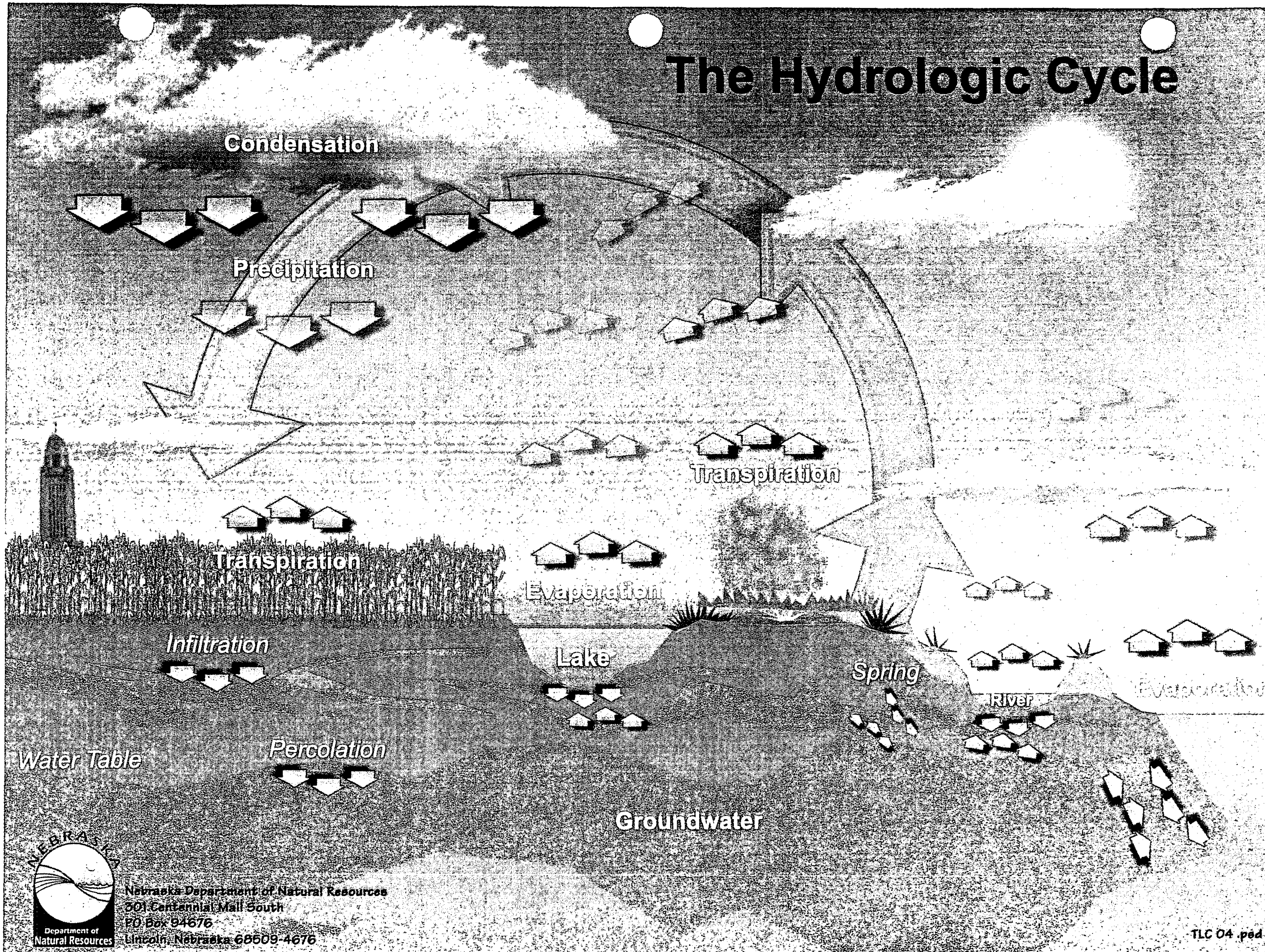
The Hydrologic Cycle
Condensation
Precipitation
Transpiration
Transpiration
Evaporation
Infiltration
Lake
Spring
River
Water Table
Percolation
Groundwater
NEBRASKA
Department of
Natural Resources
Nebraska Department of Natural Resources
301 Centennial Mall South
PO Box 94676
Lincoln, Nebraska 68509-4676
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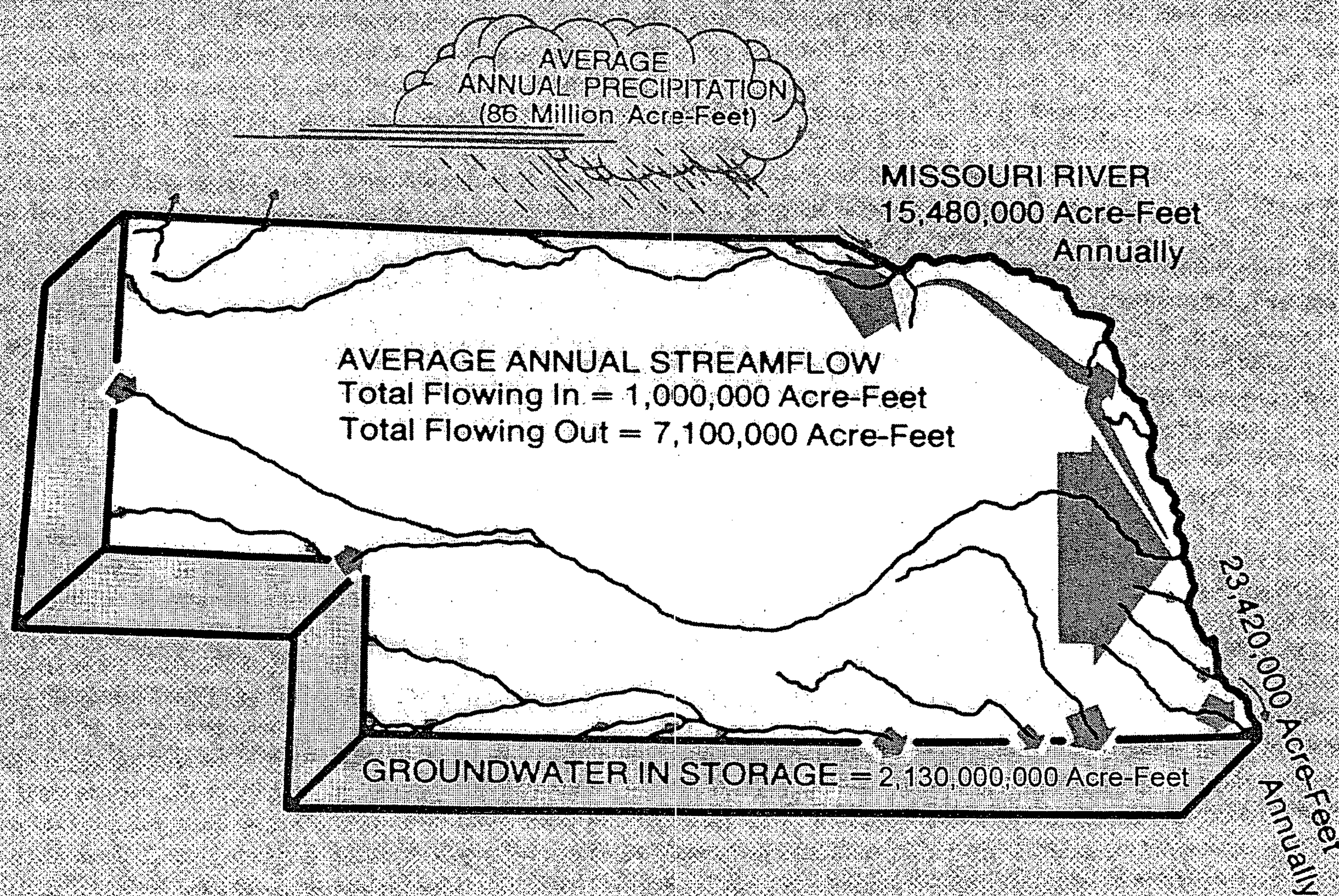
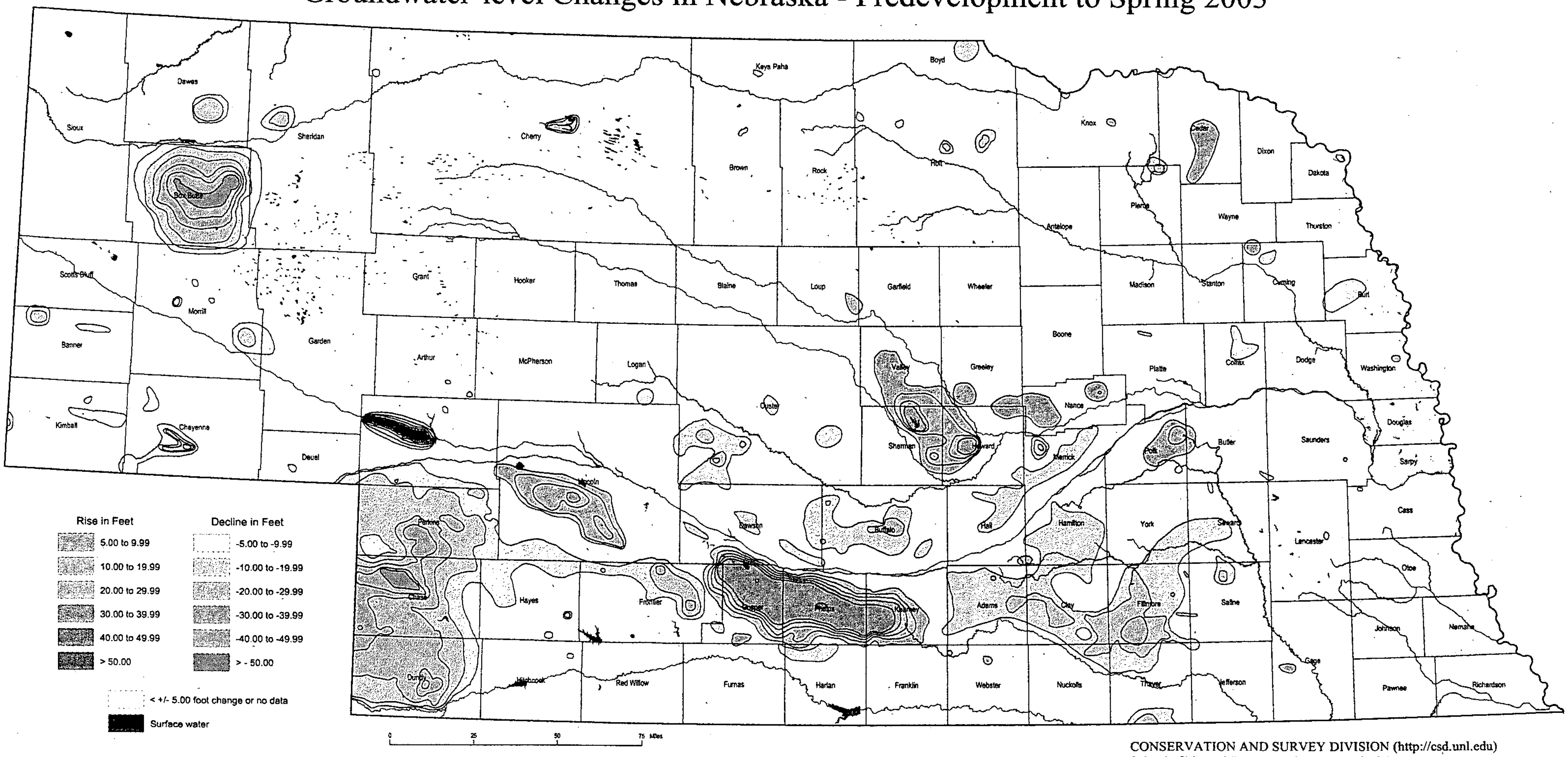
NEBRASKA'S WATER SUPPLY



Groundwater-level Changes in Nebraska - Predevelopment to Spring 2003



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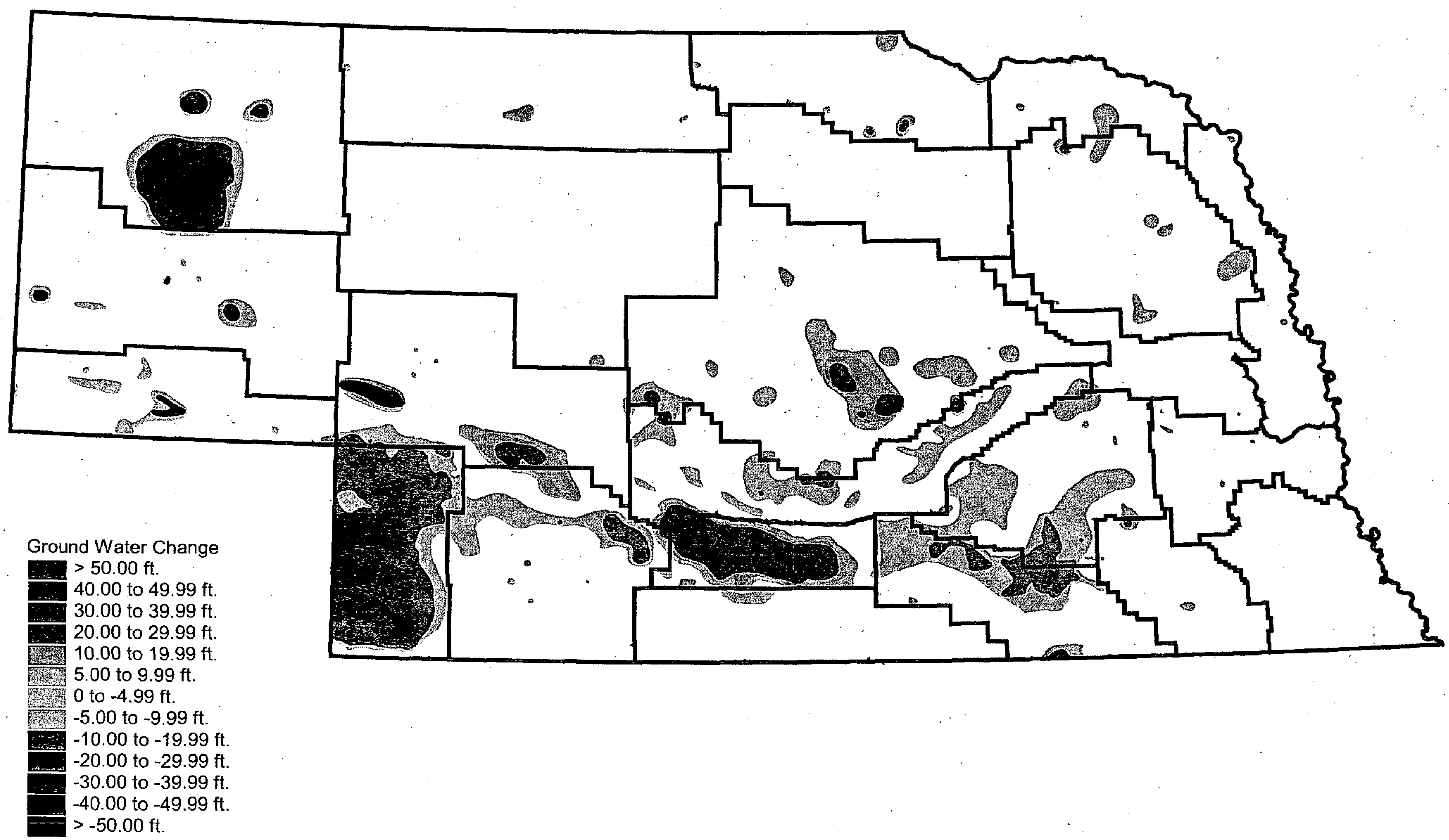
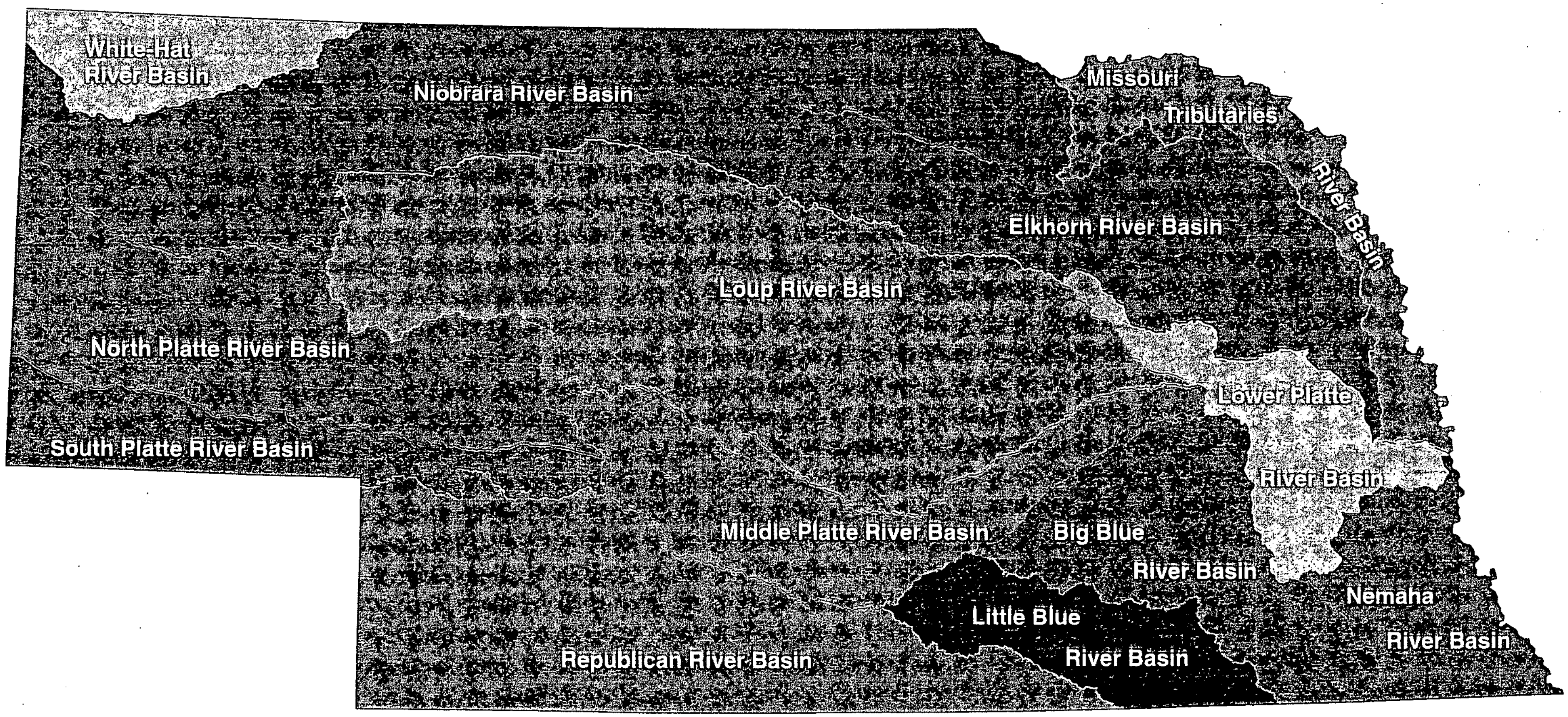
Ground Water Level Changes
Pre-Development - 2003



Source: Conservation and Survey Division, University of Nebraska - Lincoln

Nebraska Dept. of Natural Resources
jshafer, 11/5/2004

Nebraska's River Basins



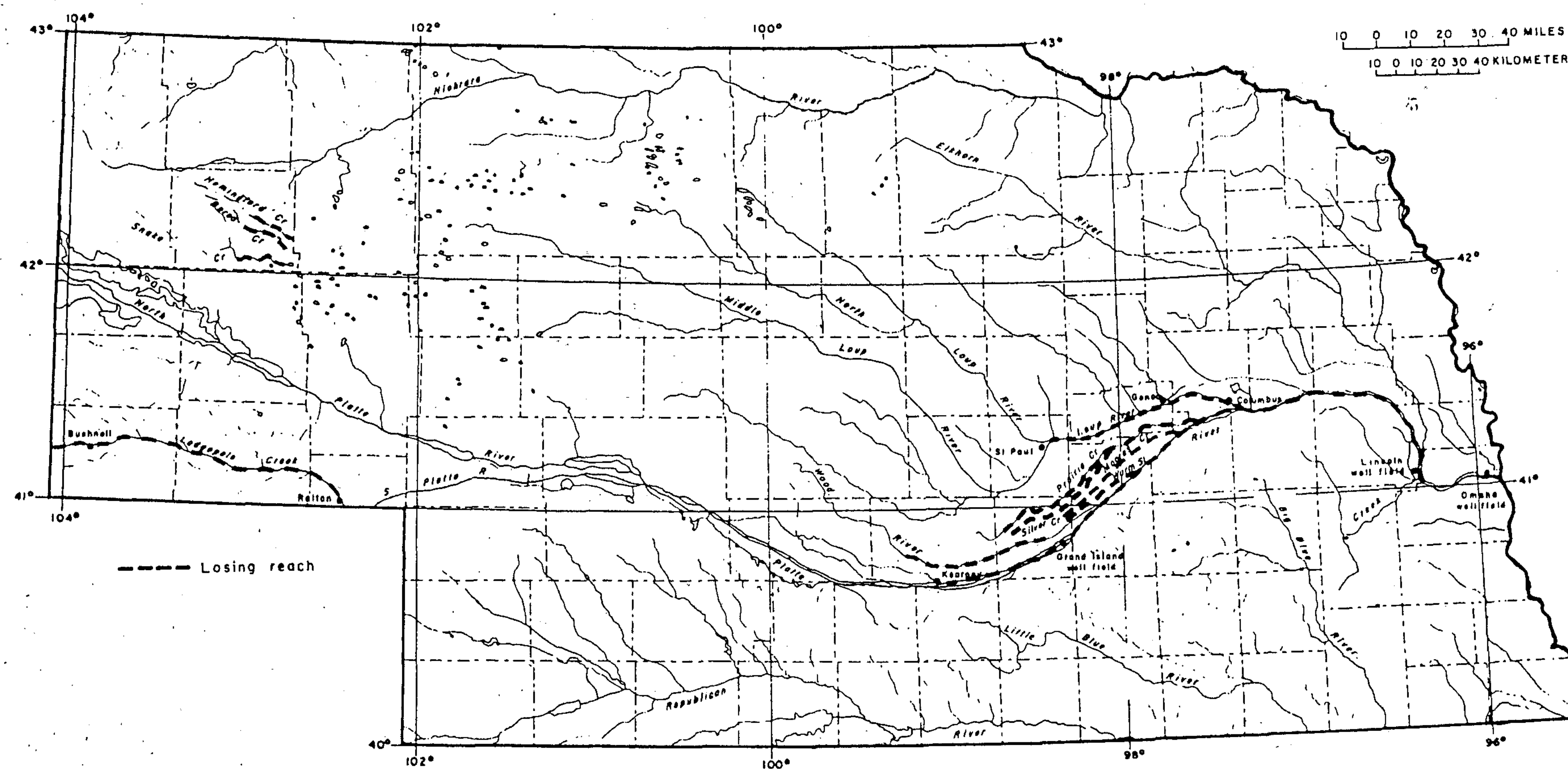
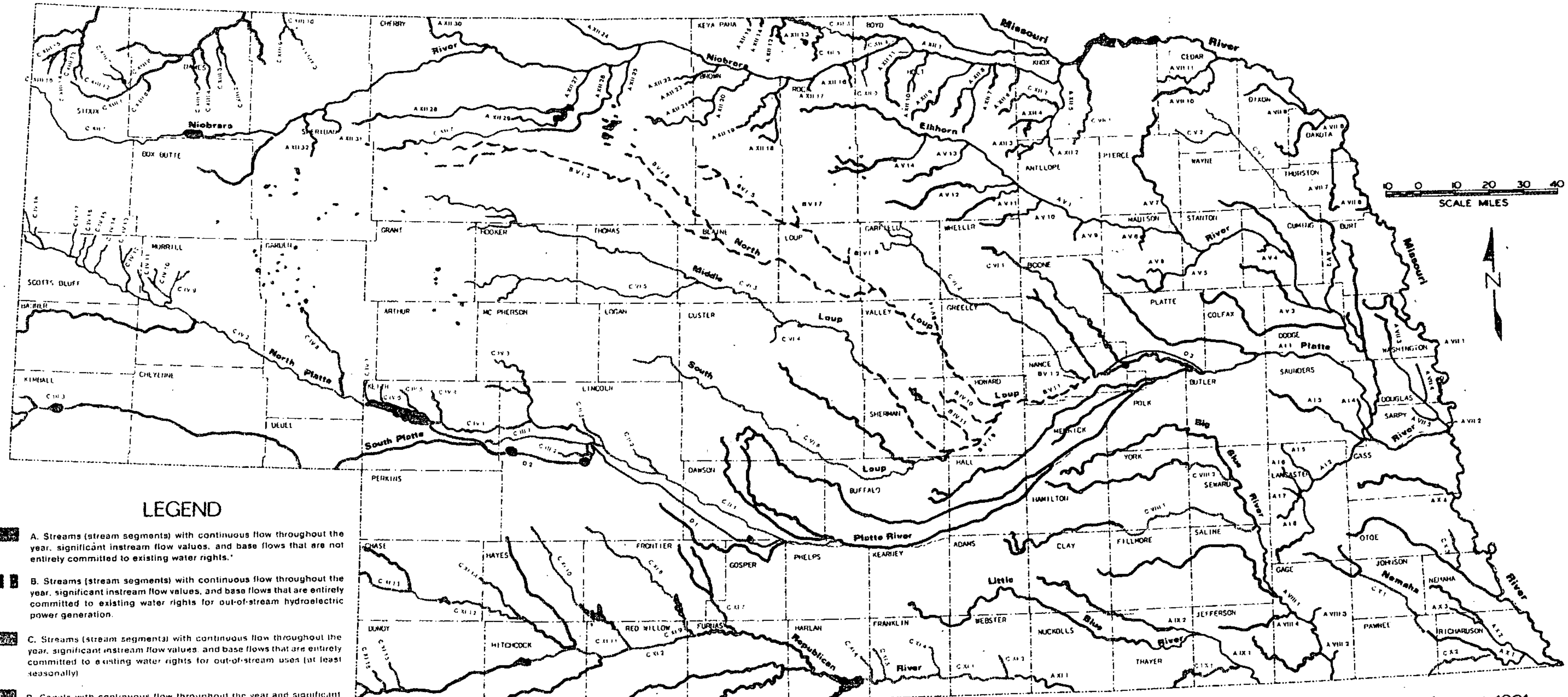


FIGURE 2

LOSING REACHES OF STREAMS

Source: Policy Issue Study on Supplemental Water Supplies, Nebraska Natural Resources Commission, 1984. From the Material Supplies by Conservation and Survey Division, University of Nebraska.

FLOWING WATERS IN NEBRASKA



LEGEND

- A. Streams (stream segments) with continuous flow throughout the year, significant instream flow values, and base flows that are not entirely committed to existing water rights.*
- B. Streams (stream segments) with continuous flow throughout the year, significant instream flow values, and base flows that are entirely committed to existing water rights for out-of-stream hydroelectric power generation.
- C. Streams (stream segments) with continuous flow throughout the year, significant instream flow values, and base flows that are entirely committed to existing water rights for out-of-stream uses (at least seasonally).
- D. Canals with continuous flow throughout the year and significant instream flow values
- E. Streams (stream segments) that do not exhibit continuous flow throughout the year. This category includes the intermittent stream segments above the point of effluence of several streams in categories A, B, and C.

*This category includes the streams covered by the Blue River Basin Compact.

Note: Numbers along stream segments correspond to segments listed in Chapter 2 of this report.

Published by the Nebraska Natural Resources Commission August 1981

Note: This map was compiled in 1981 and both physical conditions and laws have changed since that time. There was debate about whether this map should be included in this notebook because it does not accurately depict all current conditions. For instance, some areas depicted as having continuous flow in the Republican Basin have since been dry. There were also questions concerning depiction of stream segments in the Big Blue Basin. Therefore, the map should be viewed as available information as of 1981, and not necessarily specific for current conditions. *Also please note that the streams depicted in black as not having continuous flow throughout the year only needed one dry period in the ten year period prior to 1981 to be included in that category.*

Excerpt From *"Policy Issue Study on Integrated Management of Surface Water and Groundwater"* (April, 1986)

The following figures were taken from the *Instream Flow Policy Issue Study* and appear again a few pages later in connection with specific streams in the report. They illustrate some of the general types of relationships possible.

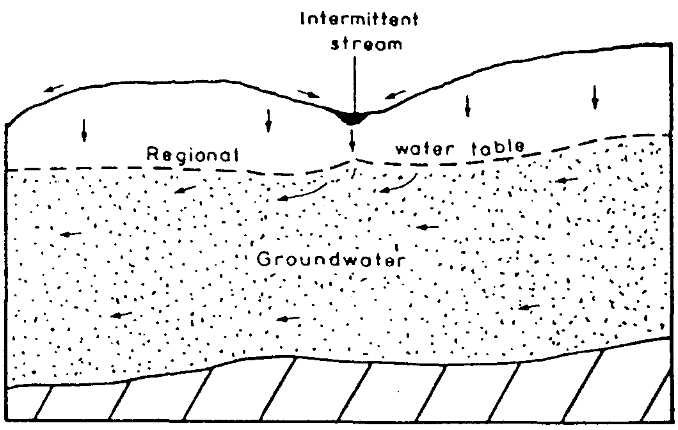


FIGURE 12

INTERMITTENT STREAM FLOWING ON RELATIVELY PERMEABLE UNSATURATED SEDIMENTS

Source: Policy Issue Study on Instream Flows, Nebraska Natural Resources Commission, 1982, compiled by Conservation and Survey Division, University of Nebraska

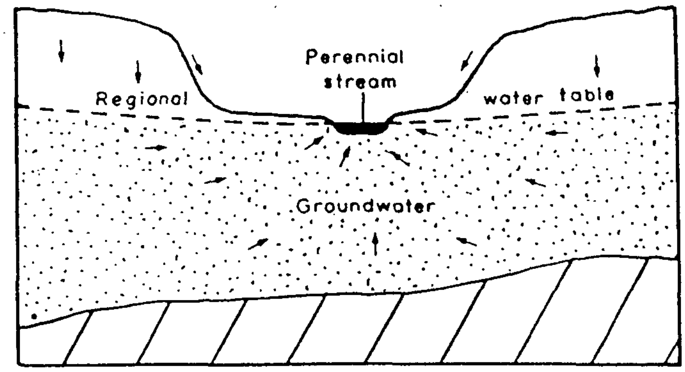


FIGURE 13

STREAM IN CONNECTION WITH THE GROUNDWATER TABLE

Source: Policy Issue Study on Instream Flows, Nebraska Natural Resources Commission, 1982, compiled by Conservation and Survey Division, University of Nebraska-Lincoln.

Figure 12 illustrates an intermittent stream flowing on relatively permeable unsaturated sediments. The stream flows when it receives overland runoff and it loses water by seepage to the underlying aquifer. In this case the stream, as well as the precipitation and runoff, is recharging the aquifer.

There is a hydraulic connection of water in streams and water in aquifers adjacent to streams where the water table intersects the streambed. Because of this hydraulic connection, water is able to flow through the streambed, either into the stream or into the aquifer depending on the hydraulic gradient. The hydraulic gradient, or slope of the water table, is the change in water table elevation per unit change in distance along the flow path of the water.

The configuration of the water table in the vicinity of a stream is important in determining whether the hydraulic gradient is toward or away from a stream. The rate of water movement is dependent on the slope of this gradient and the permeability coefficient of the adjacent aquifer. Water tables that slope steeply toward or away from streams have a greater water flux in the direction of the slope than a flatter water table, given the same aquifer permeability coefficient.

Figure 13 illustrates a stream which is in connection with the groundwater table over a relatively permeable aquifer. Such a stream will be perennial (have year-round flow) so long as the water table level does not drop below the bottom of the stream. Groundwater seeps into the stream except when the stream is in a high stage and temporarily loses water by seepage into the aquifer. Arrows indicate the groundwater flow lines at low stage of stream. In this particular diagram the hydraulic gradient does not appear to be large. However, other factors such as the transmissivity of the surrounding aquifer can determine how fast it transmits water to the stream. Water the stream receives from the surrounding aquifer is called baseflow.

The water table is sometimes nearly flat in the vicinity of stream reaches. The direction of water movement toward or away from the stream in this situation can change according to the river stage, the proximity of recharge or pumping, and rate of transpiration by nearby plants.

In addition to natural causes, some human activities also influence the quantity of water exchanged between surface water and groundwater. Pumping from wells removes water from the saturated zone, lowering the water table in the vicinity of the well. If the well is close to the stream, the gradient of the water table can be reversed so water flows from the stream to the well.

Putting more water on the surface of the ground can cause more water to enter the stream. If sufficient seepage occurs to raise the water table, the gradient toward the stream is increased and more groundwater will percolate toward it.

The magnitude and timing of the effects of withdrawals (or recharge) on streamflow are dependent on several factors. These include aquifer transmissivity, aquifer storage properties, the degree of hydraulic connection between the stream and aquifer, and the distance from the point of withdrawal (or recharge) to the stream. These relationships can also be applied to other surface bodies, including natural lakes and wetlands.

Generally speaking, pumpage or recharge close to a streambed will have a more immediate effect on streamflow than pumpage or recharge at some greater distance. Withdrawals of groundwater at some distance do not necessarily cause direct reductions in streamflows by induced infiltration, as may occur when wells are located close to streambeds. Withdrawals at some distance may reduce the hydraulic gradient toward the stream and thus decrease the amount of groundwater that otherwise would have entered the stream. Pumpage or recharge when the water table is nearly flat also has a more immediate effect the closer the proximity to the stream. Determination of the timing and extent of groundwater pumping on streamflow would require study of individual situations. Modeling studies have done this in some cases.

TYPES OF STREAM-GROUNDWATER RELATIONSHIPS IN NEBRASKA

Specific stream reaches within the state have different relationships between groundwater and streamflow. These relationships are due to river valley morphology and the aquifer occurrence. The following diagrams from representative areas within the state help illustrate these different relationships. These diagrams and most of the material in the accompanying explanations were taken from work done by the University of Nebraska's Conservation and Survey Division for the *Instream Flow Policy Issue Study*. This section is followed by a more general discussion of the flow characteristics of each of Nebraska's major stream systems.

Figure 14 illustrates a perennial stream flowing on, and incised into, relatively impermeable rock. The adjacent upland is mantled by unconsolidated and partly consolidated sediments that are saturated in their lower part. Water discharging from the upland aquifer into tributaries or issuing as springs is only partly intercepted by phreatophytic vegetation; the remainder contributes to the stream's flow.

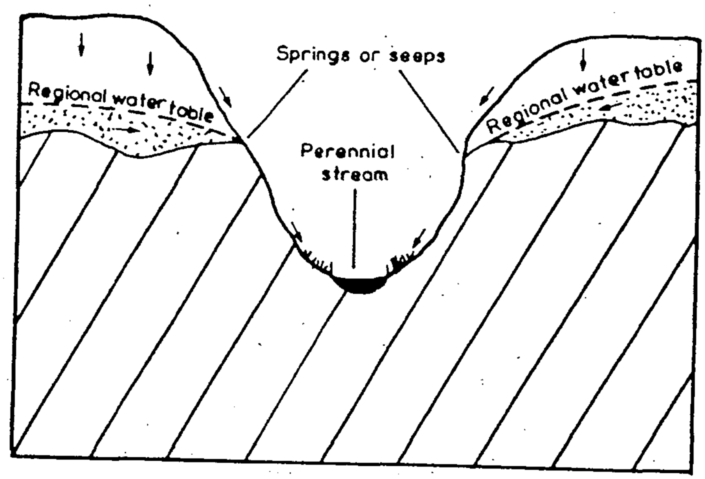


FIGURE 14

NIOBRARA RIVER IN NORTHEASTERN CHERRY COUNTY

Figure 15 illustrates a perennial stream hydraulically continuous with a limited alluvial aquifer within a valley incised into relatively impermeable rock. Adjacent upland mantled by relatively permeable unconsolidated and partly consolidated sediments are saturated in their lower part. Water discharging from the upland aquifer reaches the stream via tributaries or spring discharge or is lost, in part to evapotranspiration.

EXPLANATION FOR FIGURES 14-25

Moderately to highly permeable unsaturated sediments

Moderately to highly permeable saturated sediments (aquifer)

Relatively impermeable material

Water table

Stream

Direction of water movement

Source for Figures 14-25: *Policy Issue Study on Instream Flows*, Nebraska Natural Resources Commission, 1982, Compiled by Conservation & Survey Division University of Nebraska.

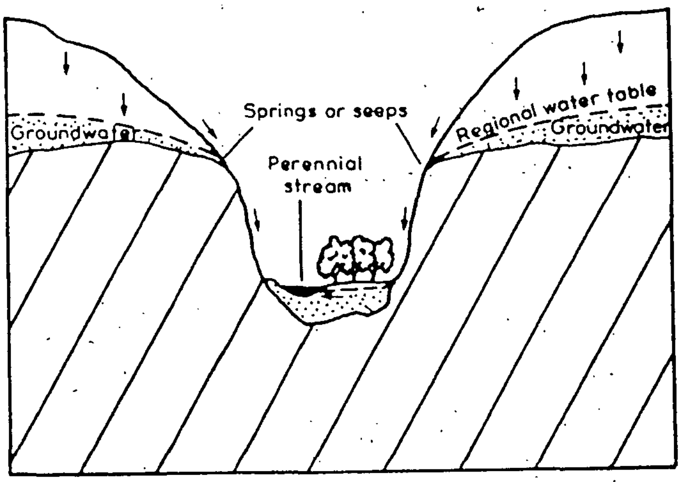


FIGURE 15

NIOBRARA RIVER ALONG NORTH BORDER OF ROCK COUNTY

Figure 16 illustrates a perennial stream incised into a relatively permeable alluvial fill aquifer that overlies relatively impermeable rock containing open water-filled fractures enlarged by a process called "piping." Pumping from wells drilled into fractures causes water to drain from the aquifer above and, in turn, may cause water to flow from the stream to the aquifer and possibly cause the stream to cease to flow.

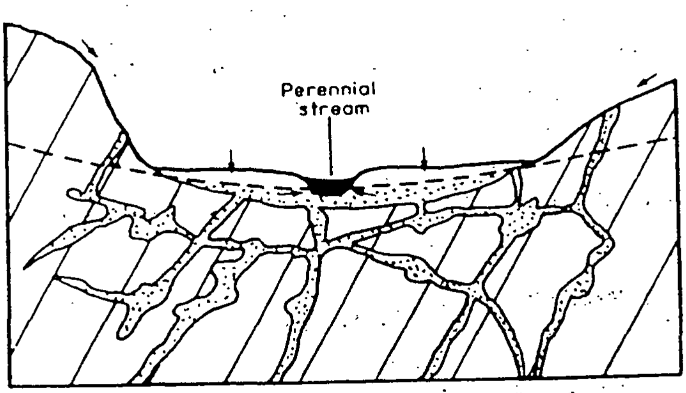


FIGURE 16

LODGEPOLE CREEK

Figure 17 illustrates a perennial stream incised into an areally extensive, relatively permeable unconfined aquifer. Groundwater seeps into the stream except when the stream is in a high stage and temporarily loses water by seepage into the aquifer. Arrows indicate groundwater flow lines at low stage of stream.

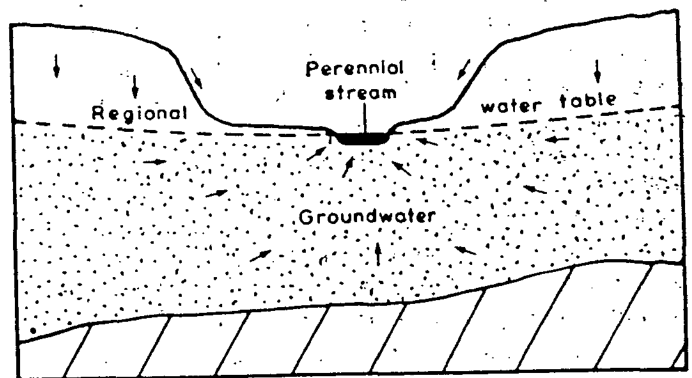


FIGURE 17

PLATTE RIVER IN EASTERN LINCOLN COUNTY

Figure 18 illustrates an intermittent stream incised into relatively permeable unsaturated sediments. There are no relatively impermeable sediments between the stream and the areally extensive zone of saturation. When the stream flows, it loses water by seepage to the underlying regional aquifer.

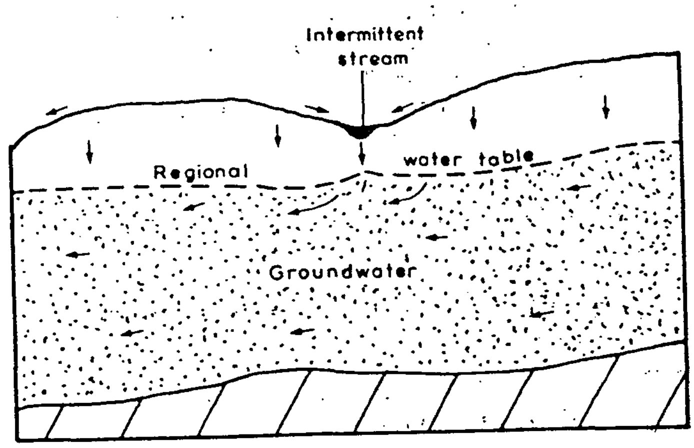


FIGURE 18

WOOD RIVER NORTH OF KEARNEY IN BUFFALO COUNTY

Figure 19 illustrates a perennial stream hydraulically continuous with the water table in an areally extensive, relatively permeable aquifer. As shown here, seepage loss leftward from the stream is caused by water uptake by phreatophytic vegetation. Pumping from wells close to the stream similarly would induce seepage from stream. Seepage loss to the right is due to a natural hydraulic gradient away from river. Such seepage losses can occur at low to high river stages.

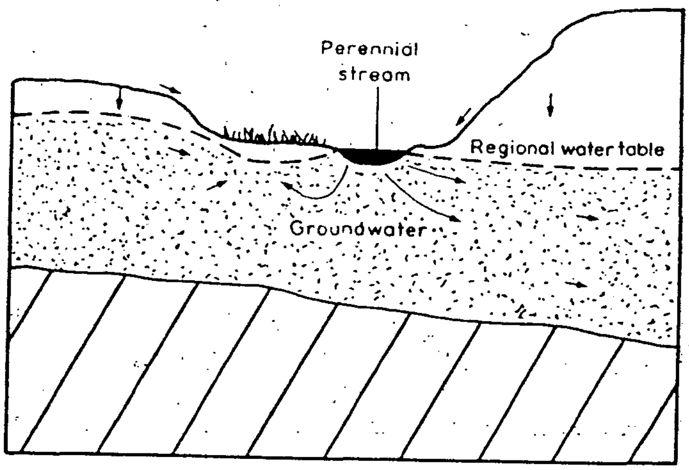


FIGURE 19

PLATTE RIVER IN WESTERN MERRICK COUNTY

Figure 20 illustrates an intermittent stream on a flat-floored interdunal valley. When infiltrating precipitation causes water table to rise above channel bottom, the stream flows. When water uptake by subirrigated vegetation lowers the water table to a level lower than the bottom of the stream channel, streamflow ceases.

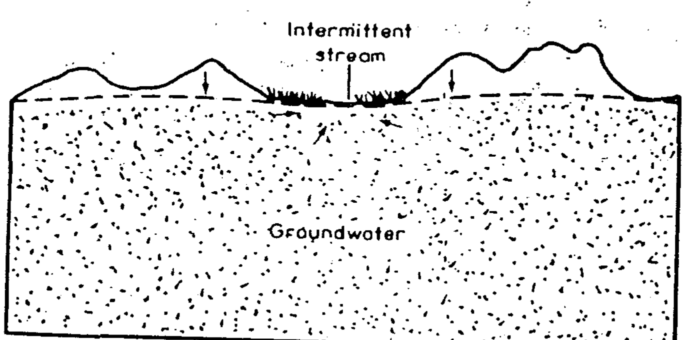


FIGURE 20

UPPER REACH OF NORTH BRANCH OF THE MIDDLE LOUP RIVER IN SOUTHWESTERN CHERRY COUNTY

Figure 21 illustrates two parallel, perennial streams, one at a lower altitude than the other. Both are incised into the same relatively permeable alluvial aquifer. The higher stream gains groundwater from one side but loses to groundwater on other side. The lower stream gains groundwater from both sides. The lower stream gain is partly loss from the higher stream.

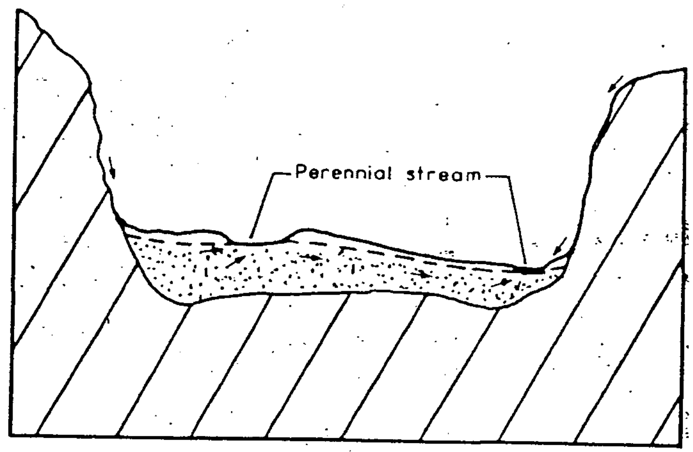


FIGURE 21

PLATTE AND ELKHORN RIVERS IN WESTERN DOUGLAS COUNTY

Figure 22 illustrates an intermittent stream flowing on thin relatively permeable alluvial deposits that are underlain and bordered by relatively impermeable materials. The stream flows when overland runoff occurs and/or when the water table in the thin alluvium remains higher than the bottom of the stream channel. During prolonged dry weather, the stream ceases to flow when water use by vegetation growing on bottom land adjacent to the stream causes th water table to decline to a level lower than the bottom of the stream channel.

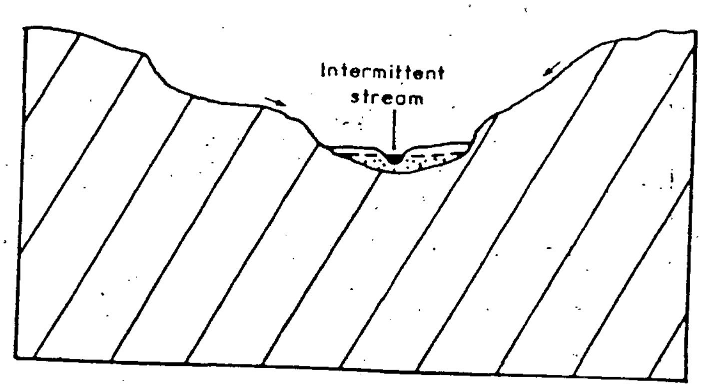


FIGURE 22

DRIFTWOOD CREEK IN SOUTHEASTERN HITCHCOCK COUNTY

Figure 23 illustrates an intermittent stream incised into relatively impermeable unsaturated sediments that are underlain by alternating layers of relatively permeable and impermeable unsaturated sediments. The regional water table at depth is not affected appreciably by influent seepage from the stream.

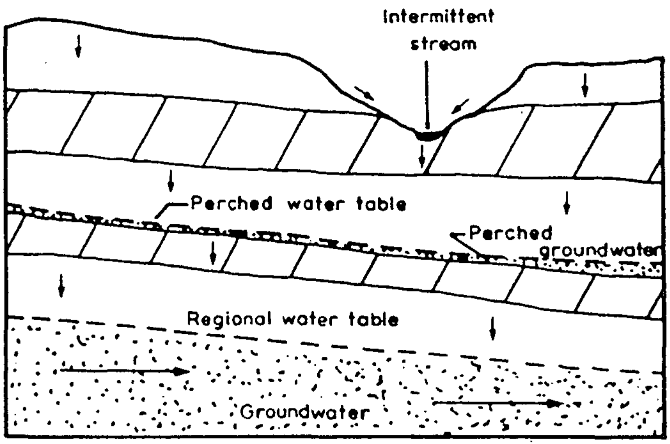


FIGURE 23

BIG BLUE RIVER IN EASTERN POLK COUNTY

Figure 24 illustrates a perennial stream incised into a relatively permeable unconfined aquifer that is hydraulically continuous with a deeper lying confined aquifer. Seepage from both aquifers contributes to the flow of the stream.

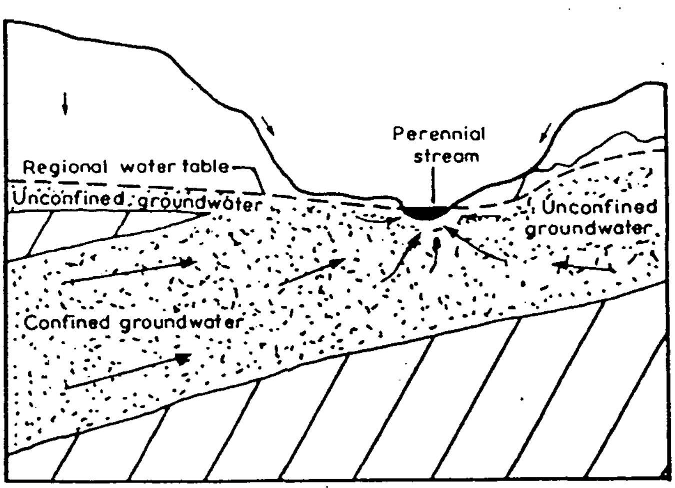


FIGURE 24

BIG BLUE RIVER IN SALINE COUNTY

Figure 25 illustrates an intermittent stream incised into relatively permeable unsaturated sediments that overlie a lens of relatively impermeable sediments. Seepage from the stream recharges a small perched aquifer which is supported by the relatively impermeable lens. The regional water table at depth is not appreciably affected by stream seepage.

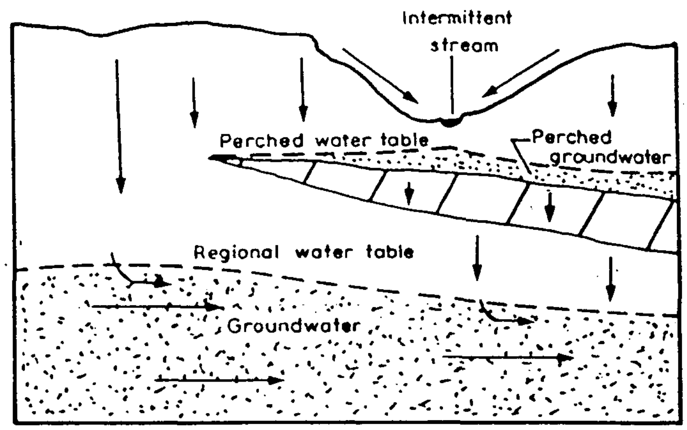


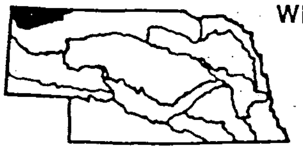
FIGURE 25

NORTH FORK JOHNSON CREEK IN FILLMORE COUNTY

The above illustrations show that a number of different relationships can exist between streams and groundwater. These flow conditions are highly dependent on the geologic conditions at any specific site. Detailed information on the geology and on the water table configuration must be gathered to fully understand the stream-aquifer flow system at specific sites. Those illustrations showing groundwater seeping into streams represent the common relationship existing along the state's perennially flowing streams.

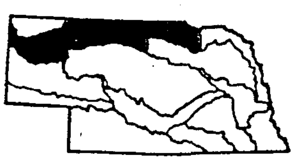
SUMMARY OF STREAMFLOW IN NEBRASKA RIVER BASINS

The following is a summary of the available data on gaining or losing reaches of streams in each river basin. Information generated for the *Policy Issue Study on Instream Flows* was used as the basis for much of the text.



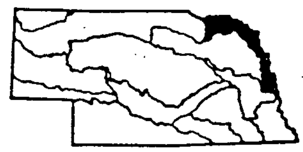
WHITE RIVER - HAT CREEK BASIN

Streams that originate along the north side of the Pine Ridge receive groundwater discharge from a shallow aquifer that receives recharge from precipitation falling on the Pine Ridge. These streams converge to form the White River and Hat Creek. North and west flowing tributaries to the White River and Hat Creek cross a gently sloping area marked with clay hills and occasional badlands and are usually dry except when carrying direct runoff from precipitation. The water supply for the city of Crawford is obtained from a continuously flowing reach of the White River. Additionally, at present about 300 allocated water rights divert water for irrigation from Hat Creek, White River, White Clay Creek and their tributaries. It is not known if Hat Creek had perennial flow as far as the South Dakota state line before these developments took place. Now it becomes intermittent before it reaches the state line because many impoundments reduce inflow from tributaries and diversions for irrigation consume all the remaining flow during the growing season. Gaging records for White Clay Creek in South Dakota and the White River and South Dakota and Nebraska indicate that they probably flow at the state line except under drought conditions.



NIOBRARA RIVER BASIN

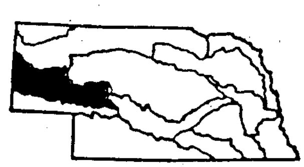
The Niobrara River and many of its tributaries along the reaches from the Wyoming state line eastward to Valentine, are in efficient hydraulic connection with the regional aquifer and in most years groundwater seepage accounts for 90 to 95 percent of the river's total discharge. The Mirage Flats and the Ainsworth irrigation projects divert water in this upper reach from the Niobrara and Snake rivers upstream from Valentine. Eastward from Valentine the river has cut its valley into fine-textured rock that underlies the regional aquifer and yields virtually no groundwater seepage. In some places the river flows on this fine-textured rock but elsewhere it flows on this valley alluvium and is in hydraulic connection with the groundwater in it. The upper reaches of the tributaries to the Niobrara River, particularly those draining the upland to the south, are hydraulically continuous with the regional upland aquifer and have a steady discharge maintained by groundwater seepage. The Snake River, Long Pine Creek and Plum Creek are the three major Sandhills tributaries providing substantial contribution to the base flows of the main stem of the Niobrara. An increase in groundwater discharge due to a rise of the water table beneath the Ainsworth irrigation project accounts for some increase in the low flow of Long Pine Creek, an important tributary to the Niobrara River. Nowhere along its course is the Niobrara known to be a natural source of aquifer recharge. Except for the surface water diversions for irrigation, no progressive loss of flow by perennial streams in the Niobrara River system is certain. However, there may be a losing segment on the Keya Paha River upstream of the Naper Gage.



MISSOURI RIVER BASIN AND MISSOURI TRIBUTARIES

The flow in the main stem of the Missouri River downstream from the Gavins Point Dam consists of releases from the Lewis and Clark Lake, inflows from tributaries and groundwater seepage from the valley alluvium. When at high stages the river may lose water by seepage into the adjacent valley alluvium, but ordinarily the river gains from groundwater seepage into the river channel throughout its length along Nebraska's eastern border.

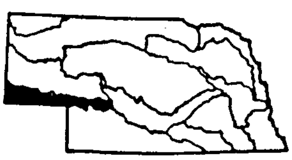
The principal tributaries flowing directly to the Missouri River between Gavins Point Dam and the mouth of the Platte River are Bazile, Beaver, Bow, Aowa, Elk, Omaha, Blackbird, Tekamah, New York, and Papillion creeks. In their uppermost reaches these streams and tributaries that join them flow only in response to overland runoff. When flow occurs, these reaches may be sources of small amounts of recharge to an underlying aquifer. Downstream from these reaches where the streams are hydraulically connected to the groundwater in the valley alluvium, groundwater discharges into the stream channel. As the fine textured valley alluvium transmits groundwater at relatively slow rates, base flow of these streams is small. In the lower reaches, several of these streams are bordered by levees and during high stages these streams probably lose some water by seepage into the Missouri River alluvium.



NORTH PLATTE RIVER BASIN

Much of the flow of the North Platte River originates as snow melt and is controlled by several reservoirs in Wyoming. A large volume of released water from the reservoirs is conveyed by the Interstate and Fort Laramie canals into Nebraska for irrigation. In most years more water enters Nebraska via these canals than enters in the North Platte's main channel. This has resulted in considerably reduced flow in a long reach of the North Platte River near the state line. Vegetation has encroached on parts of the channel no longer scoured clean by high flows and has resulted in reduced groundwater recharge from or discharge to the river. Two important tributaries, Birdwood Creek and Blue Creek rise in the Sandhills region north of the river and have perennial flow maintained by groundwater seepage.

Infiltration of irrigation water below the reach of crop roots has resulted in a buildup of groundwater beneath terrace lands on both sides of the North Platte. Seepage from the groundwater reservoir thus created has given the river a base flow that it formerly did not have. Only part of this seepage enters the North Platte River directly, the remainder reaches the river via several drains plus a series of tributaries that formerly were intermittent but now flow continuously. Thus, due to use of water stored in Wyoming for irrigation of crop land along the North Platte in Nebraska, the North Platte and several tributaries, such as Sheep Creek, have changed from intermittent to perennial streams.

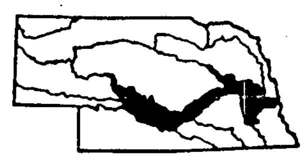


SOUTH PLATTE RIVER BASIN

There is some groundwater discharge to the South Platte River which sustains the baseflow. However, most of the groundwater in the alluvium of the valley in the high region of eastern Colorado and Nebraska is extensively developed for irrigation and the water-table in some areas has been lowered by pumping for irrigation. Seepage to groundwater from beneath irrigated lands in northeastern Colorado helps account for the river not becoming dry near the state line despite average annual inflow being much less now than under predevelopment conditions.

Seepage of groundwater into the South Platte River channel within Nebraska is much greater now than it was under natural conditions. Most of the seepage is derived from the south side of the river—a small amount from beneath the land irrigated with water diverted into the Western Canal and a much larger amount from beneath the land where seepage losses from the South Platte Supply Canal, the Sutherland Supply Canal, Maloney Reservoir, and Sutherland Reservoir have caused a steepening of the water-table gradient northward to the South Platte River. The South Platte River in Nebraska became dry at times prior to 1939 but has not been dry since then. Whereas the South Platte River formerly was a losing stream throughout its length in the state, it now is a gaining stream downstream from the Paxton vicinity because the steepened groundwater gradient has increased seepage into the river.

Throughout a little more than half its length in Nebraska, the channel of Lodgepole Creek, a tributary of the South Platte River, is incised into the Brule Formation, which contains many fractures. Replenishment of storage by seepage from Lodgepole Creek occurs when the creek flows, and in each of the last several years enough of the openings in the Brule have been dewatered that storage space became available for much if not all of the available streamflow. Lodgepole Creek is a losing stream throughout much of its course in Nebraska. In recent years, all or virtually all of the inflow from Wyoming was lost to groundwater storage within the Nebraska reach of the stream. Because of pumping of groundwater, the town of Sidney, in particular, has experienced water-supply problems and is considering relocation of its well field outside the Lodgepole Creek Valley.



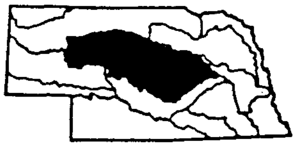
MIDDLE AND LOWER PLATTE RIVER BASINS

The gain or loss of streamflow on the main stem of Platte River is influenced more by water-resources developments than by natural conditions.

Under natural conditions, the reach from the confluence of the North Platte and the South Platte rivers to the mouth of the Loup River probably was subject to long no-flow periods, but now the no-flow occurences are limited to the downstream half of the reach and occur infrequently. These changes in the river's flow regime are the combined results of the water-storage features and the water-use developments in the Platte's drainage area.

Groundwater seepage into the river occurs from both sides of the Platte River between North Platte and Kearney. This seepage is greater now than it was under natural conditions because mounding of the water table due to canal leakage and application of water for irrigation has steepened the water-table slope toward the river. Beginning at about Kearney and continuing into Merrick County, the water table slopes northeastward away from the river instead of toward it, and the river thus becomes a losing stream by providing recharge to the adjacent aquifer. In much of the same reach, the water-table slopes away from the river on the south side also and thus the river loses water by seepage in that direction too.

From central Merrick County to about the mouth of the Elkhorn River, the Platte River loses mostly to the east and north but gains from the south and west. From the mouth of the Elkhorn to the mouth of Salt Creek, the Platte River loses to the Lincoln city well field on its west side. Downstream from the mouth of Salt Creek, it is mostly a gaining stream but in the vicinity of the Omaha well field it is a source of induced recharge. Limited available information on the Platte River tributaries indicate Wood River to be a losing stream between Riverdale and Alda. The loss of flow is believed due to the water table decline that has been caused by groundwater withdrawals for irrigation. Some other tributaries in the Middle Platte basin namely Moores Creek, Prairie Creek and Silver Creek, were formerly groundwater drains, but now are sources of groundwater recharge when they convey overland runoff.



LOUP RIVER BASIN

All of the Loup River's tributaries and in some respects the Loup River itself serve as groundwater drains, some more effectively so than others. Because soils in the Sandhills region are highly absorptive, they transmit to the underlying zone of saturation virtually all the precipitaton not returned to the atmosphere by evapotranspiration. Thus, in this region, comparatively little water reaches streams as overland runoff; instead, streamflow is maintained almost wholly by groundwater seepage into stream channels. In the hardlands region downstream in the basin, less groundwater is in storage and the water table gradient toward the hardlands stream reaches is not as steep toward these stream reaches as in the Sandhills resulting in less groundwater discharge to the streams.

Considerable quantities of water are diverted from the North Loup and Middle Loup rivers into canals that convey water to irrigation projects downstream from the Sandhills. Most diversions occur during the normal irrigation season, but diversions into the canal conveying water to Sherman Reservoir, which stores water for irrigation of the Farwell Project, generally begin earlier and continue longer than the others.

Water is also diverted from the Loup River near Genoa into the Loup River Power Canal. At times the entire river's flow is diverted and if not for inflow to the river from Beaver Creek and for seepage losses from the canal, the Loup River would be dry at its mouth. Most of the water diverted into the power canal becomes inflow to the Platte River about two miles downstream from the confluence of the Loup and Platte.

A curious feature of the Loup River is the unexplained natural loss of water from the river channel. Losses appear to be greatest in the reach between St. Paul and Genoa. For most months the sum of measured plus estimated inflows to the Loup upstream from Genoa is significantly greater than the sum of the amounts diverted into the power canal and remaining in the river. Total losses for the 10-year period 1961-70 were approximately equal to the storage capacity of Lake McConaughy. Because water losses from the reach were recognized by hydrographers at the turn of the century, the losses recorded in the 1961-70 decade can hardly be attributed to water-use developments. Moreover, the losses appear to be too great for evapotranspiration to be their sole cause. Nor due to the configuration of the acquifer can the losses be attributed to seepage into the adjacent aquifer.

A recent study on groundwater inflow characteristics of the Cedar River, Beaver Creek and some nearby streams conducted through extensive baseflow measurements has quantified the flow gains and losses in several continuous reaches of these streams. The study was conducted by the Department of Water Resources and include the following description of those streams.

"The Cedar River rises in the broad, marshy wet meadows of northern Garfield County. It begins its flow towards the Loup River as two small streams, Big and Little Cedar Creeks. Groundwater slowly oozes into the two streams from the surrounding marshes. Reach gains average less than 0.2 cubic feet per second per mile (cfs/mile) [in the upper reaches of Big Cedar Creek].

Further downstream, the small creeks enter more defined channels. It is in this region that the streams experience a considerable increase in baseflow. . . gains on Cedar Creek exceed 7 cfs/mile in the reach immediately downstream from the confluence of Big and Little Cedar Creek. . . . Large, but less dramatic gains characterize the remainder of Cedar Creek before it becomes the Cedar River at the mouth of Dry Cedar Creek near Ericson.

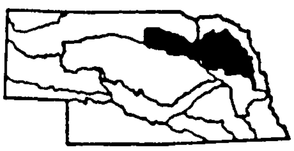
The Cedar River continues to receive substantial amounts of groundwater inflow from Ericson to Primrose. The Sandhills either bound or flank the river valley along much of this reach. Several tributaries, also supported by base flow, enter the Cedar Rier above Spalding. Groundwater enters the Cedar River above Spalding.

There is no significant base flow gain between Primrose and the Fullerton gage. A minor base flow loss occurs in the vicinity of Cedar Rapids. . . .

Beaver Creek, like the Cedar River, rises in the marshlands of the eastern Sandhills. Groundwater begins to enter the shallow channel of Beaver Creek in central Wheeler County. Gains in the headwater region. . . .average 0.2 cfs/mile.

The area of greatest groundwater inflow to the creek occurs in a 19-mile segment. In this reach [which is nearly divided by the Wheeler-Boone County line] the base flow gain amounts to over 2 cfs/mile. Groundwater inflow averages over 2.8 cfs/mile in [a] six mile long portion of the stream [in the northwest corner of Boone County].

Downstream, base flow gains drop to about 1 cfs/mile in Beaver Creek, in the reach just above Loretto. There is little increase in base flow between the gaging station at Loretto and the village of Boone. In a portion of that reach near Albion. . . .there is a slight base flow loss. Beaver Creek again becomes a gaining stream from Boone to its mouth near Genoa. Groundwater inflow amounts to roughly 1.3 cfs/mile in the lower reach of the stream."[4]



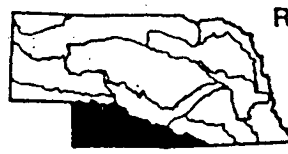
ELKHORN RIVER BASIN

Most of the upstream half of the Elkhorn River's length is in an area of sandy soils bordering the Sandhills area. All tributaries entering the Elkhorn River in this reach head in the Sandhills region lying to the south. Nearly all their flow, also of the upstream half of the Elkhorn River, is maintained by groundwater seepage.

Precipitation on the sandy terrain southwest of the North Fork of the Elkhorn River produces negligible overland runoff and the part not returned to the atmosphere by evapotranspiration infiltrates to the water table. Hence the flow of Willow Creek, a tributary flowing into the North Fork from the west, consists almost wholly of groundwater seepage.

A digital computer model of the hydrogeologic system of the Willow Creek Watershed quantified the recharge and discharge characteristics of the regional aquifer underlying the watershed.[5] According to this study, under average conditions represented by the period 1975-76, the regional aquifer of the Willow Creek Watershed receives recharge from deep percolation of precipitation at the rate of 47,900 acre-feet per year and discharges as baseflow of perennial streams at the rate of 30,800 acre-feet per year. The balance is groundwater moving down gradient.

Groundwater seepage additionally contributes to the discharge of the North Fork downstream from the mouth of Willow Creek. Thus, the Elkhorn River, and most tributaries entering the river upstream from the mouth of North Fork are probably groundwater drains throughout their entire lengths. The lower reaches of most tributaries entering the Elkhorn River downstream from the mouth of North Fork also receive contribution from groundwater, but at a slower rate. However, there are some indications that parts of Yankton Slough, Maple Creek, and part of the Elkhorn between Oakdale and Meadow Grove may be losing segments for at least part of the year.



REPUBLICAN RIVER BASIN

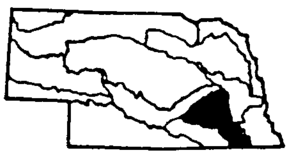
Flows in the Republican River are regulated by storage in reservoirs, reservoir releases and diversions for irrigation. In dry years, when inflows are not sufficient to fill reservoirs, river discharges immediately downstream from the dams are nil, but increase gradually with distance because of groundwater seepage into tributaries and into the river itself. Quantities of seepage are small because the hydraulic connection between water in the regional aquifer and the river or its tributaries is relatively poor. In reaches where adjacent lands are irrigated with river water there is return flow to the river.

Though the direction of groundwater movement throughout the upland in the Republican River Basin is toward the valley of the Republican, only some of the tributaries and part of the river receive enough groundwater seepage to have sustained flow. Tributaries known to have continuous flow are Rock, Frenchman, Red Willow, Medicine, Turkey, Thompson, and Elm creeks. Stinking Water Creek, which is tributary to Frenchman Creek, also has continuous flow. Each of these streams is on the north side of the Republican. Downstream from the mouth of Frenchman Creek, the Republican has continuous flow maintained largely by tributary inflow but in small part from groundwater seepage directly into the river channel. At several places along the Republican River upstream from the mouth of Frenchman Creek, the adjacent bottom land is slightly lower than the river surface and the river loses water by seepage. Phreatophytic vegetation in these low areas not only intercepts groundwater draining from beneath adjacent uplands but also consumes seepage losses from the river. Where the river swings from one side of its valley to the other in the reach downstream from the mouth of the Frenchman Creek, it probably gains from groundwater seepage along one side of its channel and loses by seepage into the adjoining aquifer along its other side.

Depletion of inflow to Enders Resevoir on Frenchman Creek is a matter of concern to irrigators dependent on releases from this reservoir. According to a recent study by Lappala (1978) [6], baseflow of Frenchman Creek near the point of inflow to the reservoir had been reduced by as much as a third by 1975. The reduction is attributed to a decrease of groundwater seepage into the stream channel. This decrease is due to the large aggregate withdrawals of groundwater for irrigation in the Frenchman Creek drainage area. However, lack of expected overland runoff in the study period may also have been a factor.

Some decline of inflow to Hugh Butler and Harry Strunk lakes may occur, via Red Willow and Medicine Creeks respectively, if groundwater withdrawals upgradient from those reservoirs continue to increase at the rate of the past few years.

Early records show periods of no inflow to the state and of no flow at gaging stations on the Republican River downstream to the mouth of Frenchman Creek before any significant water resources developments had occurred in the upstream part of the drainage basin.

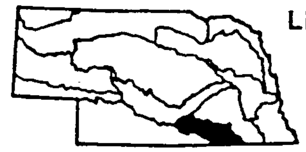


BIG BLUE RIVER BASIN

The upper reaches of most streams in the Big Blue River Basin flow only when precipitation is sufficient to produce overland runoff. Some, however, have a flow maintained by discharge of municipal waste and/or cooling water that originally was pumped from wells. Upstream reaches of all streams are higher than the water table so probably are sources of some recharge to groundwater when they flow. Amounts of recharge generally are not great because the stream beds are mostly fine-textured sediments that transmit water slowly. A research study on stream channel recharge conducted on Lincoln Creek near Bradshaw indicates a relatively low seepage rate of 0.81 inch per day.[7]

Most of the middle and lower reaches are hydraulically continuous with the water table and may be groundwater drains except at times of high flow when the stream surface is temporarily higher than the adjacent water table. However, recent seepage measurements by the Department of Water Resources have given indications that there may be a losing reach between DeWitt and Beatrice.

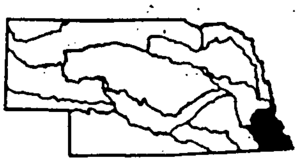
Despite the large groundwater supply beneath the western and central parts of the Big Blue River's drainage area in Nebraska, the Big Blue and its tributaries have relatively low base flows. Discharge of groundwater by evapotranspiration together with the fine texture of the sediments through which groundwater must seep to reach stream channels in this drainage area probably account for groundwater being a small component of total stream discharge. A stream-aquifer interrelationship study was conducted by the USGS in the Big Blue River Basin. It used seepage measurements at the main stem of the Big Blue and the tributaries in Gage County during the fall of 1978 to furnish data to represent groundwater contribution to the flow of these streams.[8] The findings of this study indicated that in the Big Blue River basin, the largest groundwater contributions to streamflow occur in the reaches of the river between the mouth of Turkey Creek and the Beatrice gaging station and between the mouth of Mud Creek and the dam at Blue Springs. However, recent seepage studies by the Department of Water Resources have indicated that the reach between Turkey Creek and Beatrice may not be a gaining reach. The gain in the reach between the mouth of Turkey Creek and the Beatrice gage cannot be determined exactly. The USGS study also indicated that significant groundwater contributions to streamflow occur in two tributaries from Bear Creek and Big Indian Creek.



LITTLE BLUE RIVER BASIN

The Little Blue River and several of its important tributaries namely Big Sandy, Little Sandy, Cottonwood, Rose, Sand and Spring creeks are generally hydraulically continuous with the water table and have sustained flow in their middle and lower reaches. However, the groundwater component of flow is relatively small compared to the overland runoff component. Furthermore, there may be some segments which sometimes lose flow in Spring Creek, Big Sandy Creek, and the west-central portion of the Little Blue River in Thayer County. Pumping of groundwater in the basin appears to have caused very little depletion of the base flow of the Little Blue River and its tributaries. Much of the groundwater moving toward streams is lost to evapotranspiration due to being intercepted by trees and other deep-rooted vegetation on bottom lands. However, Kansas has never made a call for administration of the Kansas-Nebraska compact requirement for apportionment of 45 to 80 cfs of flow on the Little Blue at the state line between May 1 and September 30. In fact, the low flow of some streams may have been increased by the discharge of water from wastewater treatment plants. Also possible is an increase in the low flow of some streams (Big Sandy Creek in particular) due to an increase in the discharge of groundwater from a higher (perched) zone of saturation than the regional zone from which water is pumped for irrigation. Part of irrigation water infiltrating below the root zone of crops may not reach the regional zone, but instead adds to the storage in the higher zone and causes it to discharge to streams at a greater rate than previously. However, no specific data are available to demonstrate whether those possible gains to low flow are significant in amount.

Extensive seepage measurements by USGS on the Little Blue River and its important tributaries in Jefferson County during fall of 1978 provided information on the contributions of groundwater to the flow of these streams.[9] The findings of the USGS study indicate that in the Little Blue River basin the largest contributions to streamflow occur between the mouths of Big Sandy and Little Sandy Creeks (about 6.5 cfs) and the vicinity of Fairbury (about 16 cfs). A groundwater contribution to streamflow of about 6.5 cfs also occurs in Rose Creek, an important tributary of the Little Blue River. The study also concluded that during the growing season the effect of evapotranspiration, stream diversions, and groundwater pumping probably cause the groundwater contribution to streamflow to be somewhat less. Existing groundwater development for irrigation probably has, as yet, had no significant effect on streamflow. However, even at the current degree of development, it is probable that irrigation pumpage of groundwater will cause some decrease in the groundwater contribution to streamflow in the future. The areas of groundwater development likely to have the greatest effect on streamflow are located where buried Quaternary coarse-grained deposits occur in the Rose Creek drainage basin in the vicinity of Fairbury.



NEMAHA RIVER BASIN

The flow of all streams in this southeastern part of Nebraska is highly variable. Large discharges occur in response to runoff generated by heavy rains in steep drainageways, maximum disharge in the Nemaha system of streams namely Weeping Water Creek, Little Nemaha, North and South Forks of Big Namaha, are several hundred times greater than the minimum discharges. Even though the middle and lower reaches of these Nemaha River Basin streams are incised into saturated sediments, the base flows are small because the sediments are fine textured and transmit groundwater at a very slow rate. However, it is interesting to note that certain seepage runs made on the South Fork Little Nemaha River in the vicinity of the town of Cook during fall of last several years through an UN-L Groundwater Geology class under the direction of Professor D.T. Pedersen, have observed a significantly gaining reach of that stream along the Johnson-Otoe county line.