GROUND WATER AND RIVER FLOW ANALYSES

REVISED APRIL 2002

Technical Report of the Platte River EIS Team
U.S. Department of the Interior
Bureau of Reclamation
Fish and Wildlife Service

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Executive Summary

The issue: high ground water levels

Many areas in the Central Platte Valley in Nebraska have been experiencing high ground water levels for several years, causing problems with waterlogged farm fields and flooded basements. Some local land owners are concerned that additional flows generated by the Endangered Species Recovery Program (Program) water management will cause existing problems to become worse.

Analysis of interrelated factors

To determine the range of potential effects from the Program's proposed environmental water account, Reclamation analyzed the relationships of ground water levels, river flows, and precipitation. Our major findings were:

Topography.– Aquifer recharge from precipitation in central Nebraska is relatively high due to the generally flat terrain and the sandy soil textures.

***Geology and soils*.–** The aquifer is highly permeable and has positive connection to the Platte River (meaning ground water can flow easily between the aquifer and the river).

***Climate*.–** Precipitation has been much above normal since 1980, which contributes to water tables that are higher than they have been since the 1950s (the onset of extensive irrigation pumping) and water levels are generally rising.

Irrigation.– Irrigation from river diversions has raised the water table within the irrigated areas and near canals and reservoirs. Irrigation by wells has tended to lower water tables or at least reduce the flow toward the river.

River levels

- River levels have an influence on ground water levels near the river. At distances more than a few thousand feet from the river, the water table elevation is generally several feet higher than the river and thus does not react to river levels.

- Because ground water moves slowly, river rises and adjacent ground water level rises are not simultaneous if the ground water level is responding to a change in the river. Thus, when ground water levels rise at the same time as the river rises, a third factor (e.g., precipitation) must be involved.

- Infiltration in the Platte River Valley is high and the storage capacity is about 15 to 20 percent. One inch of rainfall that reaches the water table raises the water table 5 to 6 inches.

- Ground water levels in the Central Platte Valley outside the flood plain are typically higher than the river elevation. Therefore, water movement is toward the river. Currently, the one exception is in the Upper Big Blue and Little Blue River drainage where the natural gradient is away from the Platte River to the southeast.

- Within the primary flood plain, the ground surface is typically 1 to 3 feet above the river water level. In such conditions, evaporation and plant usage work to lower the water table to roughly the same elevation as the river. When this condition develops, ground water movement tends to be down the valley parallel to the river.

- From 1980 through 1999, total precipitation at 11 stations in the Central Platte Valley averaged 42 inches greater than normal. The smallest excess precipitation for the period was 20 inches at Paxton, and the largest excess precipitation for the period was 67 inches at Loup City. Several of the stations have received 10 percent or more above normal for the past 19 years.

PROGRAM FLOWS

During the first increment of the Proposed Program (10 to 13 years), the Program will seek to provide improved flows in the Central Platte River for endangered species. Two proposed types of Program water releases were analyzed:

- **Pulse flows** of 6,000 to 10,000 cubic feet per second would raise the river level at most 10 to 12 inches (but not above full bank capacity) for 3 days. Under this regime, ground water levels would rise about 2½ inches 1,000 feet from the river and up to ½ inch 2,000 feet from the river. At 3,000 feet from the river, ground water level changes would be too small to measure.

- **Base flow augmentation** would add 500 to 1,000 cubic feet per second to existing flows. These increases would be provided several times during the year to meet various species' needs. Flows would raise the river by about 5 inches. If this continued for 30 days, ground water levels would raise about 3.5 inches 1,000 feet from the river and 2 inches 2,000 feet from the river. Ground water levels 1 mile from the river would not be affected.

PROBLEM: HIGH GROUND WATER LEVELS

Low-lying areas along the Platte River Valley in Nebraska (from North Platte east to Grand Island and beyond) are subject to high ground water levels. These levels can cause waterlogged farm fields and flooded basements. In recent years, these problems have been somewhat more widespread for a variety of interrelated reasons. In 1999, for example, rainfall totals ran almost 7 inches above normal. Irrigation was delayed well past the normal start of the irrigation season and irrigation managers reported that they had "a high water table problem all over." The only pumps running were those draining basements and flooded fields (*Kearney Hub*, "June rain surplus puts irrigation pumps on hold," July 1, 1999).

The Platte River Endangered Species Recovery Program is examining possible ways to augment flows at critical times.

People currently experiencing problems with high ground water levels are concerned that higher river flows could aggravate their problems.

Even during times of above normal precipitation, flows in the Platte River at certain times in the year are not enough to meet the needs of several endangered species. In July 1997, the states of Colorado, Nebraska, and Wyoming, and the U.S. Department of the Interior (DOI), signed a cooperative agreement to make more water available in the river at times when wildlife can use it, and to provide more habitat acreage along the river. Numerous agencies in the three states and the DOI are working with water user organizations, local farmers and landowners, and environmental groups to develop a Program aimed at improving land and water habitat for four threatened and endangered species that use the Central Platte River in Nebraska. These groups have not yet completed work on a Proposed Program. At some time in the future, this Program may modify streamflows to benefit threatened and endangered species. Some people currently experiencing water-logged farm fields and flooded basements are concerned that streamflow increases, if made in the future, could aggravate existing problems from high ground water levels.

Analyses and Report

This study analyzed:

The current situation.–Changes in groundwater levels stem from a variety of changing factors. This study analyzed these factors to form a better picture of the causes for current high groundwater levels.

Possible future.–The Program is determining potential alternatives for improving land and water habitat. This study assessed the effect of future Program flows on ground water levels.

Data Collection

In order to examine "real time" relationships between rainfall, river levels and ground water levels, Reclamation in cooperation with the Central Platte NRD, the Tri-Basin NRD, and the U.S. Geological Survey initiated an intensive data collection program in the Central Platte Valley in March 1999 and continuing through 2000.

- *Rainfall.–* Precipitation data were taken from NEXRAD radar images that can be translated into estimated precipitation amounts on a daily basis.

- *Ground water levels.–* The Central Platte and Tri-Basin Natural Resource Districts established a series of eight lines, or transects, of monitoring wells across the Platte River. On March 11, 1999, Reclamation installed continuous electronic data loggers on 26 of the wells, which recorded the water level in each well once every hour through September 17, 1999. On March 5, 2000, recorders were installed on 16 of the wells. Figure 1 shows the locations of all the wells that Reclamation monitored in each year, and the locations of the U.S. Geological Survey (USGS) transects used in the May 25-27, 1999, snapshot.

  In addition, the USGS developed a snapshot of ground water elevation for the entire Central Platte Valley for the end of May 1999. Between May 25 and 27, 1999, USGS personnel measured groundwater levels in 77 irrigation wells next to the Platte River and surface water levels at 35 locations along the Platte River. These water levels were measured when little widespead rainfall had occurred and river discharge was believed to be affected minimally by upstream rain events.

- *River Levels. –* Hourly river stage data were recovered from the USGS web site for the transect pairs near Overton, near Kearney, and near Grand Island gauges on the Platte River for the same period that the wells were monitored.

ANALYSES

To determine the range of potential effects from the Program's proposed environmental water account, Reclamation analyzed recently collected data on rainfall, groundwater levels, and riverflows which illustrate the effects of rainfall and river levels on ground water levels in the valley.

Reclamation monitored 28 existing wells daily in four lines across the Platte River (at Overton, Elm Creek, Minden, and Alda), and compared daily readings from these wells with three Platte River gauges and precipitation data from March 11 through September 17, 1999. In the spring of 2000, monitors were installed in 16 of the wells to provide supplementary data. Reclamation analyzed statistical relationships among precipitation, riverflows and ground water levels.

Conclusions are noted in the sidebars for each section. The text provides rationales and the appendices provide the analyses and results for these conclusions.

The USGS read all accessible wells within the Central Platte River corridor to provide a snapshot of groundwater levels on May 25-27, 1999. Historic precipitation trends were analyzed to assess their probable influence on ground water levels. A theoretical analysis also was done on the interaction between river levels and ground water levels using Glover's Bank Storage equations.

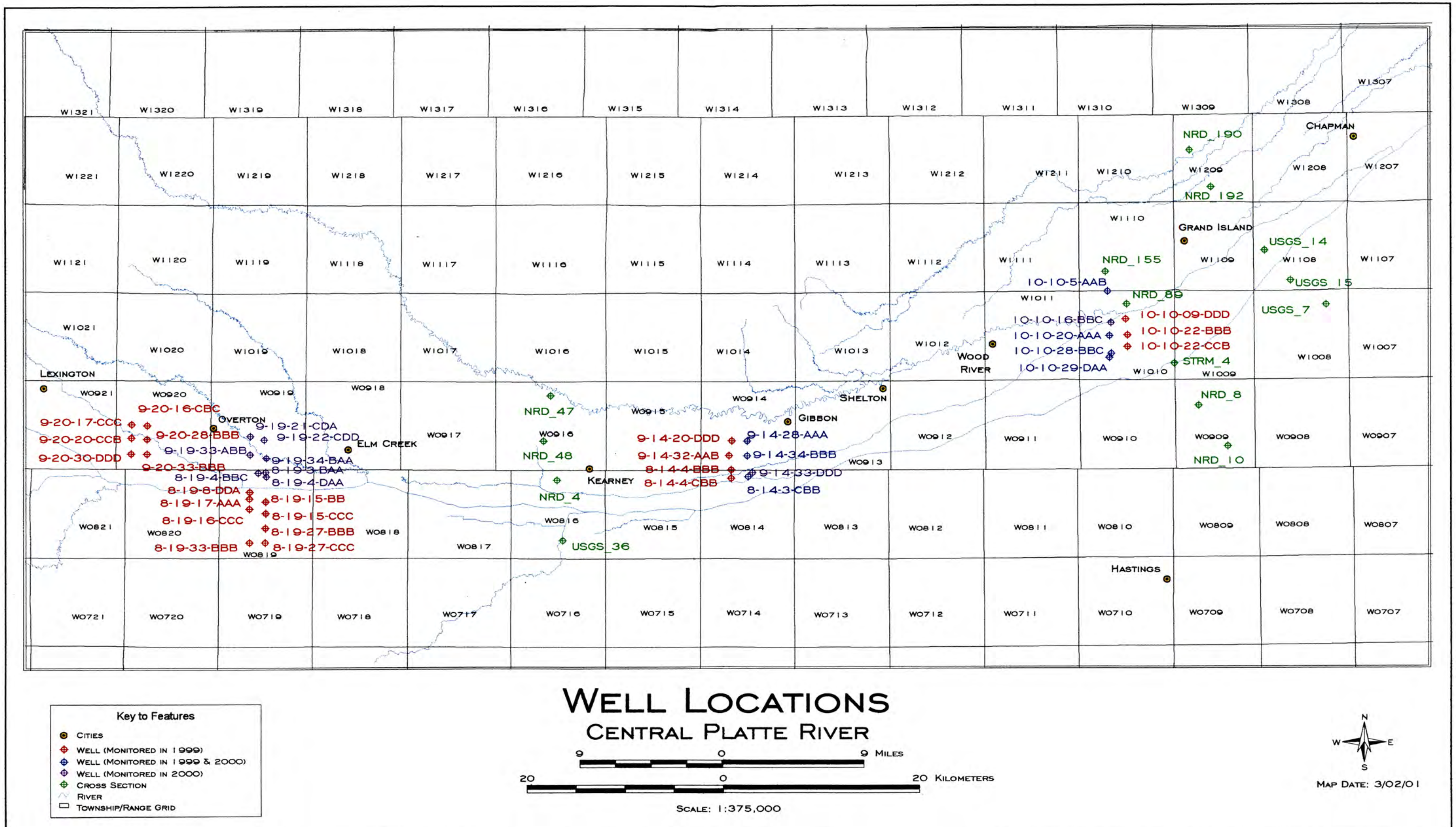
HISTORIC SURFACE AND GROUND WATER REGIMES

The Platte River flow regime has changed since pre-development times, when the river had large spring floods and often went dry in late summer.

Upstream dams and reservoirs, such as Kingsley Dam at Lake McConaughy and others farther upstream, and other irrigation features have greatly reduced the spring flood's magnitude and volume in the Central Platte. Simons (1999) reports "pre-development conditions" (pre-1930) peak flows from 15,000 to 45,000 cubic feet per second (cfs), averaging 16,000 cfs. Currently, peak flows are 3,000 to 24,000 cfs, with an average of 8,600 cfs.

Also, in more recent times, irrigation has created surface and ground water runoff to the river throughout the summer. There has not been a no-flow month on the Platte River since 1947.

Topographically, the Platte River lies at an elevation several hundred feet higher than the Republican River some 40 miles to south of the Central Platte River and significantly



Well Locations
Central Platte River
Key to Features
Cities
Well (Monitored in 1999)
Well (Monitored in 1999 & 2000)
Well (Monitored in 2000)
Cross Section
River
Township/Range Grid
9 0 9 Miles
20 0 20 Kilometers
Scale: 1:375,000
N
W
E
S
Map Date: 3/02/01
Lexington
Overton
Elm Creek
Kearney
Gibbon
Shelton
Wood River
Grand Island
Chapman
Hastings
9-20-16-CBC
9-20-17-CCC
9-20-20-CCB
9-20-30-DDD
9-20-28-BBB
9-20-33-BBB
9-19-21-CDA
9-19-22-CDD
9-19-33-ABB
9-19-34-BAA
8-19-3-BAA
8-19-4-BBC
8-19-4-DAA
8-19-8-DDA
8-19-17-AAA
8-19-15-BB
8-19-15-CCC
8-19-16-CCC
8-19-27-BBB
8-19-33-BBB
8-19-27-CCC
NRD_47
NRD_48
NRD_4
USGS_36
9-14-20-DDD
9-14-32-AAB
8-14-4-BBB
8-14-4-CBB
9-14-28-AAA
9-14-34-BBB
9-14-33-DDD
8-14-3-CBB
10-10-5-AAB
10-10-16-BBC
10-10-20-AAA
10-10-28-BBC
10-10-29-DAA
10-10-09-DDD
10-10-22-BBB
10-10-22-CCB
NRD_155
NRD_89
STRM_4
NRD_8
NRD_10
NRD_190
NRD_192
USGS_14
USGS_15
USGS_7
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W1111
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W1109
W1108
W1107
W1021
W1020
W1019
W1018
W1017
W1016
W1015
W1014
W1013
W1012
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Figure 1

higher than the Big Blue and Little Blue Rivers to the southeast. In pre-development times, ground water generally sloped from the Platte Valley toward these other streams.

LONG-TERM TRENDS

Long-term trends in ground water levels in central Nebraska can be divided into four categories using 1950 as the pre-development benchmark. Based on data retrieved from the Nebraska Department of Natural Resource website (figure 2), there are areas of accretion, areas of depletion, areas of depletion and recovery, and areas of no change.

Much of Kearney, Phelps, and Gosper Counties is in an area of accretion where a ground water mound has developed under lands irrigated by water supplied by the Central Nebraska Public Power and Irrigation District. The mound has reached elevations as high as 100 feet above historic levels, creating a distinct ground water divide between the Platte and Republican Rivers.

Ground water supplies under large parts of Dawson, Buffalo, Hall, and Adams Counties were depleted by 10 to 20 feet during the 1950 to 1970 decades. A large part of Adams County and a 40-thousand-acre area near the middle of Buffalo County have not recovered although readings since 1990 generally show an upward trend.

Most of Hall, Dawson, and Buffalo Counties began recovery in about 1980 and have reached or exceeded pre-development levels.

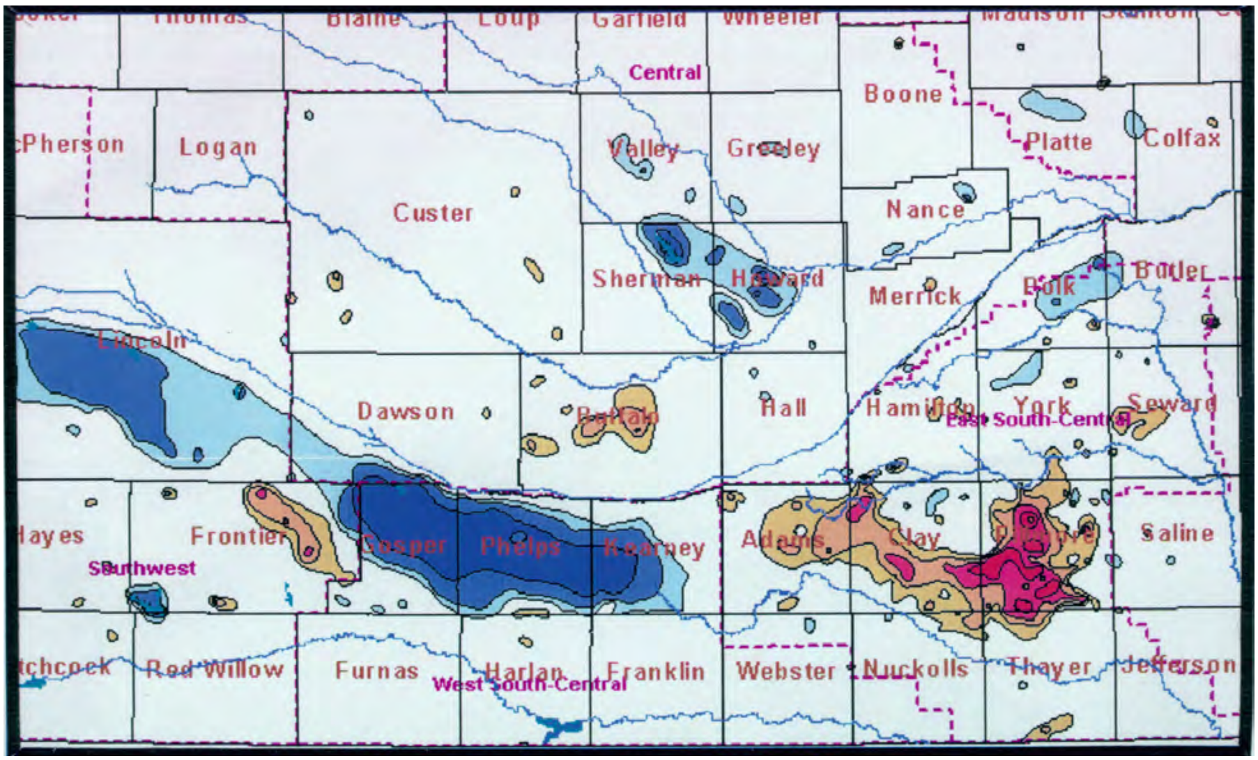
The flood plain area of the central Platte River has not changed within the recorded water level period. These areas typically are subject to water tables of less than 5 or 10 feet.

CURRENT LOCAL GROUND WATER LEVELS

Figure 3 shows the direction of ground water flow between May 25th and 27th, 1999, through the central Platte Valley and the locations of sections A-A', B-B', and C-C' (Stanton, 2000). Figures 4a, 4b, and 4c show ground surface and water table levels at sections A-A', B-B', and C-C', respectively. Ground water tends to move toward the river, except on the south side of the Platte River in the upper Little Blue River drainage basin to the southeast of Grand Island.

Monitoring of water levels in the 28 wells shows ground water changes from March to September. From March through early May, the water level in most of the wells was 1 to

Areas of Significant Groundwater Level Changes
Observation Well Database
Pre-development Changes



Legend

Changes since Pre-development

Rises in Feet

- more than 50
- 20 to 50
- 10 to 20

Declines in Feet

- -5 to -10
- -10 to -15
- -15 to -20
- -20 to -25
- -25 to -30
- more than 30
- Subdivision Boundaries
- Major Lakes and Reservoirs

Figure 2

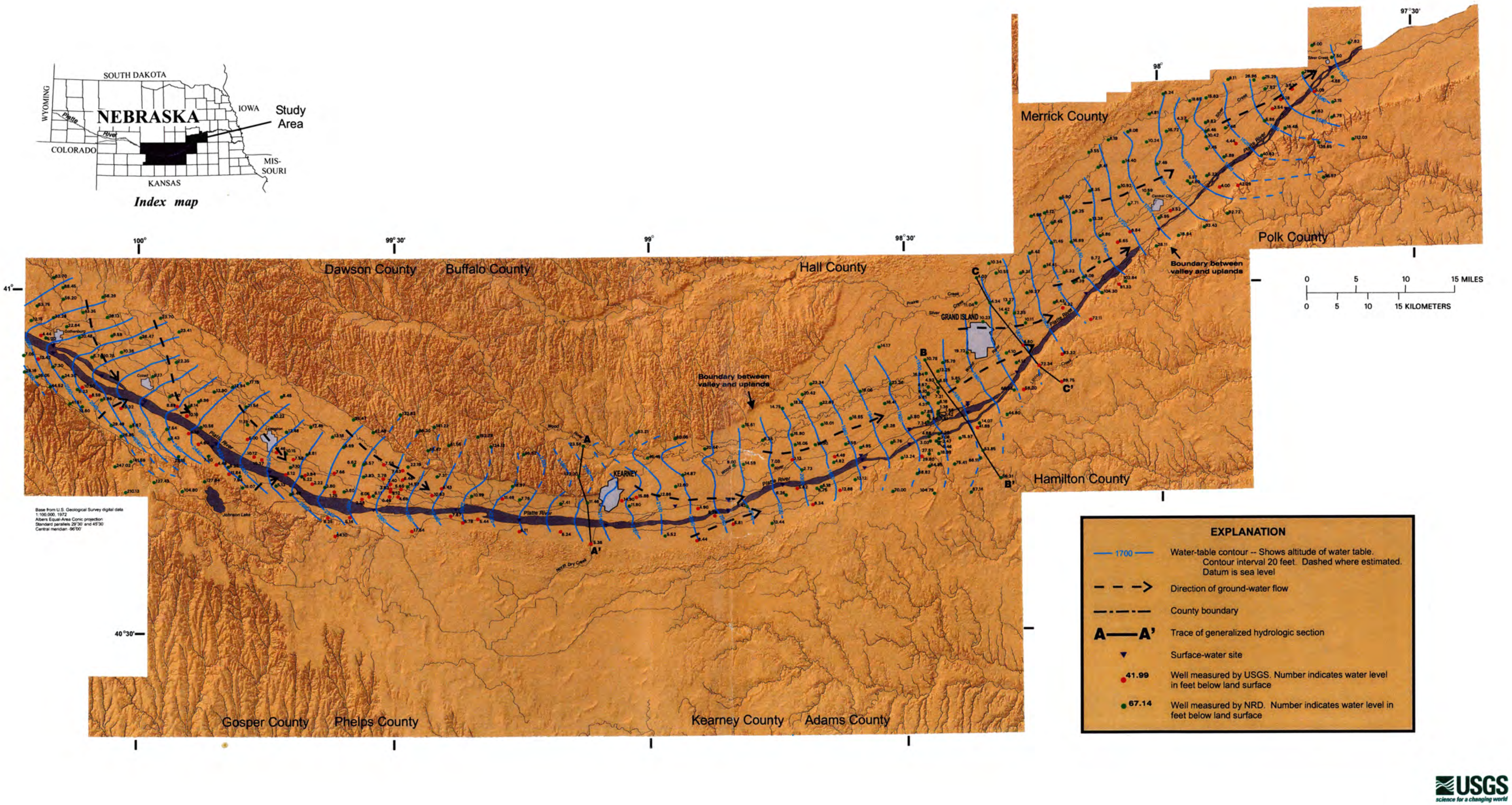


Figure 3. Generalized water table configuration and direction of ground water flow, central Nebraska, spring 1999.

Considering all these factors is essential in understanding the rise and fall of the local water table:

1. Topography
2. Geology
3. Climate
4. Crop consumption
5. Irrigation
6. Urbanization
7. Ditches and drains
8. Local river levels

2 feet lower in elevation than when the snapshot was taken on May 25th and 27th. After June 1st, nearly all of the wells that were monitored through the summer of 1999 rose to higher levels, increasing the gradient toward the Platte.

Because the ground water level is generally higher than the river and sloping toward the river, the flood plain lands have very shallow water tables. The primary flood plain generally has ground water levels that are from 1 to 3 feet above the water level in the river, and the flood plain varies in width from a few feet to as much as 2 miles on either side of the river. Any significant precipitation event causes the water table to rise to levels that are harmful to low lying agricultural lands as well as basements. Because the water table slopes toward the river, topographic lows farther from the river also experience normal water table depths in the 5 to 10 foot range or shallower. Ground water levels in topographical lows in the May 25-27, 1999, snapshot were within 5 feet of ground surface at points nearly 10 miles from the Platte River.

As figure 4-b section B-B' shows, the ground water elevation is close to the surface, particularly from the Platte River to beyond the Wood River. The right hand side of the graph shows the lower ground water levels on the south side of the Platte River.

(See appendix D for more detailed maps of the gaining and losing reaches of the Platte River.)

Ground Water Influences in the Platte River Valley

Simply put, the local depth to ground water depends upon how much water is brought into an area, both above ground and underground, and how fast that water is drained from or pumped out of the ground. Natural conditions (e.g., topography, geology, climate, and crop consumption) determine the location of the water table. Human activities (e.g., pumping for irrigation or municipal/industrial uses, urbanization and paving, water management facilities such as flood control channels and irrigation canals, and lawn watering) modify these natural factors.

Along the Platte River in Central Nebraska, records show that the water table within a few hundred feet of the river is usually 1 foot or more higher than the river. At distances

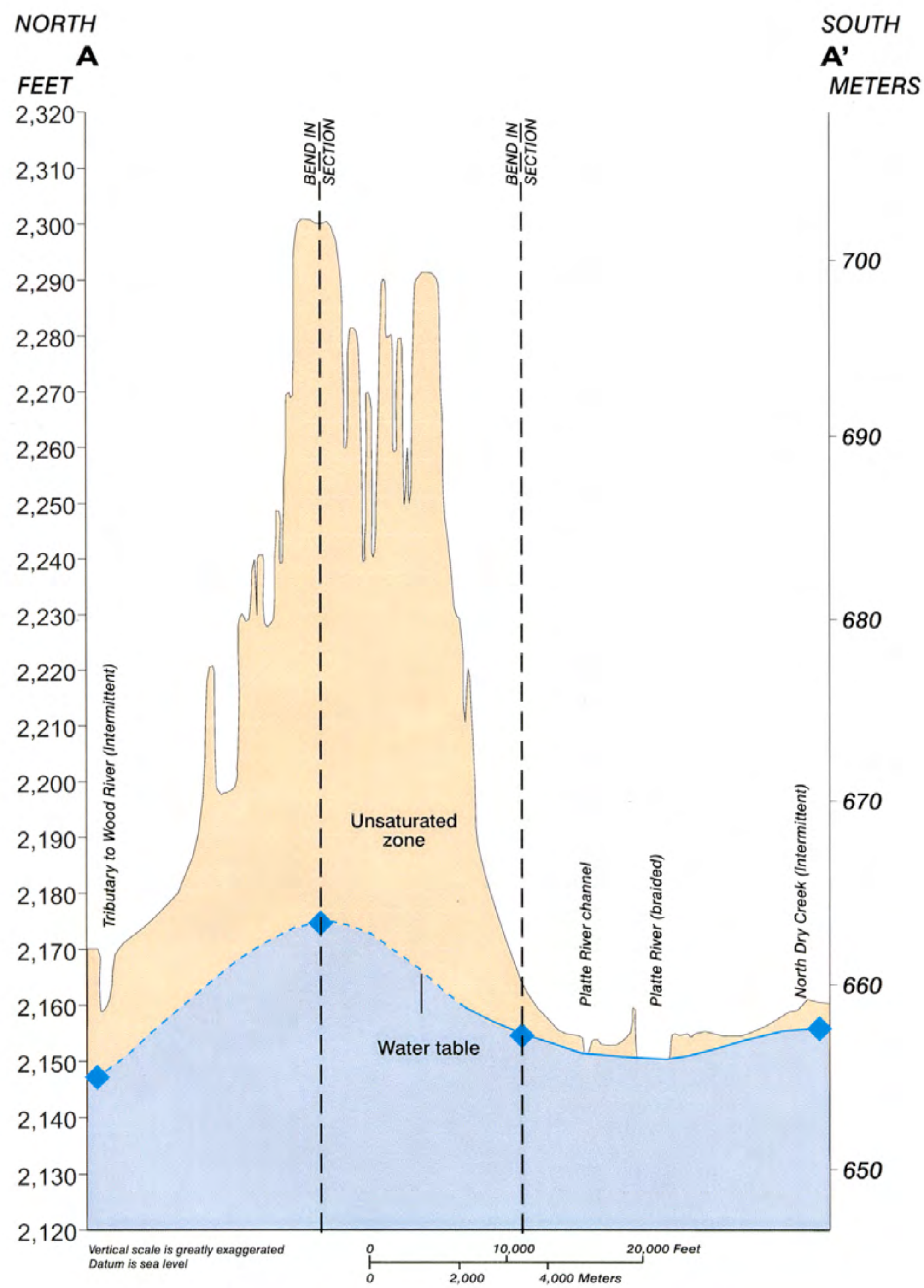


Figure 4a. Generalized hydrologic section A-A', near Kearney, spring 1999. Trace of section shown in figure 3.

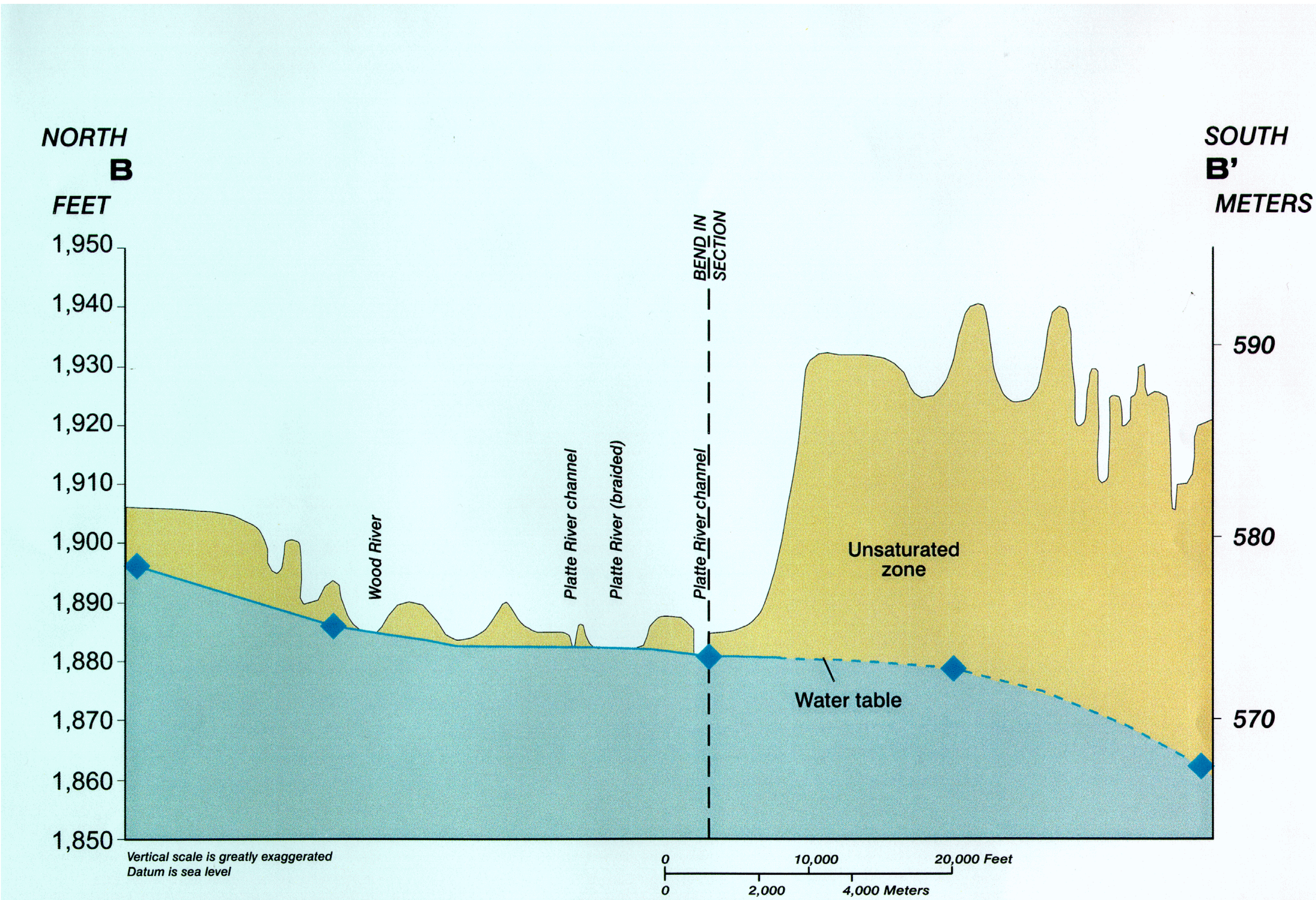


Figure 4b.—Generalized hydrologic section B-B', west of Grand Island, spring 1999. Trace of section shown in figure 3.

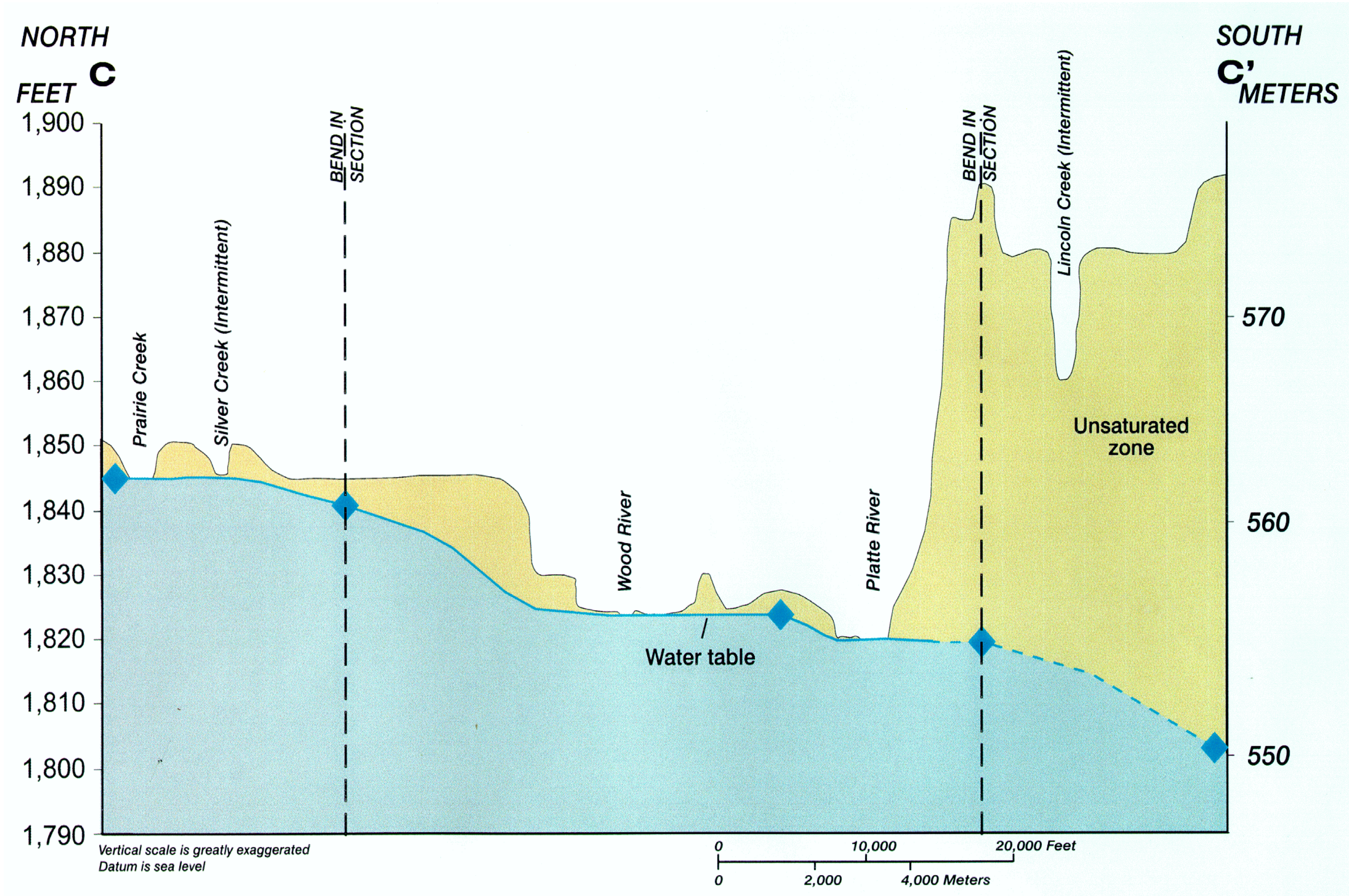


Figure 4c.—Generalized hydrologic section C-C', east of Grand Island, spring 1999. Trace of section shown on figure 3.

of several thousand feet from the river, the water table is nearly always several feet higher than the river. The exceptions that do occur are invariably related to geology and irrigation withdrawals, such as in the head waters of the Little Blue River east of Gibbon where the ground water levels are naturally lower, establishing a ground water gradient away from the river.

TOPOGRAPHY

Aquifer recharge from precipitation in central Nebraska is relatively high due to the generally flat terrain and the sandy soil textures. The three possible outlets for ground water are rivers, pumping, and consumptive use by plants.

The top of the water table depends on the elevation where ground water comes to the surface (for example at natural streams, springs, man-made drains, or pumps). Groundwater surfaces can never be lower than these discharge points.

Topography also affects how much of the precipitation seeps into the ground, thus increasing the volume of ground water. On steep slopes, a large portion of rainfall runs off as surface water. In flat to gently rolling land, less water runs off and more soaks into the soil. Water that soaks in replenishes soil moisture in the root zone for plants to use, or it moves all the way to the water table and becomes part of the ground water, thus raising the elevation of the water table.

Within the primary flood plain, the ground surface is typically 1 to 3 feet above the river water level. In such conditions, evaporation and plant usage work to lower the water table so ground water movement tends to be down the valley parallel to the river.

The Platte River Valley is characterized by flat to gently rolling topography and high infiltration rates. Through much of the valley, the primary flood plain lies 1 to 3 feet above the water surface of the river and is flat for several hundred feet away from the river. Therefore, a large portion of rainfall does not run off but infiltrates the soil and moves beyond the root zone to eventually become ground water. The Platte River channel is the lowest point in the Central Platte Valley. Because ground water moves to the lowest point, it generally moves toward the Platte River.

Geology and Soils

The surface soil texture controls how fast water can infiltrate the soil to become ground water. In the study area, soils generally are sandy, light textured, and highly permeable. Infiltration in the Platte River Valley is high and the storage capacity is about 15 to 20 percent. One inch of rainfall that reaches the water table raises the water table 5 to 6 inches.

The aquifer is highly permeable and there is no barrier between the aquifer and the river.

The Central Platte River has a strong connection to the High Plains Aquifer System (the surface soils and the underlying Ogallala formation) (figure 5). Therefore, water movement between the river and the aquifer system is relatively unrestricted, responding primarily to changes in gradient as the water seeks its lowest level.

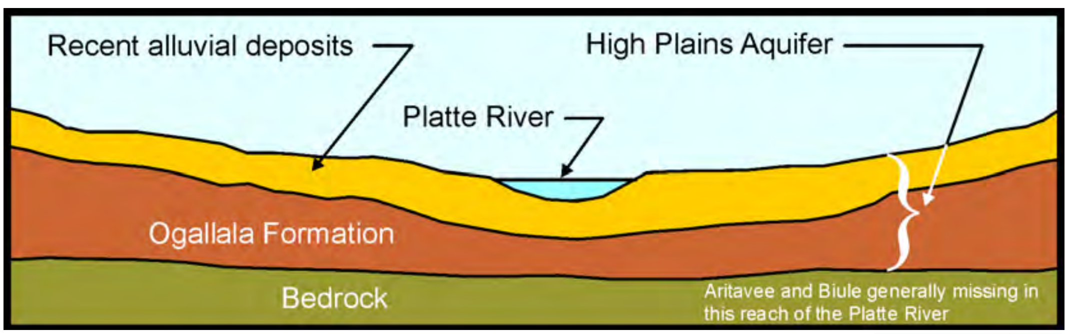


Figure 5

USGS science for a changing world

Climate

The climate dictates the amount of precipitation available for infiltration and the intensity of precipitation events. Higher intensity rainfall produces more runoff while gentler rains tend to produce more infiltration. Central Nebraska usually gets high intensity events (e.g., cloudbursts) in the late spring and summer and longer duration, gentler rains during cooler periods.

Precipitation has been well above normal since 1980, which contributes to water tables that are currently higher than they have been since the 1950s and are generally rising.

In general, water table elevations rise in years with above normal rainfall and fall in years with below normal rainfall. In the past 20 years, precipitation in the Central Platte Valley has been well above average. Precipitation during the early part of the twentieth century was well above normal. Beginning in the 1930s, it dropped below normal and did not return to above normal until the early 1980s. Since then it has been above normal except for a short period in the early 1990s. Figure 6 PRECIP compares annual precipitation at Grand Island with the one hundred year average precipitation from 1900 to 1999.

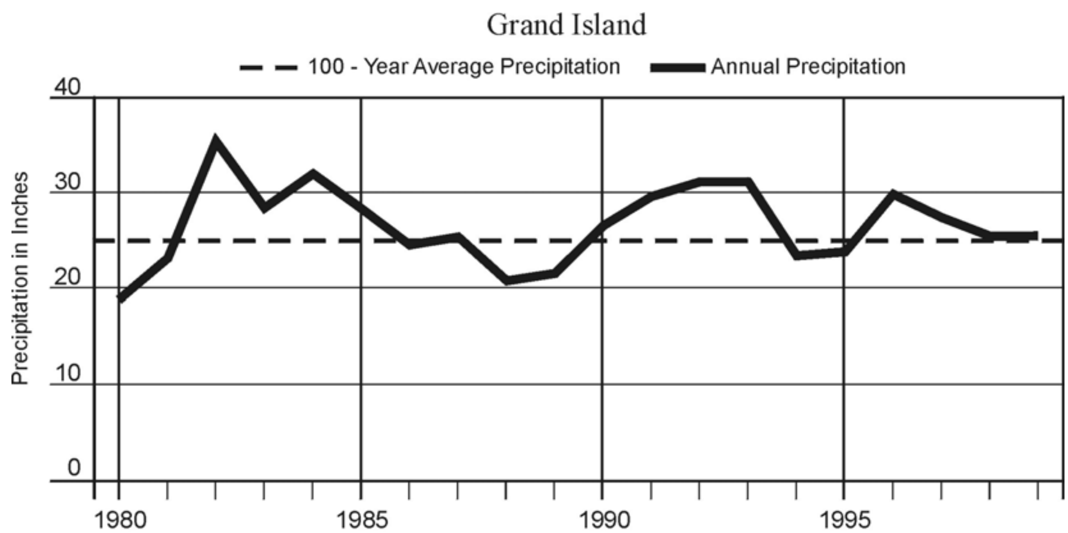


Figure 6

From 1980 through 1999, total precipitation at 11 stations in the Central Plate Valley averaged 42 inches greater than normal. The smallest excess precipitation for the period was 20 inches at Paxton, and the largest excess precipitation for the period was 67 inches at Loup City. Several of the stations have received 10 percent or more above normal for the past 19 years.

This unusually high precipitation and recharge to ground water over the last 20 years has raised the water table well above levels that existed in the 1950s. High precipitation has also produced generally higher river flows in the last few years. Seven out of the last ten years have seen annual flows higher than the 1935-99 median flows.

Crop Consumption

Vegetation consumes soil moisture, which influences the amount of water added to the water table by rainfall. Evapotranspiration is the amount of water that plants consume and that evaporates from the soil surface. This water is removed from the root zone and does not enter the ground water. Plants draw moisture from the plant root zone, which typically is 2 to 6 feet in depth. The root zone may be replenished by irrigation or by precipitation. The sandy soils in the Platte River Valley can hold 1 to 2 inches of readily available water per foot of soil (the water holding capacity). When the water holding capacity is exceeded, the surplus water percolates to the water table.

IRRIGATION

Irrigation from river diversions has raised the water table within the irrigated areas and near canals and reservoirs.

Irrigation by wells has tended to lower water tables or at least reduce the flow toward the river.

Using surface water to irrigate contributes to the ground water whereas using ground water to irrigate depletes the ground water. Up to 70 percent of the surface water brought in for irrigation can end up percolating down to the ground water table through canal and ditch losses and deep percolation. Conversely, using ground water to irrigate lowers ground water levels by the amount of water consumed by plants and evaporation.

Irrigation water in the Platte Valley comes from both ground and surface water. Often, conjunctive use systems supplement surface water with ground water. The intermixing probably tends to stabilize the water table.

Ground water irrigation magnifies the normal pattern of lower water tables in dry years and higher water tables in wet years. In dry years, there is higher demand on ground water and, therefore, more pumpage; while in wet years, the percentage of deep percolation is greater adding to the ground water recharge. Long-term intensive pumping will lower the water table locally, but if pumping is discontinued or reduced, the water table will usually recover over time.

Acreage irrigated from ground water in the Central Platte Natural Resource District has increased each year since 1950 and has increased an average of one percent a year for the last 10 years. Figure 7 tracks the increases in irrigation wells and acres under irrigation for the Central Platte Natural Resources District (Woodward, 2000, personal communication). At the same time, conservation methods may have reduced the amount of ground water pumping. The State Natural Resources Commission home page lists numerous ongoing programs designed to retard surface runoff and increase ground water storage and states that “As a result of these efforts, over 160 irrigators are now pumping 4.2 billion gallons [nearly 13,000 acre-feet] less water . . .” (Hinrichs, et al., 2000). Conservation practices such as using low energy precision application sprinkler systems and modified tillage methods decrease net depletion by 7 and 24 percent, respectively (Boldt et al., 1998). These conservation practices are being implemented by farm operators in response to environmental and economic pressures.

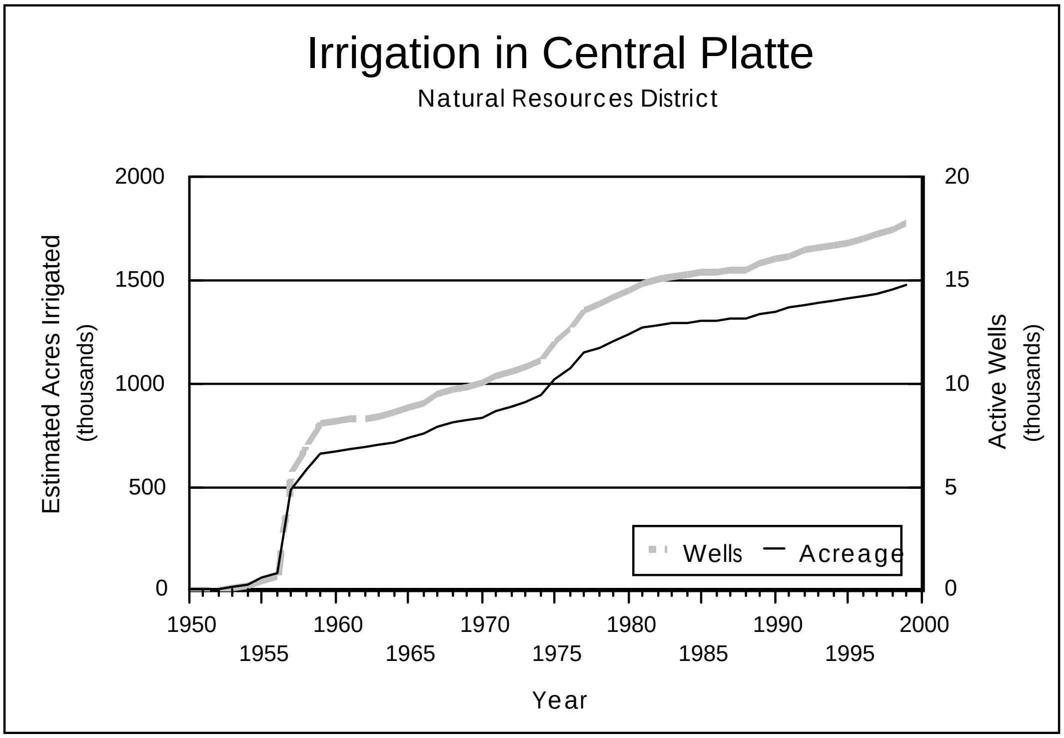


Figure 7

While no on-site data have been collected that would support a definitive analysis of how effective the conservation practices have been, a total savings of one percent or more per year over the last 10 years seems well within the realm of possibility. Therefore, even as irrigated acreage is slowly increasing, the demand on ground water may be constant or diminishing. This would tend to counteract the overdraft conditions that lowered the water table during the 1960 and 1970 decades.

URBANIZATION

> Urbanization may have some local effects on groundwater.

Urbanization has conflicting influences on the water table. Paving streets and parking lots increases the percentage of rainfall that runs off to streams rather than seeping into the ground. Although, urban lawns, parks, golf courses, etc. tend to increase recharge to the aquifer in the Grand Island area, urbanization of irrigated land is a factor that is difficult to assess. The water table in and around Grand Island seems to be rebounding from earlier depletion from pumping ground water for irrigation. The cause may be a combination of urbanization and several years of above normal precipitation.

However, hydrographs of four observation wells within the urban area appear to be consistent with well hydrographs representing Dawson, Buffalo, Hall, and Merrick Counties.[1]

Based on this rather meager data sample, urbanization does not seem to be a major factor at a regional level, but may have some local effects.

DITCHES AND DRAINS

Surface water drainage ditches (e.g., roadside ditches) usually contribute locally to the ground water as they convey surface runoff though areas of deeper ground water. Subsurface drains tend to reduce ground water levels by lowering the discharge elevation point. The extent of ditches and drains has not changed significantly in recent years.

LOCAL RIVER AND STREAM LEVELS

Rivers act as drains for both surface and ground water. The water level in a local river is, in effect, the spillway elevation for the local ground water reservoir. If the water table within the river basin is not artificially lowered by pumping, ground water levels will always be higher than a river and ground water will move toward the river.

A rise in a river's surface elevation will have some effect on the water table near the river as the ground water adjusts to a higher discharge point. The longer the rise is maintained, the farther from the river the effect will be noticed. However, river rises must persist for several months to have any impact on ground water levels outside of the immediate vicinity of the river, because ground water moves quite slowly through the ground (typically from 10 to100 feet per year in the sandy Platte Valley soils).

> Because ground water moves slowly, river rises and ground water level rises are not simultaneous if the ground water level is responding to a change in the river. Thus, when ground water levels rise at the same time as the river rises, a third factor (e.g., precipitation) must be involved.

The following factors determine the effects that a rise in river level can have on local ground water levels:

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[1] The four well hydrographs observed are 11N-9W-4CD-1, 11N-9W-12DC-1, 11N-9W-26AA-1, and 11N-9W-29BB-1; all of which have records beginning in 1935.

- *Aquifer characteristics.–*The characteristics of the aquifer determine how quickly the water table will respond to changes in river elevation and to what distance from the river significant effects will be seen.

- *Distance from the river.–* The farther away from the river, the less influence changes in river elevation will have on the ground water level. The influence drops off geometrically rather than linearly, so the effect diminishes rapidly as distance from the river increased.

- *Elevation of the river compared to the local groundwater.–* Water seeks its lowest level. If the water table is higher than the river, water moves toward the river. If the river rises suddenly but ground water levels are higher than the river, ground water further from the river will continue to move toward the river while water in the river will begin moving into bank storage. Figure 8 shows this relationship.

- *Time since any rise in river level occurred.–*Bank storage continues until the next change in the river elevation, or until the new river level reaches a balance with the water table elevation.

Ground water levels in the Central Platte Valley outside the flood plain are typically higher than the river elevation. Therefore, water movement is toward the river.

Ground water in an unconfined aquifer, just like surface water, always flows toward the lowest point. When the water table is higher than the river, ground water moves downward toward the river's lower elevation. The ground water movement can change somewhat when the river rises. This effect can be analyzed by Glover's Bank Storage method, which models the interaction between the river and ground water. Figure 8A-D depicts a conceptual model of this movement. When the river rises, the water surface of the river becomes higher than the ground water surface just outside the bank (figure 8B). Water begins to move out from the river into the bank, creating bank storage. A few hundred feet away from the river where the ground water surface is still higher than the river water surface, ground water continues to move toward the river. As these flows meet, the ground water surface must rise to accommodate the added volume of water (figure 8C). When the river returns to its previous level, the water that was stored in and near the bank begins to return to the river, until the ground water levels return to their original elevations (figure 8D). If the river stayed at the higher elevation for 3 or 4 weeks, the ground water surface very near the bank would rise to the new level of the river, but at a distance of ½ mile or more from the river the change would be too small to measure. Note that a rise in the level of the river can never cause a rise in ground water levels to an elevation higher than the river.

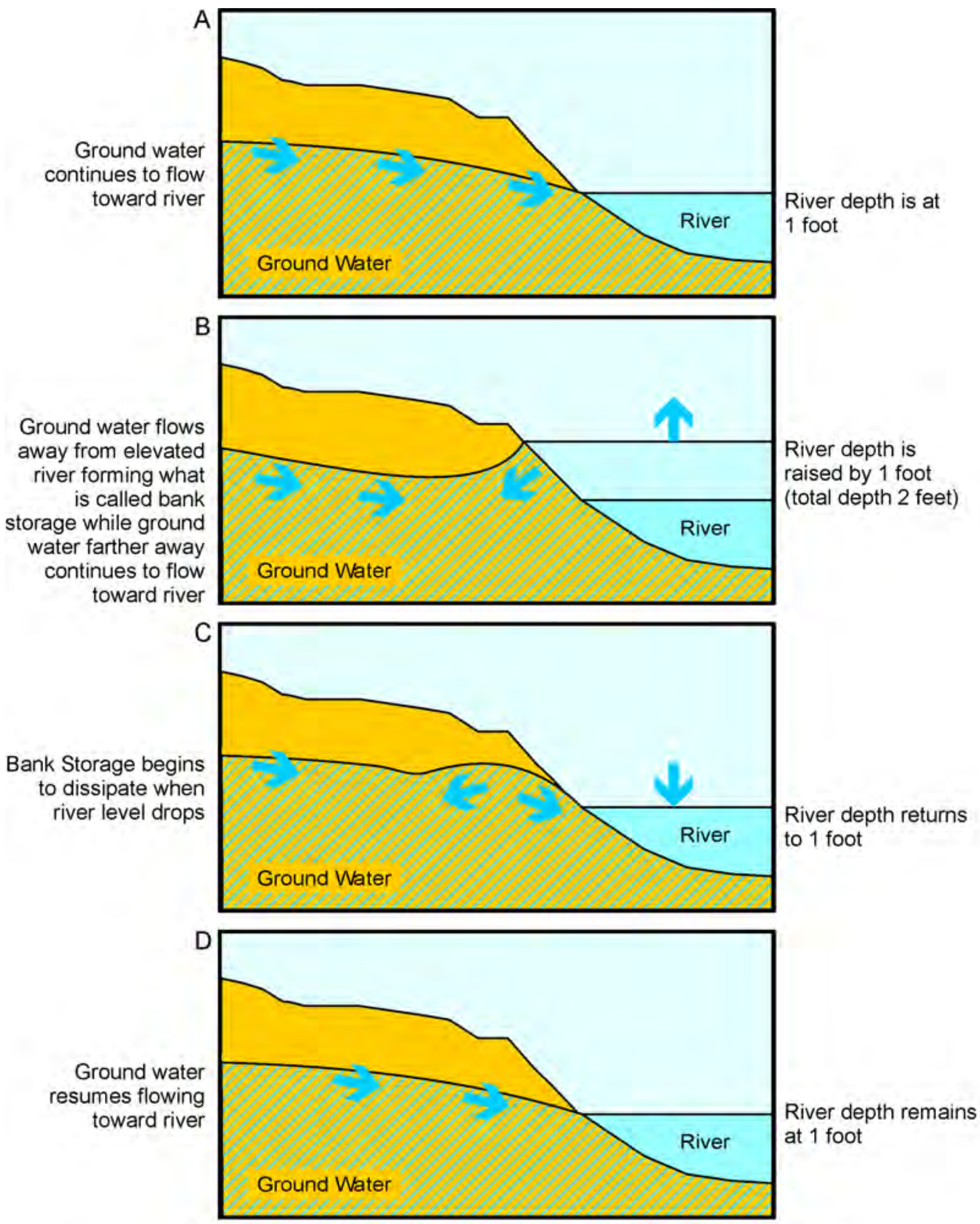
A
Ground water continues to flow toward river
River
Ground Water
River depth is at 1 foot
B
Ground water flows away from elevated river forming what is called bank storage while ground water farther away continues to flow toward river
River
Ground Water
River depth is raised by 1 foot (total depth 2 feet)
C
Bank Storage begins to dissipate when river level drops
River
Ground Water
River depth returns to 1 foot
D
Ground water resumes flowing toward river
River
Ground Water
River depth remains at 1 foot

Figure 8

RELATIONSHIPS BETWEEN PRECIPITATION, RIVER STAGE, AND GROUND WATER LEVELS

Examining the data to determine these relationships among precipitation, ground water levels, and river levels took several forms. Eventually, two approaches were judged to be the most technically supportable. Because the analyses are independent of each other, the results are consistent but not identical. The analyses are as follows:

- **Daily analysis.–**A critical day-by-day analysis of the fluctuations at individual wells superimposed on the river elevations at the well transect location.

- **Statistical analysis.–** Correlation of rises and falls in the water levels at the wells and at the river gauges.

RESULTS OF DAILY ANALYSIS

Hydrographs of several wells in the Minden transects and in the Alda transects were superimposed on the river hydrograph and the relative gains and losses on a day-by-day basis were examined. The wells were selected to represent various distances from the river. Precipitation data was also displayed. Each significant change in ground water level was studied to determine whether the water table was responding to changes in the river, to precipitation, or to some other factor.

This analysis also looked at the correlation factor between the water level in the well and the river stage (water level) and at the bank storage analysis of how the well would respond to the actual changes that occurred in the river elevation. This analysis is provided in appendix B.

Several patterns developed in the course of this analysis:

- The correlation factor consistently decreased as the distance from the well to the river increased.

- The bank storage analysis accurately predicted the water table changes resulting from river stage changes in many instances. There were no instances where the bank storage analysis falsely predicted water table changes.

The water table is far more responsive to precipitation than to changes in the river stage at all wells located more than ½ mile from the river.

- The water level in all wells responded to precipitation in a fairly predictable pattern, although the magnitude of change was sometimes out of proportion to the precipitation amount.

- The first rainfall after a long dry period replenished soil moisture in the dry root zone. Subsequent rains of more than ½ inch generally produced a rise in the water table, while rains of less than ½ inch affected water table levels only when they came within a day or two of a larger event.

- For some wells, the rise in well water levels was considerably greater than would be expected from the amount of the rainfall. This is thought to be the result of water ponding at the end of farm fields or in road ditches close to the well.

- Wells farthest from the river undergo fluctuations that cannot be attributed to the river or to precipitation. In these cases, it was assumed that fluctuations result from irrigation well drawdown or local water table recovery.

Results of Statistical Analysis

To determine the causes and effects behind the river gauge heights and well elevations, Reclamation performed a statistical analysis of 28 observation wells next to the Platte River.

Generally, well elevations and river gauge heights move in the same direction. All of the wells were significantly correlated with river levels. However, correlations can indicate that the events move in concert with one another as well as moving in response to each other. Correlations do not necessarily imply cause and effect relationships.

Significant conclusions that can be drawn from the statistical analysis of surface water and ground water elevations, changes in elevation, and precipitation are listed below. The complete set of results from this statistical analysis is presented in Appendix C.

- There is a relationship between the daily change in well water surface elevations and precipitation in the vast majority (79%) of observation wells in the study area.

- Correlations between the well water surface elevations and river gauge heights were higher for wells near the river.

- The relationship between the daily change in ground water surface elevation and precipitation was at least as significant as the one between ground water surface elevation and river gauge height.

- Correlations among the water surface elevation of all of the wells indicated that the water surface elevation of the ground water is moving in concert over most of the study area.

- The time of rises in most wells correlates better with the rises in river gauge height at the farthest downstream station (Grand Island). Because water takes 2 days to travel from Overton to Grand Island, the almost simultaneous rise in water surface elevations in wells at Overton and the river gauge at Grand Island indicates that the entire hydrological system (river and aquifer) is responding to a common influence—namely precipitation.

The river levels control groundwater within 100 feet of the river and influence levels within 700 feet of the river. Other influences become more important than river levels beyond 1,000 feet of the river. The entire hydrological system (river and aquifer) is responding to a common influence—namely precipitation.

The following conclusions were based on the lagged correlation analysis of the well water surface elevation and river gauge height at the three Platte River gauges and between precipitation and well water surface elevation.

Lagged data are developed by looking at one day's values as they relate to values for the previous day (or days). This lag time provides time for water to travel down the river or be recharged. For example, there is an estimated one-day travel time between each of the river gauges. Because of the travel time, the data for a downstream river gauge should correlate better with the previous day's flow at the next upstream river gauge than they would with data for any other time-step.

- Almost all (over 90 percent) of the observation wells varied in similar ways, even though they are in different regions of the aquifer.

- Recharge from local precipitation is rapid, 1 day or less in most cases.

The following conclusions were based on the regression analysis of groundwater flooding potential. Regression analyses develop formulas to show how changes in river gauge height affect the ground water surface elevation. If the relationship between river gauge height and ground water surface elevation is not strong, then the results of the regression prediction are not accurate. To make acceptable predications, regressions should explain at least 75 percent of the changes.

- Regressions in this relationship explain 95 to 96 percent of the variations between ground water surface elevation and river gauge height at 50 to 100 feet from the river.

- Predictability diminishes rapidly further away from the river on average: 78 percent at 700 feet, 38 percent at 1,000 feet, and 16 percent beyond 10,000 feet.

- In the Elm Creek transect, the groundwater mound under the Central Nebraska Public Power and Irrigation District apparently exerts more control over groundwater movement and elevation than the Platte River.

- Ground water levels within a few hundred feet of the river are influenced by river elevation changes. Ground water levels more than 1,000 feet from the river appear to be more closely related to precipitation.

RESULTS OF YEAR 2000 MONITORING

As of July 5, 2000, the monitoring program ended. Monitoring during 2000 produced results consistent with those of the 1999 monitoring. River levels in March and April were very similar for the two years. May 1999 saw higher river elevations, but they subsided by the end of the month to levels comparable to 2000 flows. However, beginning in mid June 2000, river flows began to decline to more normal summertime flows of less than 1,000 cfs. These low flows never occurred in 1999.

Precipitation beginning in mid April 1999 was fairly significant, whereas the 2000 precipitation was minimal up to mid June, except for two moderate events of less than 1 inch at each transect. Larger rains ranging from 1 to 6 inches fell on June 12 at the Minden transect, on June 19 to Elm Creek and Minden transects, and on July 3 and 4 to all the transects. No rains greater than 2 inches were measured at any of the locations in 1999.

The significant differences between the years in river level and precipitation patterns provide an opportunity to study the interrelationships among river level, precipitation patterns, and ground water levels under distinctly different circumstances for the 2 years.

In 2000, the wells within 200 feet of the river bank track the river very closely, as would be expected. Wells farther from the river appear to be more independent of the river. For instance, the river at the Elm Creek transects underwent a series of 6-inch fluctuations, each about 1 week duration, during March. At the same time, the water surface in well 8-19-3ABB (½ miles from the river) averaged 2 feet higher than the river and rose about 1-inch on a straight line.

Several wells in the Alda and Minden transects were monitored in both years, as shown in figure 1. Several precipitation events in 1999 appeared to produce rises in the water surface in the wells. In the absence of precipitation in 2000, the wells do not display such rises. For instance, in 2000, well 10-10-28-BBC (½ mile from the river) was nearly constant through April and May, while the river fluctuated though a wider range but was also fairly constant. In 1999, with several rain events, the well had a substantial and sustained rise during April and May, while the river had a smaller rise and then receded to near its original level.

During March 2000, the river at the Alda transect was higher than in the same period in 1999. Well 10-10-20-AAA, located 1½ miles from the river, was lower than in March 1999. None of the other wells were monitored in March of both years. There was no significant precipitation in March of either year.

The conclusions that were drawn from the 1999 data are supported by the 2000 data in several ways.

- The general rise in ground water that occurred in April and May 1999 along with frequent precipitation did not occur in 2000 when there was minimal precipitation. This difference occurred even though river levels in March and April were very similar for the two years. May 1999 saw higher river elevations, but they subsided by the end of the month to levels comparable to 2000 flows, while the ground water continued a steady rise into early July.

- Ground water levels within a few hundred feet of the river are strongly influenced by the river level. Three wells within 200 feet of the river were monitored in 2000 and, as in 1999, these wells reflect the river level on a daily basis.

- The relationship with the river weakens with distance and at ½ mile the wells appear to be fairly independent of the river elevation. The failure of well 8-19-3-ABB to detect changes of 6 inches in river level over several days demonstrates the lack of influence the river has on the ground water only ½ mile from the river.

- The wells that were monitored in 2000 appear to respond to precipitation events of one-half inch or greater. The rises were from a few tenths of an inch to a little more than a foot, and nearly always began declining the day after the rainfall.

- Excessively dry soil conditions are thought to have minimized well response to the rainfall events of June 12 and 19 and July 3 and 4. The response that did occur generally occurred at the same time or before the river rise, indicating that the water table rise and the river level rise were both responses to the precipitation.

- Some of the wells rose slightly during May without precipitation while the river level was declining. This is apparently due to regional ground water flow from areas where the water table is at a higher elevation. As shown in figure 3, the direction of regional ground water flow consistently trends toward the river, so regional ground water flow is from areas farther from the river.

- During the March through June period of 2000, the river level fell as did most of the wells. However, there is little consistency in the pattern of fall. Some wells show a greater decline than the river, while others show a lesser decline. Rarely do the declines in the well levels follow the same pattern as the decline in the river level.
- Most of the wells began a sharp decline in early to mid June, which corresponds with the onset of irrigation. Irrigation pumping was noted throughout the area during the July 5 data collection excursion.

Well hydrographs for the year 2000, river levels, and precipitation are included as appendix H. Matching hydrographs of the 1999 data are superimposed on the 2000 data for wells that were monitored in both years.

POTENTIAL EFFECT ON GROUND WATER FROM THE PROPOSED PLATTE RIVER ENDANGERED SPECIES RECOVERY PROGRAM

If an Endangered Species Recovery Program is implemented for the Platte River, water releases would be made to benefit the four endangered species. During the first increment of the Proposed Program (10 to 13 years), the states will address the impacts of all surface and ground water projects existing as of July 1, 1997, by using 130,000 to 150,000 acre-feet of water per year on average to improve flows for endangered species in times when flows are less than the Fish and Wildlife Service target flows. Two basic types of releases would be made for the species. The potential affect of pulse flows and base flow augmentation, two possible flow types, was analyzed.

PULSE FLOWS FOR CHANNEL MAINTENANCE

Pulse flows would be an increase in flows from Kingsley Dam for 3 or 4 days aimed at increasing Central Platte River flows to between 6,000 and 10,000 cubic feet per second. These releases, which will be kept within the river banks and below flood stage, would be aimed at scouring new vegetation from the channel to help maintain the existing clear channel width. These pulses would be short duration, in part because the channel modification process is substantially accomplished after only a few hours, and in part because the pulses require large volumes of water which cannot be sustained for long periods, given the volume of water expected to be allocated to a program. Each pulse flow event would require 30,000 to 40,000 acre-feet of water.

Under the Program flow types analyzed, the only measurable changes from rises in the Platte River would be in ground water levels near the river. Ground water levels more than ½ mile from the river would not be impacted. Basements and farmlands located within ½ mile of the river may experience somewhat higher ground water levels during Program augmentation flows.

Pulse flows would raise the river level at most 10-12 inches for the duration of the higher releases. A 1-foot rise in the river for a 3-day period would cause a measurable rise in ground water only within ½ mile of the river. Figure 9 shows what the effects would be from a 12-inch rise in river depth on the third and sixth days. Effects would diminish rapidly after the 6th day.

BASE FLOW AUGMENTATION

Base flow augmentation would provide flows between 500 and 1,000 cfs. These increases would be provided several times during the average year to meet various species' needs, such as spring crane roosting flows.

These flows could last from 10 days to 30 days, and would raise river levels about 5 inches. Figure 10 shows the effects of these flows after 10, 20, and 30 days. Effects would diminish as soon as the increased flows ended.

CONCLUSIONS

In the Platte River Valley, ground water is generally higher than the river and moves toward the river under natural conditions. The river is the ultimate outlet for ground water that builds up in the aquifer from precipitation. While irrigation practices have modified the natural ground water regime to some extent, the natural conditions still generally prevail. Changes in river levels have a strong influence on ground water levels very near the river, but the influence diminishes rapidly with distance from the river and is essentially nonexistent beyond 2 miles from the river. This is borne out by the theoretical analyses (appendix A), the daily analysis of well hydrographs with river flow hydrographs (appendix B), the statistical analyses (appendix C), and the snapshot of ground water conditions (appendix D). Regional ground water fluctuates more closely with precipitation than with river levels.

The Program may raise water levels in the river by as much as 1 foot for periods of 3 or 4 days and by as much as ½ foot for periods up to a month. These rises will have some effect on ground water levels within a half mile of the river while they are taking place. However, the effects will dissipate quickly when the Program flows are stopped, and there will be no significant influence at distances of more than 3,000 feet from the river at any time.

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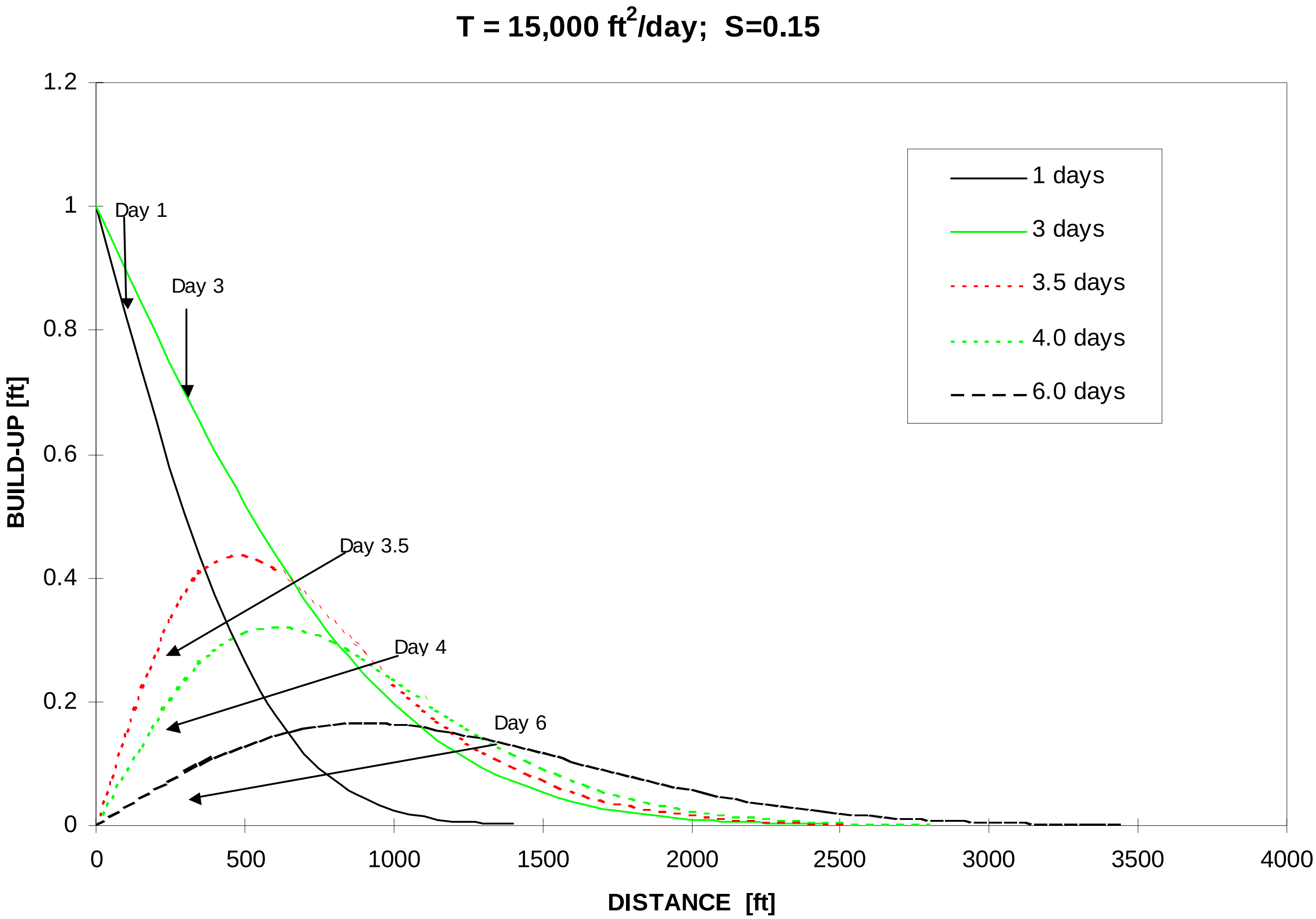
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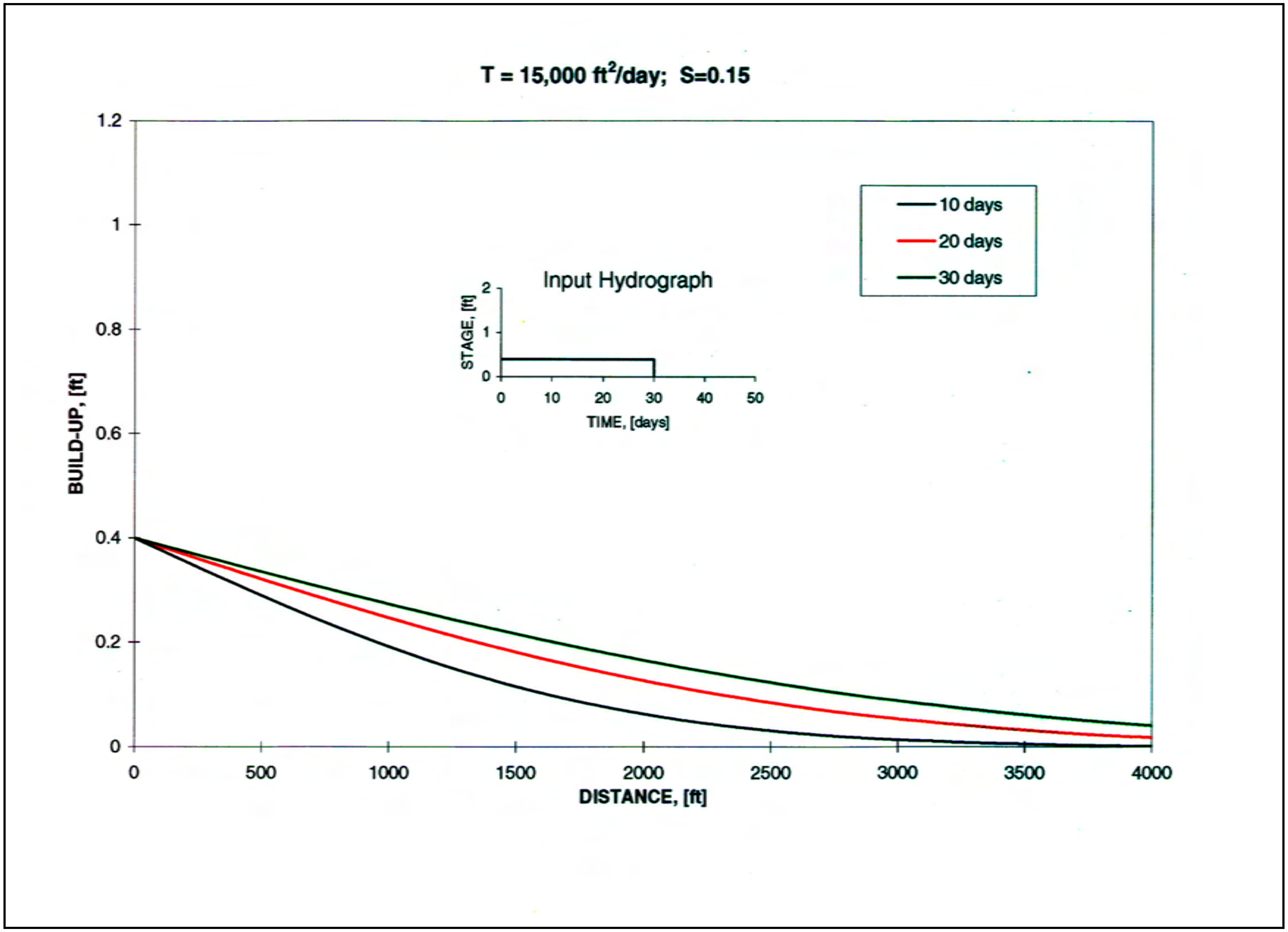
0.6
0.4
0.2
0
0
500
1000
1500
2000
2500
3000
3500
4000
1 days
3 days
3.5 days
4.0 days
6.0 days
Day 1
Day 3
Day 3.5
Day 4
Day 6

Figure 9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0
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1000
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2000
2500
3000
3500
4000
DISTANCE, [ft]
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20 days
30 days
Input Hydrograph
STAGE, [ft]
2
1
0
0
10
20
30
40
50
TIME, [days]

Figure 10