growth because of the unpredictability of the factors that control that rate. The past history of irrigation development in the State suggests that the growth will be episodic. It is reasonable to expect, however, that over time the total number of irrigation wells will reach or exceed the projected number. That total may or may not be reached in the forseeable future.

The implication of the impact on groundwater storage if the projected level of groundwater development occurs is difficult to predict. Water levels might be expected to decline in local areas of intensive groundwater withdrawal. Regional water level declines are not expected. The data base is not adequate to analyze what local water level declines might have on nearby wetlands or lakes, however, it is anticipated that locally they might be adversely impacted relative to their wetland values.

Figures 12-2 and 12-3, reproduced from the NRD policy issue study on Groundwater Reservoir Management, indicate areas in the state where townships have groundwater storage that exceeds 200 year requirements of maximum irrigated projected irrigation development. Figure 12-2 shows the areas where the demand rate equals 150 acre feet per year per well equivalent and Figure 12-3 illustrates conditions where the demand rate equals 120 acre feet per year well equivalent. All townships in the ULNRD and some adjacent to the district are shown to have that amount of groundwater in storage.

Certain assumptions were made in an evaluation of the areas in the state where annual recharge from precipitation exceeds maximum projected irrigation development in the Groundwater Reservoir Management policy issue study (Figures 12-4 and 12-5). Most townships within the ULNRD are shown to have recharge exceeding the 120 acre feet per year per well equivalent demands. Somewhat large areas in Grant, southwestern Cherry and southern Logan Counties are shown where townships are considered to have recharge rates not exceeding development at the demand rate equal to 150 acre feet per year per well equivalent. These evaluations are conservative and may not have taken into account the potential for groundwater salvage.

Increased withdrawal of groundwater for municipal use in the forseeable future does not appear likely based on the apparent loss of population in the district from 1980 to 1990. Even if that

loss were reversed in the next few decades, the withdrawal of water for municipal purposes within the ULNRD will continue to be minimal. Because the supply of available groundwater is large, there is some possibility that industrial development depending upon large quantities of good quality groundwater may occur. That potential is not known; one possibility, however, might be the use of wells for cooling water associated with energy production.

There are no programs, plans or needs at the present time to augment the groundwater supply for existing uses within the district. Stream flow originating largely as groundwater is being used downstream from the ULNRD for augmenting or supplementing water supply. Water from flowing wells augments the supply of some wetlands, lakes and streams in the ULNRD. The extent of this augmentation is not known but is to some degree observable from information displayed on the 7.5 minute quadrangle maps. The potential exists for augmentation of lake and wetland water supply from wells if the need is demonstrated.

Although no need is now indicated, there may be an opportunity in the future to recharge (or enhance the groundwater quantity in storage) in some parts of the ULNRD. Figure 12-6 reproduced from the NRC policy issue study on Supplemental Water Supplies, 1984, shows areas in parts of southern Cherry, central Hooker and Thomas, and parts of McPherson and Logan Counties where that opportunity exists. The areas shown in the shaded areas are underlain by 50 to 150 feet of unsaturated coarse material.

If recharge of any of the potential underground storage zones (Figure 12-6) is deemed advisable and feasible, a source of water for recharge would be necessary. Figure 12-7 is a map and legend reproduced from NRC policy issue Study on Supplemental Water Supplies, 1984. The map shows location and size of surface reservoir sites on the Dismal, Middle Loup and North Loup Rivers that have been studied. The legend indicates the agency conducting the study and the potential storage capacity of the reservoir

sites studies. Studies of the sites presumably did not go beyond the proposal and initial planning and study. These sites might be potential ones for storage and for diversion of water for underground storage. The stored water might also have value for recreation and migratory water fowl habitat. The ULNRD does not plan at this time to pursue efforts to determine the feasibility

of surface water storage and recharge of water underground. The need has not been proved and it is probable that state laws in regard to rights for storage of water in the surface water sites would need to be modified. In this regard, although the opportunity may exist, there is minimal need, if any, for the district to plan for or coordinate the use of water for irrigation from different sources of supply.

CHAPTER XIII
POTENTIAL CONTAMINATION ASSESSMENT

A. POTENTIAL POINT SOURCE ASSESSMENT

An assessment of existing and potential point source contamination within the ULNRD can be made from records, inquirings and knowledge of the ULNRD Board of Directors and staff, and from materials provided by NDEQ. Facility locations of potential point source contaminants are organized by community in Table 13-1 and by county in Table 13-2.

Sources indicate that within the ULNRD there are five sites registered as "All Ag Facilities", four are in rural Blaine County and one is in Thedford in Thomas County.

There are storage facilities containing chemicals categorized as immediate health risks (IMM), delayed health risks (DEL), and or extremely hazardous substances (EHS). The number of sites and their stored chemicals are as follows: 2-"Cyclone" (IMM), (DEL); 1-"Furadan" (IMM), (DEL), (EHS); 2-"Thimet" (IMM), (EHS); 1-ethylene glycol (IMM), (DEL); 2-"Counter" (IMM), (EHS); 2-"Lasso"/"Bullet" (IMM), (DEL); 2-"Atrazine" (IMM), (DEL); 2-ammonia (IMM), (EHS).

There are 35 sites where commercial or tax funded entities store gas and/or light fuel oils.

All Community Solid Waste Disposal Sites within the ULNRD closed by October 1, 1993 as required by the state.

There are nine registered Nebraska Pollutant Discharge Elimination Systems (NPDES) within the ULNRD which includes community Waste Water Treatment Facilities (WWTF).

The small communities identified in Table 13-1 that do not have Waste Water Treatment Facilities use individual septic systems to manage waste water. Septic systems are also scattered throughout the ULNRD at rural residences.

Chemigation through irrigation systems is regulated through the Nebraska Chemigation Act of 1986, requiring that irrigators who chemigate take measures to prevent chemicals from contaminating the groundwater supply. Natural Resources Districts were assigned the responsibility to inspect chemigation systems, verify safety precautions, and issue permits for chemigation. There are 146 irrigation facilities within the ULNRD that have had permits to chemigate, 93 concentrated in portions of Logan and Blaine Counties. These two counties make up less than 20% of the entire district. The locations of the remaining 53 are less concentrated yet basically still in localized areas of the district: the district's southern portion of Cherry County directly north and northwest of Mullen, the district's central and southwestern portion of McPherson County, the district's eastern 1/4 of Cherry County, the district's eastern portion of Brown County. Upon the completion of the 1993 irrigation season, there where 121 valid permits to chemigate; 82 concentrated in portions of Logan and Blaine Counties, and 39 concentrated in the other aforementioned portions of the district.

There is record of 7 Underground Storage Tank (UST) releases within the ULNRD: one at Hyannis in Grant County, one at Mullen in Hooker County, one at Thedford in Thomas County, one at Halsey National Forest in Thomas County, 3 at Stapleton in Logan County.

This potential point source assessment will help to provide a comprehensive review of pollution potential within the ULNRD. It will be useful to the ULNRD for informing the public of potential health risks related to groundwater contamination, and assisting in establishment of Wellhead Protection Areas. Consideration of these potential contamination sites when evaluating sample analysis data will help improve the effectiveness of the ULNRD's groundwater quality monitoring programs and may be helpful in identifying potential health threat risks.

The NDEQ has delineated Wellhead Protection Areas for the town of Mullen in Hooker County and the town of Thedford in Thomas County. These delineations are made to help communities protect their drinking water supply from potential contamination sources.

B. POTENTIAL NON-POINT SOURCE ASSESSMENT

Excessive fertilizer and pesticide application in conjunction with over-watering, particularly on well drained soils like most of those in the ULNRD, is the major source of NPS contamination. An assessment of potential NPS contamination is necessary in developing a comprehensive view of pollution potential within the ULNRD. This assessment will be based on the assumption that current cultivar production practices and climatic conditions within the ULNRD require supplemental water for successful production, thus limiting significant leaching of nitrates and pesticides to groundwater below land receiving supplemental water.

A maximum potential NPS contamination assessment will be helpful in preparing the ULNRD for unforeseeable circumstances that could influence groundwater management in the future. Unforeseeable circumstances could lead to land use practices that would result in extreme NPS contamination. The ULNRD needs to be aware of any such potential vulnerability to effectively manage its groundwater in perpetuity.

As reported in the "Sandhills Area Study" on p. 45, "changing economic conditions, including changes in federal tax laws, have eliminated most of the incentives to convert Sandhills land to irrigated corn production." Factors such as strict soil conservation requirements, conservation incentive programs, land suitability limitations (described on p. 12-2) and better awareness of groundwater contamination potentials and risks also discourage irrigation well development for not only corn but also other irrigated cultivars. However, unforeseeable circumstances could lead to a significant increase in irrigation well development. A maximum projection for potential irrigation well development, based on land suitability is 8,810 wells (see table 12-1). Land suitability only considers the irrigability of soil associations. Consequently this figure seems high, but it will be helpful to quantify a scenario where maximum NPS contamination would occur.

The irrigation well development potential of 8,810 multiplied by an estimated coverage area per well of approximately 135 acres (a typical center pivot size) equals an estimated 1,189,350 acres (not considering land suitability limitations) as a potential area of NPS contamination by fertilizers and pesticides. A more conservative and foreseeable estimate of NPS pollution potential acreage can be developed from 63,730 acres of irrigated land (see table 8-2) plus 16,000 acres that could potentially be returned to crop production upon completion of Conservation Reserve Program (CRP) contracts. This

estimate, however, fails to account for pollution potential of lawn and other horticultural chemical applications.

Maximum NPS pollution would exist only when all irrigated acres are producing cultivars receiving high fertilizer and pesticide applications on low fertility and low water holding capacity soils. For example, research done at the Sandhills Ag Lab near Tryon showed nitrate leaching losses of irrigated corn on highly permeable Valentine soils can exceed 90 pounds per acre where nitrogen in excess of crop requirement has been applied.

CHAPTER XIV
NEBRASKA GROUNDWATER MANAGEMENT AND PROTECTION ACT AND RELATED FEDERAL STATUTES

Several Federal statutes and related rules and regulations directly or indirectly affect groundwater quality protection and management, and are included in the plan by reference. The measures of greatest importance include the Resource Conservation and Recovery Act (RCRA): The Comprehensive Environmental Response, Compensation and Liability Act (CEFCLA or "Superfund"); the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA); the Clean Water Act (CWA); and the Safe Drinking Water Act (SDWA).

State planning and regulatory functions for these statutes are the responsibility of the Department of Environmental Control and Health Department.

The Nebraska Groundwater Management and Protection Act contains the following provision:

"46-656. Declaration of Intent and Purpose. The Legislature finds that groundwater is one of the most valuable natural resources in the state and that an adequate supply of groundwater is essential to the general welfare of the citizens of this state and to the present and future development of agriculture in the state. The Legislature recognizes its duty to define broad policy goals concerning the utilization and management of groundwater and to ensure local implementation of those goals."

"Local implementation" generally means the natural resources districts, although the Act also has a provision that "nothing in this act relating to the pollution of groundwater is intended to limit the powers of the Department of Environmental Control provided in Chapter 81, Article 15."

GLOSSARY

AF - acre-feet, covers one acre to the depth of one foot

A horizon - mineral soil horizon formed at the soil surface or below an O horizon, having accumulations of humified organic matter mixed with mineral matter

Arikaree Group - base of the High Plains Aquifer along the western part of the Sandhills, below the Ogalalla Group, composed of Upper Harrison, Monroe Creek Harrison and Gering Formations

aquifer - water bearing layers of rock or sediment capable of yielding supplies of water to springs or wells

BMP - best management practices - practices designed to prevent or reduce non-point source pollution by eliminating leaching and runoff through practices including but not limited to conservation tillage practices, irrigation water management, and fertilizer management

Brule Formation - particular layers of rock that are a part of the White River Group

cfs - cubic feet per second, equal to 450 gpm

chemigation - a delayed application technique by which chemicals are applied to a field through an irrigation system at times and rates which they can completely utilized

Chadron Formation - particular layers of rock that are a part of the White River Group

Coliforms - bacterial organisms that indicate the likely presence harmful bacteria in a water supply

conductivity (hydraulic) - the capacity of a porous material to transmit water

Cretaceous shales - sedimentary rock from the geologic time period marked by the development of flowering plants and the disappearance of dinosaurs

CSD - Conservation and Survey Division of UNL.

cultivar - a plant variety or race that has originated and persisted under cultivation

DEC - Nebraska Department of Environmental Quality

DEQ - Nebraska Department of Environmental Quality

DOH - Nebraska Department of Health

DRASTIC - an acronym developed from the following groundwater pollution potential parameters: Depth to water, Recharge to the aquifer (net), Aquifer media, Soil media, Topography (slope), Impact of vadose zone, Conductivity (hydraulic) of the aquifer

eutrophication - the enrichment of a lake, river, marsh, or ocean with nutrients (especially nitrogen and phosphorus) that promote biological productivity

ET or Evapotranspiration - the process by which water is transmitted to the atmosphere as a vapor as the result of evaporation from any surface and transpiration from plants

Formation - the primary unit of lithostratigraphy (rock layers) having a succession of layers useful for mapping or description

GIS - Geographic Information Systems

Group - a geologic stratigraphic unit usually composed of one or more formations

Groundwater reservoir - an aquifer or group of aquifers

High Plains Aquifer - and aquifer, including the Ogallala Group, that extends from southern South Dakota into Texas

Hydrology - the study of water movement through the atmosphere, underground and across the land surface

Hydrogeology - the study of water as it relates to geology

hydrograph - a graph which shows some water parameter such as water level, discharge, or velocity as a function of time

leaching - movement of water soluble minerals, in solution, below the root zone

MCL - Maximum Contamination Level, standards set for safe drinking water

Miocene - of, belonging to, or designating the geologic time, system of rocks and sedimentary deposits of the period marked by the appearance of primitive apes, whales, and grazing animals

NDEQ - Nebraska Department of Environmental Quality

nitrate - a nitrogen form susceptible to denitrification and leaching

nitrification - a process by which bacteria convert ammonium forms of nitrogen into

nitrate forms

nitrite - a nitrogen form in the chemical pathway of conversion of ammonium forms of nitrogen to nitrate forms of nitrogen

NPS - non-point source - any source of pollution other than those defined as point sources, generally considered to be those associated with poorly managed pesticide and fertilizer applications

NRC - Nebraska Natural Resources Commission

NRD - Natural Resources District

Ogallala Formation - water bearing formation of the principal aquifer in the northwestern part of the Sandhills, often recognized as the Ogallala Group composed of Ash Hollow, Valentine and Runningwater Formations

paleovalley - ancient river valley

percolating - water moving downward through soil or other earth material

permeability - the ability of rock or unconsolidated material to transmit a fluid, dependant upon the volume of the openings and pores, and on how these openings are connected to one another

Pleistocene - of belonging to, or designating the geologic time, system of rocks and sedimentary deposits of the period marked by the Ice Age

Pliocene - of, belonging to, or designating the geologic time, system of rocks and sedimentary deposits of the period marked by the appearance of humans

potentiometric surface - the upper hydrologic boundary to which a water level rises in a tightly cased well, a reflection of water pressure in the aquifer

ppb - parts per billion

ppm - parts per million

PS - Point Source - contamination source that can be located, and is caused by a single or group of single sources (see p. 8-1 for some possible point sources)

Quaternary - of, belonging to, or designating the geologic time, system of rocks and sedimentary deposits of the period marked by the appearance of humans

sidedress - a delayed application technique commonly used to mechanically apply

nitrogen to a field right before the peek demand of the plant

soil association - a group of defined and named taxonomic soil units occurring together in an individual and characteristic pattern over a geographic region

soil series - the basic unit of soil classification, being a subdivision of a family and consisting of soils that are essentially alike in all major profile characteristics, except the texture of the A horizon

surge valves - a uniform water application tool used in flood irrigation

Tertiary sediments - geologic deposits of the Tertiary time period marked by the appearance of modern flora and large mammals

Transmissivity - a measure of the capability of an aquifer or the groundwater reservoir to transmit water

ULNRD - Upper Loup Natural Resources District

UNL - University of Nebraska, Lincoln

USGS - United States Geologic Survey

vadose zone - unsaturated underground region between the root zone and the water table

water-table - the level below which the ground is saturated with water

White River Group - a geologic stratigraphic unit composed of the Brule and Chadron Formations present under all but the easternmost part of the Sandhills, generally corresponding to the base of the principal groundwater reservoir in the Sandhills

well head protection program - a program designed to protect a proposed or existing well through a search and inventory of existing and potential contaminant sources

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