NEBRASKA'S WATER
NEBRASKA'S WEALTH
Choices & Challenges

League of Women Voters of Nebraska Education Fund
1. Water: Nebraska’s Great Resource

Lack of water was considered to be the greatest obstacle to the settlement of Nebraska. Rivers played the role of transportation medium, and directed the routes of early explorers. Lewis and Clark, sent out to explore the Louisiana Territory which President Jefferson had purchased, stayed close to the Missouri River rather than venturing into this wasteland. Major Stephen Long, who was exploring the central plains a few years later, made his way across present-day Nebraska to the Rocky Mountains via the South Platte.

On his return in 1820 he wrote: “In regard to this extensive section of the country [between the Missouri River and the Rocky Mountains] I do not hesitate in giving the opinion, that it is almost unfit for cultivation, and of course uninhabitable by a people depending on agriculture for their subsistence.”

The fact is, however, Nebraska is blessed with a vast supply of high quality water. The abundance of water has directly contributed to the state’s economic growth and increase in the standards of living during the last half century. Obviously that means a great deal of public policy has been focused on how much water there is in the state, who can use it and how much they can use.

In Nebraska, water is everyone’s concern. Because water issues are perceived as being complex, sometimes the public avoids involvement, and the decisions relating to its use are left to those regarded as water specialists. This is unfortunate and unnecessary, as the citizenry need to be involved in discussions for developing long-term management options. One does not need to be a hydrologist to engage in the debate on water issues, but it is important to have an understanding of the basic principles of hydrology and geology as they apply to the state.

Understanding Hydrology

**Hydrologic Cycle**

All water on the land is referred to as surface water; all water beneath the land surface is called groundwater. Most surface and groundwater originate as precipitation in the form of rain, snow or hail. The constant movement of water above, on and below the earth’s surface is referred to as the hydrologic cycle. Simply put, the hydrologic cycle is this: it rains; the water soaks into the ground or runs off into streams; it evaporates back into the air, forming clouds which rain again. Water changes from liquid to solid or gas during the cycle. Condensation, evaporation and freezing of water occur in the cycle in response to climatic conditions.

Plants give up moisture through their leaves, an important contribution to the hydrologic cycle. This process is called transpiration. Plants often produce more vapor than does evaporation from land surface, lakes and streams.

For example, an acre of corn gives off to the air about 3,000 to 4,000 gallons of water each day, and a big oak tree about 40,000 gallons per year.

Evaporation from wet surfaces and the transpiration from plants are similar processes and are often lumped together and called evapotranspiration.

**Surface Water**

Water drains from land through streams that increase in size to larger and larger rivers until it is discharged into the oceans. Each rill, creek or river receives water from a tract of land surface that slopes toward the channel. Channels, therefore, occupy the lowest parts of the topography.
The land area from which the water drains into a channel is called its watershed. The ridge of land that separates the watersheds is called the divide.

The silt, clay, sand, gravel and other sediment that are deposited by flowing waters are called alluvium. These create the riverbed and the surrounding area, referred to as the alluvial plain.

Flooding is a natural characteristic of rivers. When more water comes down a river than can be carried within the river channel, the water spreads out over the valley floor. This area is called the flood plain.

A flood plain changes over time because natural river channels are seldom straight. This affects the manner of flow and the erosion and deposition of sediment by the river or stream.

Two types of rivers are braided (interwoven with sandbars) and meandering (winding or rambling). The rate of water movement down a river depends upon several conditions: weather, depth and volume of water, slope of the riverbed and width of the channel. The water moves faster in rain events or floods; slower during dry spells. Water in the deeper reaches of a river generally moves slower than water in shallow reaches.

Rivers also carry a sediment load derived by erosion. When a river is dammed for the construction of a reservoir (a storage area for excess surface waters), the sediment load tends to deposit in the still water of the lake. Over a period of time, the sediment may fill a reservoir, using up the storage space intended for flood control, irrigation or power. Sediment needs to be managed along with the water.

The characteristics of a river are not consistent throughout its entire length. Different segments in the river, called reaches, vary according to the runoff from the watershed, the contribution from tributaries or from groundwater, the soils of the watershed, channel and flood plain, and the amounts and location of water withdrawn for use.

**Groundwater**

When the rate of precipitation exceeds the rate of infiltration, overland runoff occurs, forming rivers and
streams, or surface water. Water that percolates through the soil and fills in the spaces between grains of soil or in cracks and crevices of rocks, much as water fills a sponge, is groundwater. Rates of infiltration into the soil vary widely, depending on land use, character of the soil, and the intensity and duration of precipitation.

Many people mistakenly think of groundwater as a series of underground lakes and rivers flowing beneath the surface of the earth in the same manner as surface rivers and streams. Groundwater moves at a considerably different rate from that of surface water, flowing both laterally and vertically, from a fraction of an inch to as much as a few feet per day.

Groundwater is usually in motion, flowing under the force of gravity from higher elevations to lower elevations, or in response to differences in pressure. Groundwater moves only if sufficient pressure is available to force water through the spaces between the porous surrounding materials—sand, gravel, silt, clay, fractures in rocks, or channels in formations such as limestone.

**Hydrogeology** is "the science dealing with the occurrence and distribution of underground water." It is the interaction of the subsurface area and water. The characteristics of the soils and underlying geologic strata determine both the rate of infiltration of precipitation to the groundwater and the rate of flow of the groundwater itself. Flow of groundwater is much faster through highly permeable materials, such as sand and gravel, and slower through finer grained deposits like clay and silts. These compositions determine how fast water will move through the connected openings in the soil or rock.

**Transmissivity** is a characteristic which reflects the geologic strata's ability to transmit fluids. It is dependent on the water-transmitting characteristics of the saturated formation and the saturated thickness. For example, if both formations are the same thickness, sand-
stone formations will conduct less water than sand and gravel formations.

**Permeability** is the capacity of a subsurface material to transmit fluids. There is less resistance to groundwater flow where particle size (and the spaces between the particles) is large, and the water readily drains out. Conversely, **impermeable** soil or rock will not allow water to pass through it. Saturated clay is vir-

![Figure 1-4: Permeability](image)

- Permeability is a measure of how fast water will flow through connected openings in soil or rock. Impermeability refers to soil or rock that does not allow water to pass through it. The specific yield is the actual amount of water that will drain out of saturated soil or rock by gravity flow. It does not drain out completely because some water forms a film that clings to soil and rock. Permeability is critical for water supply purposes; if water contained in soil or rock will not drain out, it is not available to water wells.

![Figure 1-5: Porosity](image)

- The capacity of soil or rock to hold water is called porosity. Saturated sand contains about 20 percent water; gravel, 25 percent; and clay, 48 percent. Saturated bedrock with few crevices commonly contains less than one percent water. Clay is not a good water source despite its high water content, or porosity, because the extremely small size of the openings between microscopic clay particles creates friction that effectively hails water movement. Saturated clay is virtually impermeable.

![Figure 1-6: The Unsaturated Zone](image)

- A zone is usually present between the water table and the land surface where the openings, or pores, in the soil are only partially filled with water. This is the unsaturated zone. Water seeps downward through it to the water table below. Plant roots can capture the moisture passing through the zone, but it cannot provide water for wells.
tually impermeable because the small size of the openings between the microscopic clay particles halts water movement. Water can move through rocks, like mudstone, shales and limestones, where fractures or joints provide pathways or openings for fairly rapid movement of groundwater. However, such rocks have low permeability if there are few interconnected cracks.

Porosity is the capacity of the soil or rock to contain water. The size of the particles of the soil or rock and thus the amount of pore space between the particles determines the ratio of open space to the total volume.

Twenty to twenty-five percent of the volume of saturated sand and gravel is water. In fine-grained sedimentary rocks, where cracks represent the only open space, the porosity is only one percent or less.

Groundwater occurs in zones in the earth. The first zone, which occurs immediately below the land surface in most areas, contains both water and air and is referred to as an unsaturated zone.

Below that is the saturated zone, the groundwater zone in which all the openings ( pores) in the soil and rock are filled with water. The top level of this zone is called the water table.

The water table is not static and will fluctuate according to the season and the amount of precipitation. As water seeps through the unsaturated zone, the plant roots capture the moisture passing through, but water for wells comes from the lower saturated zone.

Aquifers

If the saturated zones yield water in usable quantities, they are called aquifers, which means “water bearers.” Aquifers may be a few feet or hundreds of feet thick. They may be just beneath the surface or hundreds of feet down, and vary in area from a few acres to thousands of square miles.

Aquifers function in two important ways:
- They transmit groundwater from the point of entry to points of discharge.
- They provide storage for large volumes of water.

In a sense, they act as both pipes and storage tanks. Large aquifers or groups of aquifers are called groundwater reservoirs, just as water is stored on the surface in reservoirs.

Water enters the ground through recharge and leaves the ground at discharge points. Recharge happens when excess waters infiltrate into and are stored in the aquifer. Discharge points typically occur where water seeps into wetlands, lakes and streams, or is pumped out through wells.

Aquifers are classified into two principal types, unconfined and confined.

Confined aquifers are bounded on top and below by layers of relatively impermeable material that prevents free movement of air and water. Changes in storage are small, and recharge usually occurs slowly and in areas that are remote from the location where the discharge occurs.

Confined aquifers should be regarded as resources that are less readily replenished.

When a well is drilled into a confined aquifer which is under pressure, the water will rise within the shaft from underground pressure rather than from pumping. Such wells are called artesian wells.

An unconfined aquifer, on the other hand, is one in which the water table is free to rise and decline because the water is not sandwiched between impermeable layers of rock or sediment. Unconfined aquifers

Figure 1-7: Major Aquifers in the Continental United States
**Figure 1-8: Recharge**

Water seeping into an aquifer is known as recharge. This takes place intermittently during and immediately following periods of rain and snow-melt. Recharge occurs where permeable soil or rock allows water to readily seep into the ground. These areas are known as recharge areas. Permeable soil or rock formations where recharge occurs may occupy only a very small area or extend over many square miles. Valley aquifers may also receive recharge from hillside runoff or streams that flow down from hillsides in addition to the rain and snow that fall directly onto the land surface overlying the aquifer.

**Figure 1-9: Groundwater Discharge Points**

Groundwater enters the ground in recharge areas and leaves the ground at discharge points. Discharge is continuous, as long as sufficient water is present above the discharge point. Discharge points typically occur as seepage into wetlands, lakes and streams. Springs are visible discharge points at the land surface. If the water table is close to the land surface during the growing season, large amounts of groundwater may be withdrawn by plant transpiration.

**Figure 1-10: Confined or Artesian Aquifer**

Groundwater that becomes trapped under impermeable soil or rock is called a confined aquifer. A confined aquifer which is under pressure is called an artesian aquifer, and a well that pierces it is called an artesian well. Water pressure in an artesian aquifer will cause water in the well to rise above the aquifer level. The maximum level that the water in the well will rise to is known as the potentiometric surface, or potential water level. If this is higher than the top of the well, the well will overflow.
Figure 1-11: Unconfined or Water Table Aquifer

Aquifers that are not confined under pressure are called unconfined or water table aquifers. The water level in a well is the same as the water table outside the well.

Figure 1-12: Perched Aquifer

Overlying other aquifers, there are often perched aquifers which contain unconfined groundwater that is separated from the underlying aquifer by a layer of impermeable rock or soil.

Figure 1-13: Cone of Depression

Pumping from wells lowers the water table near wells. This is known as the cone of depression. The land surface overlying the cone of depression is also referred to as the area of influence. Groundwater flow is diverted toward the well as it flows into the depression cone.
provide water to wells by draining the materials surrounding the wells as the wells are pumped.

A cone of depression is created when pumping from a well in an unconfined aquifer lowers the water table near the well. Groundwater flow is diverted towards the well as it flows into the depression cone.

**Interrelated Ground and Surface Water**

Surface water and groundwater may be interrelated hydraulically. By discharging stored waters into a stream, groundwater aquifers maintain the stream’s base flow. **Base flow** is the amount of flow supplied by groundwater rather than by surface runoff.

Conversely, in many places surface water in streams, lakes, reservoirs and canals is a source of recharge to the adjacent aquifer. The degree of this interaction depends on the soil characteristics, the subsurface geology and the topography of each area.

**Wetlands**

"Wetlands" is a collective term used for describing potholes, marshes, bogs, swamps, and some wet areas that develop between open water and dry land. Wetlands are usually defined by their soils, hydrology and vegetation.

In wetlands, the water table can be near the surface of the land, connecting surface water and groundwater, or the land may be covered by sufficient shallow water during the growing season to support vegetation adapted to saturated hydric (high hydrogen) soil conditions.

In recent years, with increased understanding of the hydrological processes, scientists have identified many wetlands as natural resources that provide valuable connecting links between ground and surface water.
Nebraska's Water Supply

Surface Water

Most surface water arrives as rain or snow. In Nebraska, this precipitation averages about 86 million acre-feet per year, distributed across the state as shown on the map in Figure 1-16. This average annual statewide rainfall amount would be equivalent to a layer of water 1 3/4 feet deep covering the entire state.

The average annual precipitation varies across the state from about thirteen inches in the far western part of the state to thirty-five inches in the extreme southeast. Most of the rainfall quickly returns to the atmosphere by evaporation from wet surfaces or by transpiration from vegetation.

In addition to precipitation, Nebraska annually receives about one million acre-feet of stream flow from South Dakota, Wyoming, Colorado and Kansas. Another 3/4 million acre-feet are transferred into the state from Wyoming through irrigation canals in the North Platte valley. A smaller amount, 50,000 to 75,000 acre-feet, arrives by means of subsurface flow. It can be seen that the state receives nearly fifty times as much water in the form of precipitation as it does from interstate groundwater and surface water flows.

The quantity of water flowing out of the state is equivalent to only about eight percent of inflow plus precipitation. This outflow is supplied by runoff from precipitation and water seeping out of ground reservoirs into stream channels.

The average annual flow of Nebraska rivers is indicated by the width of the dark lines in Figure 1-18. The lightly shaded lines indicate major diversions for power and irrigation uses. Smaller diversions which cannot be shown add significantly to the amount diverted.

Nebraska ranks tenth nationally in the number of miles of rivers and streams within its boundaries. The Platte River and its tributaries drain the largest part of the state and account for most of the outflow to the Missouri River. The Niobrara River ranks second in both respects. Stream flow generally follows the topographic slope of Nebraska, which is downward toward the east-southeast.

An acre-foot is the quantity of water required to cover an acre of land to a depth of one foot. It is equal to 43,560 cubic feet, or 325,851 gallons.

A stream delivering one cubic foot of water per second (7 1/2 gallons per second) will yield two acre-feet in a day's time.

All the water flowing in Nebraska's rivers and streams initially comes from precipitation in the watershed above. The rain and snowmelt enter the streams as overland runoff or as outflow from groundwater reservoirs.

Most Nebraska streams are supported by both runoff and groundwater. The Niobrara, Elkhorn, Dismal and North and South Loup rivers are fed primarily by groundwater, while the rest are supplied primarily by runoff.
Figure 1-17: Annual Inflow and Outflow from Nebraska, 1950-1994, in Millions of Acre-Feet

Figure 1-18: Average Annual Discharge of Nebraska's Rivers in Thousands of Cubic Feet per Second
Surface reservoirs in the state with surface acreage of more than 100 acres have a combined storage capacity of approximately three million acre-feet, equivalent to a depth of approximately three-quarters of an inch over the entire state. In addition, there are 600 man-made reservoirs with surface areas of less than 100...
acres each, 29,000 farm ponds and hundreds of flood-water retention and stabilization structures, all of which retain additional water. More than 1,300 natural lakes in the Sandhills have a total surface of about 78,500 acres.

**Groundwater**

Compared to other states, Nebraska ranks very high in the amount of groundwater within its boundaries. Nebraska has vast supplies of good quality groundwater, nearly 1.9 billion acre-feet. That is equivalent to a body of water thirty-four feet deep over the entire state. The quantity of groundwater in Nebraska is equal to twenty-five years of the state's annual precipitation, is 250 times the annual stream flow, and is almost 700 times larger than the amount of water stored in surface reservoirs.

Unfortunately, groundwater is not equally distributed; groundwater in storage varies from zero in some areas to more than 100 feet in others, as shown on the map in Figure 1-20. Parts of the Sandhills are underlain with as much as 800 feet of saturated material, equivalent to a layer of water 150 feet deep.

### Storage of Groundwater, High Plains Aquifer

<table>
<thead>
<tr>
<th>State</th>
<th>Percentage</th>
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<tbody>
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<td>Nebraska</td>
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<tr>
<td>Texas</td>
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</tr>
<tr>
<td>Kansas</td>
<td>9%</td>
</tr>
<tr>
<td>Wyoming</td>
<td>4%</td>
</tr>
<tr>
<td>Colorado</td>
<td>3%</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>3%</td>
</tr>
<tr>
<td>South Dakota</td>
<td>3%</td>
</tr>
<tr>
<td>New Mexico</td>
<td>2%</td>
</tr>
</tbody>
</table>

*Data: Nebraska Department of Water Resources*

The Ogallala aquifer is part of the High Plains aquifer. Its greatest saturated thickness is in the Sandhills area of Nebraska, becoming shallower toward its southern end. Gravel deposits. That translates into movement of zero to 1,100 feet a year.

The rate of groundwater movement is related to the geology of the different areas of the state. Some of the characteristics are:

- **Sandhills**: High permeability and infiltration rates through sandy soils; little geographic retardation; shallow depth to water. Huge volumes of groundwater discharge excess water to steadily flowing streams.
- **Western Nebraska**: Large range of particle sizes and mineral composition makes for low permeability, but some areas have large interconnected openings that permit rapid movement of groundwater. Groundwater supplies are virtually nonexistent in the northwest edge of the area.
- **Republican River**: Geology and depth to water are variable in this region. Permeable alluvial deposits allow for fairly rapid infiltration from precipitation and irrigation practices.
- **Platte River Valley**: Saturated alluvial deposits form shallow water table; permeable soils allow high recharge from precipitation, irrigation, rivers and other surface waters.
Big Blue River Basin: Complex geology with multiple alternating layers of sediment with differing permeabilities.

Some areas have joints and fractures that provide high-speed paths for water movement. Northwest area has higher recharge rates, with short pathways through the unsaturated zones.

Eastern Nebraska: Complex assortment of unconsolidated sediment over bedrock of limestone, shale and sandstone.

Stream valleys have shallow depths to groundwater, isolated pockets of sand and perched aquifers; water from some aquifers is undrinkable because of the amounts of dissolved minerals. Some flow systems are rapidly recharged through joints and fractures in limestone or sandstone.

Obtaining Data

Surface water: Measurements of stream flow are reported in units of cubic feet per second. The U.S. Geological Survey and the Nebraska Department of Water Resources closely monitor the surface water supply through stream gaging stations, gathering data from October 1 to September 30 of the succeeding year, a period designated as a “water year.” The data are needed in the administration of water rights and in determining the feasibility of proposed projects. Most of these stations date back to the 1930s, although some date to the late 1800s. One hundred sixty gaging stations were operating in 1939. Today there are approximately 180 on streams and reservoirs, plus additional stations on canals. Recent budget cuts have decreased the number of gaging stations in the state. The Corps of Engineers, the Bureau of Reclamation and irrigation districts maintain a few gaging stations for data relating to their particular needs. The Natural Resources Commission maintains a data bank of flow information.

Groundwater: A network of over 4,000 observation wells monitor the groundwater levels in the state. This is done by a cooperative effort of the Conservation and Survey Division of the University of Nebraska-Lincoln, the U.S. Geological Survey and the natural resources districts.

Use of Nebraska’s Water

The estimated volume of water used in Nebraska in 1990 was 24,018,000 acre-feet, equivalent to an average of 21,247 million gallons per day. Of this total, surface water supplied 77.4 percent, while the remaining 22.6 percent was groundwater.

It is important to keep in mind that much of the water withdrawn is used, but not consumed. A nonconsumptive use returns the water used to the stream or groundwater. Examples would be hydropower generation, power plant cooling, maintenance of fish and wildlife habitat and recreation.

A consumptive use does not immediately return used water to the stream for other uses. In irrigation, for example, 25 to 50 percent of the water withdrawn is lost to evaporation from the land or transpiration through vegetation. The water eventually returns to the earth as precipitation, but somewhere else.

While power generation requires the highest volume of water of all uses, that water is returned to the same stream and is available for reuse. On the other hand, most irrigation water is lost to reuse through conveyance loss, deep percolation and field runoff, besides evapotranspiration. Therefore irrigation is considered to be Nebraska’s most consumptive use of water.

The breakdown of surface and groundwater uses is shown in Tables 1-1 and 1-2.

Power Production

The 1990 water use for power generation of 15,124 million gallons per day was 70.6 percent of the total water used for all purposes. Surface water supplied 99.9 percent of the water used for power production. Hydroelectric power generation, classified as a nonconsumptive instream water use, represented 85.6 percent of the total water used for power generation.

Fossil fuel power generation accounted for 7.8 percent of the total water used for power generation, with 1,176.8 million gallons per day from surface water and 7.9 million gallons per day from groundwater.

Nuclear power generation accounted for 6.6 percent of water used for power and was supplied from surface water.

Public-Supplied Domestic Use

The average daily public-supplied domestic water use in 1990 was 115 gallons per person per day. Per
person domestic water use tends to be inversely related to rainfall; it is higher in western Nebraska than in the eastern portion of the state.

Nearly all Nebraska communities rely on groundwater for their principal supply of water. Groundwater provided 78.2 percent of publicly supplied use, while surface water provided the remaining 21.8 percent. Only the Metropolitan Utilities District (Omaha and surrounding communities), Blair, Crawford, Chadron,

Figure 1-23: Irrigated Acreage, 1990 in millions of acres

Cedar-Knox Rural Water District and Beaver Lake Sanitary District use surface water for municipal needs. MUD pumps 50 percent of its domestic water from the Missouri River; the remainder is groundwater from well fields near the Platte River.

Self-Supplied Domestic Use

Virtually all self-supplied domestic water used for drinking and domestic livestock is from groundwater sources. In 1990 self-supplied domestic water use for Nebraska counties ranged from 0.01 million gallons per day in Pawnee County to 6.9 million gallons per day in Douglas County.

Commercial Water Use

Water use in this category was estimated to be 50.5 million gallons per day during 1990. Of this, 99.5 percent came from public sources. The commercial category includes restaurants, lodging places, retail stores, office buildings and military facilities.

Industrial Water Use

This category includes water used in manufacturing processes. The total use in 1990 was estimated at 74 million gallons per day, nearly equally divided between public-supplied and self-supplied sources.

Mining Use

This category includes secondary oil recovery, quarrying limestone and washing gravel or rock. The total estimated use in 1990 was 135.6 million gallons per day, most of which came from surface sources.
Livestock Production Use

Estimated livestock water use of 139.1 million gallons per day during 1990 was only 0.7 percent of total water use in the state. Ninety percent of water used for livestock came from groundwater, while ten percent was supplied from surface water.

Sewage Treatment Use

Part of the public supplied commercial, domestic and industrial use of water is for sewage treatment. This use is nonconsumptive, as the water is treated and returned to a surface water system. Use for this purpose totaled 165.8 million gallons per day in 1990.

Irrigation

History of Irrigation in Nebraska

Nebraska’s first irrigation occurred in 1859 with the construction of a small irrigation ditch on the South Platte River near the present site of North Platte. The 1860s recorded developments near Fort McPherson on the Platte River, and on the Republican and the Big and Little Blue rivers.

Ditches were dug by hand and lined with wooden flumes. Unfortunately, these ditches did not maintain a steady flow of water for irrigation; the flows were high in the spring and low in the summer when water was most needed. By 1889, western Nebraska had 214 irrigators, most of them using water from the North Platte River.

The Nebraska legislature passed the first irrigation law in 1889. People could take water from streams for “beneficial use” after they had posted notice at the diversion point. Farmers in western Nebraska, however, were disappointed with the law. They wanted a stronger law that would allow them to create irrigation districts with power to issue bonds so they could build canals to get the water from the North Platte onto their lands.

In 1893, the farmers formed the Nebraska Irrigation Association, pressing the legislature to act on their proposal to form irrigation districts. By then, 9,026 acres of land were under irrigation. Two years later, in 1895, the legislature did enact the Irrigation District Law, empowering existing associations to be refinanced, to make assessments for water and to generate tax funds for construction, operation and maintenance of their systems, and allowing for new irrigation districts to be formed.

The 1890s were an important decade in the history of Nebraska’s water resources. Irrigation development was stimulated by several drought years. By 1900 as many as 150,000 acres were irrigated from streams and as many as 1,000 acres with water from wells.

Surface water development was given a boost with the passage of the Reclamation Act of 1902. The first major irrigation project in Nebraska was the North Platte Project, with water supplied from the Pathfinder Reservoir in Wyoming.

Development of surface water reservoirs and canal distribution systems followed as a means to store water when it was in excess and to release it when needed during the drier crop production season. This was the principal supply for irrigation until the mid-1950s.

Although some groundwater had always been pumped for irrigation, it was the drought of the mid-1950s, the development of the center pivot in the late 1960s, and the drought in the mid-1970s that led to groundwater irrigation expansion.

Other factors that brought about this transition were: accessibility to farmers of inexpensive electric

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Table 1-1: Estimated Surface Water Use in Nebraska, 1990

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<th>Category</th>
<th>Millions of Gallons per Day</th>
<th>Percent of Total Use</th>
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<tr>
<td>Hydroelectric power</td>
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<td>Fossil fuel power</td>
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<td>Nuclear power</td>
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<td>Irrigation</td>
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Table 1-2: Estimated Groundwater Use in Nebraska, 1990

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interest rates. When these were coupled with important technological advancement in center pivot systems which allowed irrigation of land that was not flat, and pumps which allowed pumping from greater depths, thousands of farmers tapped into the groundwater underlying their lands.

**Current Irrigation Use**

Water used for irrigation in Nebraska during 1990 was estimated at 5,632.8 million gallons per day, or 6,310,000 acre-feet for the year. This was 26 percent of the total water use. Water from surface diversions, or reservoirs, of 1,224.7 million gallons per day, supplied 21.7 percent of irrigation water use. The remaining 78.3 percent, or 4,408.2 million gallons per day (4,938,100 acre-feet), was pumped from groundwater aquifers.

Surface water irrigated 862,700 acres in 1990, at an average rate of 1.6 feet per acre. There were 77,956 registered wells, irrigating 6,104,400 acres in 1990, at an average rate of 0.8 feet per acre.

Corn was the principal irrigated grain crop grown, with an estimated acreage of 5,050,000 in 1990. The second largest acreage was that for soybeans, with 685,000 acres. Other irrigated crops include silage, corn, grain sorghum, sorghum for silage, dry beans, alfalfa, wheat, popcorn, sugar beets and hay and pasture.
Select Bibliography


Table 2-1: Brief Summary of Nebraska Water Law Related to Water Quantity

<table>
<thead>
<tr>
<th>Source</th>
<th>Groundwater</th>
<th>Surface Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ownership</td>
<td>&quot;Publicly owned&quot;</td>
<td>&quot;Dedicated to the people of the state.&quot;</td>
</tr>
<tr>
<td>Administrative agency</td>
<td>Local natural resources district</td>
<td>Nebraska Department of Water Resources</td>
</tr>
<tr>
<td>Limitations on use</td>
<td>Good supply: &quot;reasonable and beneficial use&quot; which does not injure others; subject to statutory preference system. Short supply: each user entitled to &quot;reasonable proportion of the whole&quot;; subject to statutory preference system and NRD regulations.</td>
<td>Good supply: amount granted by appropriation. Subject to constitutional and statutory preference system. Short supply: priority according to date appropriation granted; subject to preference system.</td>
</tr>
<tr>
<td>Transfer to another site</td>
<td>Only if type of transfer is permitted by statute; except for agricultural use, must be approved by DWR.</td>
<td>Must be approved by DWR.</td>
</tr>
<tr>
<td>Transfer of right to use</td>
<td>To be used on land where it is pumped, except as allowed by statute. Transfer must be approved by DWR.</td>
<td>Not prohibited by statute. Must be approved by DWR.</td>
</tr>
</tbody>
</table>

Interrelated Groundwater and Surface Water

1. An NRD has first option to regulate use of groundwater to mitigate problems caused by use of interrelated groundwater and surface water.

An NRD may also request that the DWR begin the process of creating an action plan to regulate use of both groundwater and surface water, the plan to be developed jointly by the district and the DWR.

2. If use of interrelated groundwater and surface water is contributing to a dispute over an interstate compact or decree, or to difficulties with a state contract or agreement, the DWR may ask the NRD to designate a management area, or develop an action plan, to mitigate the problem. If the NRD chooses not to do so, power to create a management area and to prescribe controls vests in the DWR.

An Interrelated Water Review Committee may be appointed by the Natural Resources Commission to arbitrate disagreements between the DWR and the district.

*Effective date: In the Republican River Basin, July 19, 1996. In the rest of the state, January 1, 1999.*
12. Quality Issues Relating to Water Quantity

The focus of this study is water quantity. However, water quality must be mentioned as an issue. When there is competition for good quality water sources, especially in water-short areas, the quantity of that water becomes intertwined with its quality. Water that is not consumed when used for agriculture, industry or municipal purposes eventually returns to a water source, either by percolation back down through the ground, or by runoff or direct discharge to the stream. So the processes in how water is used can be limited and regulated to protect the quality of the water resource.

To deal adequately with the vast subject of water quality would take a different, lengthy study. The information presented in this chapter is to acquaint the reader with the geohydrological principles in relation to water quality. Just as an understanding of basic hydrology is necessary for considering issues relating to water quantity, it is needed also for understanding the movement of contaminants in that environment.

Additional information on water quality can be obtained through several government sources: the U.S. Environmental Protection Agency, the Nebraska Department of Environmental Quality, the Nebraska Department of Health (drinking water), natural resources districts, and local and county health departments. Many local, state and national organizations offer a wealth of information on this subject, as do publications readily available in public libraries.

Contamination

Contamination of surface water sources has been regulated through the federal framework of the Clean Water Act (1972), which sets water quality standards for lakes and streams. It basically addresses point sources of pollution—contaminants coming from single, isolated sources such as a drainpipe or a leaking tank. Contamination from a nonpoint source—a diffused or dispersed source such as runoff or fertilizers percolating into the soil—has not been adequately addressed until recently. It is the main cause of contamination of groundwater. Because of the importance of groundwater for domestic, municipal, agricultural and industrial use, the issue of protecting groundwater is of extreme importance.

Once groundwater becomes contaminated, it may remain so for hundreds or thousands of years. Lack of sunshine, oxygen and significant water movement inhibits the process of degradation. The contaminant may render the groundwater unsafe as a source of drinking water. Clean-up of the source of contamination can be difficult, and because of the cost, is often impractical.

The 1992 Nebraska Water Quality Report points out the extreme importance of groundwater as a resource for Nebraska in the following terms: "The quality and quantity of ground water and the potential for its contamination varies across the state. . . . Although natural ground water quality is good, many areas have experienced degradation from human activities. Hundreds of individual cases of ground water contamination have been documented in Nebraska, with numbers increasing each year."

Contaminant Movement in Soils

Darryll Pederson, from the Conservation and Survey Division of the University of Nebraska, stresses that knowledge of the geology of an area and the nature of the contaminant's reaction to water is critical for protecting aquifer systems from contamination or for restoring them to usable condition. The questions that must be asked regarding a particular contaminate are: Is it soluble? Does it degrade to other chemicals? Does it attach itself to other particles?
Pederson points out that groundwater is part of the hydrologic cycle that continually adds water to flow systems through recharge, and moves water out of the systems along flow lines or paths into discharge areas. While recharge is continually replenishing groundwater supplies, different soil compositions determine the amount of these surface discharges and the length of time needed for them to reach the aquifer.

Where contaminants enter the flow system, the geological matrix of that area and the characteristics of the contaminant determine its movement into the groundwater. If the recharge time is short owing to the type of soils, the immediate area around the source will have a high probability for contamination. If contaminants travel slowly to the recharge area, geological, chemical and biological processes can break down, capture and/or alter the contaminants, thus reducing the risk of groundwater pollution.

Each contaminant is unique and reacts differently with water and geological material. Some are soluble and can travel quickly and are readily dispersed, thus affecting a larger area of the groundwater source. Some soluble contaminants react to geologic material in a number of ways, bonding to some soils, altering their physical form or changing their chemical composition, thus slowing the overall movement of the contaminants. This retardation rate is difficult to determine; it depends upon the depth of the unsaturated zone and the length of the pathway before discharge. The density of non-soluble contaminants becomes a factor when the less dense contaminants migrate to the top of a saturated zone and float. The heavier contaminants sink, ponding on top of a low permeability layer of geological material.

Intermittent recharge, fractures or joints in the unsaturated zone that form pathways for more rapid groundwater movement, and microorganisms existing in the flow system which digest organic molecules also factor into the complexity in dealing with groundwater contamination. That is why clean-up of contamination is difficult and expensive. The best option is to prevent pollution in the first place.

The surface water flow recharges the surrounding alluvial aquifer. In Nebraska, many municipal and other well fields are adjacent to the rivers, especially in the Platte River valley. Large quantities of dissolved solids as well as other contaminants in the stream from runoff and erosion can have a significant effect on the surrounding wells.

Vice versa, groundwater that has become polluted or is of lower natural quality will have an impact where it discharges into streams.

**Hydrogeology of Nebraska**

The hydrogeology of the different areas of the state relate to contaminant movement. Very generally, some of the characteristics are:

**Sandhills:** High permeability and infiltration rates because of sandy soils; little runoff; recharge to groundwater rapid because of shorter flow pathways and shallow depth to water; huge volumes of groundwater result in the discharge of excess waters to steadily flowing streams. A contaminant would move rapidly to the water table.

**Western Nebraska:** Large range of soil particle sizes and mineral composition makes for low permeability, but some areas have large interconnected openings that permit rapid movement of groundwater; groundwater supplies virtually nonexistent in northwest edge of area. Low vulnerability to contamination because of low recharge rates, deep water table, slow movement, and a wide range of minerals for interaction with contaminant. The exceptions to this are the areas that might have interconnected openings which would allow a contaminant to migrate.

**Republican River:** Geology is variable in this region, depending on depth to water; permeable alluvial deposits allow for fairly rapid infiltration from precipitation and irrigation. Contamination could occur from surface spills and move rapidly to the groundwater because of the limited area of alluvial sediments and the short flow pathways.

**Platte River valley:** Saturated alluvial deposits from shallow water table; coarse, permeable soils allow a high volume of recharge from precipitation, irrigation and runoff, and recharge from rivers and other surface waters. Intensive irrigated systems, well fields, some industrial production, and concentrations of population increase the risk of contamination.

**Big Blue River basin:** Complex geology with multiple alternating layers of sediment with differing permeabilities; some areas have joints and fractures and some areas have been dewatered, both of which provide high-speed paths for water movement; northwest area has higher recharge rates with short pathways through the unsaturated zones. Contamination could
occur because of the large number of wells, localized industrial sites and feedlots.

**Eastern Nebraska:** Complex assortment of unconsolidated sediment over bedrock of limestone, shale and sandstone; stream valleys have shallow depths to groundwater; isolated pockets of sand and perched aquifers; some aquifers (bedrock) mineralized; some flow systems rapidly recharged through joints and fractures in the limestone or sandstone. This allows for contaminant intrusion. Many domestic wells are contaminated from improper well construction. Contamination also occurs because of population density and industrial activity and from wastewater disposal activities.

**Quality Management**

Groundwater quality management falls to the natural resources districts and the Department of Environmental Quality. The DEQ regulates activities pertaining to surface water or point sources of contamination. The NRDs can set up management areas for water quality just as they can to regulate the quantity of water within their districts. This has been done by the South Platte NRD in a small area at Sidney, while the Tri-Basin and the Central Platte NRDs have established quality management areas that encompass their entire districts. In order to control contamination around a specific water source, the Department of Environmental Quality, following a study at the request of an individual, local government and/or NRD, can establish a management area (formerly called a special protection area, or SPA). To date SPAs are located at Superior-Hardy in the Lower Republican and Little Blue NRDs, the Red Willow–Hitchcock area in the Middle Republican NRD, and the entire area encompassed by the Upper Big Blue NRD.

**Tradeoffs**

Agricultural management practices that promote efficient use of water directly relate to the amount of contaminants that infiltrate into the groundwater source. Spaulding and Exner point out that the desired effect of agriculture practices is “maximum crop uptake and minimal leaching.” For example, the amount of chemicals that leach into the soil is better controlled through application of chemicals by sprinkler irrigation, and sprinklers also are more efficient in the amount of water needed to irrigate. They note that there are some tradeoffs that must be considered when comparing which agricultural practice best protects water resources from degradation. An example is minimum tillage systems or no-tillage systems, where more residue is left on the field, which increases water infiltration rates and reduces erosion of the topsoil, a contributor to the nonpoint contamination of rivers and streams. However, minimum tillage systems require use of more herbicides and pesticides, increasing the risk of agrochemical contamination of the groundwater. They further state that all best management practices do not curtail all leaching problems and need to be monitored for their environmental impact.

On this issue relating to water quality and water quantity, research is needed to broaden the management options so as to encompass both production efficiency and resource protection goals. It has been demonstrated that farmers can reduce some of their chemical inputs without suffering financially.

A summer, 1996 project, designed to track how much water is really needed for adequate crop production, examined production costs vs. profits on experimental test corn plots in Chase County at Imperial. Through deep soil testing to track both water and residual nitrogen uptake by the plants, it was discovered that some plants do not use nitrogen which is carried over from previous years and is from 24 to 36 inches below the soil surface. At that level unused nitrogen may leach into groundwater instead.

Another surprising conclusion emerged: When producers used less nitrogen fertilizer, there was more carryover water in the soil.

Thus this experiment suggests a way to lower production costs for both water and fertilizer, while helping to protect groundwater quality as well.

**Next Steps**

What should happen beyond such research? It is generally agreed that objective information and demonstrable farm management practices have a positive effect on protecting water quality and the public health. **What is the fairest and most effective way to modify farmers’ practices: education/information, incentives or regulation?**

Recommendations from an agricultural chemical conference of the Freshwater Foundation included removal of incentives built into bank loans and governmental programs which encourage excessive
agricultural use, and that flexibility must be allowed for other practices such as strip cropping, integrated pest management or crop rotation systems.

The March-April, 1990 Journal of Soil and Water Conservation states: "While groundwater contamination has complex technical characteristics, its underlying causes are human activities in response to incentives provided by public policies. . . . New knowledge about groundwater quality has uncovered linkages between people using rural land and water resources. Society is thus faced with the policy question of who will use groundwater and for what purpose."

Contamination Sources

Contamination can come from many sources. Quick action and effective regulations can prevent spills and accidental releases from long lasting pollution of the water resource. More insidious are the slowly released or nonpoint sources. The public is generally not alarmed over out-of-sight contamination, but it is the one that is difficult and extremely expensive to clean up.

Some contaminants, from both point and nonpoint sources, of which the public needs to be aware include the following:

- **Spills**: Spills from industrial sites or transportation of contaminants with one-time events from accidental releases as for example from a ruptured tank, or from slow releases over time, as in the case of successive small spills.

- **Nitrate and pesticides**: Agricultural chemicals infiltrate into the groundwater through irrigation and precipitation and contaminate rural wells. Exner and Spalding of the Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, reported in their 1990 study of the Occurrence of Pesticides and Nitrate in Nebraska’s Groundwater that these are the most frequently encountered groundwater contaminants. Widespread use of large quantities of nitrogen fertilizer and pesticides and their potential for contamination cause them to be the greatest concern to water consumers in Nebraska. Pesticides are manufactured pollutants, but nitrate can come from several sources: commercial fertilizer, manure and leachates of organic matter, leachates from septic tanks, sewage treatment lagoons and animal feedlots. Atrazine was reported as the most frequently detected pesticide.

- **Runoff and agricultural practices**: Sources are: waste and runoff from livestock operations; storage sheds for fertilizer, pesticides and herbicides; spills in loading application equipment; excessive or ill-timed application of chemicals; improper disposal of chemical waste containers; refuse piles and land application of sludges and wastewaters.

- **Runoff from erosion**: A major problem in lakes, ponds and streams; can come from poor land-use practice in agriculture and large construction sites in urban areas.

- **Poorly constructed or abandoned wells**: Both irrigation and domestic wells permit contaminants to enter the groundwater through the gravel pack around the well casings or through openings in the wells themselves. Identification of abandoned wells not properly sealed is of major concern.

- **Small disposal pits, holding ponds and storage lagoons**: These may have ruptured liners, slow leaks, overflows or structural collapse, or may be constructed in poor locations.

- **Leaks from underground storage tanks**: Leaking is usually from old corroding gasoline or petroleum products tanks.

- **Leachate from landfills**: This is from the unregulated waste dumps of the past.

- **Septic systems and drain fields**.

- **House and garden chemicals, improperly disposed household hazardous waste**.

- **Floods**: Some developments allowed in flood plains (cemeteries, landfills, petroleum storage facilities, industrial sites) are potential sources of contaminants in event of flooding. Erosion and deposition of soils that are treated with agrichemicals also present problems. Flood events cause massive recharge, dissolving of contaminants, and interaction of contaminants.

- **Stream infiltration**: Natural stream recharge to groundwater in areas where the natural hydrological gradient has been affected by well pumping and/or water withdrawn from streams; streams carry many pollutants from runoff and waste discharges.

- **Urban runoff, deicing salts**.

- **Atmospheric pollutants**, from emissions from motor vehicles, power plants and industries, which return to water sources through precipitation.

- **Naturally occurring substances** such as minerals or radioactive materials.
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Bishop, Ron, Director, Central Platte Natural Resources District. Personal communication, Lincoln, NE, March 15, 1994.


