A Report of Preliminary Findings from

A Study of Hydrologically Connected Ground and Surface Water and its Contribution to Conflicts between Ground Water Users and Surface Water Appropriators in the North Platte Natural Resources District

The Nebraska Department of Natural Resources

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A Study of Hydrologically Connected Ground and Surface Water and its Contribution to Conflicts between Ground Water Users and Surface Water Appropriators in the North Platte Natural Resources District

Summary

On September 5, 2002, the North Platte Natural Resources District (NPNRD) sent a letter requesting the Department of Natural Resources (DNR) to consult with the NPNRD concerning studies and a hearing on the preparation of a joint action plan for the integrated management of hydrologically connected ground water and surface water under the Nebraska Ground Water Management and Protection Act, Section 46-656.28.

This study addresses the NPNRD's request. It specifically addresses 1) the causes of any conflicts, disputes or difficulties resulting from the conjunctive use of hydrologically connected ground water and surface water resources, 2) the extent of the areas affected by such conflicts, disputes or difficulties in the North Platte Natural Resources District and 3) the question of whether a joint action plan could reduce or eliminate the causes of conflict.

To conduct this study the DNR examined available data from previous studies for the area. Many studies have been conducted by the United States Geological Survey and other entities concerning the hydrogeology of this area, especially the area involving the large surface water canals in the North Platte River Valley. The Department determined that the existing data was adequate to make the determination regarding the cause of the conflicts in the NPNRD and the extent of the area affected. For the purposes of this study, the NPNRD was divided into three study areas the North Platte Valley, the Northern Tablelands – Sand Hills and the Southern Tablelands. These areas are distinguished by different geological and hydrological characteristics.

In the **North Platte Valley** study area the ground water and surface water are very closely connected. Surface water appropriators along the North Platte River and its tributaries divert water stored in reservoirs in Wyoming. Water from these diversions seeps from the canals and irrigated fields and fills the alluvial ground water aquifer between the canals and the river. This seepage turned historically dry or intermittent streams into perennially flowing streams. Surface water supplies in this area are often inadequate to fill the needs of the irrigation districts. Since the 1970's many irrigators have drilled ground water wells in order to supplement existing surface water supplies and irrigate new land. As a result of inadequate supplies, in 1993 the then Department of Water Resources declared a moratorium on issuing new surface water permits. Since 1993, 1,345 new depletive wells, including 350 irrigation wells, were drilled in aquifers connected to the North Platte River. Water consumed by these wells has further depleted stream flows. Because of the high degree of interdependence between the ground water and the canals and because of the fact that the surface water supply is over appropriated, the additional consumptive use due to wells that are hydrologically connected to the river is reducing surface water supplies and is contributing to conflicts

between ground water users and surface water appropriators. The extent of the area affected is the entire North Platte Valley study area.

In the **Northern Tablelands – Sand Hills** study area the hydrologic connection between ground water and surface water extends to Blue Creek and the North Platte River. Here ground water flows mainly from west to east and drains through Blue Creek. Currently there are 14 surface water permits on Blue Creek and 383 high capacity wells in this area. The number of registered wells completed in this area has been steadily increasing since the 1970's. A monitoring well in this area shows localized water level declines of 12 feet since the mid-1980s. Statistical analysis shows a significant declining trend of average annual flows on Blue Creek between 1961 and 2002. Surface water irrigators on Blue Creek are shut off due to an inadequate amount of stream flow in most years. Continued development of ground water wells will cause further water level declines. The nature of hydrologically connected ground water and surface water dictates that any water level decline will impact the stream. Therefore, ground water wells that further deplete stream flows in an area already subject to frequent regulation of surface water diversions is contributing to conflicts between ground water users and surface water appropriators. In addition to the conflicts within the study area, because the ground water is connected to the North Platte River, the conflicts of the North Platte Valley study area also apply to this study area. The extent of the area affected is the entire study area.

In the **Southern Tablelands** study area the ground water is also hydrologically connected to the over appropriated North Platte River; therefore, additional depletions to the river from ground water wells are also contributing to the conflicts between surface water appropriators and ground water users. The extent of the area affected is the entire study area.

Because the conflicts are caused by the increased consumptive use of ground water in an over appropriated surface water system, better management via a joint action plan of the ground water resources as an integral part of the surface water system will reduce or eliminate the causes of conflict.

I. Introduction

Background and Authority

The State of Nebraska recognized the relationship between ground and surface water with the passage of LB 108. According to Nebraska law, surface water is regulated by the Department of Natural Resources and ground water is regulated by the 23 Natural Resources Districts. To address the separation of powers, § 46-656.28 allows a Natural Resources District to request a study from the Department of Natural Resources (DNR) to examine the interaction of hydrologically connected ground and surface water and develop a joint action plan.

In § 46-656.28(2), the Director of the DNR is charged with making a preliminary determination of whether there is a reason to believe that the use of hydrologically connected ground water and surface water resources is contributing to or is in the reasonably foreseeable future likely to contribute to (a) conflicts between surface water appropriators and ground water users (b) disputes over interstate compacts, or (c) difficulties fulfilling the provisions of other formal state contracts or agreements.

On September 5, 2002, the North Platte Natural Resources District (NPNRD) sent a letter requesting the DNR to consult with the NPNRD concerning studies and the possible preparation of a joint action plan for the integrated management of hydrologically connected ground water and surface water under the Nebraska Ground Water Management and Protection Act. The DNR responded on November 1, 2002, with a preliminary decision according to subsection (2) of Section 46-656.28, R.R.S., 1998. The DNR found reason to believe that the use of hydrologically connected ground water and surface water resources in the NPNRD is contributing to or is in the reasonably foreseeable future likely to contribute to conflicts between ground water users and surface water appropriators. This decision was made based on information found in the NPNRD's ground water management plan (GWMP) and other records, various United States Geological Survey (USGS) reports and various DNR records. A copy of both letters can be found in Appendix I.

Based upon the preliminary determination, the DNR initiated a more detailed study to determine the cause of such conflicts, disputes or difficulties and the extent of the area affected. Within 90 days of completing the study the Director is to issue a written report of preliminary findings and makes a determination as to whether or not the conflicts between surface water appropriators and ground water users could be eliminated or reduced through the exercise of the authority granted in § 46-565.28(5).

Acknowledgements

The study was overseen by the Deputy Director of DNR, Ann Bleed. Jennifer J. Schellpeper of the DNR Planning Department was the primary author of the study with Shuhai Zheng also of the DNR Planning Department as primary author of Appendix II. Tom Hayden of the Bridgeport Field Office and Jim Cannia of the North Platte Natural Resources District provided important suggestions to the study. Thanks are due to Tina Kurtz for her many reviews of the study and editorial comments.

Study Methodology

The major objectives of the study were to 1) determine the extent of the area affected i.e. extent of the area with a hydrologic connection between ground water and surface water within which conflicts among water uses are occurring, and 2) the cause of (a) conflicts between ground water users and surface water appropriators, (b) disputes over interstate compacts or decrees or (c) difficulties fulfilling the provisions of other formal state contracts or agreements which have resulted from the use of any hydrologically connected ground water and surface water now or in the reasonably foreseeable future.

To meet the first objective the hydrogeology of the study area needed to be understood. DNR reviewed the available data from a variety of sources such as the Bureau of Reclamation (BOR), DNR, USGS, NPNRD, Conservation and Survey Division (CSD) and others. These data included but were not limited to geologic cross sections, water table maps, water chemistry, surface water canal diversions, stream gage records and precipitation records. To determine whether conflicts existed, the DNR examined water administration records and logged complaints of insufficient water. After consideration of the available data the DNR decided that both objectives could be met using the data and information that were already available; no new study to gather more data was needed.

Since 2001, this area has suffered from one of the most extreme droughts of the century. In droughts, lack of sufficient water supplies is likely to cause conflicts between surface water appropriators and ground water users that would not occur under more normal conditions. While conducting this study, the DNR did not focus on data pertaining to this recent severe drought. Rather the examination and conclusions are based on more normal wet and dry cycles since the 1960's.

The initial review of data revealed three distinct areas of hydrologically connected surface water and ground water. Characteristics such as type of surface water system, topography, principal aquifer properties, the water table and existing management sub-areas determined the relative boundaries of the three study areas. The study report was organized according to these study areas.

For each area the nature of the hydrologic connection between surface water and ground water was determined by examining whether the geologic materials were capable of transmitting water, the water table indicated a connection between ground water and surface water flows, the stream gage records showed evidence of base flow at some point in time or other evidence from previous studies concluding that the stream and ground water were in hydrologic connection. Hydrogeologic characteristics examined in determining whether or not a geologic formation was capable of transmitting water included hydraulic conductivity, which is defined as the volume of water that will flow through a unit cross-sectional area of aquifer in unit time, under a unit hydraulic gradient and at a specified temperature, and transmissivity which is the hydraulic conductivity multiplied by the full thickness of saturated aquifer.

Once a hydrologic connection was determined in a study area, the second objective of the study is to determine if there is evidence of current or future conflicts between surface water appropriators and ground water users in the area. To make this determination the DNR had to find that both surface water appropriators and ground water users relied on the hydrologically connected ground water supplies and that these supplies were not sufficient to meet all uses resulting in a conflict among users.

As part of this study, Shuhai Zheng of the DNR completed a report using statistical analysis to determine possible relationships between the various parameters which control the amount of stream flow. The parameters included canal diversions, stream flows, precipitation, the number of registered ground water wells and surface water acreage data. A complete copy of this report can be found in Appendix II.

General Conclusions

In almost all areas of the NPNRD the ground water is connected with and is flowing toward the North Platte River or one of its tributaries, indicating that the majority of the ground water in the NPNRD supplies flow to the North Platte River. Only a small area of ground water in the northern portion of the NPNRD flows into Box Butte County and the Upper Niobrara White Natural Resources District (UNWNRD). Thus, in all cases it was determined that the geologic formations surrounding the stream network were in hydrologic connection with the streams to varying degrees.

Data from the DNR showed both surface water appropriators and ground water users were present in each study area as well as in outside areas which could also potentially be affected by the use of hydrologically connected ground water and surface water in the study area. Hydrogeologic evidence linked all of the study areas to the North Platte River and its tributaries. In most years surface water rights are closed because of insufficient stream flow. In 1993, the DNR determined that due to insufficient stream flow the North Platte River above Lake McConaughy should be closed to any new surface water appropriations. Therefore, any new use of surface water or hydrologically connected ground water that increases the consumptive use of water would injure an existing senior surface water appropriator or ground water user and increase conflict.

Basic Principles of Ground Water - Surface Water Interactions

1) Where there is a hydrological connection between surface water flow and ground water aquifers, a consumptive use of one depletes the supply in the other.

2) In such areas a decrease in surface water supplies, precipitation, canal seepage or seepage from irrigated fields, will decrease the amount of water infiltrating from the land surface to recharge the ground water aquifer. A decrease in recharge will decrease the ground water supplies available for use.

3) Stream flows are supplied by surface water runoff and by water seeping from the ground water aquifer to the stream as baseflow. Surface water runoff tends to be sporadic, depending on precipitation events. Baseflow from ground water is more constant.

4) Changes in baseflow to a stream result from any factor that either changes the water pressure in the aquifer or the water table elevation. Consumptive use of the aquifer by wells or vegetation affects both the aquifer pressure and water table elevation.

5) If a ground water aquifer is closely connected to a surface water stream, decreases in aquifer water pressure or elevation will either decrease the movement of water to the stream or induce the movement of water from the stream to the aquifer. In either case, the first noticeable impact of increased consumptive use from an aquifer hydrologically connected to a stream will likely be a change in the quantity of stream flow rather than a change in the water table elevation of the aquifer. In many cases, changes in water table elevations are detected only when stream flows decline to the point they are no longer able to recharge the aquifer. Thus, any steady decline in stream flow that cannot be explained by a change in precipitation or other factors affecting ground water recharge is a good indication that current level of consumptive use of the hydrologically connected ground water aquifer cannot be sustained in the long term.

6) Aquifer Properties: Hydraulic Conductivity (K) – the volume of water that will flow through a unit cross-sectional area of aquifer in unit time, under a unit hydraulic gradient and at a specified temperature, basically K is a measure of how easily water flows through the aquifer. For instance, water flows much easier through a sand and gravel aquifer than an aquifer composed of silts and clays; Transmissivity (T) – the hydraulic conductivity multiplied by the full thickness of saturated aquifer. The more saturated thickness the higher the value of T; Saturated Thickness – the thickness of the aquifer where all available pore space is filled with water.

Study Area – The NPNRD

The NPNRD is bounded on the west by the state line of Nebraska and on the east by the eastern edge of Garden County, Nebraska. The southern border follows the southern boundaries of Garden, Morrill and Banner Counties. The northern border follows the northern boundaries of Morrill and Garden Counties and the northern boundary of Township 26 across southern Sioux County. The North Platte River, which runs northwest to southeast through the NPNRD, rises in the mountains of northern Colorado, flows north through the mountains of southern Wyoming and then east through the plains of central and eastern Wyoming and western Nebraska. Pumpkin Creek is a major tributary to the North Platte River in this area (App. III Figure 1)[1].

Topographically, the NPNRD varies from flat valley lands and terraces along the river to rugged bluffs and escarpments along the valley sides. In the northeast is the Sand Hills area and to the north and south of the North Platte River Valley lie the plains (App. III Figure 2). Figure 3 in App. III is a digital elevation map of the NPNRD. The basic stream network, major canals and laterals can also be seen on this figure. The numerous lakes and dunes of the Sand Hills region are a prominent feature in the northeast corner of the figure, as are the rugged bluffs and valley side slopes along the North Platte River.

[1] All Figures larger than 8.5 by 11 inches are in Appendix III (App.III).

Annual precipitation at the Mitchell 5E Station ID 25-5590 in the NPNRD has minimum, maximum and average values of 5.68, 19.64 and 13.15 inches respectively for the period of record 1931 to 1998. Annual precipitation at the Crescent Lake National Wildlife Refuge Station ID: 25-2000 in the NPNRD has minimum, maximum and average values of 10.24, 26.22 and 17.03 inches respectively for the period of record 1949 to 2002. Precipitation data were retrieved from the DNR website Data Bank. Figure 1 shows the 30 year precipitation normals for four stations located throughout the NPNRD. The figure indicates that since 1941, the most recent 30 year period, 1971-2000, has had precipitation normals greater at the Scottsbluff and Bridgeport stations than any previous 30 year normals, and at the Oshkosh and Crescent Lake stations, precipitation normals are higher than the driest 30 year normal for each station.

Land cover in the NPNRD consists primarily of range land, dry land and irrigated crop land. The primary crops grown in the area are dry beans, corn, alfalfa and winter wheat. A more complete listing of crops and an approximate aerial distribution can be found in App. III Figure 4. The irrigated crops are concentrated in the valley areas and those areas of the tablelands where topography, soils and depth to water make irrigation practical. There is a lack of cropland in the northwest corner and Sand Hills region of the NPNRD; this can be attributed partly to the soils which are not suitable for cropland and the topography in the area.

The boundaries of the DNR surface water division 1A and lands irrigated with surface water via the major canals as well as the canals and laterals themselves are shown in Figure 5 of App. III. (Table 1 in Appendix IV lists the surface water appropriations in the NPNRD. A stick diagram of the canal network can be seen in Appendix II Figure 1.) Ground water wells used for irrigation and surface water appropriation diversion points are also shown on Figure 5 App. III, including areas outside of the NPNRD. The NPNRD has a large number of both surface and ground water users. There are 27 surface water irrigation districts in the NPNRD supplying water to more than 360,000 acres. Figure 2 shows the cumulative number of surface water appropriations in the NPNRD by priority year. The largest numbers of appropriations are for irrigation. As of October 20, 2003, there were approximately 2,150 non-replacement, non-abandoned registered irrigation wells and 3,794 depletive wells in the NPNRD, excluding the wells in the Pumpkin Creek Management Sub-Area (Figure 3). Depletive wells are those wells that consume water and thus remove water from the ground water system. Depletive wells include uses for: aquaculture, commercial, domestic, irrigation, public water supply, dewatering, stock, and other, except those in the other category noted as sparge, vapor extraction, or another non-consumptive use. The irrigation wells supply water to more than 150,000 acres of land, including lands commingled with surface water and lands solely irrigated with ground water. To the north of the NPNRD, in Box Butte County in the UNWNRD, there is a large concentration of irrigation wells, approximately 1,200. To the south in the South Platte Natural Resources District (SPNRD), there are numerous irrigation wells in the valley of Lodgepole Creek.

Figure 6 in App. III shows five geologic cross-sections, which are located near or pass through the NPNRD, and a surface map showing the locations of the cross-sections. A-A', B-B' and C-C' are north to south cross-sections moving from west to east respectively. D-D' and E-E' are northeast to southwest cross-sections. The underlying bedrock is predominantly Pierre Shale; above this lies various undifferentiated Cretaceous deposits, the Chadron Formation, Brule Formation, Arikaree Group, Ogallala Group, Pliocene deposits and Quaternary deposits including the Sand Hills, which are easily recognizable on the C-C' and E-E' cross-sections.

In 1969, ground water regions across the state of Nebraska were defined by the CSD in cooperation with the then Department of Water Resources and the Nebraska Soil and Water Conservation Commission. There are four distinct ground water regions within the NPNRD: the Platte River Valley, the Northern Panhandle Tablelands, the Sand Hills and the Southern Panhandle Tablelands (App. III Figure 7). A more detailed description of the principal aquifers in the NPNRD is shown on a map compiled by the CSD in 1993 for the NPNRD's GWMP (App. III Figure 8). The principal aquifers include Undifferentiated Cretaceous, Chadron Sand, Brule, Arikaree, Ogallala, Sand Hills and Alluvium. The hydrogeologic properties of these aquifers are quite varied and are discussed in more detail later in this study.

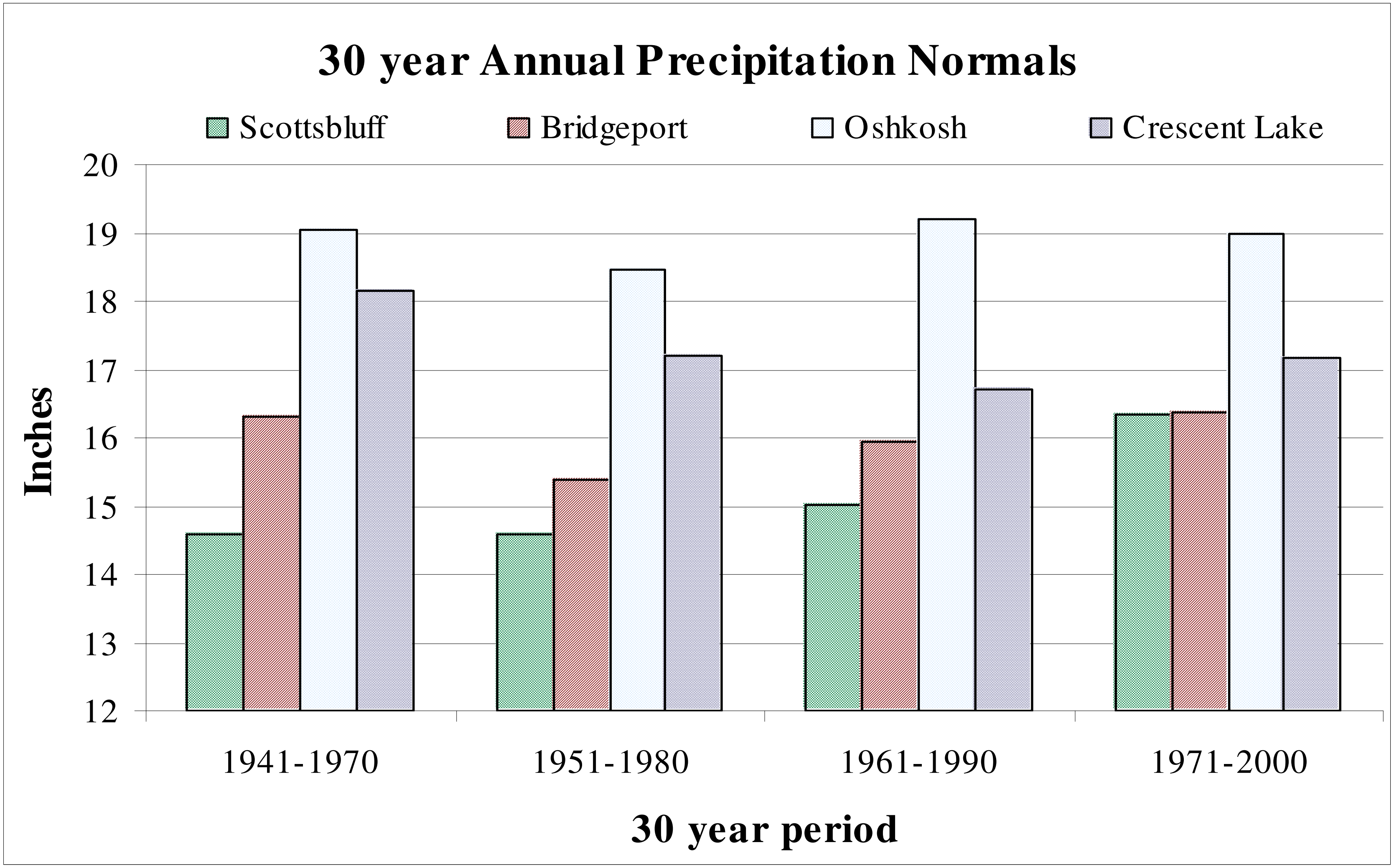


Figure 1: 30 year annual precipitation normals at four weather stations located within the NPNRD, Scottsbluff AP #185, Bridgeport #030, Oshkosh 8 SW #162 and Crescent Lake #048, according to United States Department of Commerce: Climatography of the United States No 81.

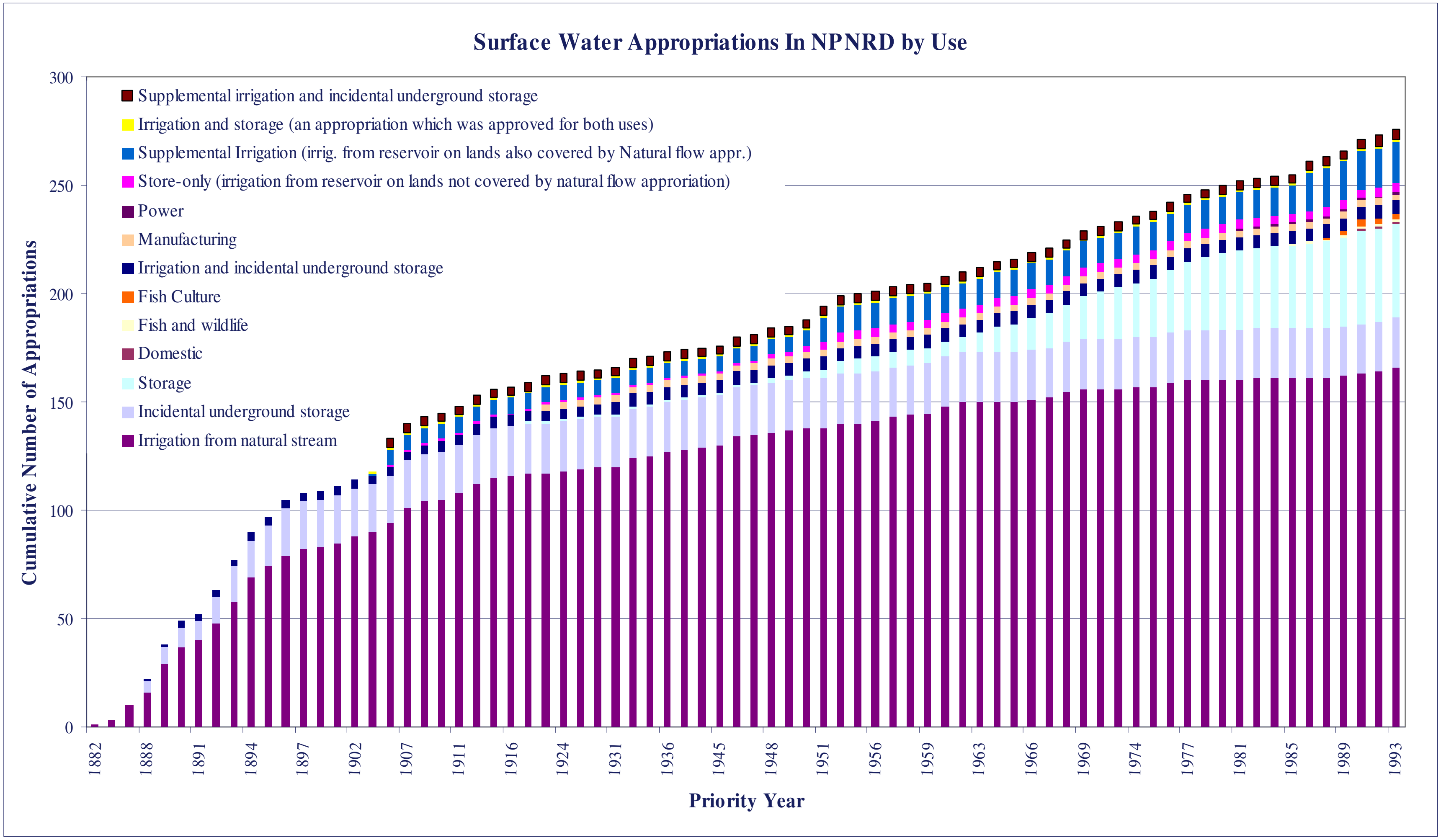


Figure 2: Surface water appropriations in the NPNRD listed by priority year and approved use.

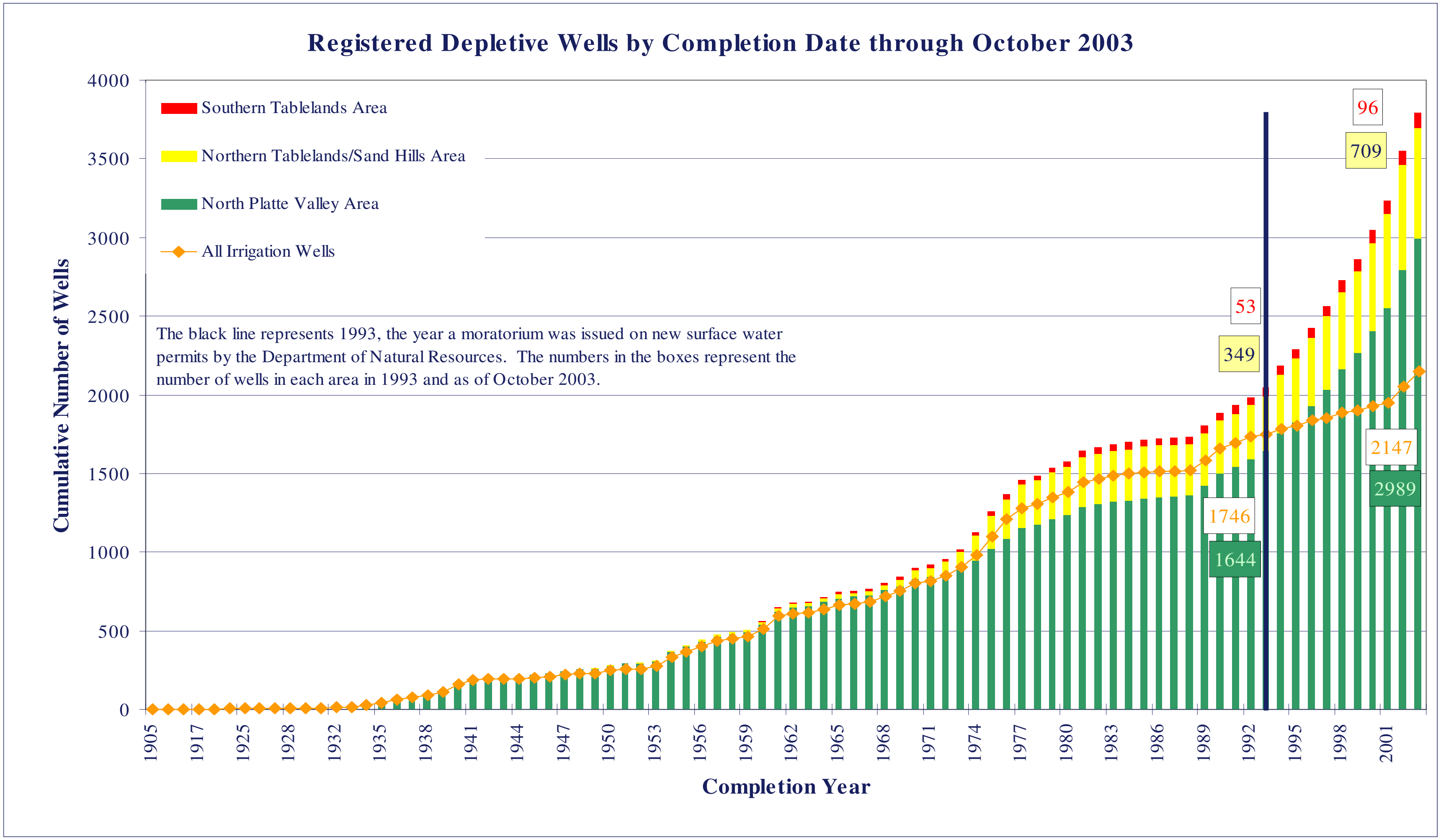


Figure 3: This graph is of registered wells only. In 1993 the Department of Water Resources began to require stock and domestic wells to be registered. This will account for some of the steep increases in depletive wells after 1993. Depletive wells include those with the following uses: aquaculture, commercial, domestic, irrigation, public water supply, dewatering, stock, and other, except those in the other category noted as sparge, vapor extraction, or another non-consumptive use.

The water table in the NPNRD and surrounding area from the spring of 1995, as developed by Vince Dreezen and others with the CSD, shows areas of recharge and discharge (App. III Figure 9). A major area of recharge, where surface water infiltrates to the ground water, is reflected in the water table contour map as an area of higher water table elevation and occurs in the Sand Hills region in the northeast corner of the map. There is also a ground water table high located in the northwestern corner of the map. Both of these water table highs cross the boundary between the NPNRD and the UNWNRD. Discharge areas, where ground water emerges onto the land surface, can be seen along the major streams in the NPNRD including the North Platte River and Blue Creek. Ground water flows into the NPNRD in the west and leaves the NPNRD along its eastern boundary, generally flowing from west to east. More maps including depth to water, transmissivity, base of principal aquifer, saturated thickness, ground water in storage, specific yield, the water table in 1979 and 1987, average annual precipitation and others can be found in the NPNRD's 1993 GWMP.

Currently the NPNRD has a District-wide Ground Water Management Area and two Ground Water Management Sub-Areas (App. III Figure 10). The Lisco-Oshkosh-Lewellen Sub-Area, established in 1999, includes regulatory controls to address existing and potential nitrate contamination concerns. Since this sub-area does not speak to the issue of integrated management of ground water and surface water, it will be included in this study. The Pumpkin Creek Basin Ground Water Management Sub-Area was created in 2001 to provide for integrated management of ground and surface water and to address ground water quality and quantity issues. Regulatory controls established for the Pumpkin Creek Sub-Area include a moratorium on new water well permits and an allocation of ground water use. Because of the existing regulations, the Pumpkin Creek Sub-Area will not be included in the study area for consideration in this possible joint action plan.

Based upon characteristics such as the nature of the surface water system, topography, principal aquifer properties and existing management sub-areas, the NPNRD was divided into three study areas (App. III Figure 11). The central region is called the North Platte Valley area and is approximately defined by the valley side slopes, escarpments or the extent of the canals on the north side of the river, whichever is further from the river. The southern border follows the existing Pumpkin Creek Sub-Area boundary as far east as possible and then follows the valley side slopes. South of the North Platte Valley area, but excluding the Pumpkin Creek Sub-Area, lie the Southern Tablelands. To the north is the Northern Tablelands – Sand Hills area. Both tableland areas consist of the Brule, Ogallala and Arikaree Aquifers. The Ogallala and Brule are predominant in the Southern Tablelands whereas the Northern Tablelands – Sand Hills area trends from a Brule and Arikaree predominant aquifer in the west to an Ogallala and Quaternary sands aquifer in the east (Appendix III Figure 6).

II. North Platte Valley Study Area

Hydrogeology – Extent of the Area Affected

Geology

From west of the NPNRD in Wyoming to Lake McConaughy the water in the North Platte River Valley flows through a narrow trough that Pliocene and Pleistocene geologic and hydrologic processes carved into the bedrock and then filled with highly permeable sands and gravels (Rapp et al., 1957; Morris and Babcock, 1960; Crist and Lowry, 1972; Wenzel et al., 1946). These sands and gravels lie in thick deposits beneath the bottomlands and parts of the lower terraces in the NPNRD. The hydraulic conductivity (K) in this region is in excess of 300 feet per day, and may range as high as several thousand feet per day. Values of transmissivity (T) range widely from 20,000 to more than 500,000 gallons per day per foot and corresponding wells yield as much as several hundred to several thousand gallons per minute (Olsson Associates, 1993).

The Brule Formation lies beneath a major portion of the alluvial sands and gravels in the valley region and can be found at the surface in the Bluffs and Escarpments north and south of the valley. The Brule consists primarily of silts and clays and has a minimal hydraulic conductivity of less than 25 feet per day (Olsson Associates 1993). In some areas there may be a significant saturated thickness that contains a great deal of water; however, as was mentioned above, the hydraulic conductivity of unfractured Brule is very low (Wenzel et al., 1946). Hence, a well drilled in this area can fill and be pumped, but a person may only get one casing volume of water and then have to wait days and/or months for the well to refill. However, channels of sandstone and fractures within portions of the Brule conduct water easily and have high transmissivity values ranging from 10,000 to 100,000 gallons per day-foot (Olsson Associates, 1993). The large range of transmissivities results from the variation in the fracture network. To be a viable source of ground water for irrigation, the fractures need to be well connected or have another source of water. In some areas the upper portion of the Brule Formation is significantly fractured. Any overlying Quaternary deposits such as alluvium and dune sand, which generally have high hydraulic conductivity, allow water to percolate down into the fractures. In these areas an economically viable ground water resource can be found. The same can be true in cases where the Ogallala Group overlies the Brule. The fractures in the Brule transmit sufficient water for irrigation both north and south of the North Platte River in Scotts Bluff and Morrill Counties. Water supplies from the Brule are greatest in areas nearest the surface water irrigation canals and least where precipitation is the source of recharge (Wenzel et al., 1946). The main sources of water supply in the outer portions of the North Platte River Valley are the fractures and perhaps the channel fill deposits in the Brule Formation.

In addition to the Brule Formation, the Chadron Formation and other undifferentiated Cretaceous rocks underlie the North Platte River Valley in Scotts Bluff County. Because the water quality in these aquifers is so poor and the depth to water is great, these aquifers are rarely developed. Typically, water is found under confined conditions and some wells were artesian when first drilled. In the western portion of Scotts Bluff County, the Chadron

Formation outcrops (Wenzel et al., 1946). The Chadron aquifer is confined by bentonitic mudstone and claystone of the Chadron confining unit, which is thought to underlie most of the area in the NPNRD west of Range 56 West and North of Township 22 North (Verstraeten et al., 1995). The extent of this confining layer throughout the NPNRD is unknown. A map of the extent and thickness of the Chadron Formation can be found as Figure 12-18 in the NPNRD's 1993 GWMP. Yields of wells range from only a few gallons per minute to 1,000 gallons per minute (Olsson Associates, 1993). These aquifers are only used when other sources of water are unavailable, mainly in the western portion of Scotts Bluff County (Wenzel, et al., 1946). If these aquifers are truly confined they are most likely not hydrologically connected to the surface water.

Ground water levels range from 0 to 100 feet below land surface. As can be seen from the water table contour map (App. III Figure 9), ground water flow direction is generally from west to east and toward the North Platte River and its tributaries.

Development of the Canal System

As described by Bleed (2000), snowmelt from the Rocky Mountains in Colorado and Wyoming is the primary source of water for the North Platte River. Prior to the construction of reservoirs and development of surface water irrigation in the valley, the flows on the North Platte River were high in the spring, but relatively low to zero in the summer and fall (Fremont, 1845; Smith, 1897; Channel, 1901; Eschner et al., 1981). Early reports indicate that there were no perennially flowing tributaries to the North Platte River between the state line and Bridgeport, Nebraska. Further downstream there was sufficient flow in Pumpkin Creek and Blue Creek for diversion (Darton, 1899; Willis, 1910; Wenzel et al. 1946; Rapp et al., 1957).

The building of reservoirs, which captured spring runoff for later summer releases, and the development of irrigation delivery systems between 1905 and 1925, allowed crops to be watered not just in the spring, but also in the summer, when the crops had the greatest need for water. Along with surface water irrigation development came surface water spills from canals and surface water runoff from fields (Bleed, 2000).

Thus, the major source of water for the North Platte River comes from Wyoming. Figure 4 shows the hydrograph of flows that enter Nebraska either from the North Platte River at the state line or from canals that divert water in Wyoming but serve land in Nebraska.

The high permeability of the valley geologic materials also allowed surface water leaked from canals to readily migrate to the water table, which is not far from the ground surface. Seepage from the canals and deep percolation of water applied to fields increased recharge to the ground water aquifer. In 1946, Wenzel, Cady and Waite observed that the importation of surface water was the major cause of ground water level rises in the valley, noting that the general rise in the water table was 10 feet and as much as 100 feet in some areas. They also noted that the water level fluctuations in alluvial wells coincided with diversions into nearby canals (Rapp et al., 1957). This affect can still be seen today. An example is the hydrograph of a well near Sheep Creek and the Interstate Canal (Figure 5). Figure 6 is a hydrograph of a well that is not influenced by a nearby canal. In this monitoring well there is no irrigation season upward flux, as the well is not located near a canal system, and the water level has declined nearly 23 feet since 1977.

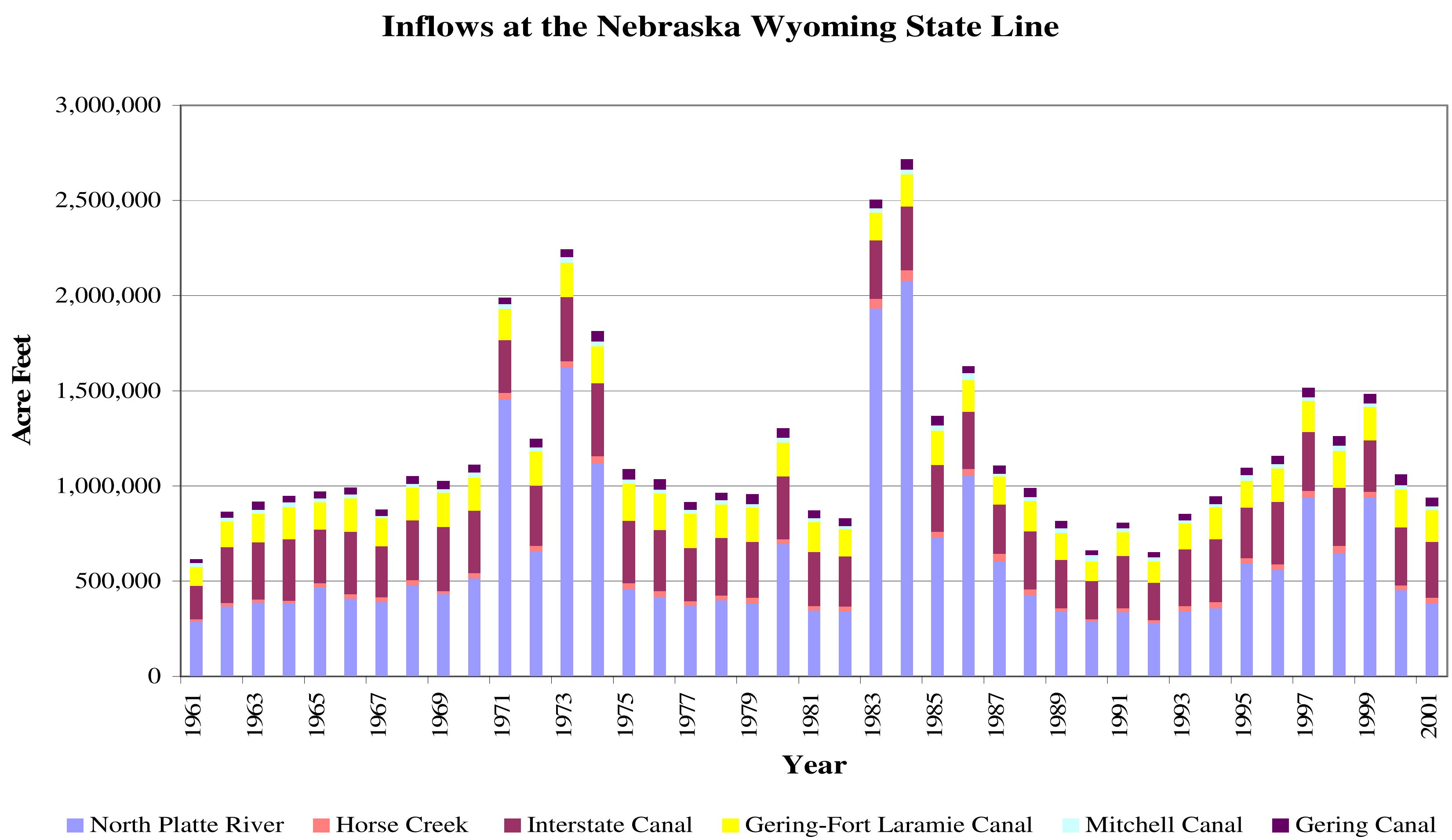


Figure 4: Inflows at the Nebraska – Wyoming state line. Interstate Canal, Gering-Ft. Laramie Canal and Horse Creek diversions were adjusted to reflect the amount of diverted flow that actually reached the state line (Adapted from Bleed, 2000).

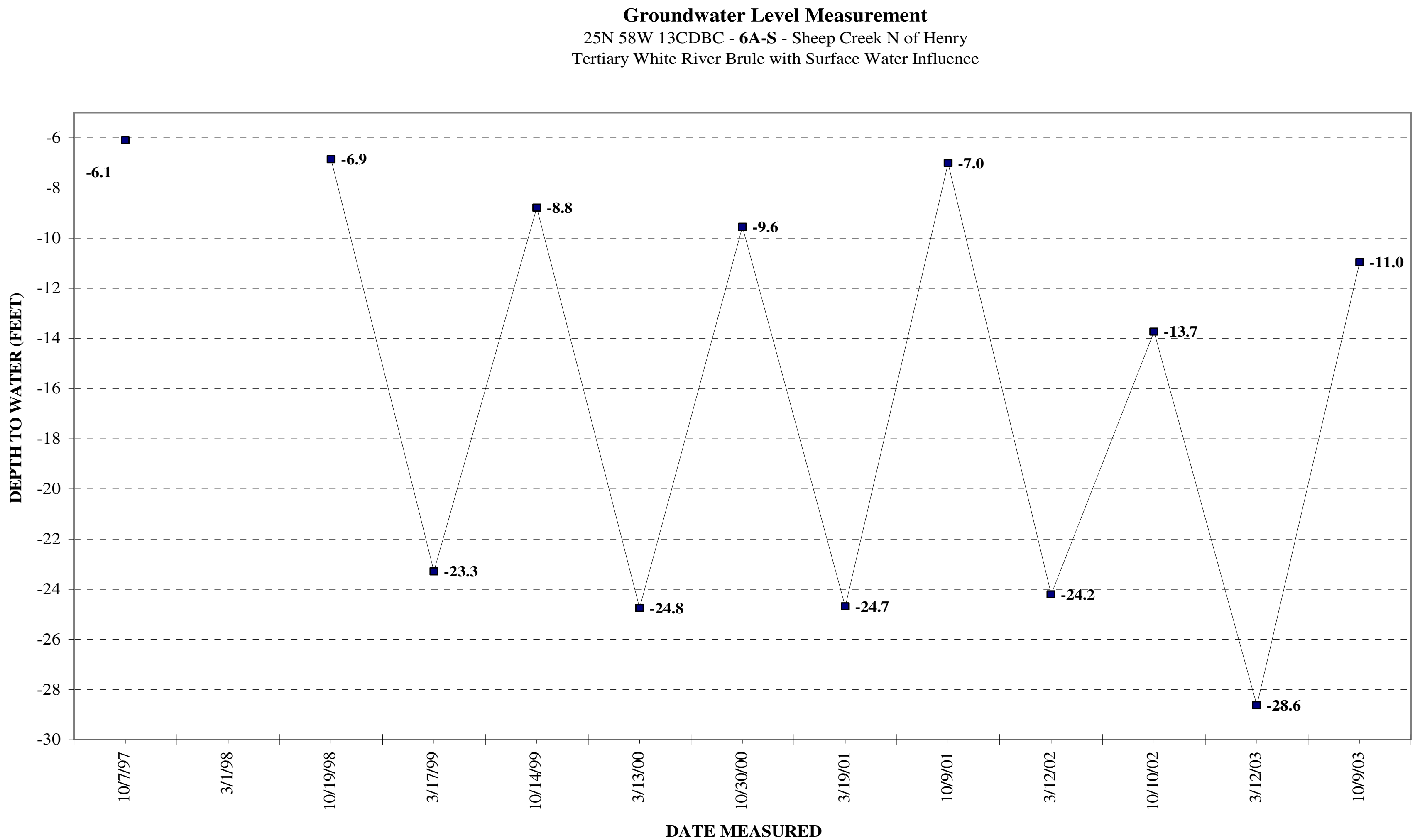


Figure 5: Hydrograph of a well near Sheep Creek and Interstate Canal, DNR registration number G-093083.

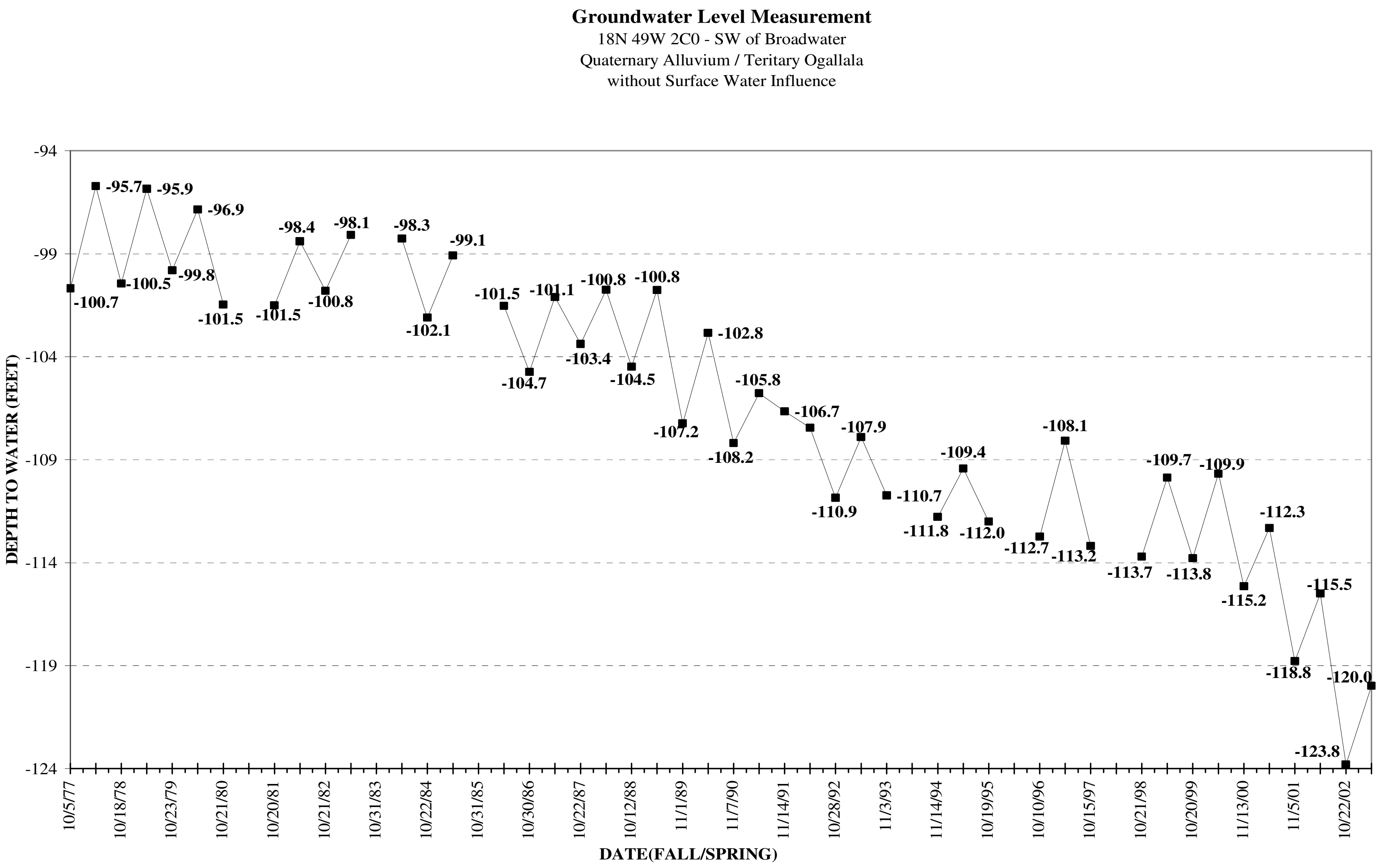


Figure 6: Hydrograph of a well not influenced by surface water canals, DNR Registration number G-029574.

As the ground water reservoir began to fill, it started to spill into low-lying areas creating wetlands. In 1911, there was no perceptible return flow west of Bridgeport (Willis, 1930), but between 1931 and 1938, the return flow between the state line and Minatare, Nebraska was over 326,000 acre feet (Wenzel et al., 1946). Eventually the combination of increased surface water runoff and higher water tables produced perennially flowing streams, such as Sheep Creek, Dry Spotted Tail Creek, Wet Spotted Tail Creek, Akers Draw, Nine Mile Creek and Tub Springs (See Figures 5 & 7 and tributary trend Figures in App. II). Some of these streams, such as Nine Mile Creek in Scotts Bluff County, now boast trout fisheries. Rapp et al. (1957) concluded that if irrigation diversions were terminated, these tributary flows would cease and the water table in the alluvial aquifer along the North Platte River would continue to drop (Figure7A). The dashed lines represent the projected water table elevation if the canal did not divert during the following irrigation season. The difference between the projected low water level and the high water level is approximately 8 feet/year. This significant influx of water to the ground water aquifer fills the alluvial aquifer in the areas influenced by the surface water canals and provides the major source of water for the many irrigation and domestic wells in the western portion of the NPNRD.

In a study of streambed hydraulic conductivity (K), David L. Rus et al. (2001) tested 10 sites in the Platte River watershed. In all cases, tests performed in the flood plain of the Platte or North Platte Rivers, the streambed contained no materials that would limit the ground and surface water interaction. Most of the K values ranged between 100 and 1,000 ft/d.

Figures 8 and 9 depict the basic hydrologic connection between a canal and the North Platte Valley respectively. In Figure 8 the leakage from the canal is creating a small ground water mound in the immediate area beneath the canal, similar to what is seen along canals in the North Platte Valley. Figure 9 shows a wider view of the system, which includes not only the large amount of recharge from deep percolation beneath irrigated fields and canal leakage, but also recharge from precipitation and discharge to evapotranspiration. The configuration of the bedrock and ground water flow are also depicted.

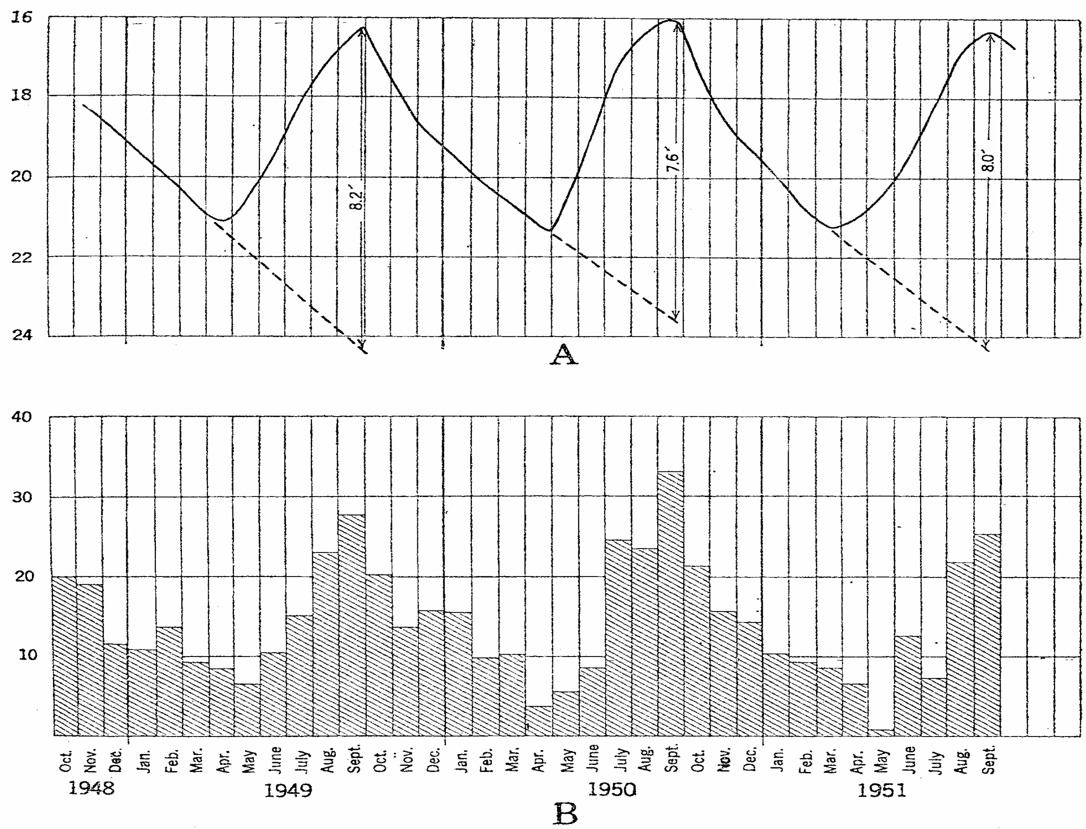


Figure 7: Hydrographs showing (A) the average water level in 12 wells in the valley fill, and (B) the invisible pickup in the North Platte River between Whalen Dam and the Wyoming-Nebraska State line (Rapp et. al, 1957).

Schematic Hydrologic Models

Basic Canal

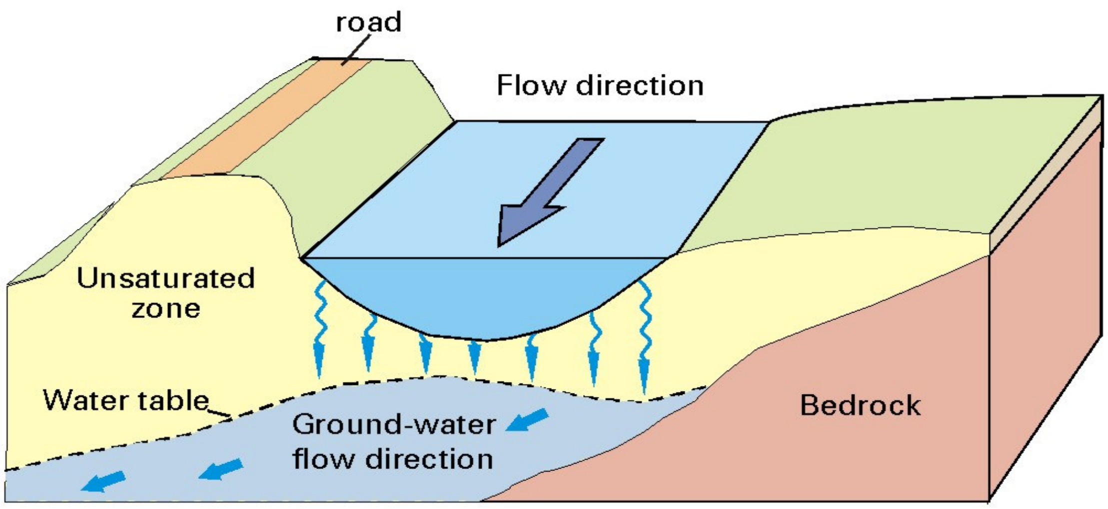


Figure 8: Canal leaking surface water to the ground water table.

North Platte Valley

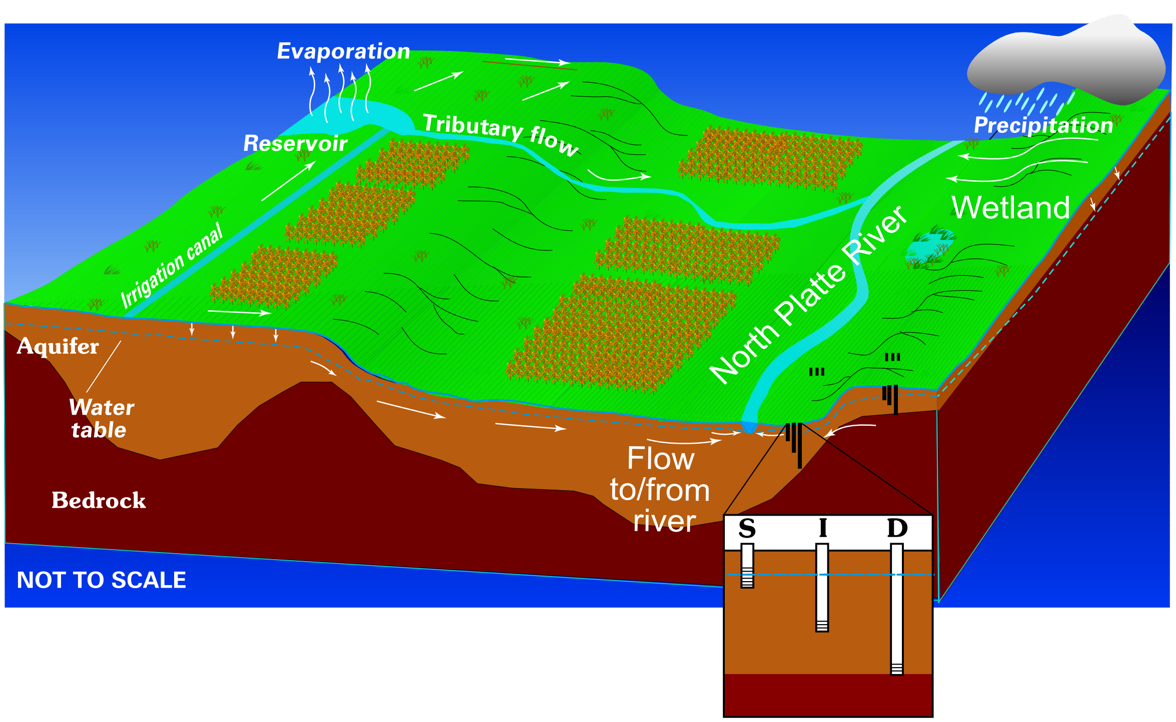


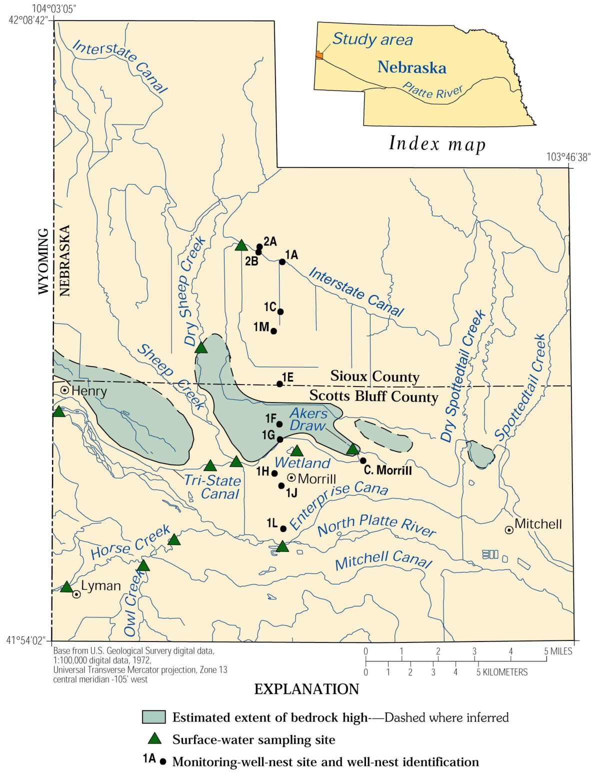
Figure 9: Modified from Winter and others, 1998; monitoring wells: S – Shallow, I – Intermediate, & D – Deep.

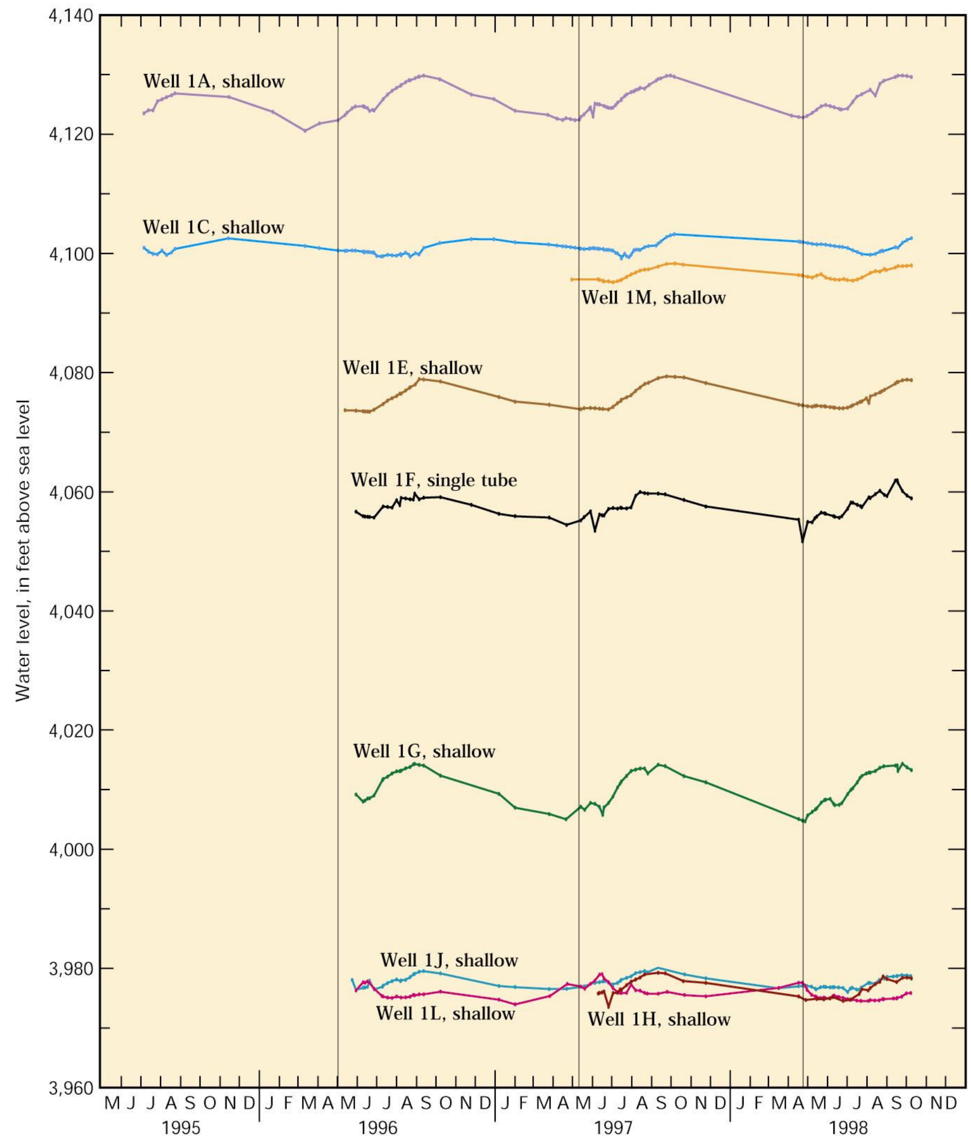
Chemical data gathered during the course of other studies in the region also indicate that there is a strong connection between surface and ground water in the area between the canals and the river (Harvey & Sibray, 2001 & Verstraeten et al., 2001). Figure 10 shows a graph from the Steele et al. (2001) USGS Fact Sheet on the Dutch Flats area of Scotts Bluff County, which indicates the elevations of water levels from the North Platte River to the Interstate Canal and their cyclic change throughout the year based on surface water delivery and related recharge. Water level rises appear shortly after surface water is diverted to the canal. The magnitude of change that occurs in the ground water system due to surface water recharge is significant. Water levels in some monitoring wells within 1000 feet of a canal rose 10 feet during the irrigation season (Steele et al., 2001). In the area near Interstate Canal recharge was estimated, and generally agreed with the estimate of Babcock and Visher (1951), of three feet per summer (Verstraeten et al., 2001). By comparison, the local precipitation recharge in the North Platte Valley is estimated at 3 to 5 inches per year (CSD, 1984).

The same 2001 USGS study on Dutch Flats states that based upon nitrate concentrations, within one month surface water appears to replace ground water in the upper 30 feet of the alluvial aquifer within about one mile of Interstate Canal. Most of this water is less than 30 years old (Verstraeten et al., 2002). Figure 11 illustrates the age of ground water found along a transect of monitoring wells running south to north across the North Platte Valley in the Dutch Flats study area. Consequently, most of the ground water in the alluvium is water originally diverted from the North Platte River that is seeping from canals and irrigated lands. It is reasonable to expect similarly aged ground water in most areas of the North Platte Valley where surface water is applied or transported through ground water areas, which indicates the ground water to be the result of leakage from recent surface water irrigation diversions. The majority of recharge within the valley comes from water that percolates down from the canals and fields. When and where irrigation recharge water is available, the concentration of pollutants such as nitrates is diluted allowing the water to meet safe drinking water standards (Verstraeten et al., 2001). The dilution effects can be seen in Figure 12, as the water level rises due to canal leakage the contaminant concentration decreases.

Though the canal system was not designed to set up a water reuse system, that is in fact what developed. One person's waste becomes the next person's supply. Return flow from water diverted by Interstate Canal in eastern Wyoming becomes a major source of the supply for the Tri-State Canal. In turn, return flow from the Tri-State Canal provides water for other canals downstream, such as the Alliance, Chimney Rock, Browns Creek and Beerline Canals. Even ground water wells in the alluvium are dependent upon the yearly supply of ground water recharge from the surface water irrigation system. Thus, water originally diverted in Wyoming is diverted repeatedly until the final returns flow into Lake McConaughy at Lewellen. As a result, a decrease in return flows at the upstream end of the system will result in a decreased water supply for downstream water rights and alluvial ground water wells.

Ground Water Levels





Canals seepage raises ground water levels about 10 feet above seasonal low water levels near the canals.

From The Dutch Flats Report USGS-NPNRD; USGS Fact Sheet 074-01, September 2001.

Figure 10: Water Level change looking north from the North Platte River.

Age of Ground Water

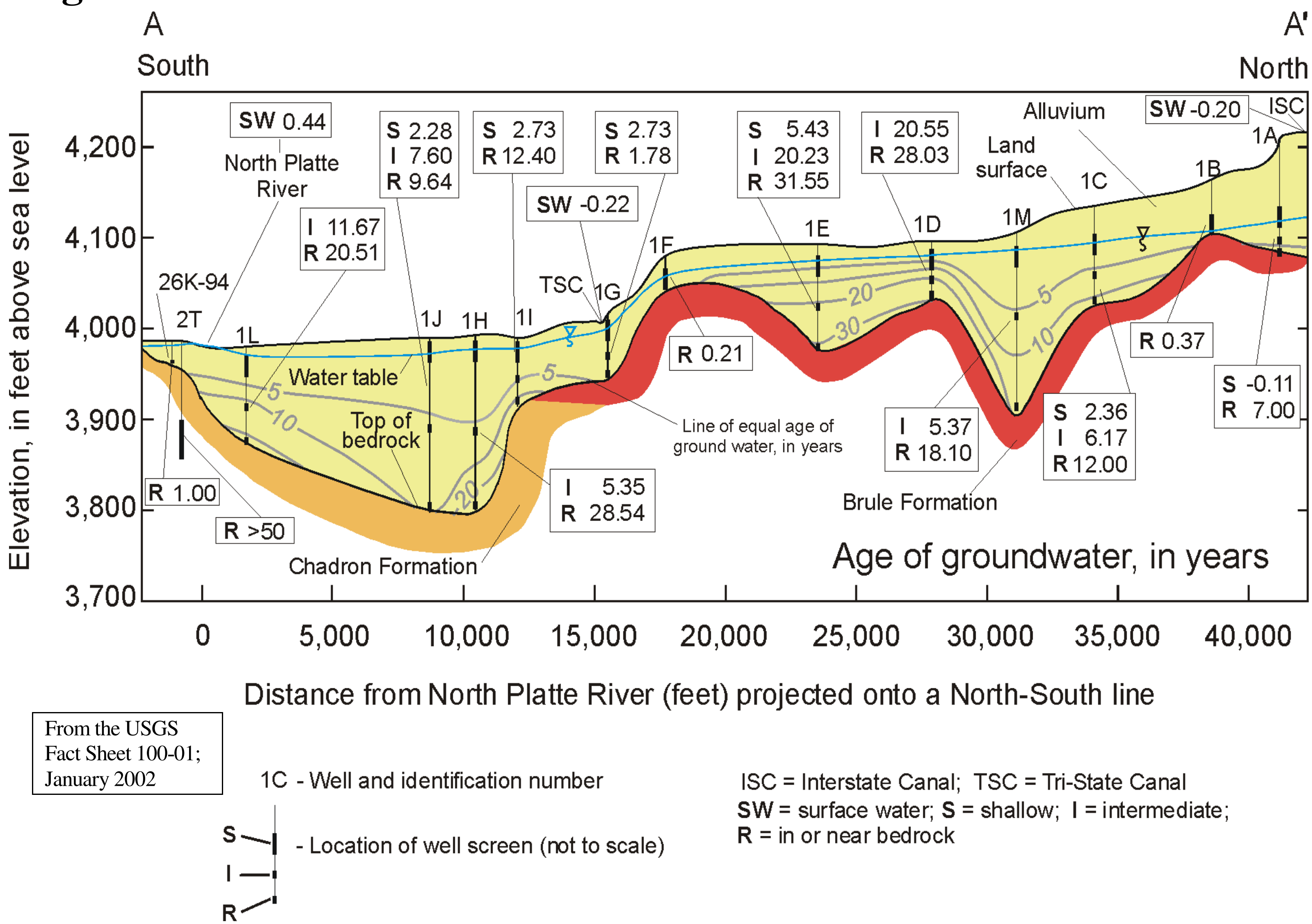
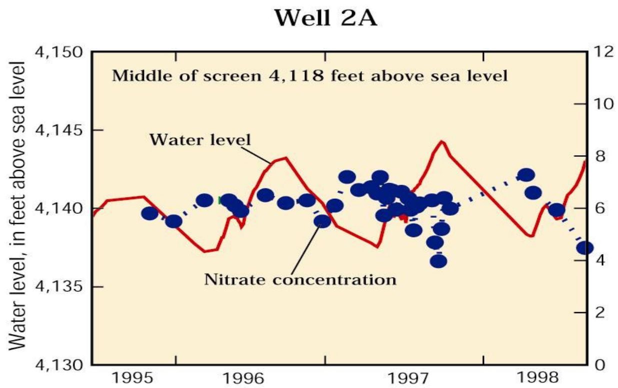


Figure 11: Ground Water in alluvial aquifer < 30 years old, overall mean age is 8.8 years. The numbers in the boxes above are the age of the water in years.

Canal Water affects Ground Water



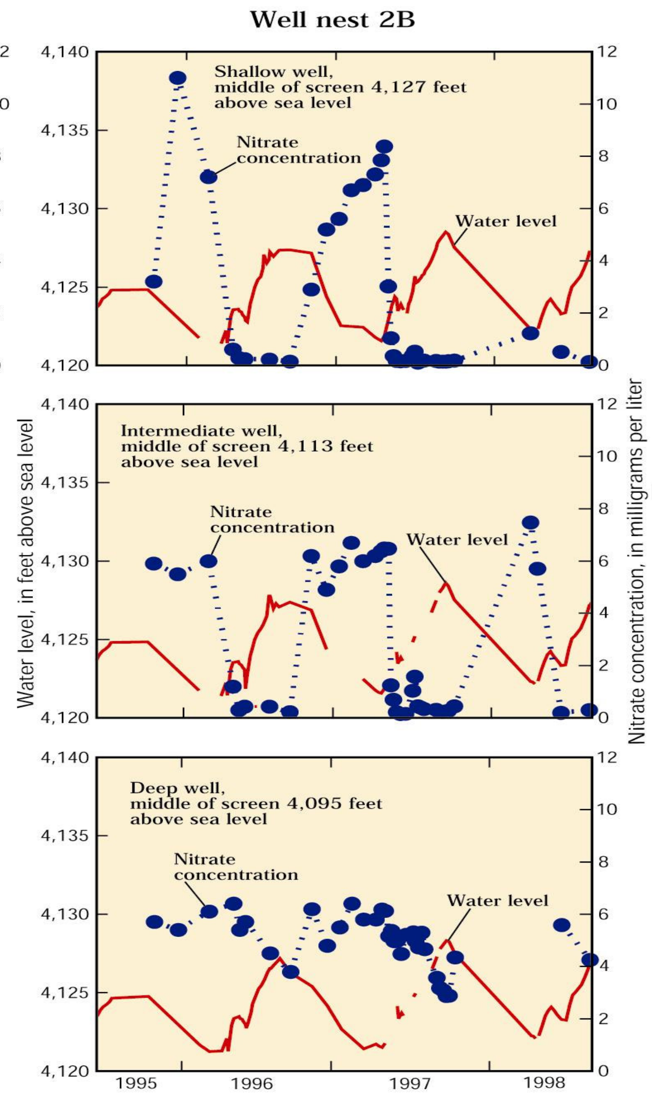


Figure 3. Variation of nitrate concentrations and water levels in monitoring wells 2A and 2B, Dutch Flats area, western Nebraska, July 1995 through September 1998.

From The Dutch Flats Report
USGS-NPNRD; USGS Fact Sheet 074-01,
September 2001

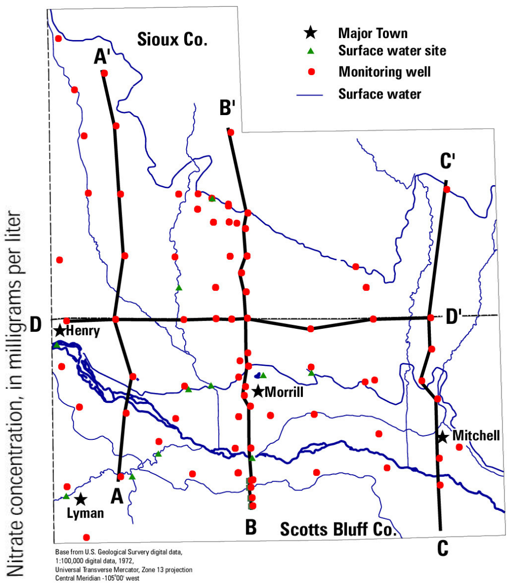


Figure 12: Leakage from canals locally causes decreases in nitrate and uranium in shallow ground water. As the water level rises due to increased canal leakage the contaminant concentration decreases.

Conflicts - Causes

Surface Water Appropriators/Ground Water Users

Figure 13 shows the 273 surface water appropriations filed in the offices of the DNR by their priority date and use as well as the corresponding number of current permitted acres. The majority of the irrigation from natural stream flow rights have priority dates older than 1920, with the oldest being 1882. The majority of the storage rights for dams within the NPNRD have priority dates after 1960. These two uses added together account for 77 percent of the 273 total appropriations in the NPNRD. The other uses have been added over time as the DNR had a larger variety of applications and the statutes changed to accommodate these uses.

Figure 14 shows the year-by-year progression of registered irrigation wells as they were completed in each study area of the NPNRD. Whereas the majority of the development of surface water appropriations occurred in the late 19th and early 20th centuries, ground water well development did not really get started until the late 1950's with development intensifying in the 1970's.

Currently in this section of the North Platte River, regulation of surface water rights is a yearly occurrence. The only time rights are not regulated has been in flood years, the most recent example being the early 1980's. Since 1993, the North Platte River above Lake McConaughy has been closed to new surface water appropriations because there is an insufficient supply of water to meet the demands of any additional appropriations. Once a stream is over appropriated any further depletion of stream flow would cause more surface water appropriators to be closed in any given year resulting in increased conflict.

Today, there is increasing concern over an apparent decrease in irrigation return flows supplying the tributary streams and recharging the ground water aquifers. In response DNR completed a statistical analysis of the flows in the NPNRD and factors that might impact those flows (Appendix II). According to the statistical analysis, generally the streams along the north side of the river, as well as flows at the Lewellen gage, show a negative slope in a trend analysis of their total annual flow from 1961 to 2002. Tri-State Canal has shown a decreasing trend in diversions from tributaries and an increasing trend in diversions from the North Platte River. This could be due to the fact that there is less water available in the tributaries for Tri-State to divert.

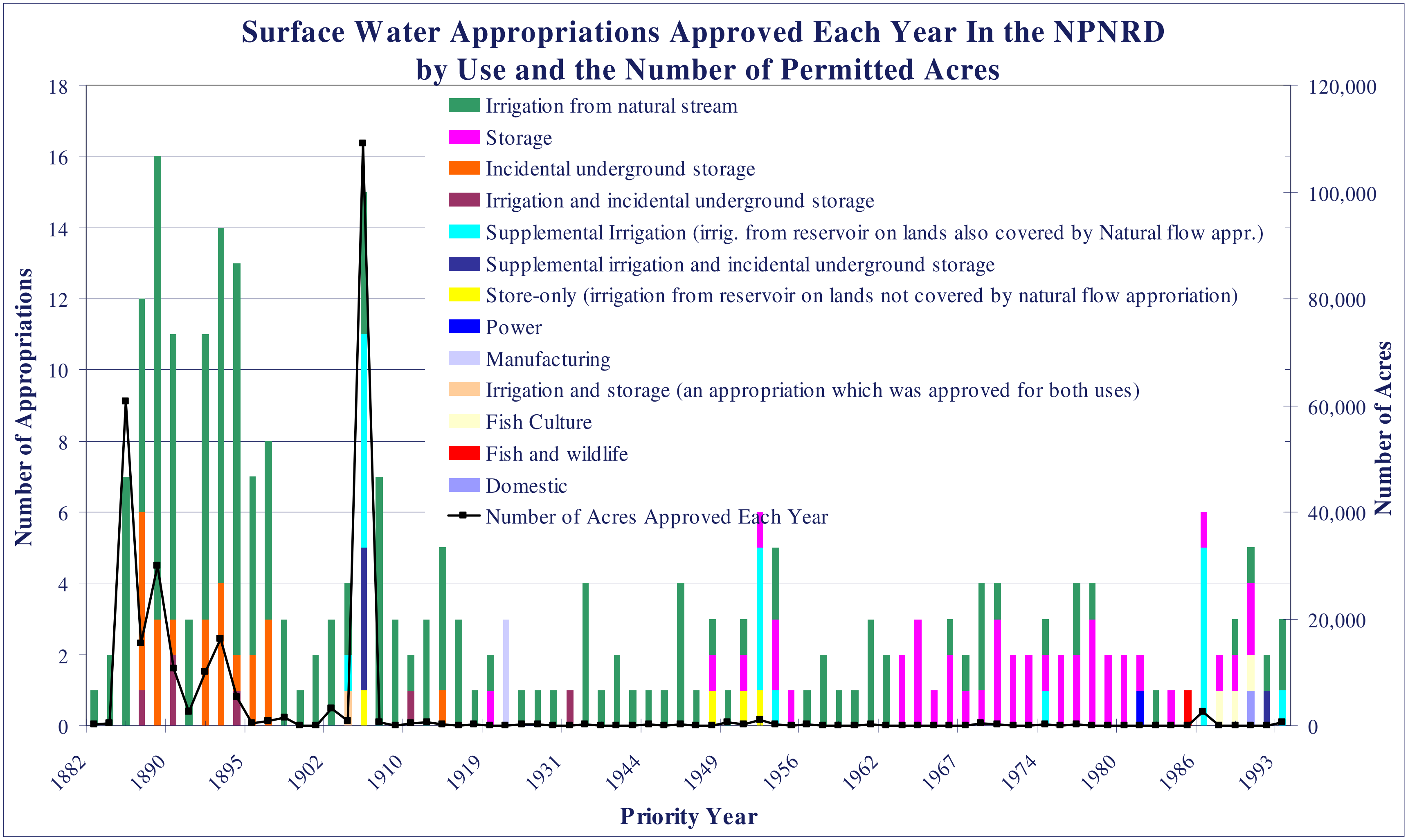


Figure 13: Surface water appropriations filed in the offices of the DNR shown by their priority date and use. On the right side axis is the number of current acres represented by the line on this graph.

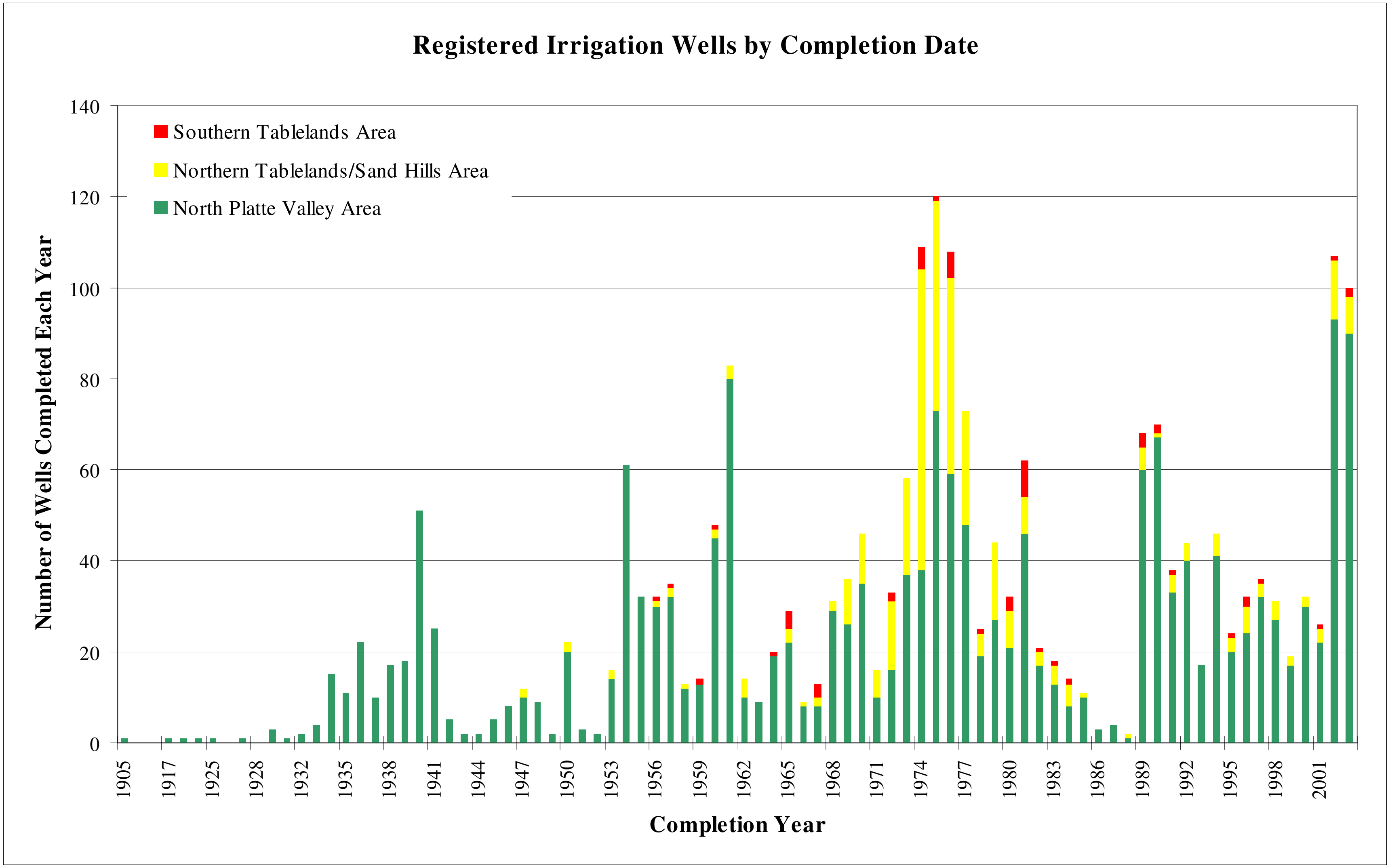


Figure 14: Year-by-year progression of irrigation wells as they were completed in each study area of the North Platte Natural Resources District.

The statistical analysis examines several possible causes for the declines in tributary flows. Possible causes include a decrease in precipitation, the outflows from Guernsey Reservoir, and the diversions of Interstate Canal, or an increase in surface water irrigated acres and ground water wells. The number of surface water irrigated acres showed a significant decrease over time; therefore, it is unlikely that increased consumptive use from surface water irrigated acres is a cause for decreases in return flows. There was however a significant increase in the number of irrigation wells. Unfortunately there are no good data describing the number of acres irrigated with ground water on a year by year basis. Therefore, the number of registered irrigation wells was used as an index of the amount of ground water irrigation. The step-wise regression analysis found several significant factors affecting stream flows. Variances in outflows from Guernsey Reservoir in Wyoming explained 91% of the annual variation in the flow at Lewellen (App. II, Table 4). Approximately 74% of the annual variation of the tributary streams (return flows) on the north side of the river can be explained by the diversions into Interstate and Tri-State Canals. Annual changes in precipitation account for only 7.1% of the variation in total tributary flow. The numbers of irrigation wells were not statistically significant factors in the regression analysis. There are several reasons why the number of wells might not emerge as a significant factor. First, the number of active wells every year does not directly correlate with the actual amount of water pumped by those wells on a year by year basis. Second, the volumes of water being recharged by the canals are so immense that in comparison to the consumptive use from wells it is difficult to find the effects of the ground water wells using a simple regression analysis. .

Using a different statistical approach, the non-parametric Mann-Whitney U Test, the large impacts of canal diversions and precipitation on tributary flows were eliminated by choosing two time periods 1971-1982 and 1993-2001, for which statistical tests showed there was no significant difference in canal diversion and precipitation. The same statistical tests did however show a significant decrease in tributary flows in the later period. There was also a significant increase in the number of irrigation wells between these two time periods.

The regression analyses emphasize the importance of flows from reservoirs in Wyoming on the water supplies of the NPNRD. Whereas, the Mann-Whitney U Test indicates that wells are very likely having an impact on the tributary flows.

Ground water wells allow more acres to be irrigated as compared to the lands historically irrigated with surface water alone and allow for increased delivery of water to existing surface water acres during times when surface water is in short supply. The number of depletive wells (wells that consumptively use ground water) in the North Platte River Valley study area has increased from 1 in 1905 to approximately 2989 as of October 20, 2003 (Figure 3).

In addition to wells found inside of the NPNRD, wells downstream in the SPNRD, Twin Platte Natural Resources District (TPNRD) and Central Platte Natural Resources District (CPNRD), which consumptively use ground water that is hydrologically connected to the Platte River and its tributaries, can cause injury to surface water appropriators in the NPNRD. To the extent these wells decrease the surface flows of the Platte River downstream from the NPNRD they decrease the natural flow available to senior surface water rights. When natural flow is insufficient to meet the senior surface water rights downstream, the DNR is called upon to shut off junior rights upstream in the NPNRD, causing injury to surface water appropriators in the NPNRD.

Other State Agreements

As the result of a Cooperative Agreement signed by the states of Nebraska, Wyoming, Colorado and the U.S. Department of Interior, the State is currently involved in negotiations that could result in the implementation of an Endangered Species Recovery Implementation Program for the Platte River. An important component of this Program is the requirement that depletions to river flow caused by uses begun on or after July 1, 1997, that would adversely affect endangered species target flows be prohibited or offset with replacements. If Nebraska eventually agrees to implement the Recovery Program, an integrated management plan with the NPNRD will be required. Therefore, any new uses of ground water that deplete stream flow needed to satisfy the endangered species target flows are likely in the foreseeable future to be a cause for conflict.

III. Northern Tablelands – Sand Hills Area

Hydrogeology - Extent of the Area Affected

The composition of the aquifer in this study area trends from predominantly the Arikaree Group in the west to a mix of Arikaree and Ogallala Group near the center to predominantly the Ogallala Group in the east. On the ground water regions map (Figure 7 App. III) this area consists of two distinct regions, the Northern Panhandle Tablelands and the Sand Hills. In this study the regions were combined to reflect the fact that ground water in the Northern Panhandle Tablelands flows east into the Sand Hills toward Blue Creek and the North Platte River without any major barrier such as the low conductivity material found in the Brule Formation. Even though in terms of hydrologically connected ground water and surface water, these areas are considered one, it is important to remember that there are many characteristics which still distinguish the two regions.

The Arikaree Group, which is predominant in the Tablelands region, consists mostly of very fine to fine-grained and some medium-grained sandstone. These sandstone beds can yield moderately large amounts of water to wells that penetrate a saturated thickness of more than 100 feet in the tablelands of Sioux and Box Butte Counties (Wenzel et al., 1946). According to the 1993 NPNRD GWMP, the saturated thickness of the aquifer ranges from less than 100 feet to 500 feet. This results in a highly variable total amount of ground water in storage, ranging from 0 to 60 feet. The hydraulic conductivity is generally 100 to 300 ft/day or less and, depending on aquifer thickness, values of transmissivity range from less than 20,000 to as much as 50,000 gallons per day per foot (Olsson Associates, 1993). Generally hydraulic conductivity and transmissivity in the Arikaree is lower than the same hydraulic properties of the Ogallala Group.

The Sand Hills portion of this area occurs mainly in northeastern Morrill and northern Garden Counties. A significant ground water resource is contained in this area. In this region the main aquifer is the Ogallala Group and the overlying Quaternary sand deposits. The Quaternary sand deposits are hydrologically important due to their ability to absorb precipitation and transmit it downward to the underlying Ogallala deposits. Because these sand deposits reach to the land surface, most precipitation infiltrates into the soil and overland runoff is greatly reduced. The Ogallala Group consists of gravelly sand, sand, siltstones and clay. The Ogallala has high hydraulic conductivity and specific yield, with transmissivity values ranging from less than 50,000 to 100,000 gallons per day per foot (Olsson Associates, 1993). The Ogallala Group will yield water to wells more readily than an equivalent thickness of Arikaree or Brule. In places large yields can be obtained from wells of moderate depth tapping the Quaternary sands, while elsewhere large yields can be obtained from deeper wells tapping the Ogallala. The depth to water in this area can vary from zero to more than 300 feet below the land surface, which is mainly a result of the topography of the sand dunes. The saturated thickness of the aquifer ranges from 100 to more than 500 feet, with most of the area having a thickness greater than 300 feet and an estimated total supply of water between 40 and 60 feet in the western half and over 60 feet in the eastern half (Olsson Associates, 1993). This area represents a potential source for future development.

Unlike the North Platte Valley, surface water is not transported into this area by a network of canals from large storage reservoirs located upstream. The source of water is local precipitation and underflow of ground water primarily from the north and west. Local recharge rates from precipitation range from 0.5" to 0.8" per year in the Northern Tablelands (CSD, 1984) to 2" to 2.5" per year in the Sand Hills (COHYST, 2003). The difference in recharge rates can be mostly attributed to the sandy soils of the Sand Hills.

The ground water contour map (Figure 9, App. III) shows that ground water flows in a variety of directions due to the ground water divide through this area. The map shows that most of the ground water in the Sand Hills flows south and east toward Blue Creek and toward the North Platte River. The ground water also flows north and east into the UNWNRD in the direction of Snake Creek and tributaries to the Niobrara River. Toward the eastern edge of the study area the ground water flows into the Twin Platte (TPNRD) and Upper Loup (ULNRD) Natural Resource Districts eventually flowing to the Platte River downstream of the NPNRD.

David L. Rus et al. (2001) tested streambed hydraulic conductivity (K) at one site on Blue Creek, out of the North Platte River flood plain. Large variability in K (<0.01 to 170 ft/day) was found at this site because of interspersed layers of silt and sand. Though the silt layers could impede the ground and surface water connection at this site, the extent of these layers is not well known, nor would they impede any horizontal flow of ground water to the creek. Stream gage data showing very constant seasonal flows and water level contour maps support the theory that Blue Creek is a predominantly ground water-fed stream. The Sand Hills Atlas (1989) also refers to Blue Creek as a predominantly ground water-fed stream.

<u>Conflicts - Causes</u>

Surface Water Appropriators/Ground Water Users

The oldest surface water rights on Blue Creek date from 1890 (Table 1 Appendix IV). In total, there are 16 surface water rights on Blue Creek and its tributaries, with 15 of them totaling 143.25 cfs and 1 storage right for 4.93 ac-ft. According to DNR registered well records, ground water wells were first completed in this area in 1910 (Figure 3), and as of October 2003, there were approximately 710 depletive wells in this study area. A historical high of 66 wells completed per year was reached in 1974 and a recent high of 73 per year in 2002 (Figure 15). A band of well development can be seen paralleling the North Platte River Valley to the north above the escarpment (Figure 5 App. III). Further west and north the area is not suitable for row crop development as can be seen from the lack of crops in the area on Figure 4 App. III. There are very few wells, even though the potential exists to develop ground water wells, and no surface water rights in the northwest portion of the study area. Outside of the NPNRD boundaries, but hydrologically connected to the ground water within the NPNRD, are approximately 1,200 active registered irrigation wells in Box Butte County (Figure 5 App. III).

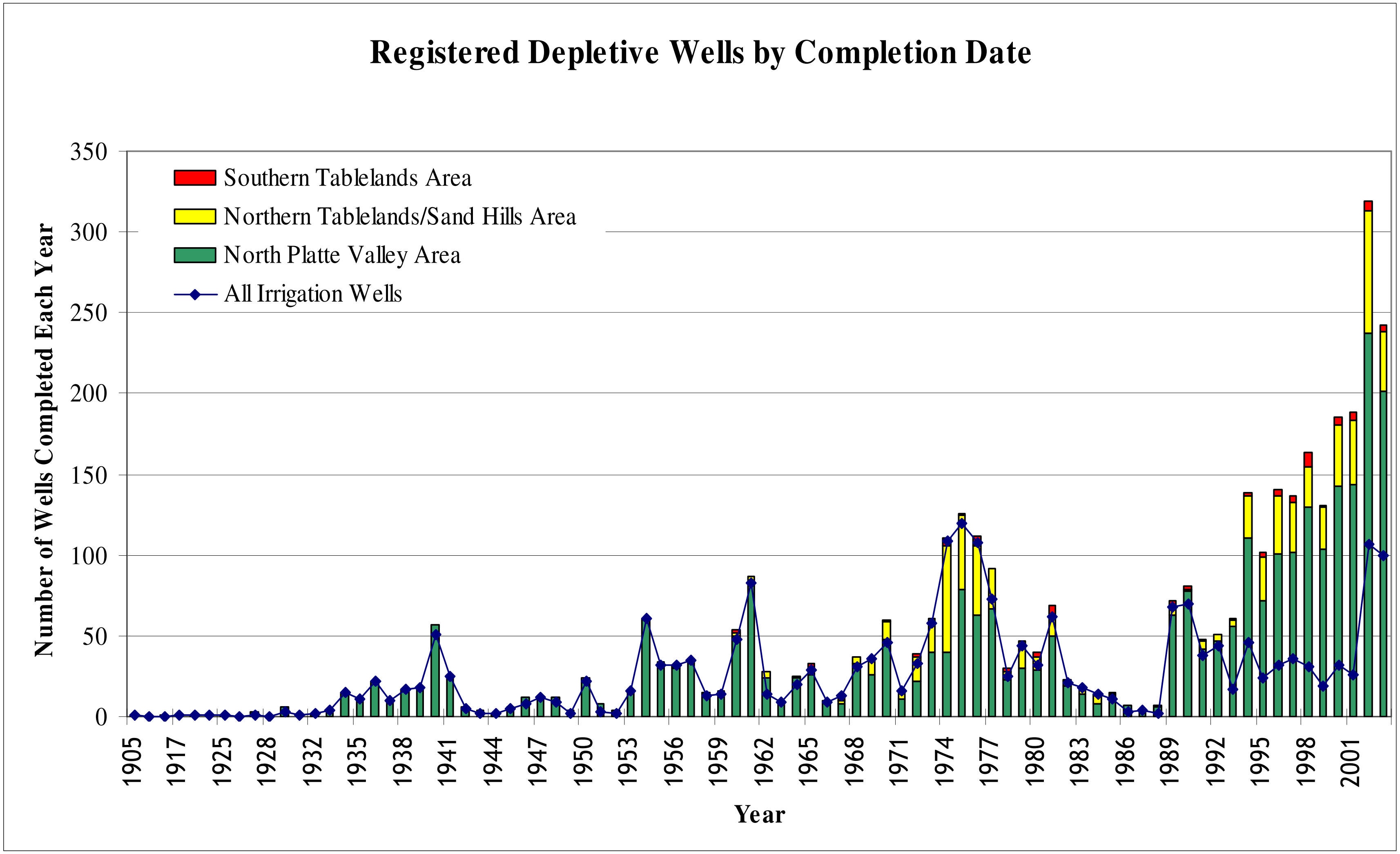


Figure 15: Depletive ground water wells listed by completion date and by study area.

A monitoring well in this study area shows a steady decline in water table elevations of approximately 12 feet since 1984 (Figure 16). On Figure 17 in the area of Box Butte County, the USGS ground water contour lines show a steep decline, +50 feet, that reaches slightly into Morrill County, and flow lines show ground water in the surface water drainage of the North Platte River to be flowing toward the depression in Box Butte County, into the UNWNRD. This is not surprising considering the large water level declines seen in the area around the City of Alliance. Continued well development in this area will ultimately impact the surface water supply of the North Platte River as well as streams in the UNWNRD.

Even though there is currently little ground water development in the far northwestern corner of this area, there is more than 60 feet of total supply in some areas (Olsson Associates, 1993) that may be attractive for development of industrial or commercial consumptive uses as other sources of ground water are regulated.

In § 46-656.06, the Legislature recognized that ground and surface water use in one NRD may have adverse effects on water supplies in another NRD, and that each NRD is expected to accept responsibility for ground water management in these areas in the same manner and to the same extent as if the conflicts were contained within their own district. In a letter dated February 26, 2003, the Department of Natural Resources made a preliminary determination that the use of hydrologically connected ground and surface water was contributing to conflicts in the UNWNRD. Similar letters stating that the use of hydrologically connected ground water and surface water was contributing to conflicts were sent to the CPNRD, TPNRD, and SPNRD. Evidence of conflicts in these various NRDs which are adjacent to or near the NPNRD must be taken into consideration in developing any joint action plan.

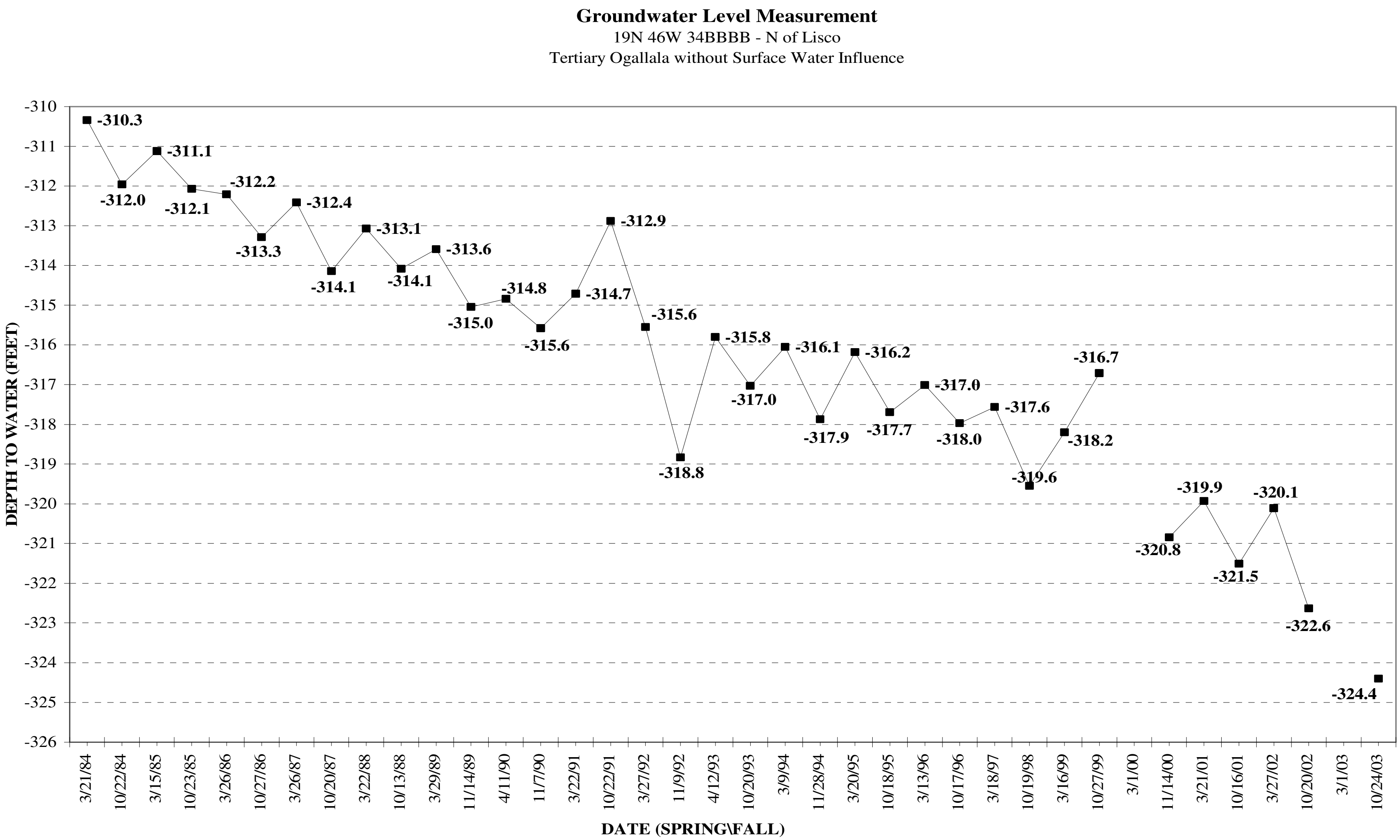


Figure 16: Monitoring well showing an approximate a 12 foot decline since 1984 when monitoring began at this site, no DNR registration number.

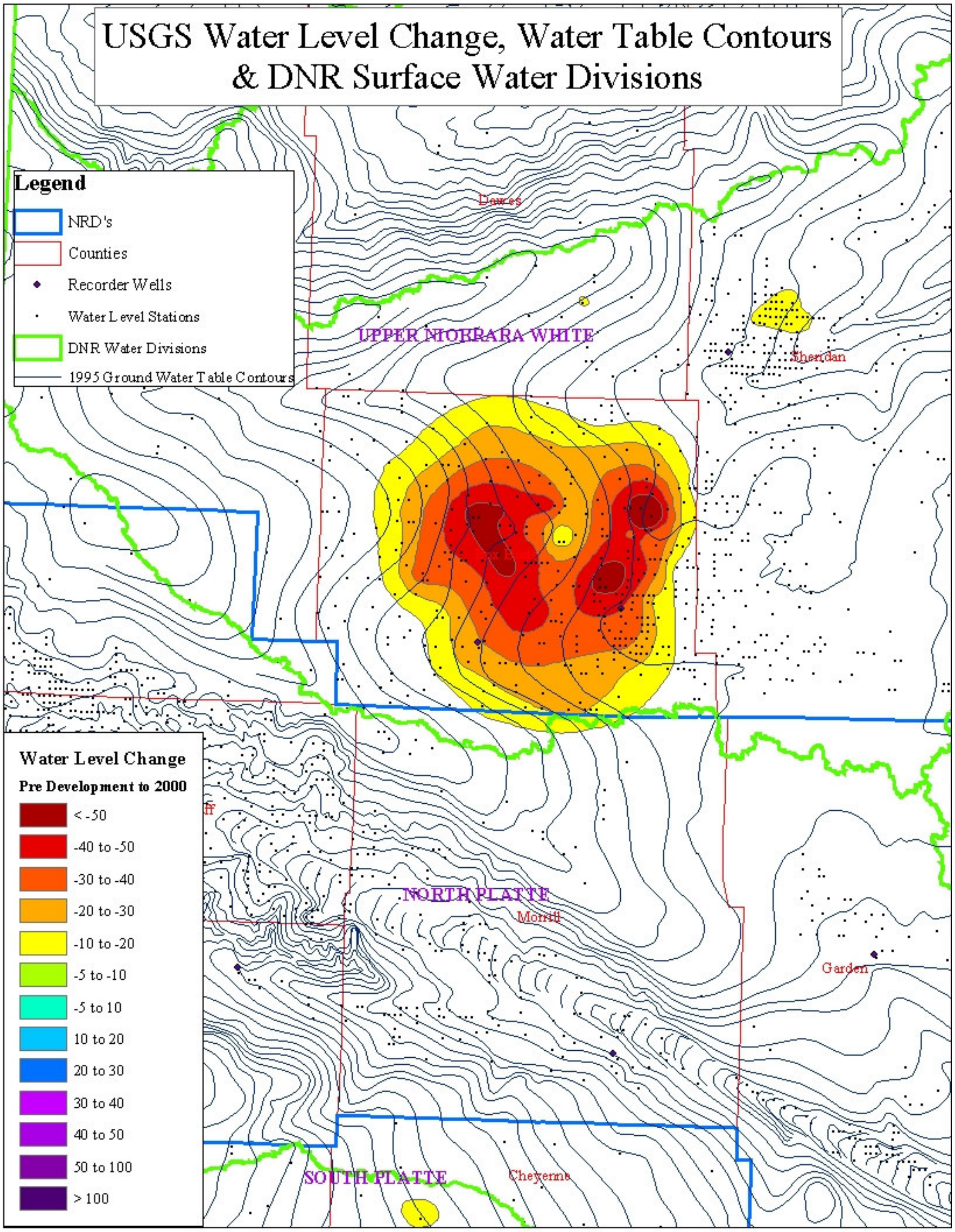


Figure 17: USGS Pre-Development to 2000 ground water level declines, 1995 water table contours & DNR surface water division boundaries, depicting the contrast between the surface water boundary and the direction of ground water flow in northern Morrill County.

Though outside the scope of this study, the question of what, if any, impacts increased numbers of depletive ground water wells might have on the many sub-irrigated meadows, wetlands and lakes in the Sand Hills area was raised by persons in the stakeholders group. Many of these lakes are a manifestation of the natural high water table and the ground water supply is critical to the existence of Sand Hills Lakes (Winter, 1986; Bleed and Flowerday, 1989). In these areas a small change in the elevation of the water table due to the consumptive use of ground water can have large impacts on the number and/or size of these lakes and wetlands. In addition the combination of a high water table, sandy soils, hydraulic conductivity and other factors create an area with high vulnerability to contamination from surface water sources (Olsson Associates, 1993). Future development in this area needs to be considered carefully to minimize any impacts not only on the quantity, but also on the quality of the ground water.

IV. Southern Tablelands Area

Hydrogeology – Extent of the Area Affected

The Southern Tableland area is underlain by the Ogallala Group, which is the most important water-bearing stratigraphic unit in this region. As described in the 1993 NPNRD GWMP, the Ogallala Group ranges from 45 to 540 feet in thickness and is composed of gravelly sand, sand, siltstones, and clay. The depth to ground water is generally 100 to 200 feet from the surface and as much as 300 feet below the surface near the southern boundary of Banner County. Values of transmissivity range from less than 50,000 to 100,000 gpd/ft in most of the region, which would indicate well yields of 1,000 gallons per minute. The potential for larger yielding wells (2,000 to 3,000 gallons per minute) exists in a narrow stretch along the southern boundary of Banner County (Olsson Associates, 1993). As mentioned previously, the Ogallala Group has a higher average permeability than the Arikaree Group and Brule Formation, meaning that ground water flows more easily through the Ogallala than the Arikaree. Influencing the direction of ground water flow in this area is a paleovalley (Figure 12 Appendix III). Ground water coming into this paleovalley is funneled toward the North Platte River.

Although this area is underlain by a fairly thick sequence of Tertiary deposits, zones of saturated permeable rock that are thick enough to yield adequate water for irrigation use occur only in localized areas. Based on information from the test holes of a previous study, only a relatively small portion of the total volume of the Ogallala sediments is saturated (Smith and Souders, 1975). Thus, the supply of ground water is limited in quantity and extent.

Generally, ground water flow is toward the North Platte River. In the westernmost portion of the study area, the ground water flows into the SPNRD from Banner County and then flows back toward the North Platte River in the paleovalley mentioned above. In Banner County the ground water also converges along the Lawrence Fork and its tributaries, ultimately reaching an area where it issues from springs and seeps, is lost to evapotranspiration or flows to stream channels, if not intercepted by pumping wells (Smith and Souders, 1975). The ground water in southern Morrill and Garden Counties flows toward the North Platte River and its tributaries.

The source of water is similar to the Northern Tablelands – Sand Hills area in that the source is local precipitation. The local recharge rate is low ranging from 0.2" to 0.8" per year (CSD, 1984).

This region is relatively flat with incised drainages. Currently, the majority of agriculture in the area is dry land wheat fallow rotation (Figure 4 App. III).

<u>Conflicts – Causes</u>

Surface Water Appropriators/Ground Water Users

Within the Lawrence Fork drainage, seven surface water rights exist, six direct flow diversions totaling 4.99 cfs and one storage right for 25.05 ac-ft. The oldest surface water rights on Lawrence Creek date from 1891 (Table 1 Appendix IV). Surface water rights are also found on Deep Holes Creek and Cedar Creek, which have contributing drainage areas originating in the southern tablelands of Morrill and Garden Counties.

According to registered well records, ground water wells were first completed in this area in 1956 (Figures 3 & 15). As of October 2003, there were 93 depletive wells in this area (Figure 3).

Whatever ground water there is to be found in this area moves toward the North Platte River or its tributaries and the stream network is tributary to the North Platte River. However, the aquifer is limited in quantity and extent, the depth to ground water is large and the recharge rate is small. Ground water level measurements show declines in some areas (Figure 18) and slight increases in other areas (Figure 19). The hydrologic properties indicate a connection between this study area and the North Platte River; however, the degree of connection is not well understood given the available data. Generally, it can be said that this study area is less directly connected to the North Platte River than the Northern Tablelands – Sand Hills study area. Use of the ground water supplies could impact the water table and consumptive use of ground water in this region would, however minimally, affect the surface water appropriators on the North Platte River or its tributaries.

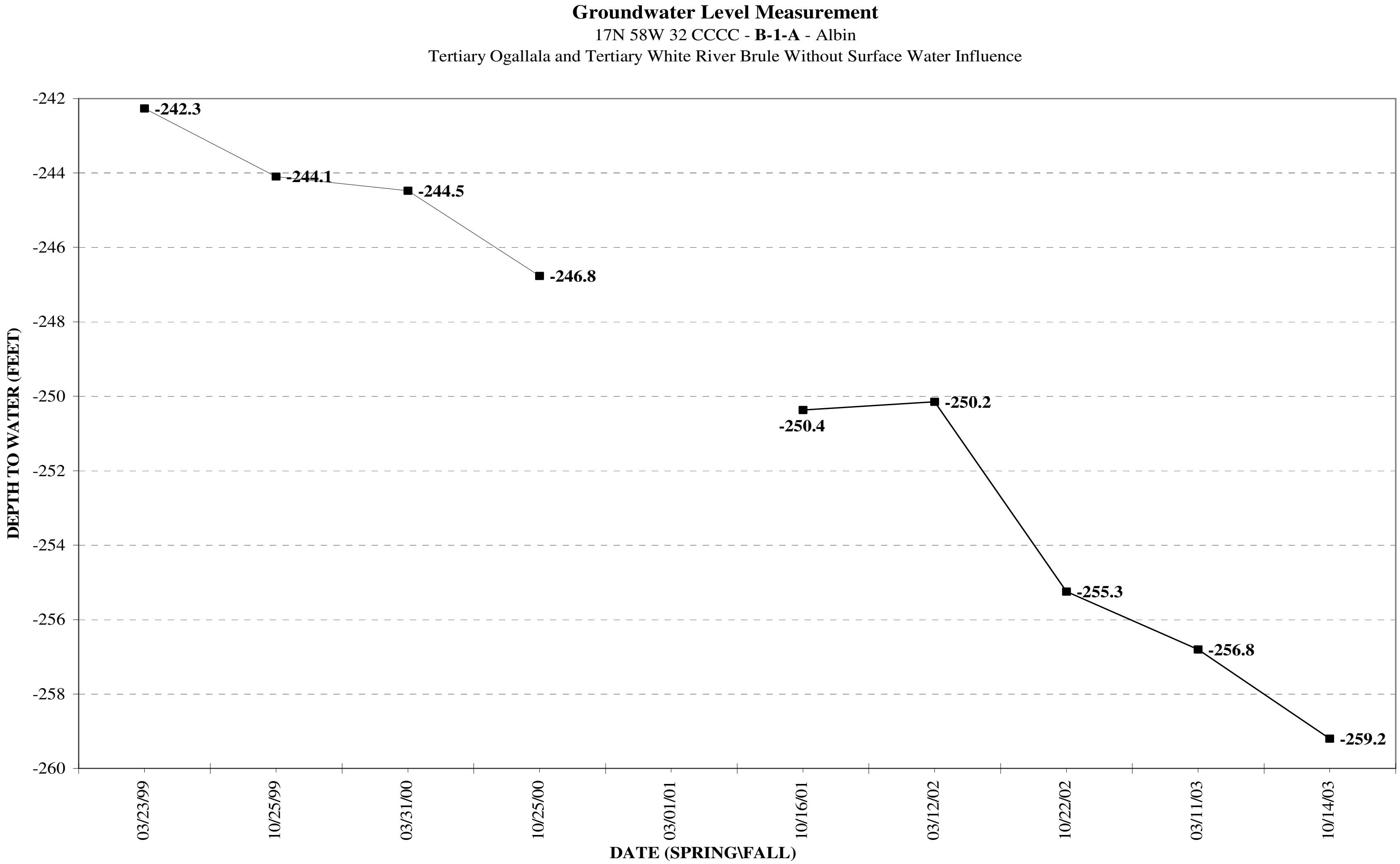


Figure 18: Ground Water level measurement in a well with DNR Registration number G-097606.

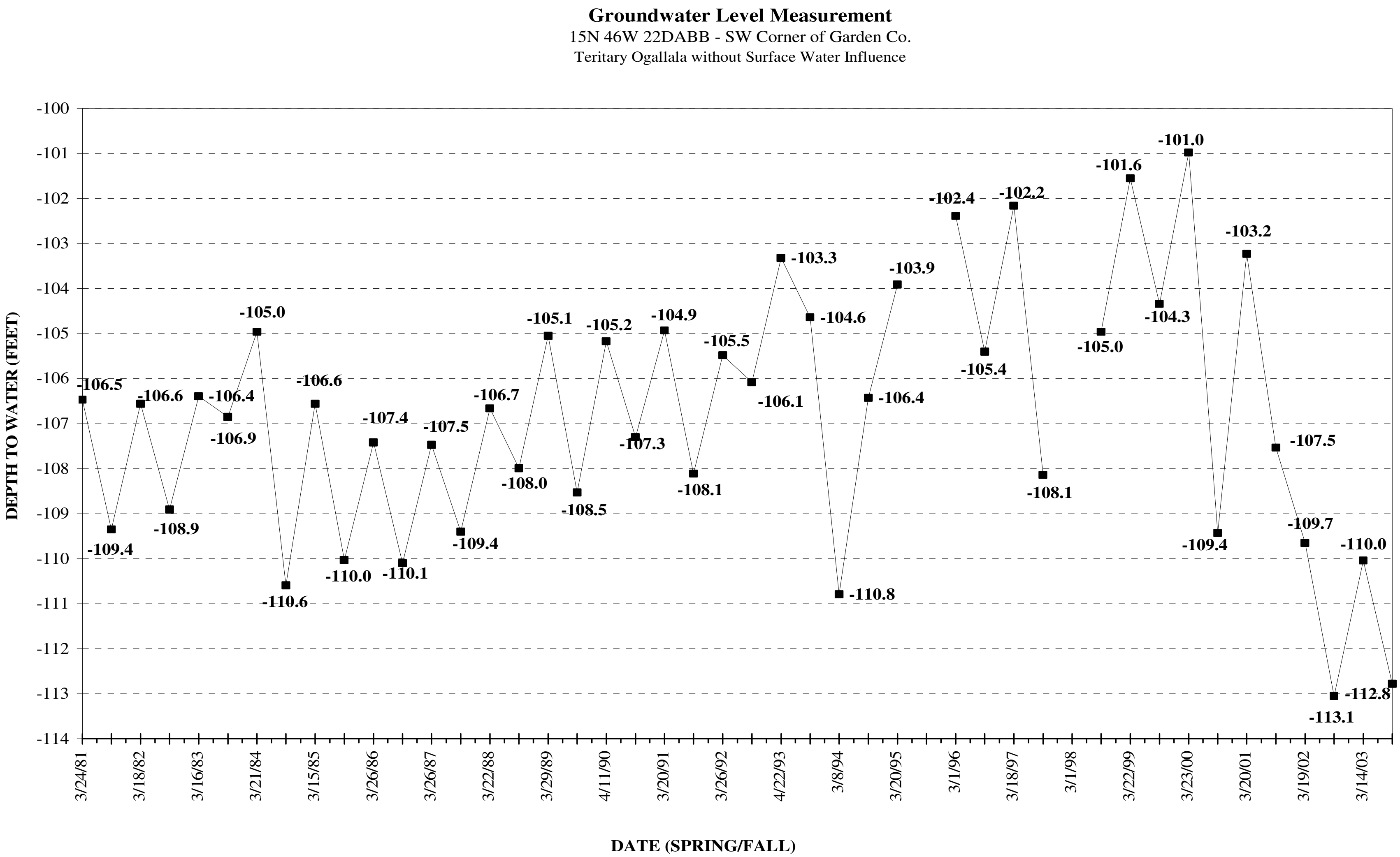


Figure 19: Ground water level measurement in a well with DNR registration number G-042220.

V. Other Considerations

Meetings with the NPNRD Board of Directors and the stakeholders group brought forward some questions which apply to the entire NPNRD study area and need to be addressed. Concerns were raised over changes in the intensity of precipitation since the 1970's. Discussions with Al Dutcher, Nebraska State Climatologist, suggest that given the current data available, any analysis would be extremely difficult, if not impossible, and very suspect as to reliability. Studies of this type have been done in the South and have shown increased runoff with increased precipitation intensity on clay soils. However, Mr. Dutcher stated that the highly permeable soil types in the NPNRD would not likely result in increased runoff and reduced infiltration even if precipitation intensity had increased.

Group members also questioned whether the change from a predominantly gravity irrigated system to sprinklers and center pivots would affect stream flows. The DNR spoke with Dean Eisenhauer, Ph.D, UNL Biosystems Engineering, who stated that the switch by itself would not result in increased consumptive use of water; however, increased numbers of acres and increased number of plants in a field, resulting from a more efficient use of water would increase the consumptive use. Basically, any increase in yield would result in increased consumptive use. Other conservation measures such as no-till, terraces, reuse pits, etc. which would result in an increased yield would also increase the consumptive use. At this time there is no good data available to test this hypothesis. The question of the effect of cropping pattern changes was also raised. Dean Eisenhauer stated that changes in cropping patterns could produce a small difference in consumptive use, but that there are currently no good data to make a conclusion one way or another. Further study would be required to understand the impact these practices are having on stream flow.

During periods of drought more conflicts naturally occur because demand for water increases while the overall supply is diminished. However, because of the nature of ground water, by the time a drought is occurring it is much too late to alter the management of ground water to address the shortage of water. Therefore, in periods of plenty, the ground water as well as the surface water system needs to be managed to plan for the periods of drought. Note on the various water level figures throughout this report the effect of the recent drought. The fall 2002 water level measurement in Figure 5 is 4 feet lower than any previously recorded low. Figure 6 shows a steeper level of decline in the period from 1999 to 2003 than previously recorded. Figure 19 shows no winter recovery in water levels between the fall of 2001 and spring 2002.

An indication of increasing demand and limited supply in this period of drought comes from the general public. At three NPNRD board meetings during 2003, citizens voiced their concerns regarding wells and surface water features going dry. Also during 2003, the NPNRD recorded 21 complaints on wells going dry as well as 3 complaints concerning a shortage of surface water. In 2002, though the complaints were not logged, both the NPNRD and the DNR received numerous calls from the public stating that domestic wells and some irrigation wells were pumping air.

VI. Summary

The **North Platte Valley** study area has a very close connection between surface water and ground water due to the hydrogeology of the area and the presence of many large and small irrigation canals. The surface water diverted by the canals and leaked into the ground is the major source of water for recharging the ground water supply on an annual basis. Without this annual recharge most now perennial tributaries would return to the pre-development state and be dry most of the year. Ground water irrigation wells draw on this supply to irrigate land without any surface water supply and to supplement acres served by surface water irrigation. Without the canal leakage and deep percolation from surface water irrigation, the large supply of ground water would not be available to the ground water wells. Return flows, on which downstream surface water appropriators depend, would also disappear. Statistical analyses of return flows show general declining trends between 1961 and 2002. Increased ground water use is one cause of these declines.

In most years the DNR must reduce diversions on the North Platte River because of insufficient stream flow. In 1993, the DNR stopped issuing new surface water rights because of insufficient unappropriated water. Any new depletion to the water supply by surface or ground water uses would cause increased injury to existing surface water appropriators. This constitutes one conflict between surface water appropriators and ground water users. In addition, as canal diversions decrease due to a decrease in supplies, recharge to the ground water supply for wells in the area will also decrease causing further conflict.

The **Northern Tablelands – Sand Hills** study area has a large supply of ground water, due mainly to the recharge in the Sand Hills area. Surface water features such as the ground water-fed Sand Hill lakes and Blue Creek are driven by ground water supplies. Most of the ground water in this study area flows toward the North Platte River and its tributaries downstream of Broadwater where the Brule Formation is overlain by the Ogallala Group, which, with the overlying Quaternary Sands, becomes the main aquifer. Essentially, this study area feeds the baseflow of the North Platte River from the north side, downstream of Broadwater.

Because in this study area ground water is hydrologically connected to the North Platte River, any new depletion to the water supply will cause injury to existing surface water appropriators on the North Platte River, as well as on Blue Creek. Statistical analysis on Blue Creek shows a significant declining trend in average annual flows from 1961 to 2002. Blue Creek and other North Platte River tributaries in this study area are also subject to the 1993 DNR determination of over appropriation. The number of new depletive ground water wells has increased since 1993 and there is potential for further development of depletive wells in this study area. This constitutes a conflict between surface water appropriators and ground water users.

Within the bounds of the **Southern Tablelands** study area the surface water supply is at a minimum. Yet, the water table contour map and geologic evidence show that ground water does flow to the North Platte River and its tributaries; particularly through the paleovalley that runs to the North Platte River. However, the quantity and extent of ground water supplies and the geology in this study area suggest that this area has the least direct hydrologic connection to the North Platte River, which over time are likely to deplete flows in the North Platte River.

The number of new depletive ground water wells has in this area increased since 1993. The potential for further development is limited within the NPNRD; however, in the area of the paleovalley in the SPNRD, the potential does exist for the increased development of ground water supplies.

Preliminary Findings of the Director

In most years numerous surface water appropriations in the North Platte Natural Resources District are regulated or shut off because of insufficient flow in the North Platte River and its tributaries.

In 1993, the Department of Water Resources placed a moratorium on issuing new surface water permits in the North Platte River Basin because of insufficient unappropriated water.

The ground water aquifers throughout the North Platte Natural Resources District are hydrologically connected to the North Platte River and its tributaries.

Current uses of that hydrologically connected ground water are causing depletions to stream flows of the North Platte River and/or its tributaries and any increase in consumptive use of water in these aquifers will cause further depletions to stream flows of the North Platte River and/or its tributaries.

Any such increased depletion will further decrease already over appropriated stream flows and cause additional conflicts between surface water appropriators and ground water users, both within the North Platte Natural Resources District and downstream of the District.

During the study conducted by the Department, I, as Director, considered all relevant portions of the NPNRD Ground Water Management Plan developed by the District pursuant to § 46-656.12 to § 46.656.16 of the Nebraska Revised Statutes and have determined that the use of hydrologically connected ground water and surface water resources in the NPNRD, excluding the area along Pumpkin Creek because it is already within an integrated management area, is contributing to and in the reasonably foreseeable future is likely to continue to contribute to conflicts between ground water users and surface water appropriators and that conflicts between ground water users and surface water appropriators could be eliminated or reduced through the exercise of the authority of subsection (5) of § 46-656.28 of the Nebraska Revised Statutes.

February 27, 2004

Roger K. Patterson
Director, Department of Natural Resources

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Appendix I

NORTH PLATTE
Natural Resources District

P.O. Box 36 Gering, NE 69341 Phone: 308-436-7111 Fax: 308-436-2452

September 5, 2002

Mr. Roger Patterson, Director
Nebraska Department of Natural Resources
P.O. Box 94676
Lincoln, NE 68509-4676

Dear Mr. Patterson:

Studies performed by the North Platte Natural Resources District and others indicate that the ground water and surface water within the North Platte River Basin are hydrologically connected. This has implications for protection of the ground water resource, surface water flows in the river and its tributaries, and the future administration of programs such as the Platte River Cooperative Agreement for Endangered Species. We believe it would be in the public interest to establish an integrated management area to manage these waters. Therefore, the North Platte Natural Resources District hereby requests that the affected appropriators, the affected surface water sponsors, and the Department of Natural Resources consult with our District and that studies and a hearing be held on the preparation of a joint action plan for the integrated management of hydrologically connected ground water and surface water. This request is made under the Nebraska Ground Water Management and Protection Act, section 46-656.28.

Sincerely

James Olson, Chairman

STATE OF NEBRASKA

DEPARTMENT OF NATURAL RESOURCES
Roger K. Patterson
Director

IN REPLY REFER TO:

Mike Johanns
Governor

November 1, 2002

Jim Olson
North Platte Natural Resources District
P.O. Box 36
Gering, NE 69341

Dear Mr. Olson:

This letter is to notify your district that in accordance with the requirements of subsection (2) of Section 46-656.28, R.R.S., 1998, I have made a preliminary determination in response to your written request dated September 5, 2002 for use of the joint process authorized by that section of the Nebraska statutes. That preliminary determination is that there is reason to believe that the use of hydrologically connected ground water and surface water resources in the North Platte Natural Resources District is contributing to or is in the reasonably foreseeable future likely to contribute to conflicts between ground-water users and surface-water appropriators.

In order to make this preliminary determination Department staff reviewed the records of the Department, including reports generated by experts during the course of the Nebraska v. Wyoming litigation; the district's ground-water management plan, rules and regulations, and ground-water monitoring records; the Department's "Hydrographic Reports" and USGS "Water Resources Data – Nebraska" showing stream flow and canal diversions; the Department's "Biennial Reports" showing surface water appropriations; and the ground water well registrations data. Other resources reviewed include the following: "Selected Field and Analytical Methods and Analytical Results in the Dutch Flats Area, Western Nebraska, 1995-99, Open File Report 00-413; "Surface-Water/Ground-Water Interaction and Implications for Ground-Water Sustainability in the Dutch Flats Area, Western Nebraska, USGS Fact Sheet 074-01; "Use of Environmental Tracers and Isotopes to Evaluate Sources of Water, Nitrate, and Uranium in an Irrigated Alluvial Valley, Nebraska", USGS Fact Sheet 100-01; "Vertical Profiles of Streambed Hydraulic Conductivity Determined Using Slug Tests in Central and Western Nebraska", Water Resources Investigations Report 01-4212.

Uranium in an Irrigated Alluvial Valley, Nebraska", USGS Fact Sheet 100-01; "Vertical Profiles of Streambed Hydraulic Conductivity Determined Using Slug Tests in Central and Western Nebraska", Water Resources Investigations Report 01-4212.

The following findings were determined from the above resources:

1. Water Resources Investigations Report 01-4212 tested streambed conductivities at three sites in the North Platte NRD and at 7 other sites in the Platte River Basin. The study concluded that all the main stem and tributary streambed sites situated on the flood plain of the main stem contained no restrictive materials. Therefore, the interactions between the stream and aquifer at these sites are not restricted by streambed materials with low conductivities.

2. Open-File Report 00-413, Fact Sheet 074-01, and Fact Sheet 100-01 all discuss the same study sites, which are located in Scotts Bluff and Sioux Counties. The focus of these studies was the ground-water and surface-water sources and their interactions. From Fact Sheet 100-01: "Groundwater in the area was found to be generally less than 30 years old, with an average age of 8.8 years and the ground-water was derived from the North Platte River by either river channel recharge or as recharge from surface-water irrigation." From Fact Sheet 074-01: "The continued recharge of surface water to the aquifer during the irrigation season sustains ground-water levels in the aquifer and sustains springs that supply base flow to perennial streams in the study area…. Seasonal infiltration of surface-water from canal seepage raises ground-water levels about 10 feet above seasonal low water levels near the canals and locally dilutes nitrate concentrations in ground-water near the canals and their laterals. However, away from the canals, ground-water level rises are not as pronounced." All of these studies contain evidence to support the premise that ground-water and surface-water in the study area are hydrologically connected.

3. Monitoring wells reported by the USGS on their online database show ground-water declines in some wells in the district. (Figures 1 & 2)

4. The Department's database on water well registrations show that the number of new irrigation water wells constructed annually within the North Platte NRD hit a peak in 1975 then declined until 1990 when another peak was reached and construction has been declining since 1990. However, new wells are still being completed. As of October 22, 2002, 42 new irrigation wells have been registered and completed in the district for the calendar year 2002. 216 total new depletive wells have been registered and completed in the district in the same time period. (Figures 3 & 4) While the number of ground-water wells has been growing, analysis of stream discharge shows declines in the annual flows of Pumpkin Creek and Bayard Creek. (Figures 5, 6, 7 & 8)

5. The North Platte NRD created a ground-water management sub-area on March 21, 2002, in the Pumpkin Creek Basin. This was done for several reasons, one being the decline of ground-water levels in 15 of the 17 monitoring wells in the sub-area over a 10-year period. The district had also received numerous complaints about the lack of irrigation water from ground-water irrigators, and complaints of insufficient stream flow from surface-water irrigators with water

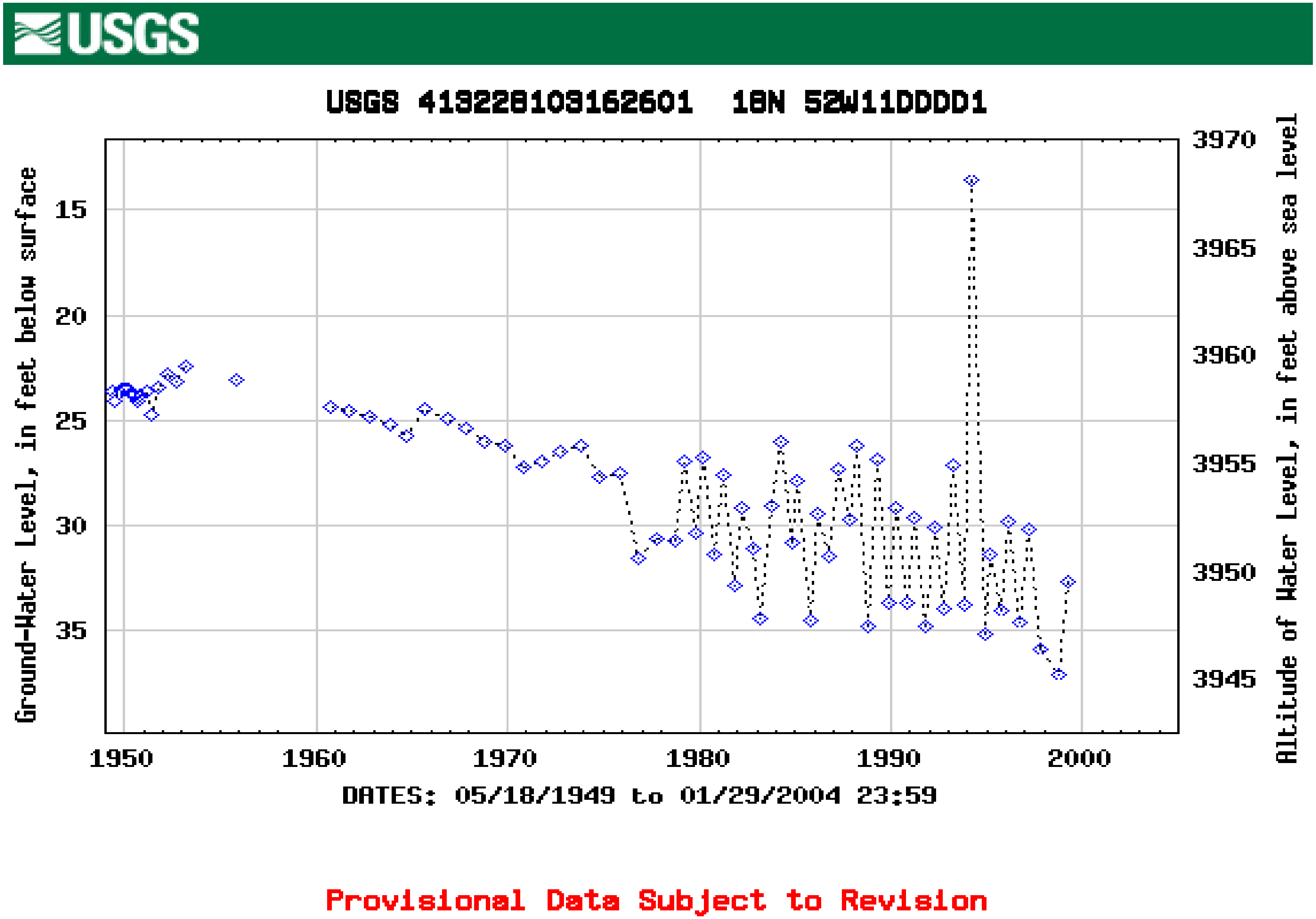
rights on Pumpkin Creek. The district also cited the policy memorandum released by the Department of Natural Resources declaring an informal moratorium on new appropriations on Pumpkin Creek since 1979 as a reason for creating the sub-area. One of the purposes of the sub-area is to provide integrated management of hydrologically connected ground-water and surface-water.

The above findings support a preliminary determination that there is reason to believe that the use of hydrologically connected ground-water and surface-water resources is contributing to or is in the reasonably foreseeable future likely to contribute to a conflict between ground-water users and surface-water appropriators. Accordingly, Jennifer Schellpeper is authorized to work with the district to conduct studies to determine the extent and precise cause of the conflict.

Sincerely,

Roger K. Patterson
Director

jjs
Enclosures


USGS
USGS 413228103162601 18N 52W11DDDD1
Ground-Water Level, in feet below surface
15
20
25
30
35
Altitude of Water Level, in feet above sea level
3970
3965
3960
3955
3950
3945
1950
1960
1970
1980
1990
2000
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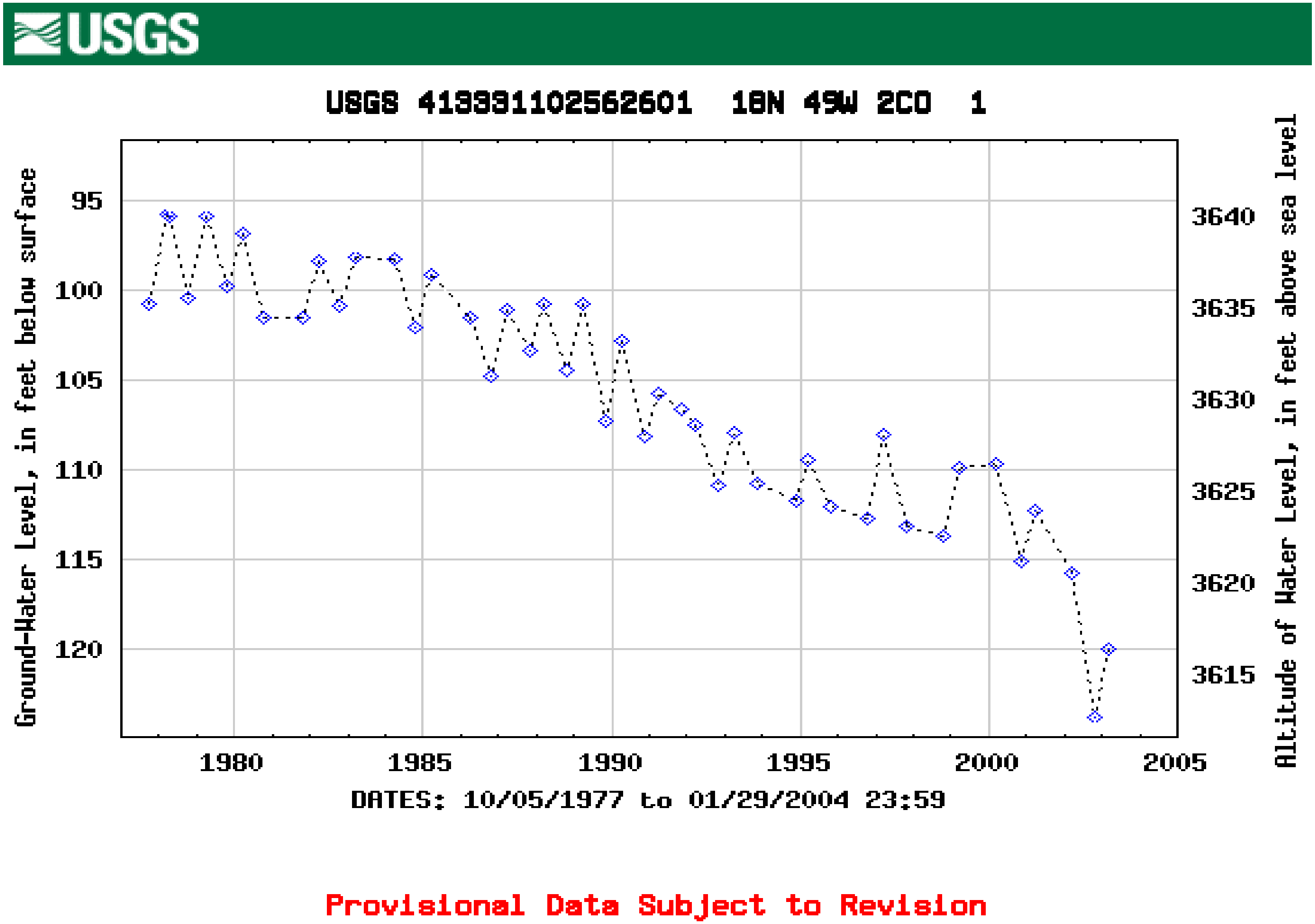
Provisional Data Subject to Revision

Figure 1


USGS
USGS 413331102562601 18N 49W 2CO 1
Ground-Water Level, in feet below surface
95
100
105
110
115
120
Altitude of Water Level, in feet above sea level
3640
3635
3630
3625
3620
3615
1980
1985
1990
1995
2000
2005
DATES: 10/05/1977 to 01/29/2004 23:59
Provisional Data Subject to Revision
Figure 2

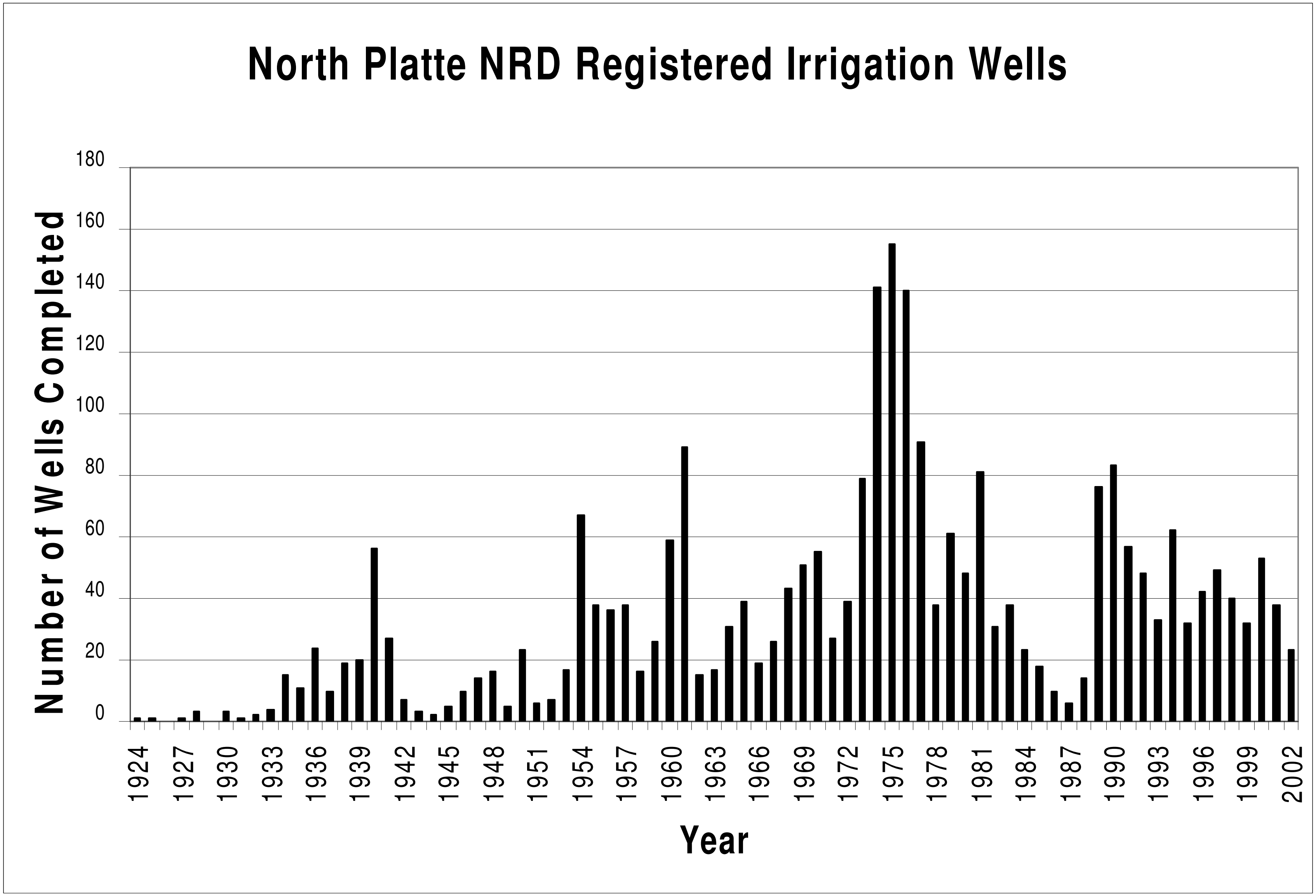

North Platte NRD Registered Irrigation Wells
Number of Wells Completed
180
160
140
120
100
80
60
40
20
0
1924
1927
1930
1933
1936
1939
1942
1945
1948
1951
1954
1957
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
Year

Figure 3

Registered Irrigation Wells in the North Platte NRD

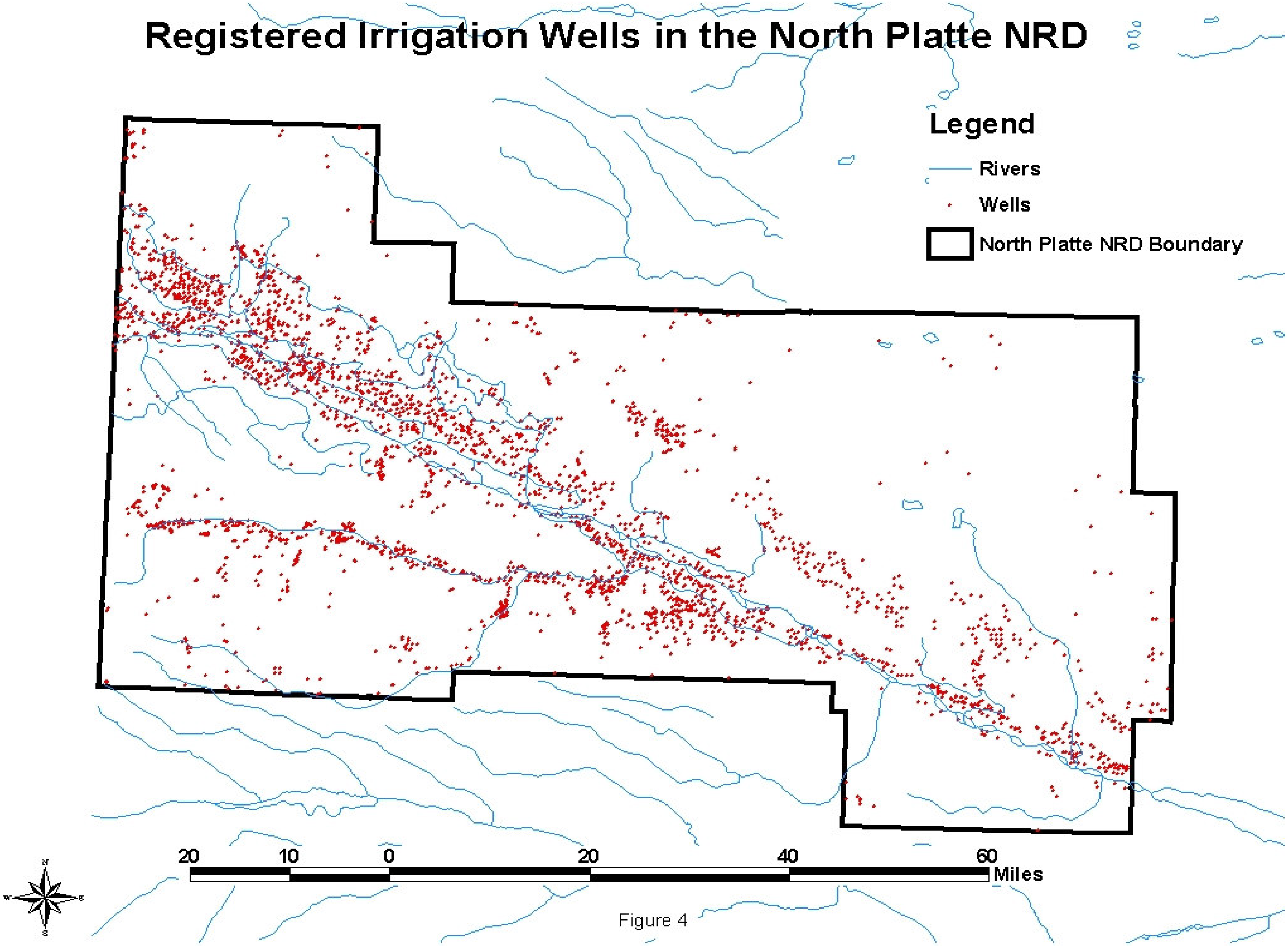


Figure 4

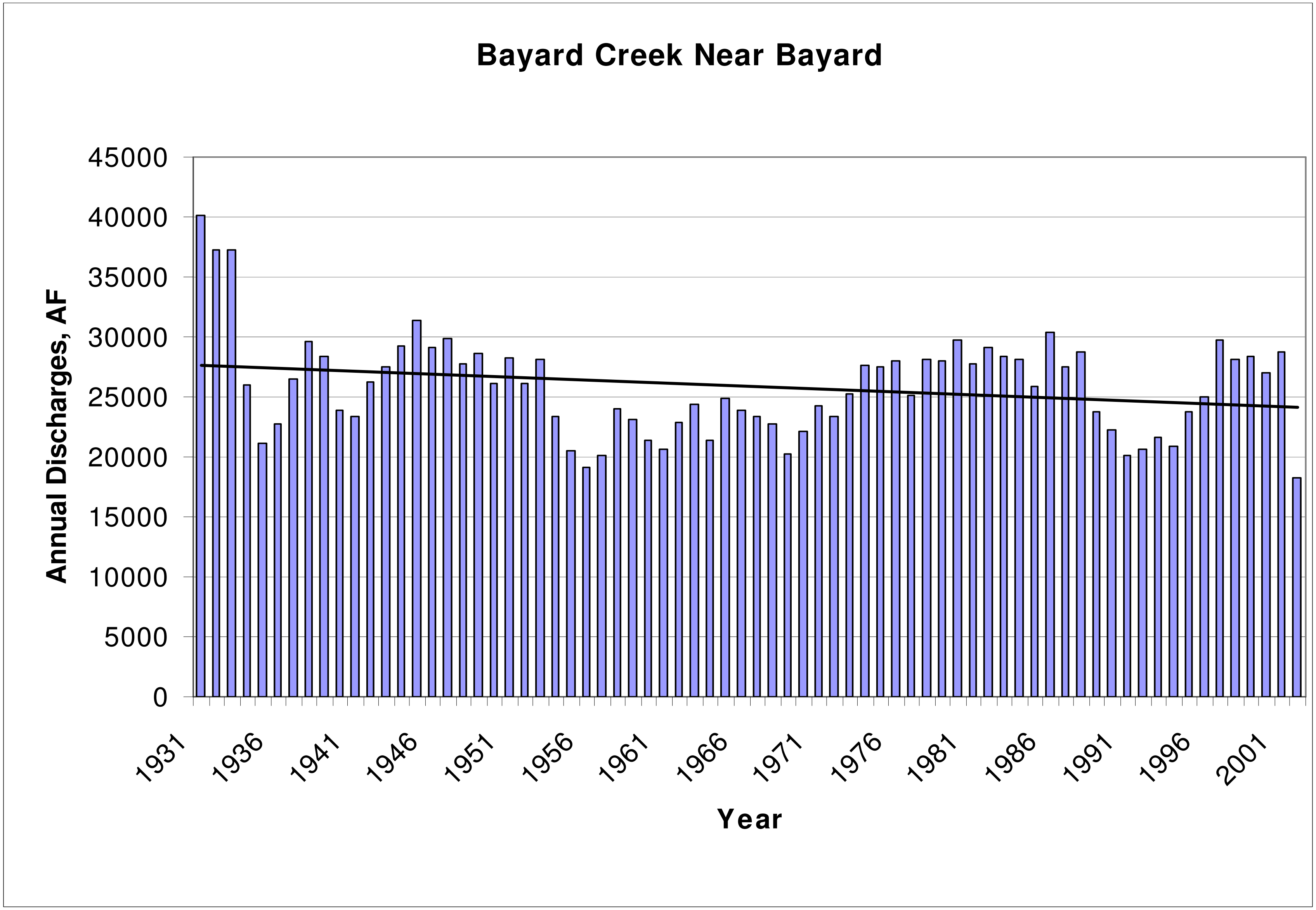

Bayard Creek Near Bayard
Annual Discharges, AF
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year

Figure 5

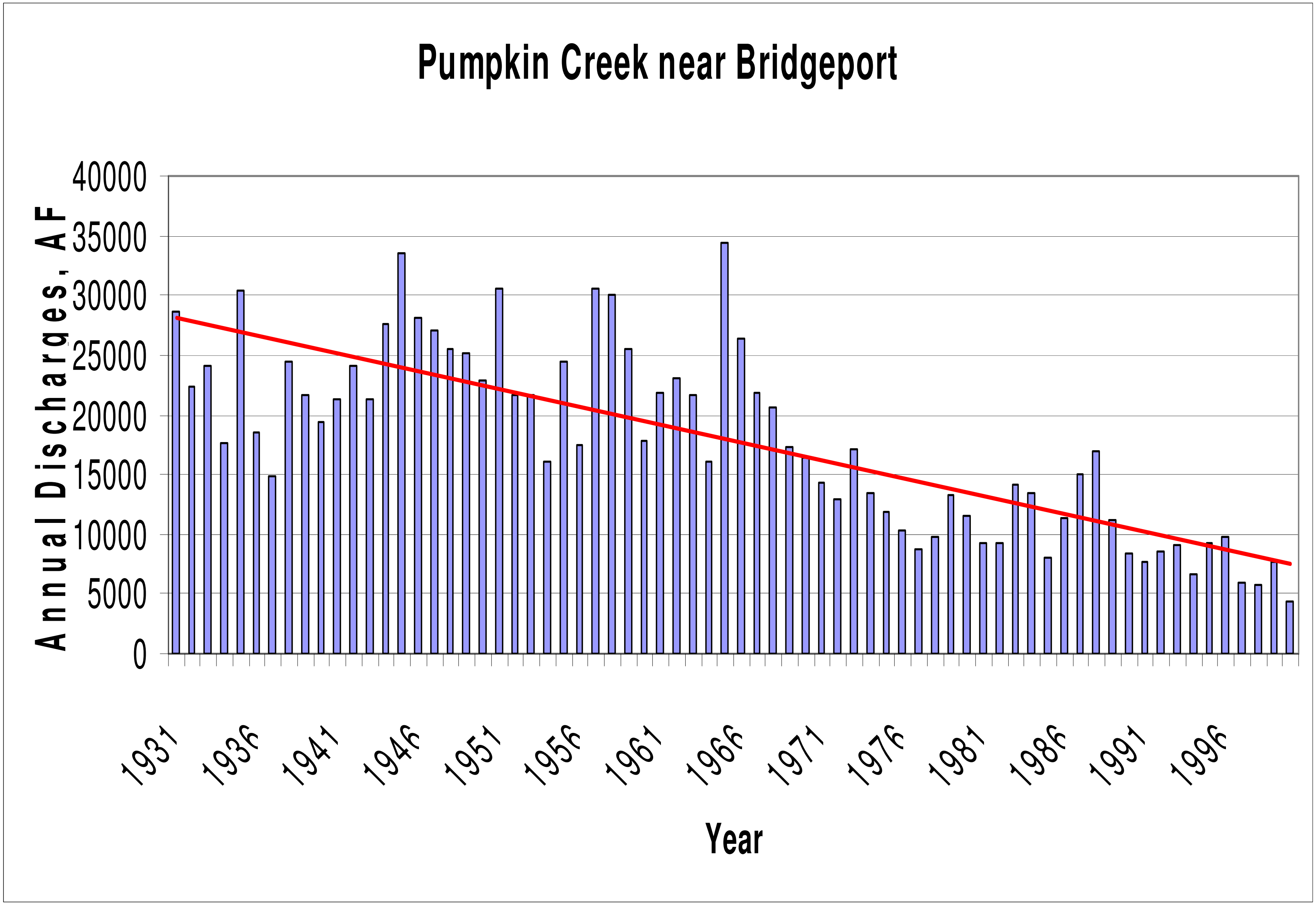

Pumpkin Creek near Bridgeport
Annual Discharges, AF
40000
35000
30000
25000
20000
15000
10000
5000
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
Year

Figure 6

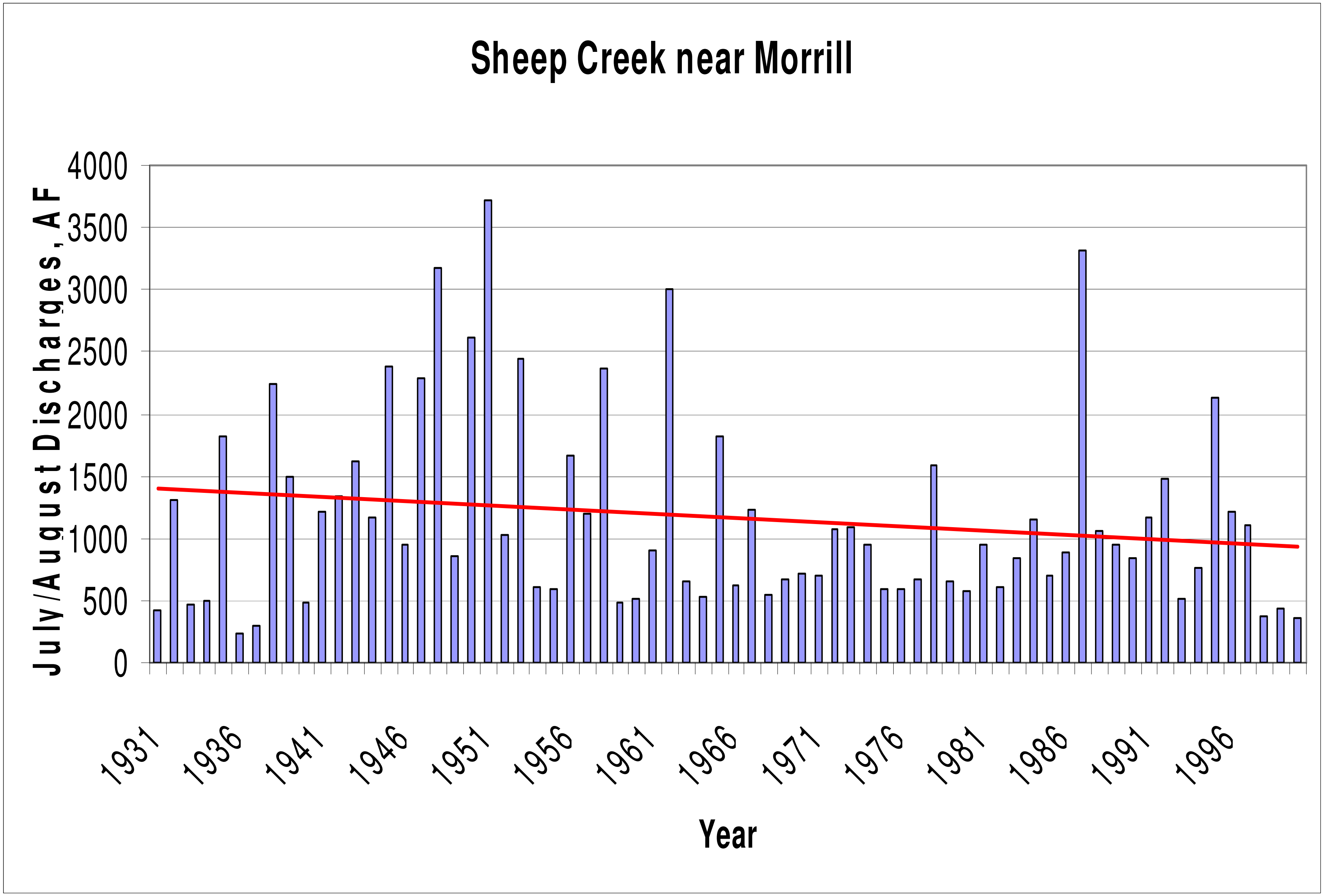

Sheep Creek near Morrill
July/August Discharges, AF
4000
3500
3000
2500
2000
1500
1000
500
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
Year

Figure 7

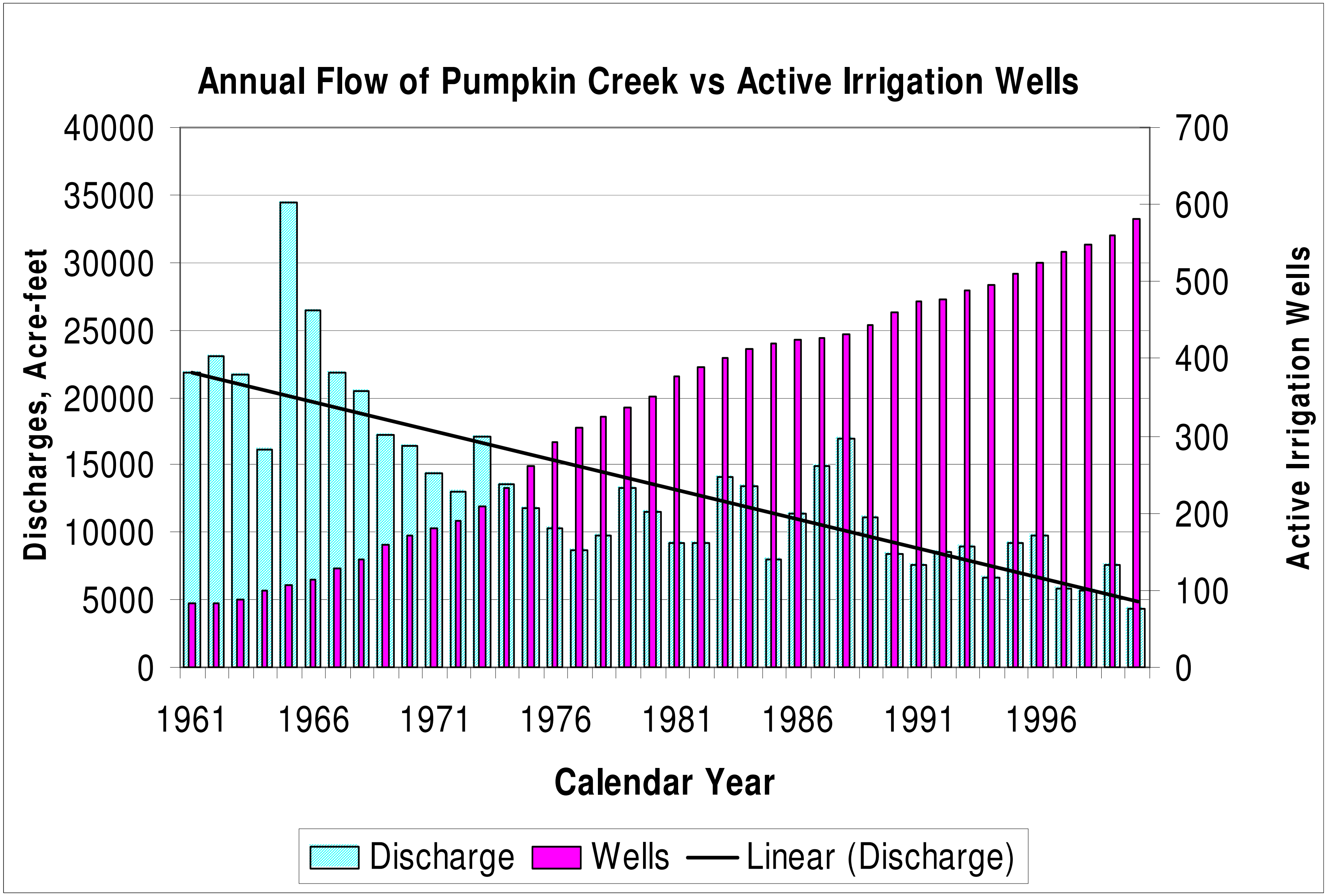

Annual Flow of Pumpkin Creek vs Active Irrigation Wells
Discharges, Acre-feet
40000
35000
30000
25000
20000
15000
10000
5000
0
700
600
500
400
300
200
100
0
Active Irrigation Wells
1961
1966
1971
1976
1981
1986
1991
1996
Calendar Year
Discharge
Wells
Linear (Discharge)

Figure 8

Appendix II

STATISTICAL ANALYSES OF FLOWS IN THE NORTH PLATTE RIVER AND ITS TRIBUTARIES BETWEEN THE STATE LINE AND LEWELLEN

NEBRASKA DEPARTMENT OF NATURAL RESOURCES
February 2004

INTRODUCTION

Objective of the Study

The objective of this study is to determine if stream flows in the Stateline to Lewellen reach of the North Platte River and its tributaries have declined and if so to try to ascertain the possible causes of any declines. The major source of water for the North Platte River between the Wyoming-Nebraska state line and Lewellen is the release of storage water for irrigation from the U. S. Bureau of Reclamation reservoirs in Wyoming. The majority of this water is diverted in Wyoming by the Interstate and Fort Laramie canals and a number of smaller Wyoming canals or by the Tri-State and Mitchell-Gering Canals at the state line. The Interstate and Fort Laramie Canals serve land both in Wyoming and Nebraska; Tri-State and Mitchell-Gering Canals serve land in Nebraska. All these diversions produce a large amount of return flow, which provides water for the numerous tributaries in this reach (Figure 1).

In 1911 before these canals were built, there were no perceptible tributary flows west of Bridgeport, Nebraska (Willis, 1930), but starting in 1911, with the beginning of diversions by the large canals, the flows in these tributaries increased. By the 1930s, the return flow in tributaries from irrigation between the state line and Minatare, Nebraska was over 326,000 acre-feet (Wenzel, et al. 1946). These return flows in turn provide the major source of natural flow in the main stem and on the tributaries of the river between the state line and Lewellen. Figure 2 shows the historic contribution to flow from the major North Platte River tributaries.

In recent years concerns have been raised that these return flows have been decreasing. Currently identified potential factors that could be causing any observed stream flow declines include a decline in the release of reservoir storage water, a decline in local precipitation, an increase in the number of acres served by surface water, increased use of ground water by wells and the impact of soil and water conservation measures that cause an increase in consumptive use.

Methods

A step-wise linear regression was used to try to determine what factors may be causing any observed changes. The factors examined included reservoir releases, local precipitation, canal diversions and ground water pumping. Gaging records for streams and canal diversions between the Wyoming-Nebraska State Line and Lewellen were also analyzed using graphical, simple linear trend analysis and the Mann-Whitney U test to determine if there were any increasing or decreasing trends.

Acknowledgements

This report was written by Shuhai Zheng, of the Planning and Technical Assistance Division. Thanks are also due to Ann Bleed for her guidance for this study and critical review of this report. Tom Hayden of Bridgeport Field Office and Jim Cannia of North Platte Natural Resources District provided invaluable suggestions and inputs to the study. Jennifer Schellpeper provided irrigation well information for the study area and helped review the report. Steve Gaul's help in reviewing and editing the report is also greatly appreciated.

DATA INVENTORY

Data used in the study include gaging records from the U.S. Geological Survey (USGS) web site; the Nebraska Department of Natural Resources (NDNR) Data Bank, including the registered well database; the former Nebraska Department of Water Resources (NDWR) Biennial/Hydrographic Reports; and the U.S. Bureau of Reclamation (USBR) North Platte River Compiled Water Records.

Stream Flow and Canal Diversion

Figure 3 depicts the main stem and tributary gaging stations and canal diversions from the North Platte River between the state line and Lewellen that were used in the study. Diversions for the Interstate and Fort Laramie Canals in Wyoming and reservoir release data from the Guernsey Reservoir were also analyzed. Table 1 is a list of the gaging stations analyzed and their period of record.

Precipitation

Monthly precipitation at the Mitchell 5E Station (#25-5590) was retrieved from NDNR Data Bank. The Mitchell 5E station was selected because it had continuous data since 1930. For years 1999 and 2002, the data at Scottsbluff AP (#25-7665) were used because the Mitchell station was discontinued in 1998. Precipitation data at the Crescent Lake Station (#25-2000) for the period of 1949-2002 were also included in the study.

Irrigated Acreage

A number of data sources were checked to try to determine the number of irrigated acres through the entire study period. Although various data sets exist, the data conflict and no one source provided a reliable measure of the number of acres irrigated by surface water and or groundwater during the entire study period. Data developed for Nebraska's lawsuit against Wyoming (Figure 4) provide the best assessment of surface water irrigated acres in the North Platte Basin (Martin, 2000), but the data are only available up to 1994. However, since 1993 there has been a moratorium on new surface water permits in the North Platte River Basin. Therefore it is unlikely that surface water irrigated acres have substantially increased since the termination of Martin's study.

Ground Water Pumping

Historical measurements of ground water pumping do not exist. Therefore, the study relied on records of ground water well registrations to provide an indication of the amount of ground water pumping that occurred through time. Well registrations are a poor indicator of ground water pumping because not all registered wells pump every year and even when the wells are pumped, the amount pumped may vary considerably. Variations in pumping from year to year are particularly pronounced on wells that are not the sole source of irrigation but are used to supplement surface water supplies. Figure 5 shows the cumulative number of registered irrigation wells by year.

Conservation Practices

Other than center pivot inventories and sporadic irrigation district records showing when and where canals were lined, records on the implementation of conservation practices in the basin are practically nonexistent.

Total Contribution from Tributaries

Figure 2 shows the historic contribution to flow in the NPR from major tributaries between the state line and Lewellen. Diversions from those tributaries were included as part of the total water supply.

Data on the historic tributary stream flows into the North Platte River reach were inventoried. A list of those gauging stations is shown in Table 2. Because the reporting for some of the tributaries was discontinued in 1988, the annual total tributaries into the North Platte River reach for 1988-2002 was adjusted by the average annual amount of total tributaries from those discontinued gauges during the period of 1931-1987. Historical diversions from return flows were obtained from canal diversion records (Table 3).

To display a consistently gauged historical contribution from tributaries (1931-2002), the total contribution of nine tributaries for which there is continuous data is presented in Figure 6.

REGRESSION ANALYSES

Regression analysis can be used to determine the correlation relationship between a dependant variable (response) and independent variables (predictors). The coefficient of determination (R^2) of a resulting regression equation indicates the amount of variation in response accounted for by selected predictor(s). A step-wise regression technique was used to identify causal factors for some selected response variables.

Step-wise regression is a procedure that generates a model by including variables in or excluding variables from the model based on the specified Alpha-to-Enter and Alpha-to-Remove values. For this analysis, Alpha-to-Enter and Alpha-to-Remove of 0.05 were selected. Thus, at each step of the procedure, a predictor is added to the model, because it has the smallest p-value among those predictors with p-values less than 0.05. Similarly, at each sequential step of the procedure, a predictor is only removed from the model if it has the largest p-value among those predictors with p-values greater than 0.05.

For regression analyses, the following annual response data series of 1961-2002 were selected:

- Flow of North Platte River at Lewellen, *Lewellen*
- Total tributaries between Wyoming-Nebraska state line and Bridgeport, *TotTrib*
- Total tributaries from the north side of the North Platte River reach between state line and Bridgeport, *NorthTrib*.
- Tributaries of Sheep Creek, Akers Draw, Dry Spotted Tail Creek, Tub Springs, and Winters Creek, *TotalFive*
- Total tributary of Sheep Creek, *Sheep*
- Total Tri-State Canal irrigation diversion from tributaries, *TStrib*
- Total irrigation diversion from tributaries, *DivTrib*

The potential predicting data series variables for the above response data series used in this analysis are:

- Annual precipitation at station Mitchell 5 E, *Precip*
- Guernsey Reservoir outflow, *Guernsey*
- Interstate Canal diversions in present year, 1-year ago, 2-year ago, 3-year ago, and 4-year ago respectively, *IntState, IS1, IS2, IS3*, and *IS4*
- Tri-State Canal diversions from the North Platte River in present year, 1-year ago, and 2-year ago respectively, *TSNP, TSNP1*, and *TSNP2*
- Fort Laramie Canal diversion, *Laramie*
- Cumulative number of irrigation wells within the surface water drainage of the reach of the North Platte River below the Nebraska State Line to Bridgeport, Nebraska, excluding those above the Ft. Laramie Canal on Horse Creek, *IrrWells*

- Cumulative number of irrigation wells below the Nebraska State Line, along the North Platte River Basin above Bridgeport, on the north side of the river only, *NorthWell*
- Cumulative number of irrigation wells within the drainage areas of Sheep Creek, Akers Draw, Dry Spotted Tail Creek, Tub Springs, and Winters Creek, *FiveWell*
- Cumulative number of irrigation wells in the drainage area of Sheep Creek, *SheepWell*

The impact of wells on the tributaries on the south side of the river, Horse Creek and Gering Creek, was not tested because there is little or no aquifer and few wells that affect south side tributary flows.

Results

Regression analyses results for each response variable, potential causal variables used for regression analysis, and the resulting regression equation (model) for each data series are summarized in Table 4. The coefficient of determination (R^2) for each equation presents the percentage variation in the response variable that can be explained by those predictors in the equation.

Discussion

The hydrographs (Figure 7) and statistical analyses indicate the importance of the outflow from Guernsey Reservoir on the North Platte River flows at Lewellen with Guernsey outflow accounting for 91% of the variance in flow at Lewellen. Also important are the return flows from irrigation diversions of Interstate Canal and Tri-State Canal. Interstate Canal diversions account for 88% of the variance in the flow of Sheep Creek. Interstate Canal diversions, Tri-State Canal diversions and precipitation account for 64%, 9%, and 6.3%, respectively of the variance in the five tributaries of Sheep Creek, Akers Draw, Dry Spotted Tail Creek, Tub Springs, and Winters Creek. Interstate Canal diversions also account for almost 69% of the variance in the total Tri-State Canal irrigation diversion from tributaries. These results indicate that the Interstate Canal diversion is a major source of flow in the tributaries. For the variations in the total flow of north side tributaries in the North Platte River reach, Interstate Canal diversions are also a major source of flow to other tributaries on the north side of the North Platte River accounting for almost 72% of the variance. Local precipitation and Tri-state Canal diversions from the North Platte River account for 7.6% and 2.3%, respectively of the variance in flow of these tributaries.

Although the numbers of registered irrigation wells were tested in the regression equations, they were never considered to be a significant variable. This result is not surprising because the relative importance of canal diversions is so great in comparison to the impact from groundwater pumping, the statistical test used may not have been sensitive enough to pick up the impact of wells.

TREND ANALYSES

A study period of 1961-2002 was selected to account for the full effect of major North Platte River projects. 1961 is the year when Glendo Reservoir filled providing the capacity to store up to 100,000 acre feet of irrigation water, which increased the amount of water available for diversions and return flows. Simple linear trend analyses were performed using the MINITAB Statistical Software (MINITAB Inc., 2000). By selecting a confidence level of 95-percent, a trend was considered to be statistically significant if the probability (p) value (probability that a true null hypothesis of no trend is erroneously rejected) was less than or equal to 0.05. Those fitted trend lines with a p-value greater than 0.05, are statistically considered to be insignificant at the selected confidence level of 95-percent.

Results

Hydrographs, along with the 1961-2002 trend lines, 10-year period moving average trends for data 1931 onward are also depicted in Figures 8-37. A moving average trend displays the average trend of a data series by smoothing out individual high and low values. Trend analyses results are presented in Table 5. A positive sign and a negative sign represent an increasing and decreasing trend, respectively. There are no significant trends in precipitation, the outflow from Guernsey Reservoir or for total Tri-State Canal diversions for the study period of 1961-2002. There were significant decreasing trends at the 95-percent confidence level for Interstate Canal annual diversions, Tri-State Canal annual diversion from tributaries, total October and November tributary flows between the state line and Bridgeport, total tributary flows on the north side of the river, flows of Sheep Creek and Blue Creek and the number of surface water irrigated acres up to 1994. Statistically significant increasing trends were observed for the number of registered irrigation wells, Tri-State Canal annual diversion from North Platte River, and for flows in Dry Spotted Tail Creek, and Gering Creek.

Discussion

Trend analyses can be somewhat misleading because the trend can change depending on what years were chosen to be analyzed. If the analysis starts in a wet period and ends in a dry period, a downward trend will be detected even though starting the trend during a different part of the cycle would have shown an upward trend. However, trend analyses of Guernsey Reservoir releases and area precipitation, the two major sources of water supply for the area, showed no significant decreases for the study period. On the other hand there were significant declines in tributary flows in the area.

The decrease in diversion to Interstate Canal may reflect the decrease in available natural flow for a junior water right. The decrease in diversion by Tri-State Canal from tributaries most likely reflects decreases in available water supply.

The decreasing trend in surface water irrigated acreage indicates that increases in consumptive use from surface water irrigation are not the likely cause for decreased tributary flows. On the other hand, the number of registered irrigation wells showed a significant increase during the study period. Although the number of registered wells does not provide an accurate estimate of the volume of groundwater pumped in any given year, the significant increase in the number of irrigation wells indicates that groundwater use has increased during the study period.

The pattern of monthly trends for the tributaries is of particular interest. Tributary flows (including surface water diversions from the tributaries) show no significant change from 1961-2002 for the months of July, August, and September. In fact they show a slightly increasing trend in July and August. Flows start to decrease in September with a statistically significant decrease in October and November. A possible explanation for those patterns could be related to the timing of the impacts of ground water pumping on stream flows. In July and August, some of ground water used for irrigation runs off the field as surface water flow and tends to augment stream flow, offsetting declines in stream flow due to ground water pumping during the months of July and August and possibly some of September. However, much of the decrease in water table elevations as a result of pumping may not impact stream flows for several months. This lag effect of the impact of stream flow is likely the cause of decreases in tributary flows in September, October, and November.

The Mann – Whitney U Test

A second statistical test was utilized in order to better understand the potential impact of ground water wells on tributary flows. The Mann-Whitney U test is a nonparametric statistical test similar to the Student T test that determines if there is a significant difference between the statistical parameters of two different populations. Two time periods, one during a period at the beginning of well development, and one toward the later period of well development were compared using the Mann-Whitney U test. Figure 38 is a plot showing the relationship among the total flow of north side tributaries, Interstate Canal diversions, local precipitation, and the cumulative number of irrigation wells. To further examine the factors affecting tributary flow, the Mann-Whitney U Test was used to test if there was a significant difference between the medians of north tributary flows, Interstate Canal diversions, local precipitation, and the cumulative number of wells for the two periods.

At a confidence level of 95-percent, the Mann-Whitney U Test results indicate that the median flow of north tributaries during 1993-2001 was significant lower than median flow of north tributaries during 1971-1982. The median of the cumulative number of wells was significant higher in the later period. However there was not a significant difference between the medians of Interstate Canal diversions and local precipitation during the two time periods. These results indicate that the north side tributaries decrease in median annual flow was at least partially caused by the increase in the number of wells.

DISCUSSION

The hydrographs and statistical analyses indicate the importance of the outflow from Guernsey Reservoir on the North Platte River flows at Lewellen, with Guernsey outflow accounting for 91% of the variance in flow at Lewellen. Also important are the return flows from irrigation diversions of Interstate Canal and Tri-State Canal. Interstate Canal diversions account for 64% of the variance in the five tributaries of Sheep Creek, Akers Draw, Dry Spotted Tail Creek, Tub Springs, and Winters Creek on the north side, with Tri-State Canal diversions and precipitation accounting 9% and 6.3% of the rest, respectively. Although precipitation is a significant contributor to the water supply of the North Platte River above Lewellen, the major source of water is clearly from the North Platte River in Wyoming.

The outflow from Guernsey Reservoir and local precipitation, the major source of water for all the North Platte tributaries above Bridgeport, showed no significant change during the study period. Nevertheless, Interstate Canal diversions, the north side tributaries, the October and November tributaries flows, and the flows on Sheep Creek and Blue Creek all showed statistically significant declines. The flows on Gering Creek, Bayard Creek, and Dry Spotted Tail Creek, on the other hand, showed a significant increasing trend. The increasing trend in Dry Spotted Tail Creek is most likely due to the fact that in recent times Western Sugar stopped diverting from Dry Spotted Tail Creek and the Dutch Flats tributary, which empties into Dry Spotted Tail Creek, has been better maintained.

There are several potential causes for the decrease in tributary flows: the decline in surface water diversions, the increase in groundwater irrigated acres as reflected by the increased number of groundwater wells, and increased consumptive use due to increased efficiencies of water use.

The results of the Mann-Whitney U test indicate that during two periods during which there was no significant difference in Interstate Canal diversions and in precipitation. However, significant declines in tributary flows during a period of significant increases in the number of wells in the area clearly indicates groundwater pumping as a probable cause of stream flow declines. Though not analyzed because of lack of data, other factors such as increased water use efficiencies due to canal lining and increased use of center pivots and other conservation activities may also be contributing to stream flow declines. Thus, although important, ground water use is probably not the only factor causing recent declines in streamflow in the North Platte River Basin.

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Table 1. North Platte River Gaging Stations

Station_ID	Station Name	First Year	Last Year
200500	AKERS DRAW NEAR MORRILL	1959	1994
6683000	BAYARD CREEK NEAR BAYARD	1931	2002
7000	BEERLINE CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1941	2002
9000	BELMONT CANAL FROM NORTH PLATTE RIVER (15-FOOT PARSHALL RIVER)	1933	2002
6687000	BLUE CREEK NEAR LEWELLEN, NE	1931	2002
19000	BROWNS CREEK CANAL FROM NORTH PLATTE RIVER (8 FOOT PARSHALL FLUME)	1933	2002
21000	CASTLE ROCK-STEAMBOAT CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
204000	CEDAR CREEK NEAR BROADWATER	1931	1989
22000	CENTRAL CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
24000	CHIMNEY ROCK CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
206000	CLEVELAND DRAIN NEAR BAYARD	1931	1990
207000	COLD WATER CREEK NEAR LISCO	1953	1989
6679000	DRY SPOTTED TAIL CREEK AT MITCHELL	1931	2002
209000	DUGOUT CREEK, UPPER, NEAR BRIDGEPORT	1931	1990
39000	EMPIRE CANAL FROM NORTH PLATTE RIVER VIA BELMONT CANAL (4-FOOT PARSHALL FLUME)	1957	2002
40000	ENTERPRISE CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
52200	FT. LARAMIE CANAL AT MILEPOST 85.3, NE (STATE LINE)	1981	2002
6681500	GERING CREEK NEAR GERING, NE	1931	2001
6677500	HORSE CREEK NEAR LYMAN, NE	1931	2002
217000	INDIAN CREEK NEAR NORTHPORT	1931	1990
71000	INTERSTATE CANAL	1933	2002
82000	LISCO CANAL FROM NORTH PLATTE RIVER (WEIR)	1933	2002
224000	MELBETA DRAIN NEAR MELBETA	1931	1990
98000	MIDLAND-OVERLAND CANAL FROM NORTH PLATTE RIVER 4 FOOT (PARSHALL FLUME)	1933	2002
99000	MINATARE CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
106000	NINE MILE CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
6682500	NINE MILE CREEK NEAR MCGREW	1931	2002
6684500	NORTH PLATTE RIVER AT BRIDGEPORT, NE	1923	2002
6687500	NORTH PLATTE RIVER AT LEWELLEN, NE	1941	2002
6686000	NORTH PLATTE RIVER AT LISCO, NEBR.	1932	2002

Table 1. North Platte River Gaging Stations -- Continued

Station_ID	Station Name	First Year	Last Year
6679500	NORTH PLATTE RIVER AT MITCHELL, NEBR.	1923	2002
6674500	NORTH PLATTE RIVER AT WYOMING-NEBRASKA STATE LINE	1930	2000
6682000	NORTH PLATTE RIVER NEAR MINATARE, NE	1924	2002
6685000	PUMPKIN CREEK NEAR BRIDEGPORT, NE	1931	2002
6684000	RED WILLOW CREEK NEAR BAYARD	1931	2002
6678000	SHEEP CREEK NEAR MORRILL	1931	2002
133000	SHORT LINE CANAL FROM NORTH PLATTE RIVER (RATING FLUME)	1933	2002
230000	SILVERNAIL DRAIN NEAR BRIDGEPORT	1956	1989
145100	TRI-STATE CANAL FROM NORTH PLATTE RIVER	1933	2002
6680000	TUB SPRINGS NEAR SCOTTSBLUFF	1931	2002
147500	WET SPOTTEDTAIL CREEK NEAR MITCHELL	1931	1987
6681000	WINTER CREEK NEAR SCOTTS BLUFF	1931	2002
148000	WINTERS CREEK CANAL FROM NORTH PLATTE RIVER (8-FOOT PARSHALL FLUME)	1933	2002
GUER	GUERNSEY RESERVOIR OUTFLOW	1946	2002

Table 2

A Station List of Historic Drains into the North Platte River

(Between State Line and Bridgeport)

Station_ID	Gauging Station Name	Data Period
	Bald Drain	1931-1987
6683000	**Bayard Sugar factory Drain**	**1931-2002**
	Camp Clark Seep	1931-1936
	Castle Rock Seep	1938-1941
	Cleveland Drain	1931-1990
	DeGraw Drain	1931-1987
	Dugout Creek, Upper	1931-1990
	Fairfield Seep	1931-1987
	Fanning Seep	1931-1987
6681500	**Gering Drain**	**1931-2002**
6677500	**Horse Creek**	**1931-2002**
	Indian Creek	1931-1990
	Lane Drain	1931-1987
	Melbeta Drain	1931-1990
	Mitchell Spillway	1931-1942
6682500	**Nine Mile Drain**	**1931-2002**
6684000	**Red Willow Creek**	**1931-2002**
	Scottsbluff Drain No. 1	1931-1987
	Scottsbluff Drain No. 2	1932-1987
6678000	**Sheep Creek**	**1931-2002**
6679000	**Spottedtail, Dry**	**1931-2002**
	Spottedtail, Wet	1931-1987
	Toohey Drain	1931-1935
	Toohey Spill	1931-1942
6680000	**Tub Springs**	**1931-2002**
6681000	**Winters Creek**	**1931-2002**

Note: Bold stations have continuous data records from 1931 to present.

Table 3

A Station List of Historic Canal Diversions from Drains

(Between State Line and Bridgeport)

Station ID	Gauging Station Name	Data Period(s)
2000	Alliance Canal from Bayard Drain	1931-2002
3000	Alliance Canal from Red Willow Creek	1931-2002
42000	Enterprise Canal from Morrill Drain	1931-1996
43000	Enterprise Canal from Tub Springs	1931-1996
44000	Enterprise Canal from Winters Creek	1961-1996
41000	Enterprise Canal from Dry Spottedtail Creek	1960-1996
42500	Enterprise Canal from Stewart Drain	1931-35;1948
42700	Enterprise Canal from Wet Spottedtail Creek	1931-60;1995-96
106100	Nine Mile Canal from Nine Mile Creek	1931-46; 63-65; 70-77; 88-2002
144400	Tri-State Canal from Alliance Creek	1931-44; 1996-97
144500	Tri-State Canal from Akers Draw	1931-2002
144700	Tri-State Canal from Sheep Creek	1931-2002
144600	Tri-State Canal from Dry Spottedtail Creek	1931-2002
144900	Tri-State Canal from Wet Spottedtail Creek	1931-2002
144800	Tri-State Canal from Tub Springs	1931-2002
149000	Winters Creek Canal from Winters Creek	1931-2002

Table 4. Step-wise Regression Analyses of Annual Data Series

(In the parentheses, each individual variable's contribution to the variation of the response variable is listed in *italics*.)

Response	Potential Predictors	Regression Equation	Coefficient of Determination, R^2 (%)
North Platte River Flow at Lewellen, *Lewellen*	Precip, IrrWells, Guernsey	Lewellen = 1.271Guernsey + 22.6Precip – 748.1	93.67 (*Guernsey=91, Precip=2.7*)
Total Drains Between Stateline & Bridgeport, *TotTrib*	Precip, IrrWells, IntState, IS1-4, TSNP, TSNP1-2, Laramie	TotTrib = 0.94IntState + 0.38IS2 + 0.86TSNP1 + 7.1Precip – 325.32	66.87 (*IntState=54.7, TSNP=5, Precip=7.1*)
Drains from the Northside of the N. Platte River Reach, *NorthTrib*	Precip, NorthWell, IntState, IS1-4, TSNP, TSNP1-2,	NorthTrib = 0.39IntState +0.282IS2 + 0.316IS1+4.8Precip + 0.185IS3 + 0.35TSNP – 249.88	81.71 (*IntState=71.8, Precip=7.6, TSNP=2.3*)
Total Drain of Sheep, Akers, DrySpot, Tub Springs, and Winters Creek, *TotalFive*	Precip, FiveWell, IntState, IS1-4, TSNP, TSNP1-2	TotalFive = 0.210IntState + 0.081IS2 + 0.247TSNP1 + 1.27Precip + 0.055IS3 – 42.46	79.29 (*IntState=64, TSNP=9, Precip=6.3*)
Annual Total Drain of Sheep Creek, *Sheep*	Precip, SheepWell, IntState, IS1-4, TSNP, TSNP1-2	Sheep = 0.055IntState + 0.055IS1 + 0.023IS3 + 0.039IS2 – 0.051TSNP2 + 0.29Precip + 0.014IS4 – 16.85	92.77 (*IntState=88.1, TSNP=3.4, Precip=1.3*)
Tri-State Canal Diversion from Drains, *TStrib*	Precip, IntState, IS1-4	TStrib = 0.074IntState + 0.037IS2 + 0.032IS1 – 25.446	68.64
Total Irrigation Diversion from Drains, *DivTrib*	Precip, IntState, IS1-4, TSNP, TSNP1-2	DivTrib = 0.079IntState + 36.42	33.69

Table 5. Results of Trend Analyses of Data Series

[Shading indicates statistically significant at the 95-percent confidence level (probability value less than 0.05). Insignificant trend is likely to be a result of chance.]

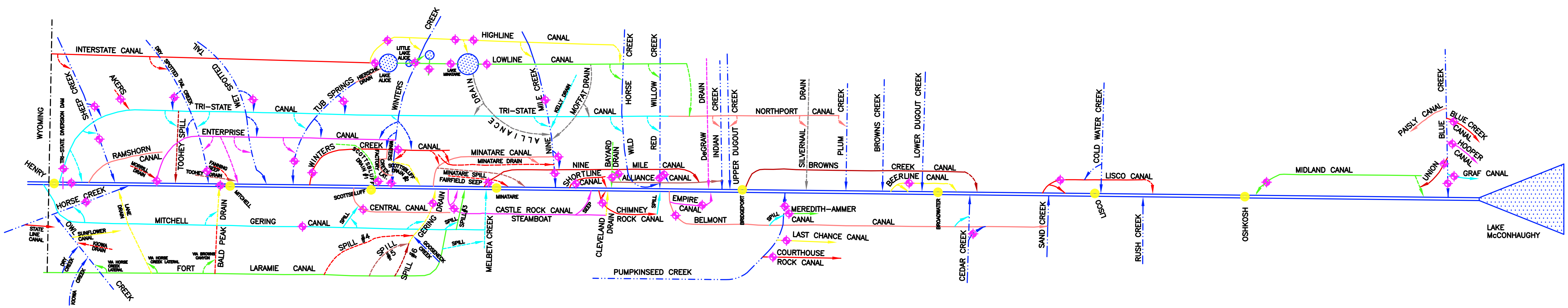
Annual Data Series Name	Probability (p-value)	Slope [KAF/Year]	Increasing (+) or Decreasing (-) Trend
Annual Precipitation at Mitchell 5E	0.495	-0.031*	
Guernsey Reservoir Outflow	0.952	-0.284	
Interstate Canal Diversion	0.011	-2.125	-
Ft. Laramie Canal Diversion	0.599	-0.134	
Tri-State Canal from N. Platte River	0.004	1.090	+
Tri-State Canal from Tributaries	0.003	-0.302	-
Total Tri-State Canal Diversion	0.072	0.788	
Total July Tributary Flows	0.945	0.012	
Total August Tributary Flows	0.740	0.058	
Total September Tributary Flows	0.210	-0.285	
Total October Tributary Flows	0.000	-0.293	-
Total November Tributary Flows	0.001	-0.183	-
Total Summer Tributary Flows (July-October)	0.348	-0.557	
Total Tributaries from South Side of the River	0.710	0.168	
Total Tributaries from North Side of the River	0.024	-1.679	-
Total Tributaries between Stateline & Bridgeport	0.181	-1.511	
Total Diversion from Tributaries	0.566	-0.067	
Horse Creek near Lyman	0.123	0.510	
Sheep Creek	0.000	-0.371	-
Dry Spotted Tail Creek	0.041	0.128	+

Table 5. Results of Trend Analyses of Data Series---Continued

Annual Data Series Name	Probability (p-value)	Slope [KAF/Year]	Increasing (+) or Decreasing (-) Trend
Tub Springs	0.909	-0.007	
Winters Creek	0.267	-0.065	
Gering Creek near Gering	0.017	0.299	+
Nine Mile Creek	0.291	-0.140	
Bayard Creek	0.210	0.052	
Red Willow Creek	0.556	-0.101	
Blue Creek	0.037	-0.078	-
North Platte River at Lewellen	0.787	-1.689	
Surface Water Irrigated Acres	0.003	-312.319**	-
Number of Registered Wells	0.000	20.1504***	+

*The slope for precipitation is in inches per year,
** The slope for the surface water irrigated acres is in acres per year, and the data period is 1961-1994, and
***The slope for the number of wells is in number per year.

Canal Network from the Nebraska-Wyoming Stateline to Lake McConaughy along the North Platte River



NOTE:
* ALL CANALS HAVE A GAGING STATION
* RAMSHORN CANAL IS CANCELLED

NOT TO SCALE

LEGEND

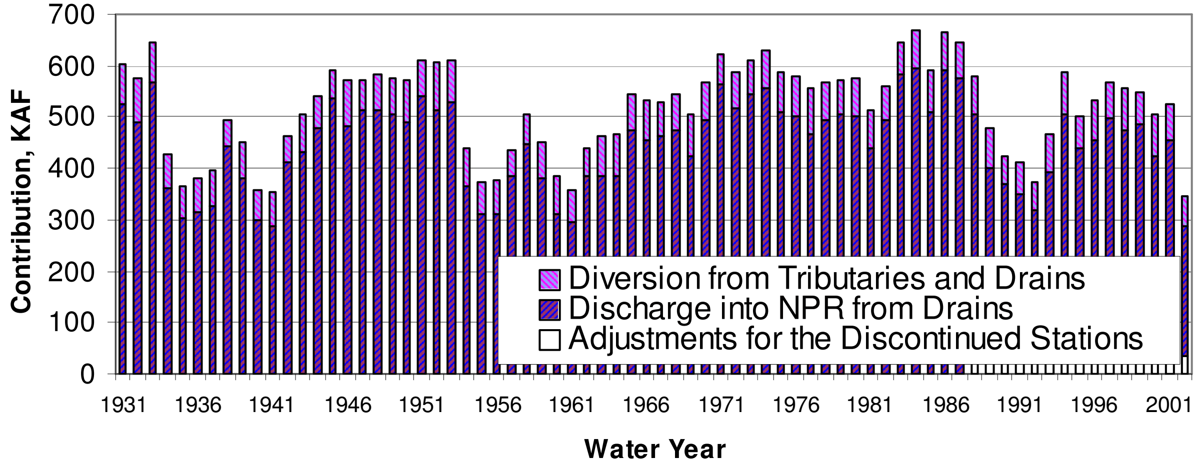
- GAGING STATION
- CITIES
- RESERVOIR
- CANAL
- CREEK
- DRAIN

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.	TITLE: CANAL SCHEMATIC	SCALE:	SHEET:	DWN BY:	APP'D BY:	DATE:	PROJECT NUMBER:	REV:
				MGL		AUG 94	10387.01	

Figure 1

Figure 2 Historic Contribution from Tributaries and Drains

(Between State Line and Bridgeport)



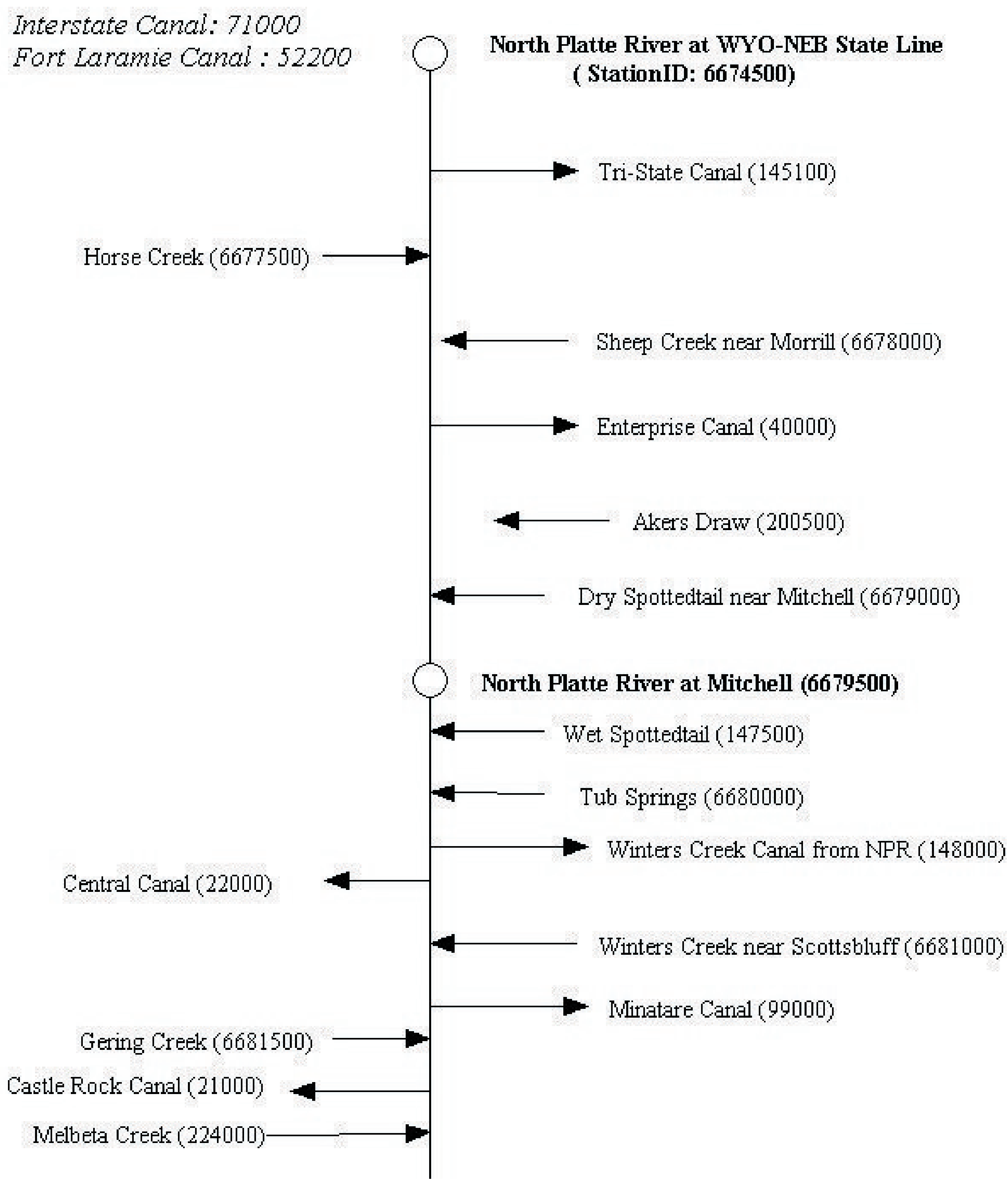
Tributaries and Drains are as of 1986:

Bald	Fairfield	Lane	Scottsbluff #2
Bayard	Fanning	Melbeta	Sheep
Cleveland	Gering	Nine Mile	Dry Spottedtail
DeGraw	Horse	Red Willow	Wet Spottedtail
Upper Dugout	Indian	Scottsbluff #1	Tub Sprins, and Winters

Figure 3

North Platte River Reach Gain/Loss Computational Schematic

(State Line to Lewellen)



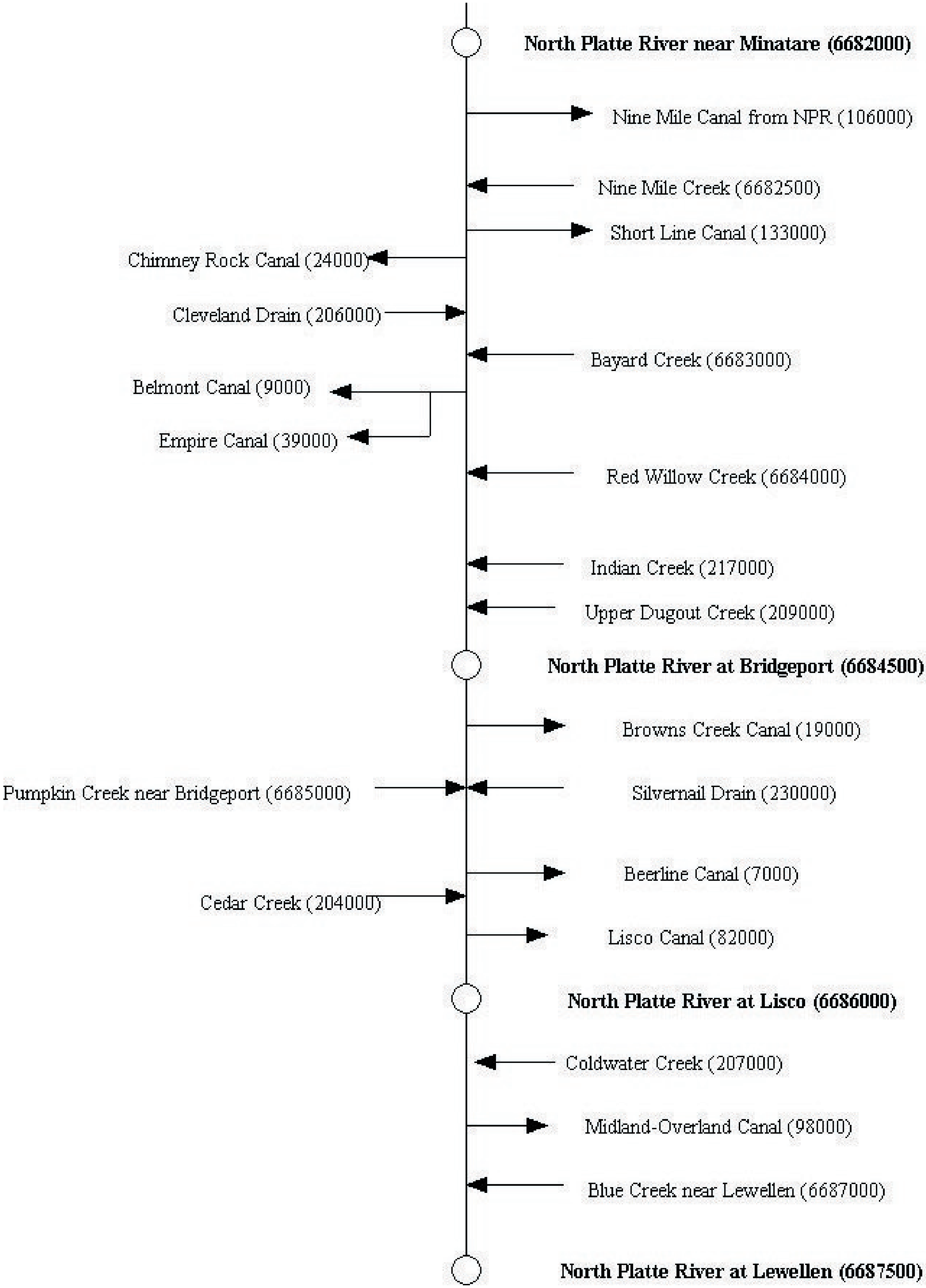
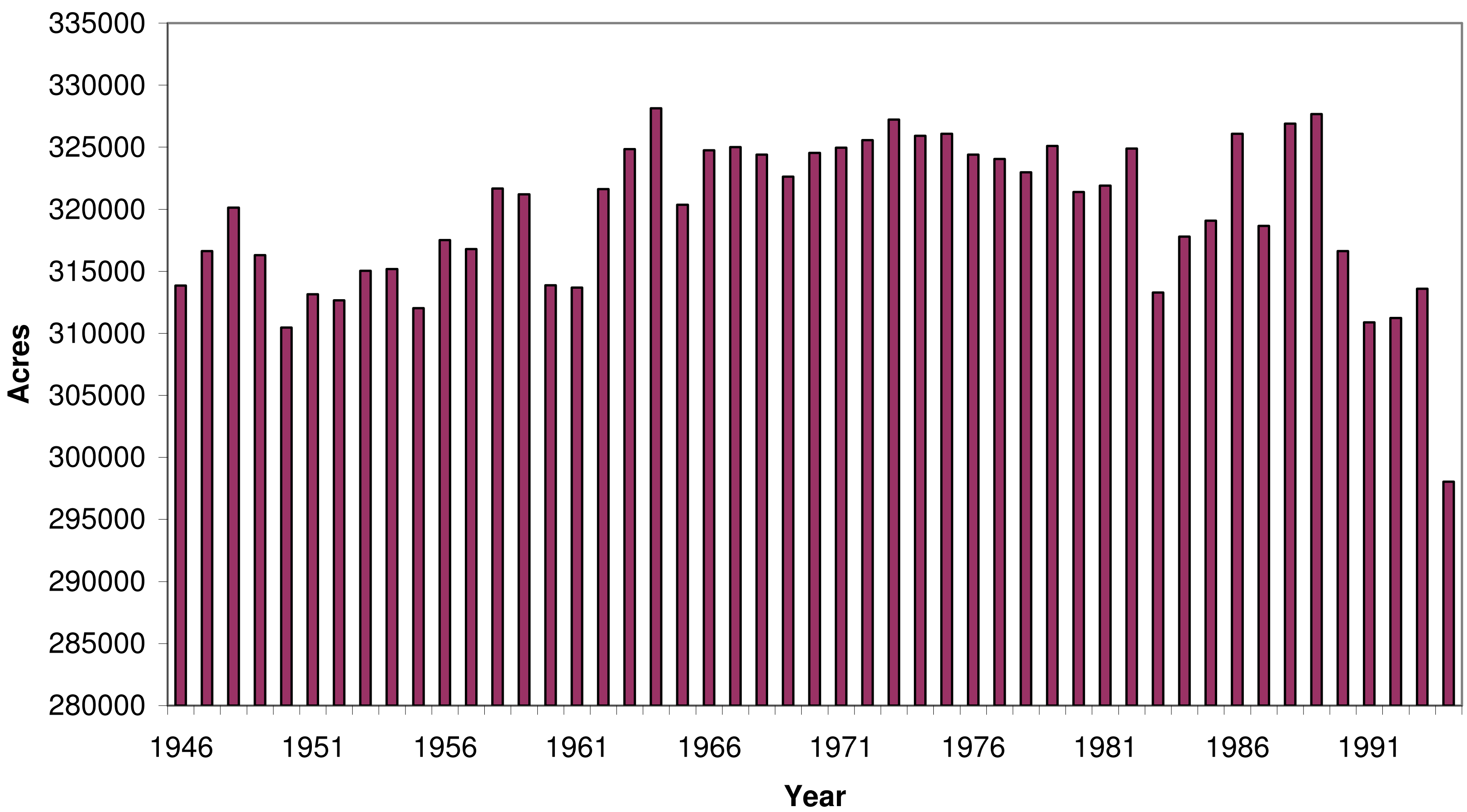

North Platte River near Minatare (6682000)
Nine Mile Canal from NPR (106000)
Nine Mile Creek (6682500)
Short Line Canal (133000)
Chimney Rock Canal (24000)
Cleveland Drain (206000)
Bayard Creek (6683000)
Belmont Canal (9000)
Empire Canal (39000)
Red Willow Creek (6684000)
Indian Creek (217000)
Upper Dugout Creek (209000)
North Platte River at Bridgeport (6684500)
Browns Creek Canal (19000)
Pumpkin Creek near Bridgeport (6685000)
Silvernail Drain (230000)
Beerline Canal (7000)
Cedar Creek (204000)
Lisco Canal (82000)
North Platte River at Lisco (6686000)
Coldwater Creek (207000)
Midland-Overland Canal (98000)
Blue Creek near Lewellen (6687000)
North Platte River at Lewellen (6687500)

Figure 4 Irrigated Acres by Surface Water



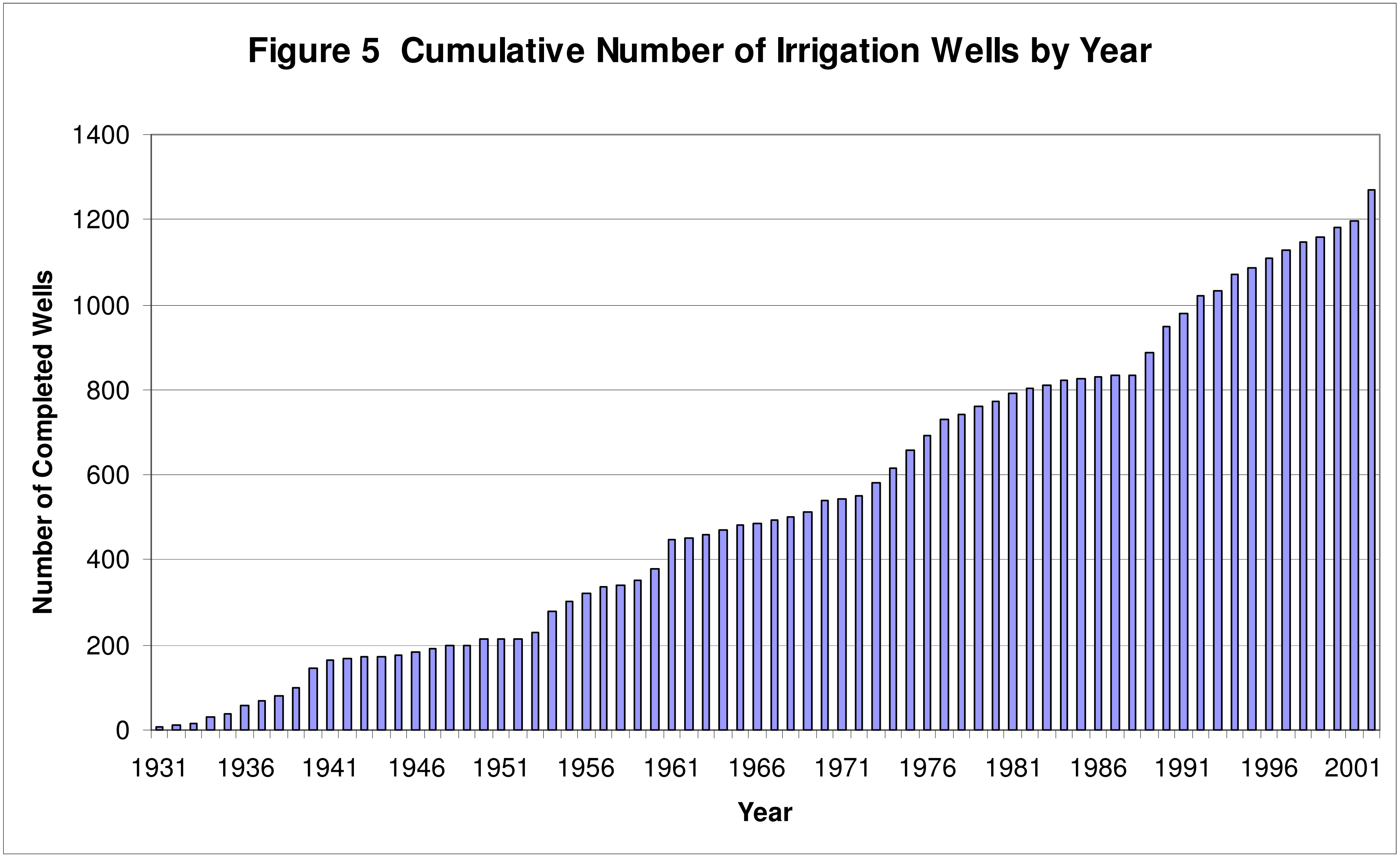
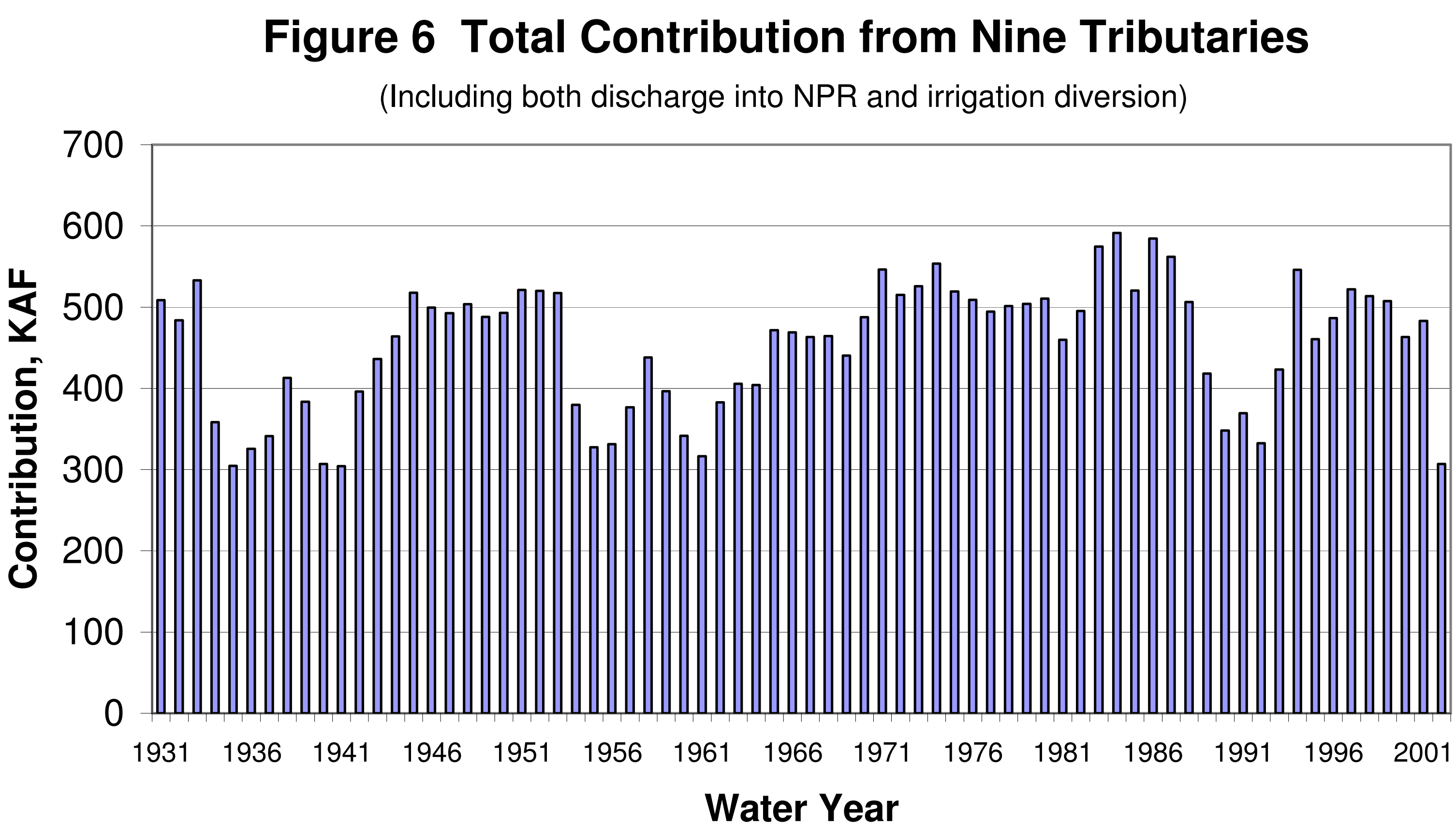


Figure 5 Cumulative Number of Irrigation Wells by Year
Number of Completed Wells
Year
0
200
400
600
800
1000
1200
1400
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001



Nine tributaries are:

Bayard Drain	Red Willow Creek	Dry Spotted Tail Creek
Gering Drain	Nine Mile Drain	Tub Springs
Horse Creek	Sheep Creek	Winters Creek

Figure 7 North Platte River Flow at Lewellen vs. Guernsey Reservoir Outflow

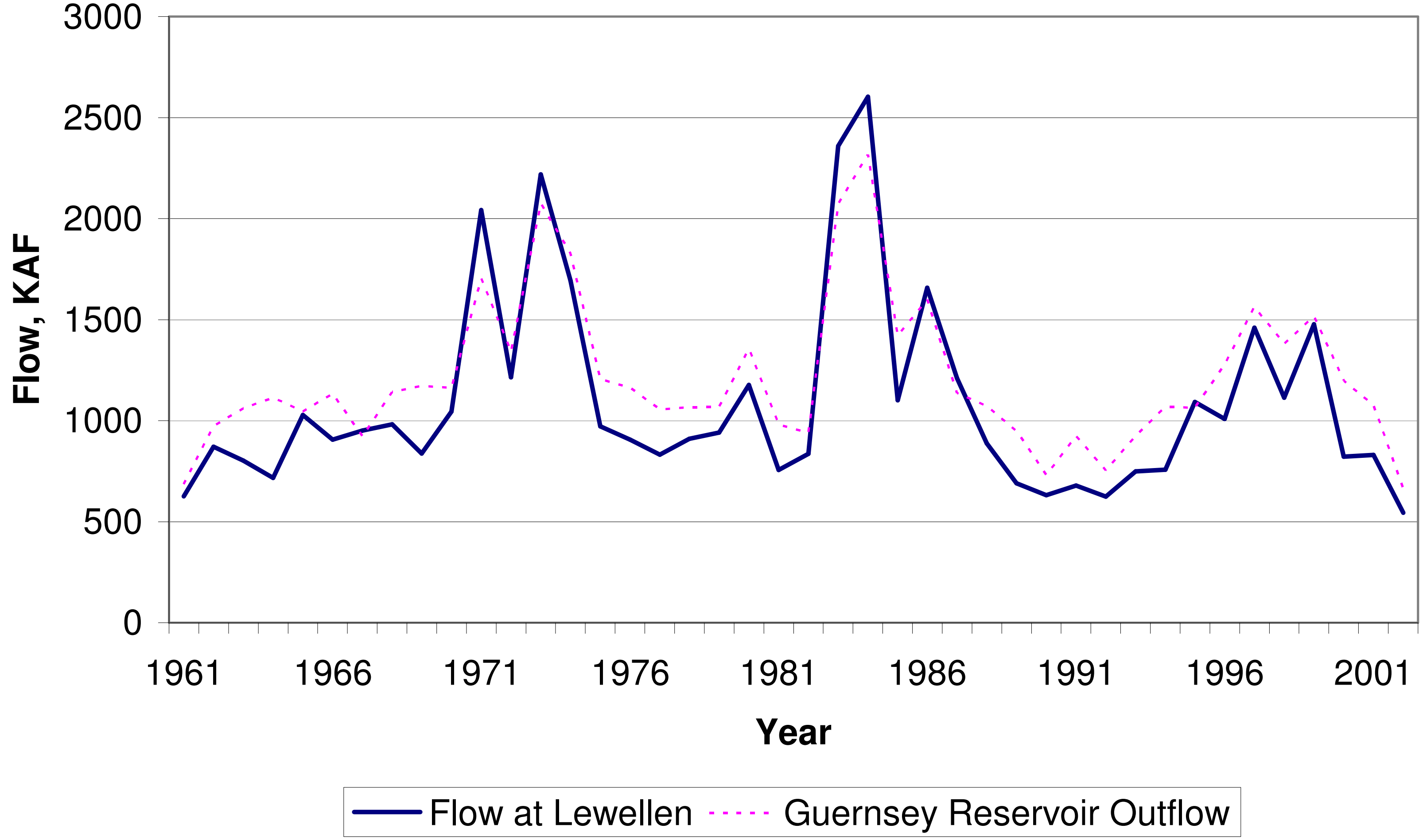
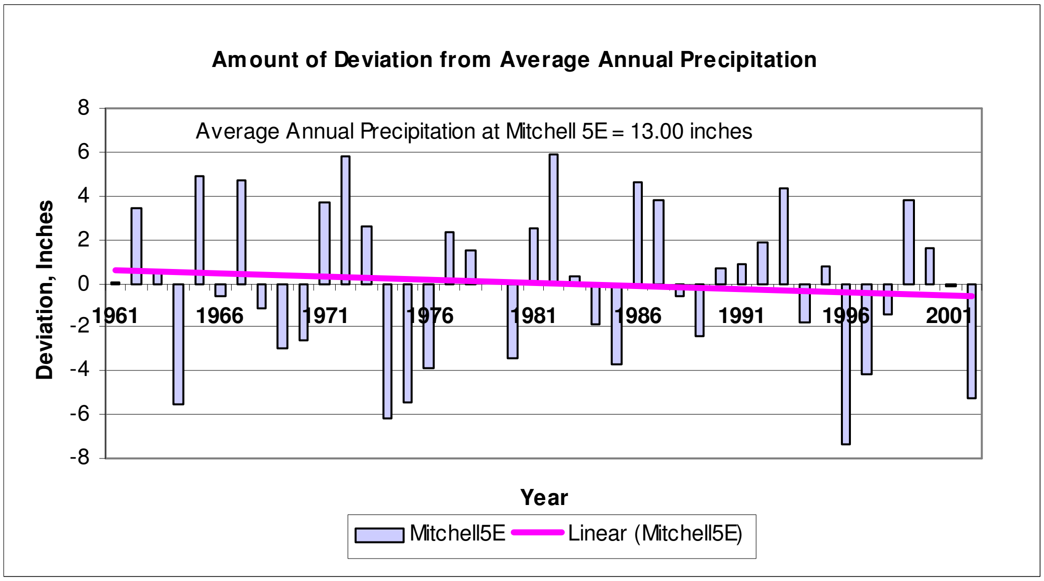
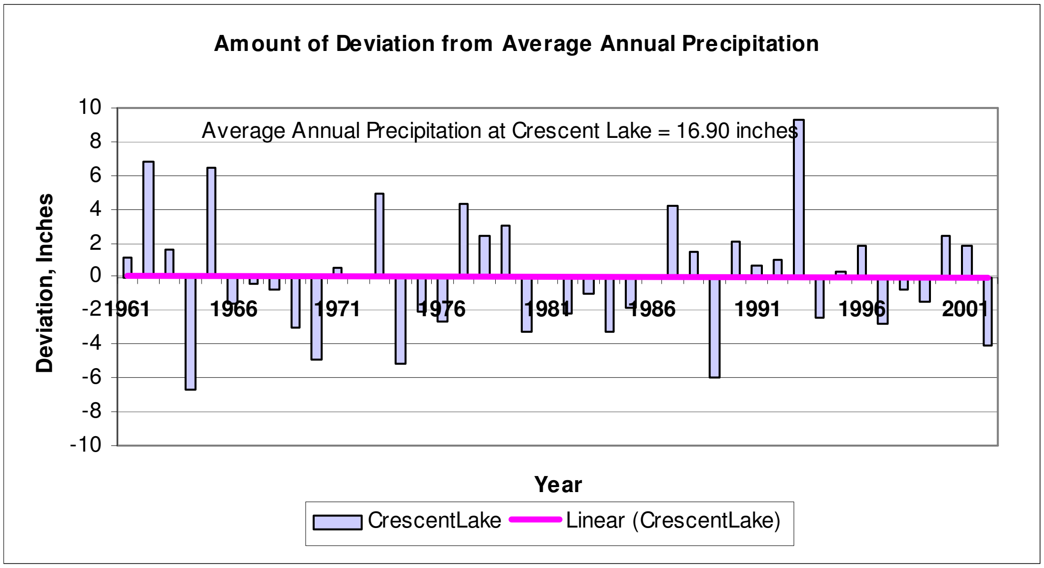


Figure 8: Deviations from Average Annual Precipitation





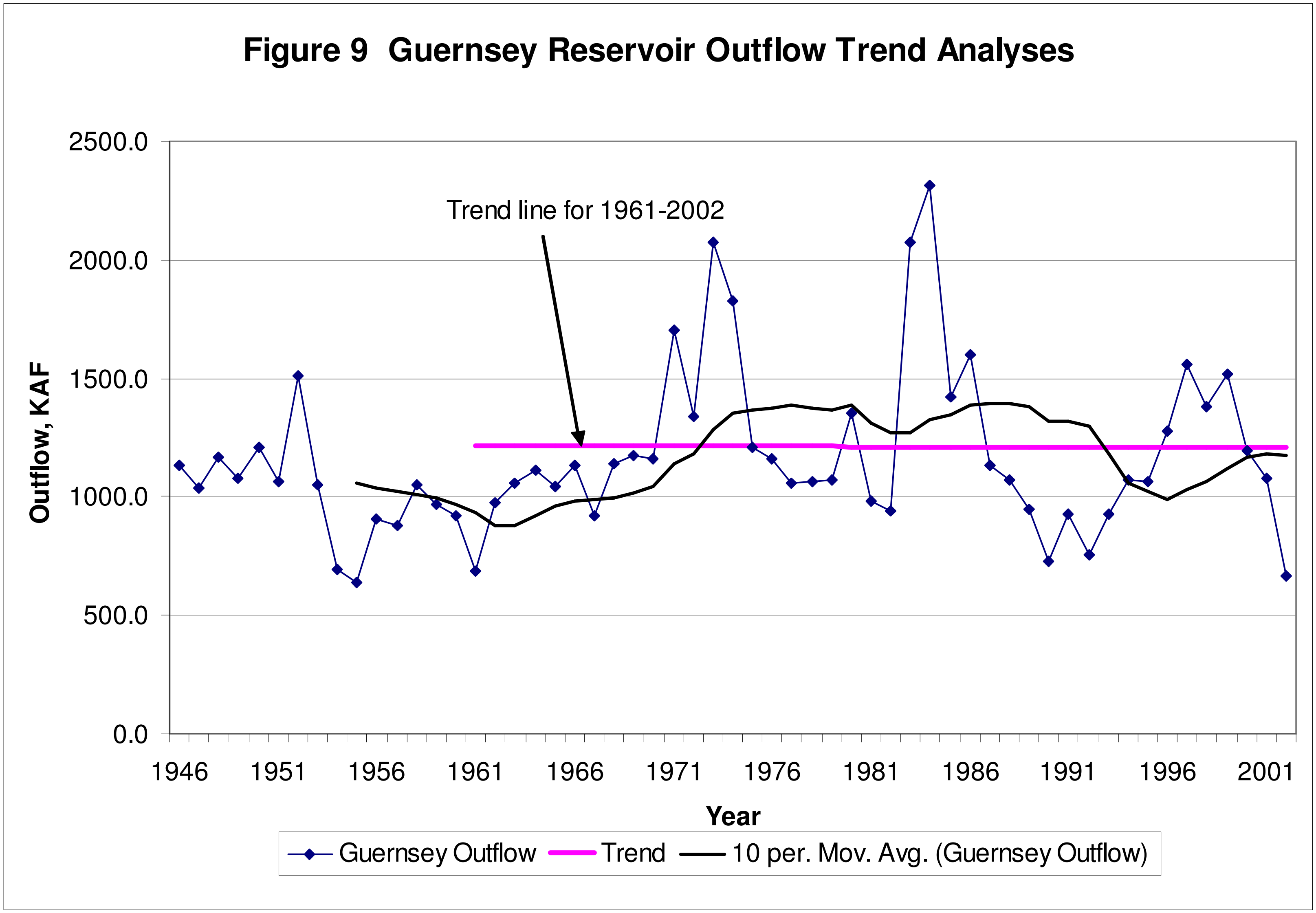


Figure 9 Guernsey Reservoir Outflow Trend Analyses
Trend line for 1961-2002
2500.0
2000.0
1500.0
1000.0
500.0
0.0
Outflow, KAF
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Guernsey Outflow
Trend
10 per. Mov. Avg. (Guernsey Outflow)

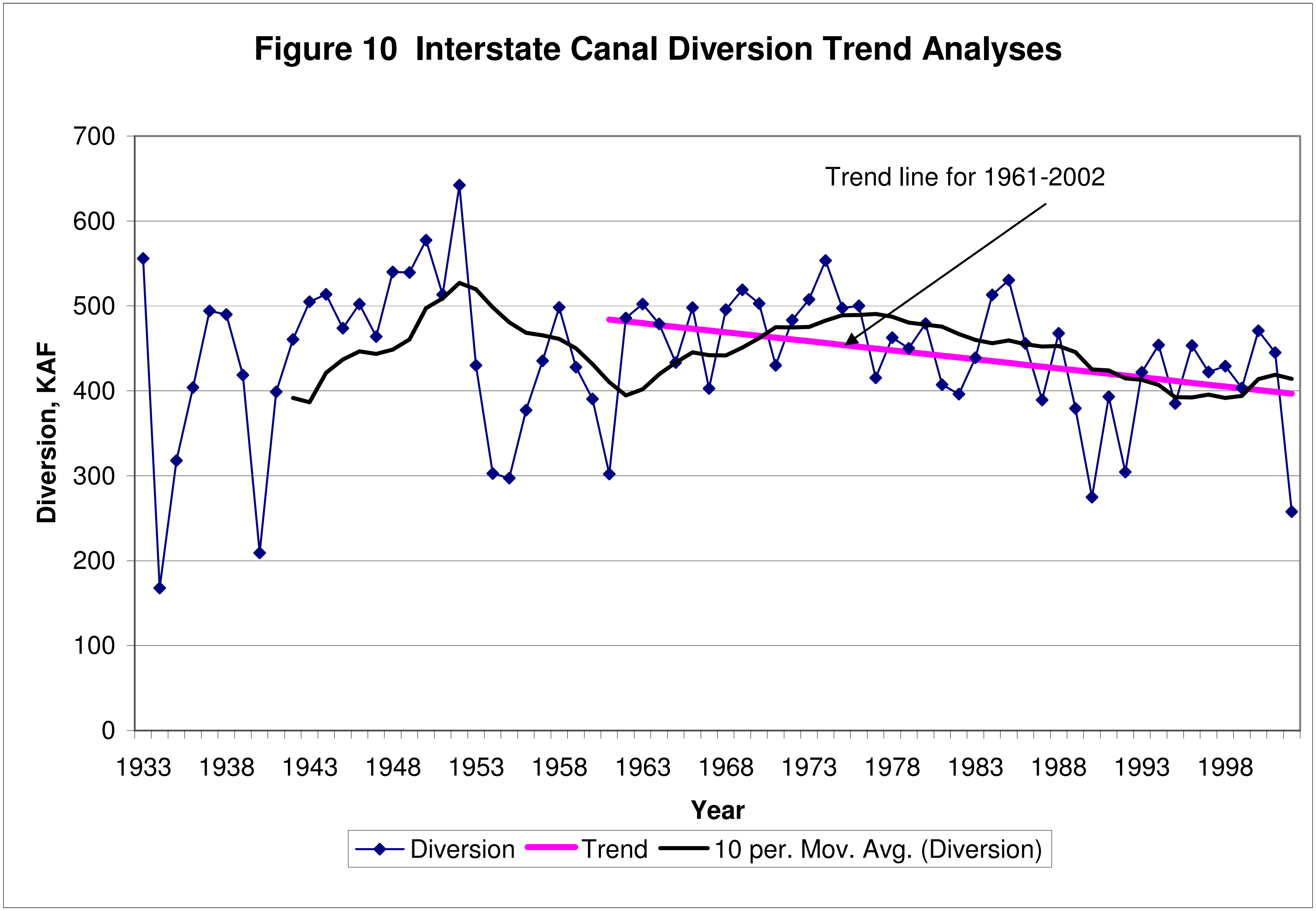


Figure 10 Interstate Canal Diversion Trend Analyses
Trend line for 1961-2002
Diversion, KAF
0
100
200
300
400
500
600
700
1933
1938
1943
1948
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
Year
Diversion
Trend
10 per. Mov. Avg. (Diversion)

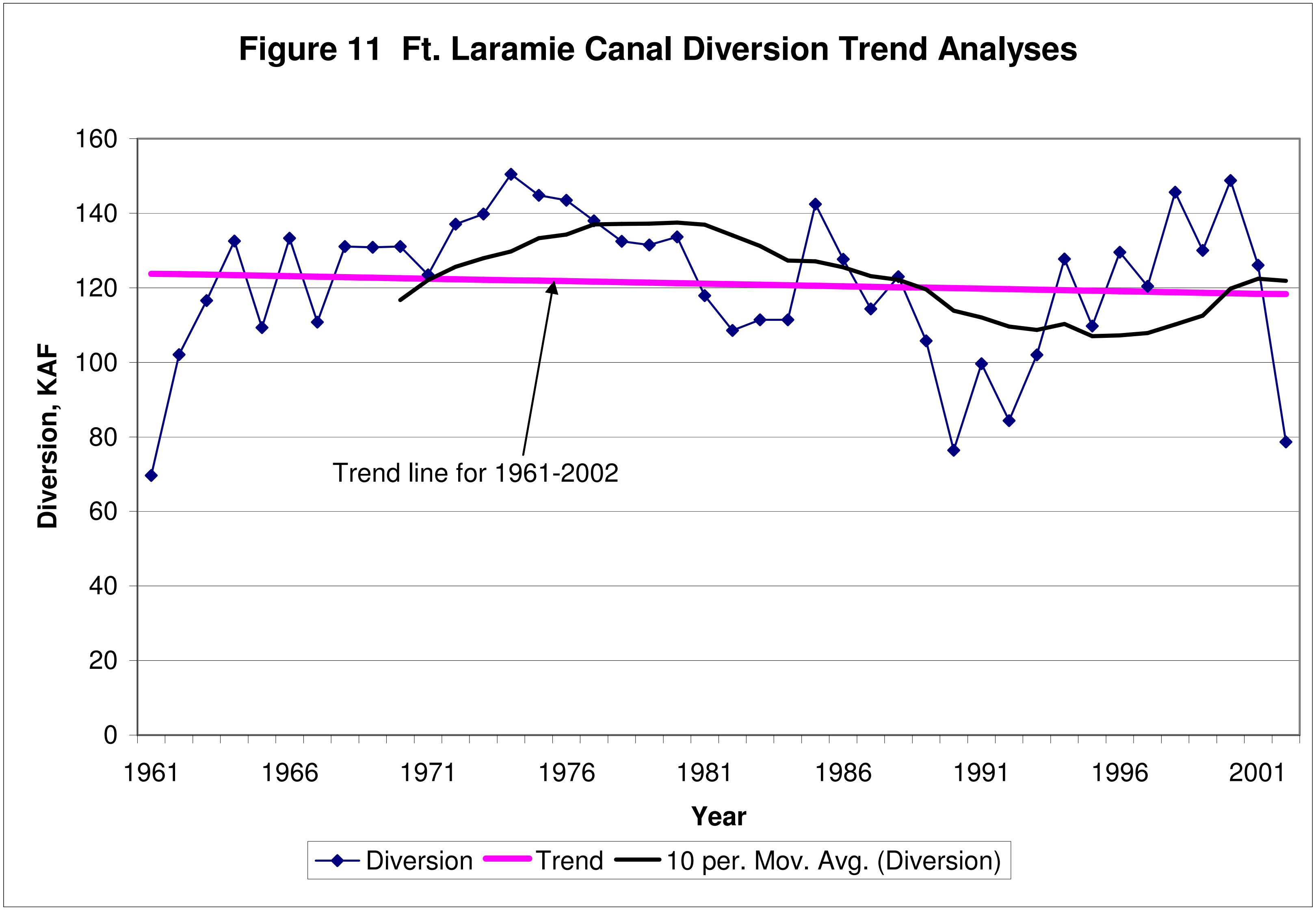


Figure 11 Ft. Laramie Canal Diversion Trend Analyses
Diversion, KAF
160
140
120
100
80
60
40
20
0
Trend line for 1961-2002
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Diversion
Trend
10 per. Mov. Avg. (Diversion)

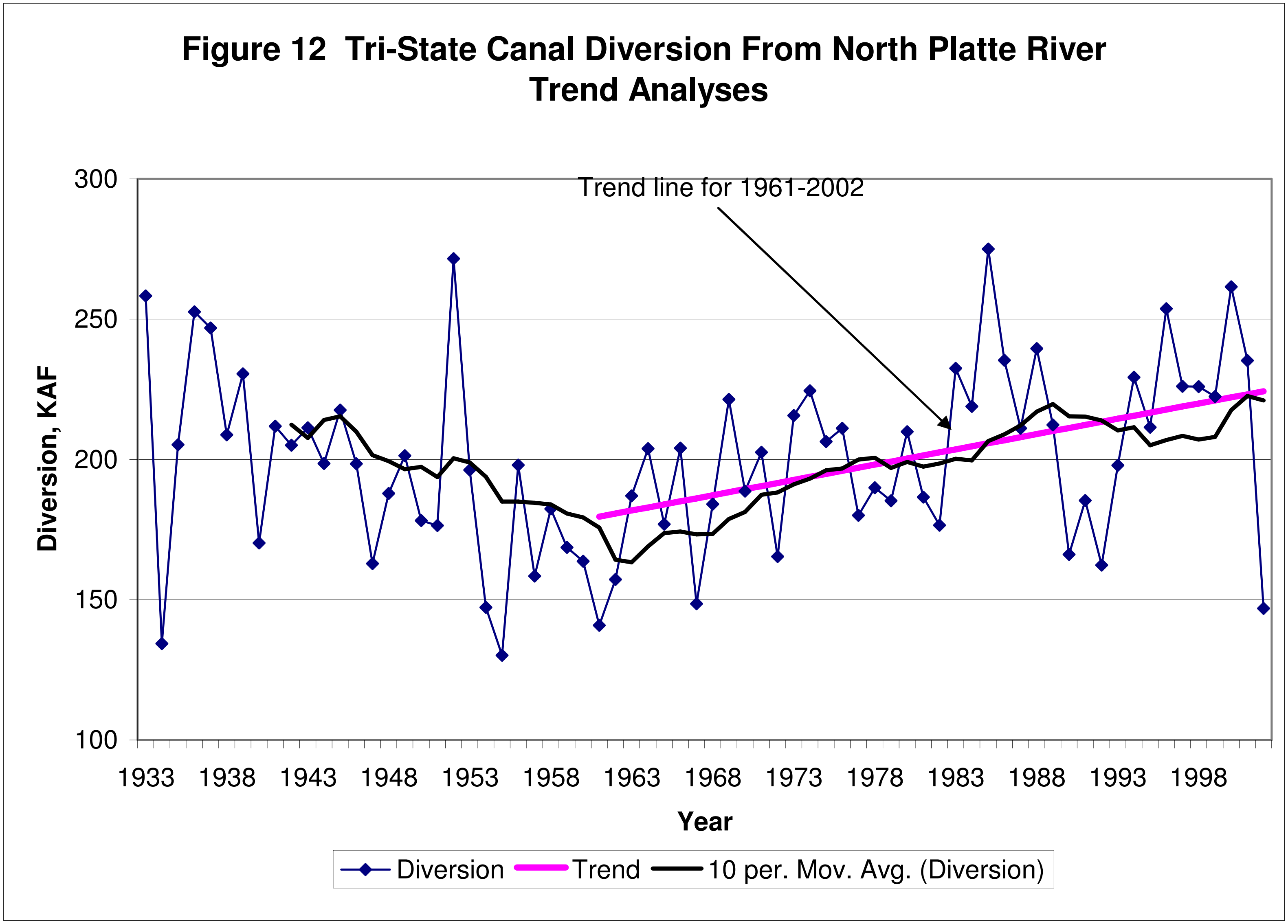


Figure 12 Tri-State Canal Diversion From North Platte River
Trend Analyses
Trend line for 1961-2002
300
250
200
150
100
Diversion, KAF
1933
1938
1943
1948
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
Year
Diversion
Trend
10 per. Mov. Avg. (Diversion)

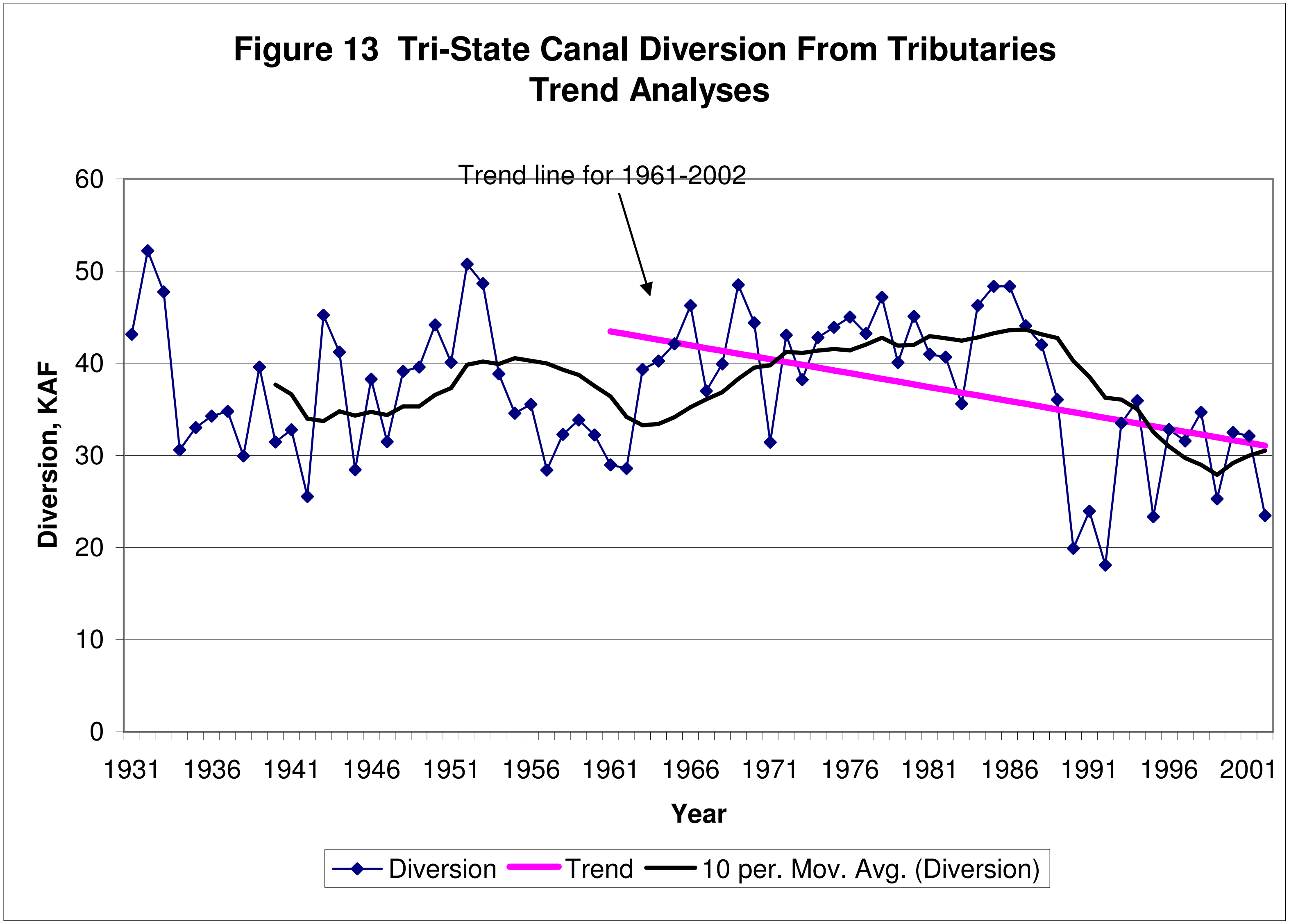


Figure 13 Tri-State Canal Diversion From Tributaries
Trend Analyses
Trend line for 1961-2002
Diversion, KAF
60
50
40
30
20
10
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Diversion
Trend
10 per. Mov. Avg. (Diversion)

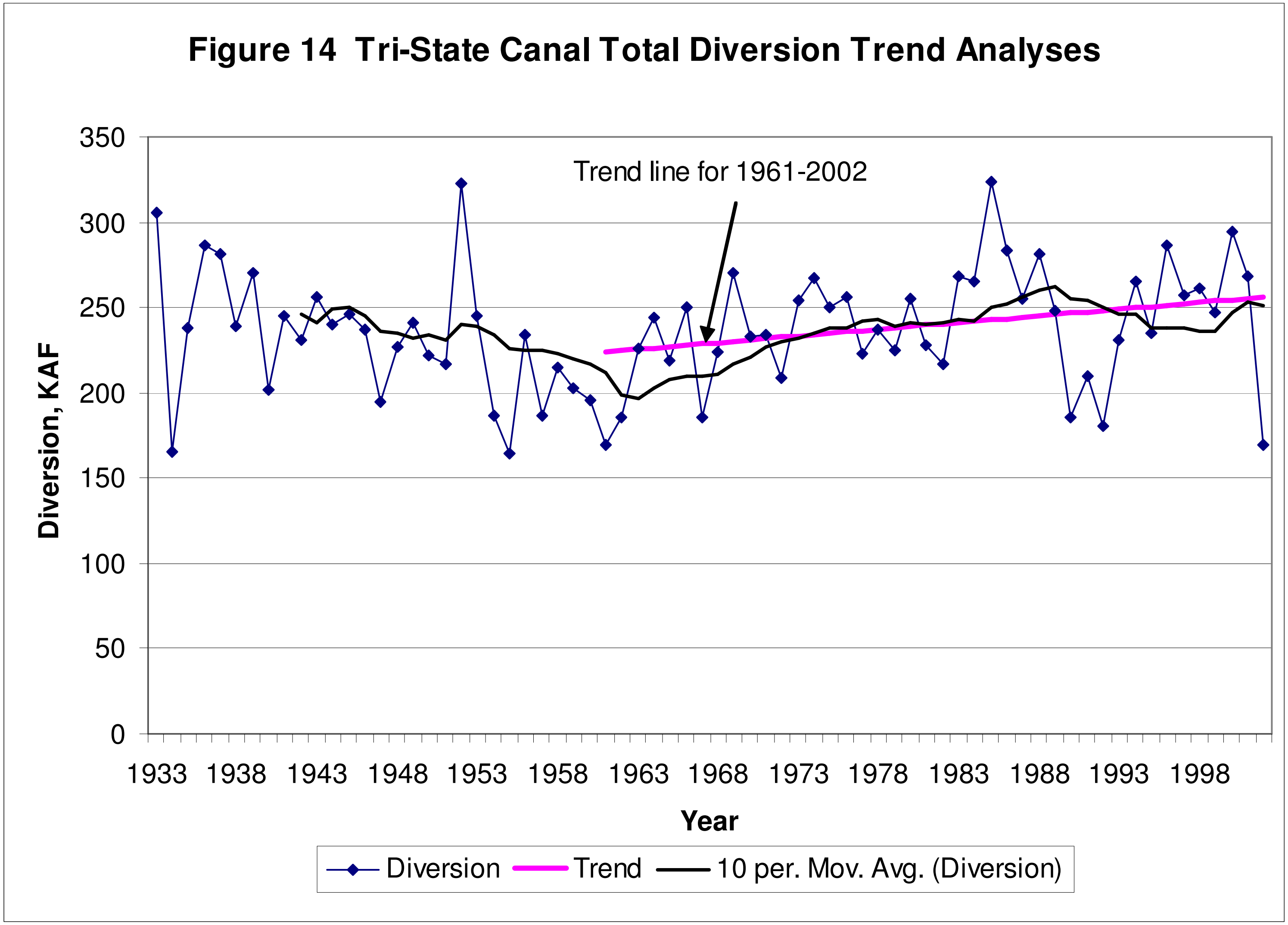


Figure 14 Tri-State Canal Total Diversion Trend Analyses
Trend line for 1961-2002
350
300
250
200
150
100
50
0
Diversion, KAF
1933
1938
1943
1948
1953
1958
1963
1968
1973
1978
1983
1988
1993
1998
Year
Diversion
Trend
10 per. Mov. Avg. (Diversion)

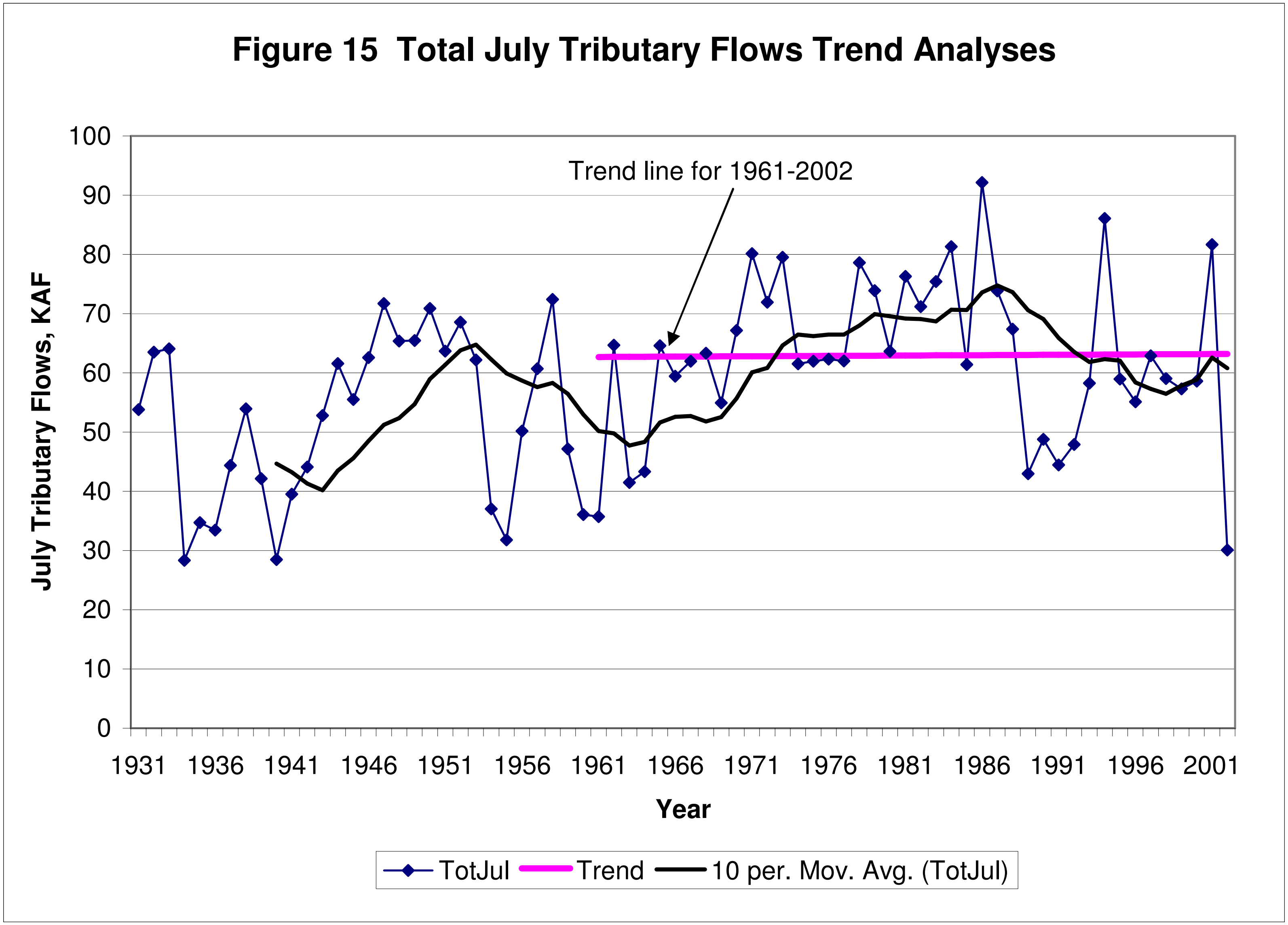


Figure 15 Total July Tributary Flows Trend Analyses
Trend line for 1961-2002
July Tributary Flows, KAF
Year
0
10
20
30
40
50
60
70
80
90
100
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
TotJul
Trend
10 per. Mov. Avg. (TotJul)

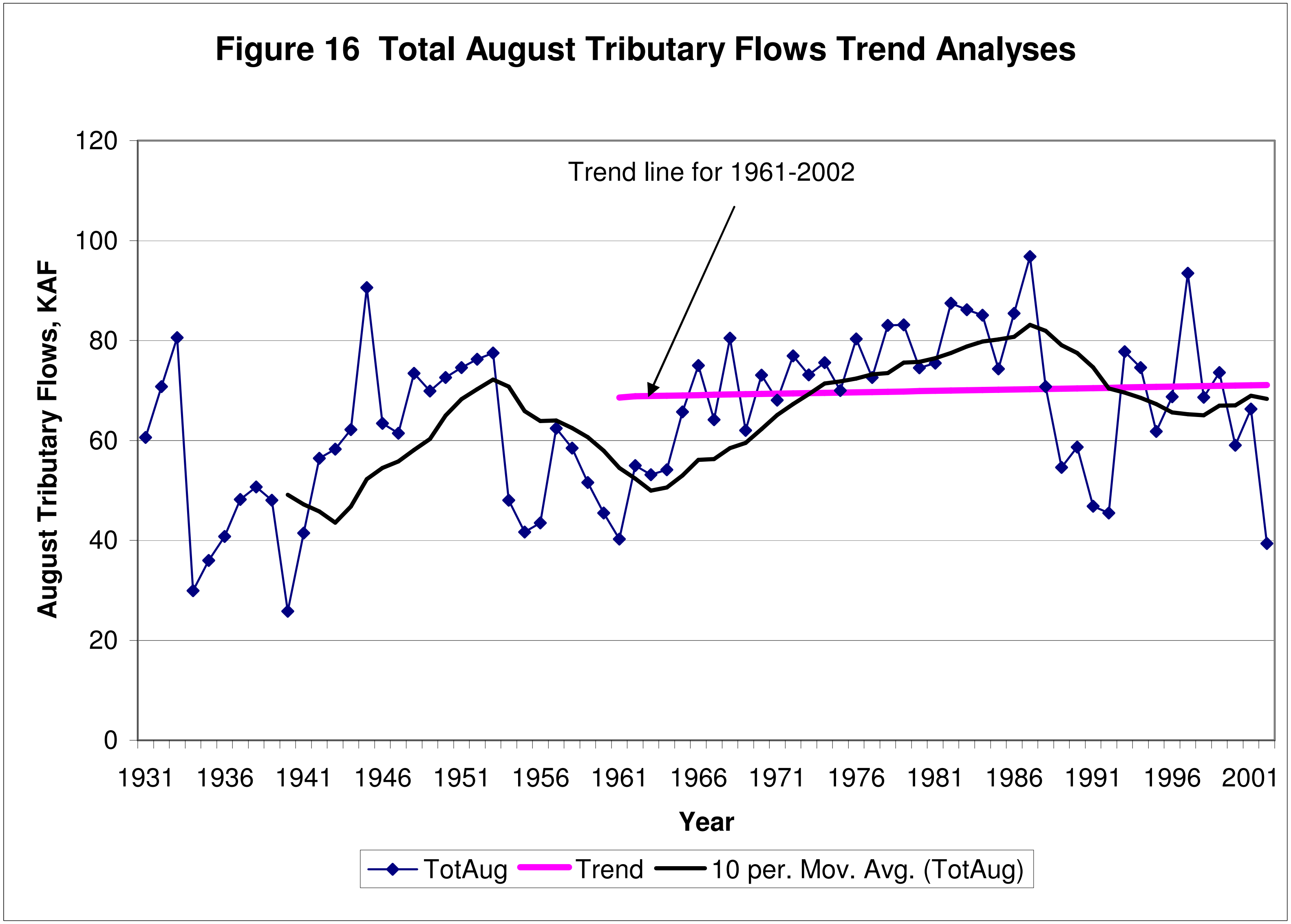
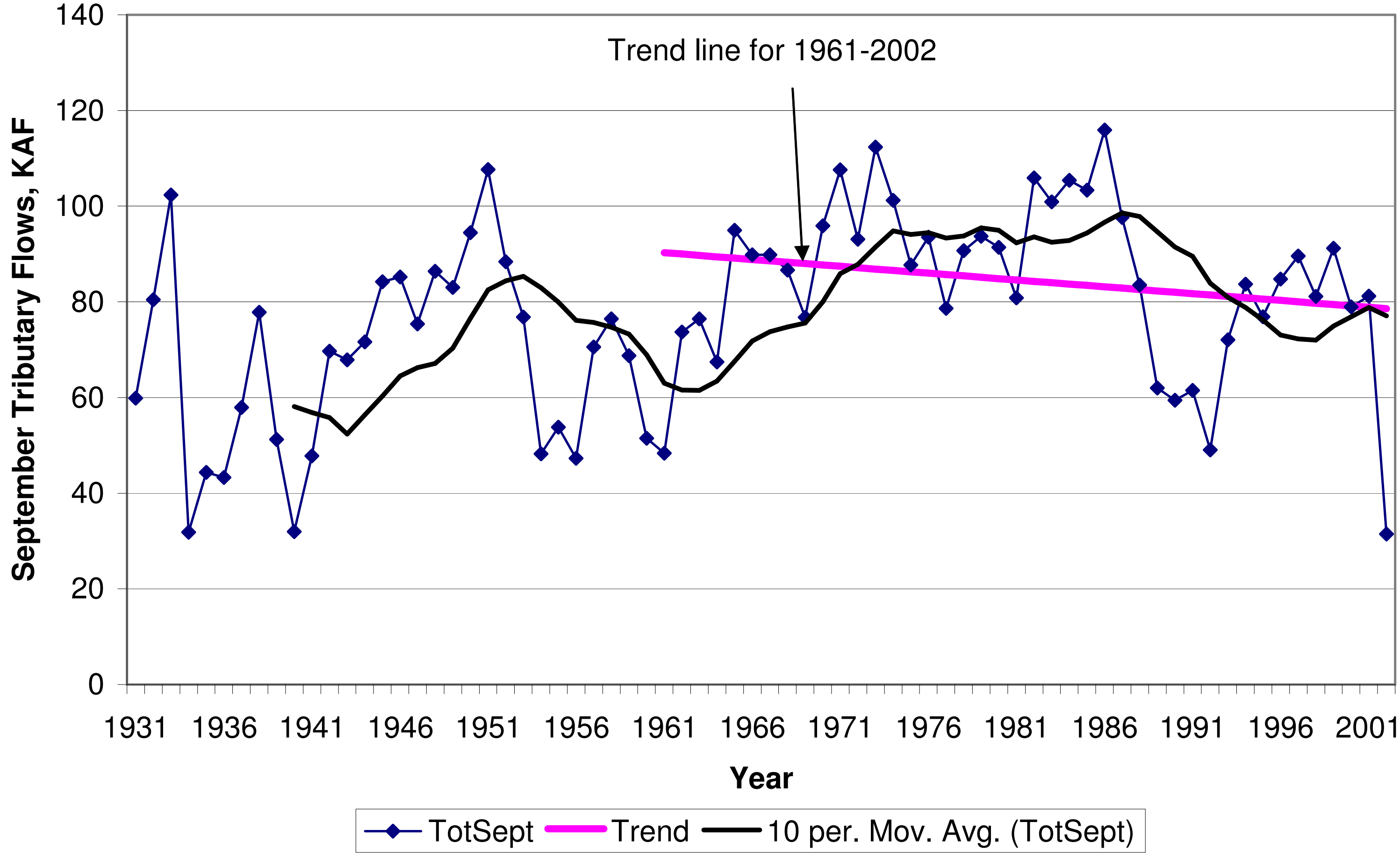


Figure 16 Total August Tributary Flows Trend Analyses
Trend line for 1961-2002
August Tributary Flows, KAF
120
100
80
60
40
20
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
TotAug
Trend
10 per. Mov. Avg. (TotAug)

Figure 17 Total September Tributary Flows Trend Analyses



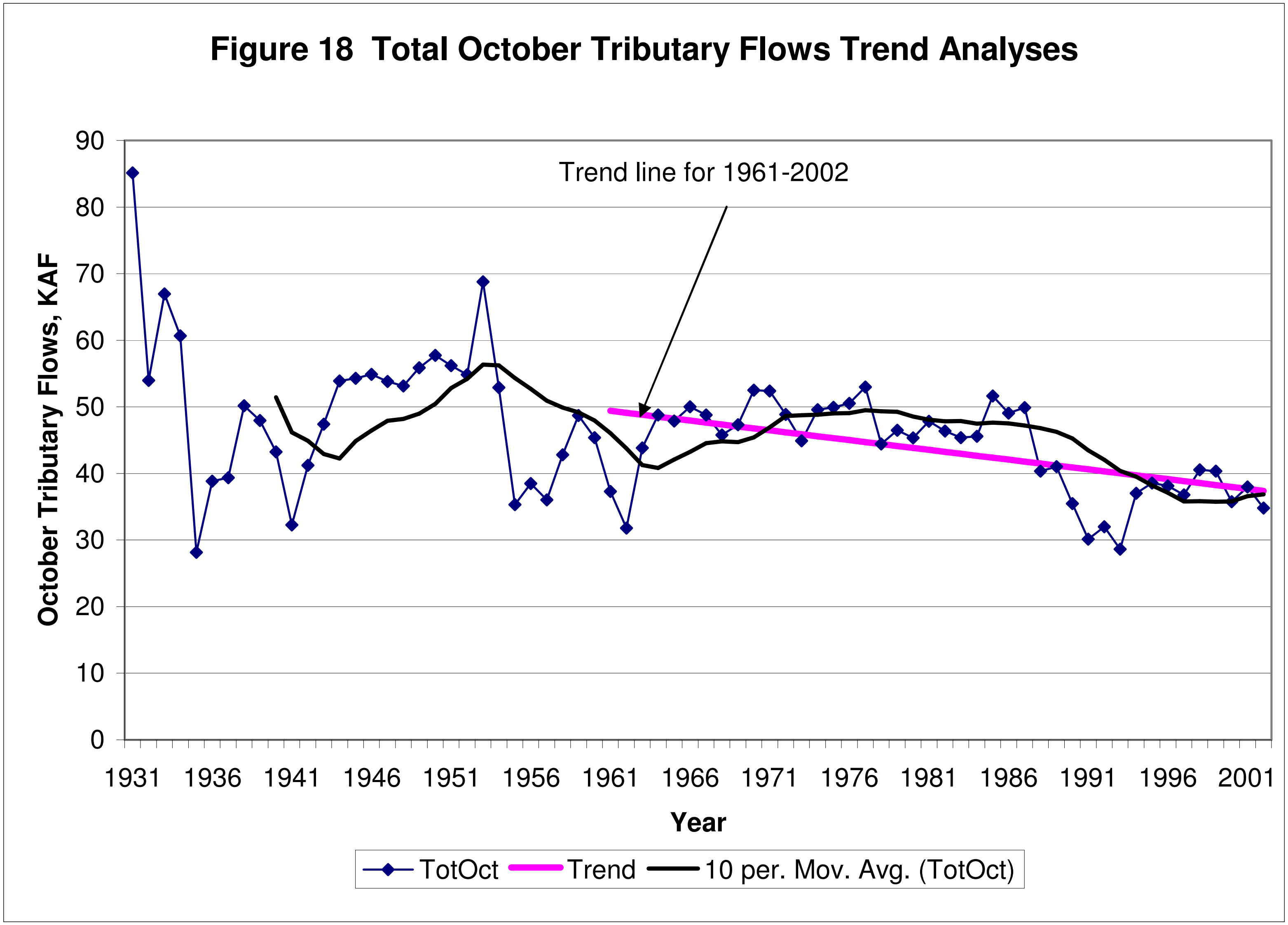


Figure 18 Total October Tributary Flows Trend Analyses
Trend line for 1961-2002
October Tributary Flows, KAF
0
10
20
30
40
50
60
70
80
90
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
TotOct
Trend
10 per. Mov. Avg. (TotOct)

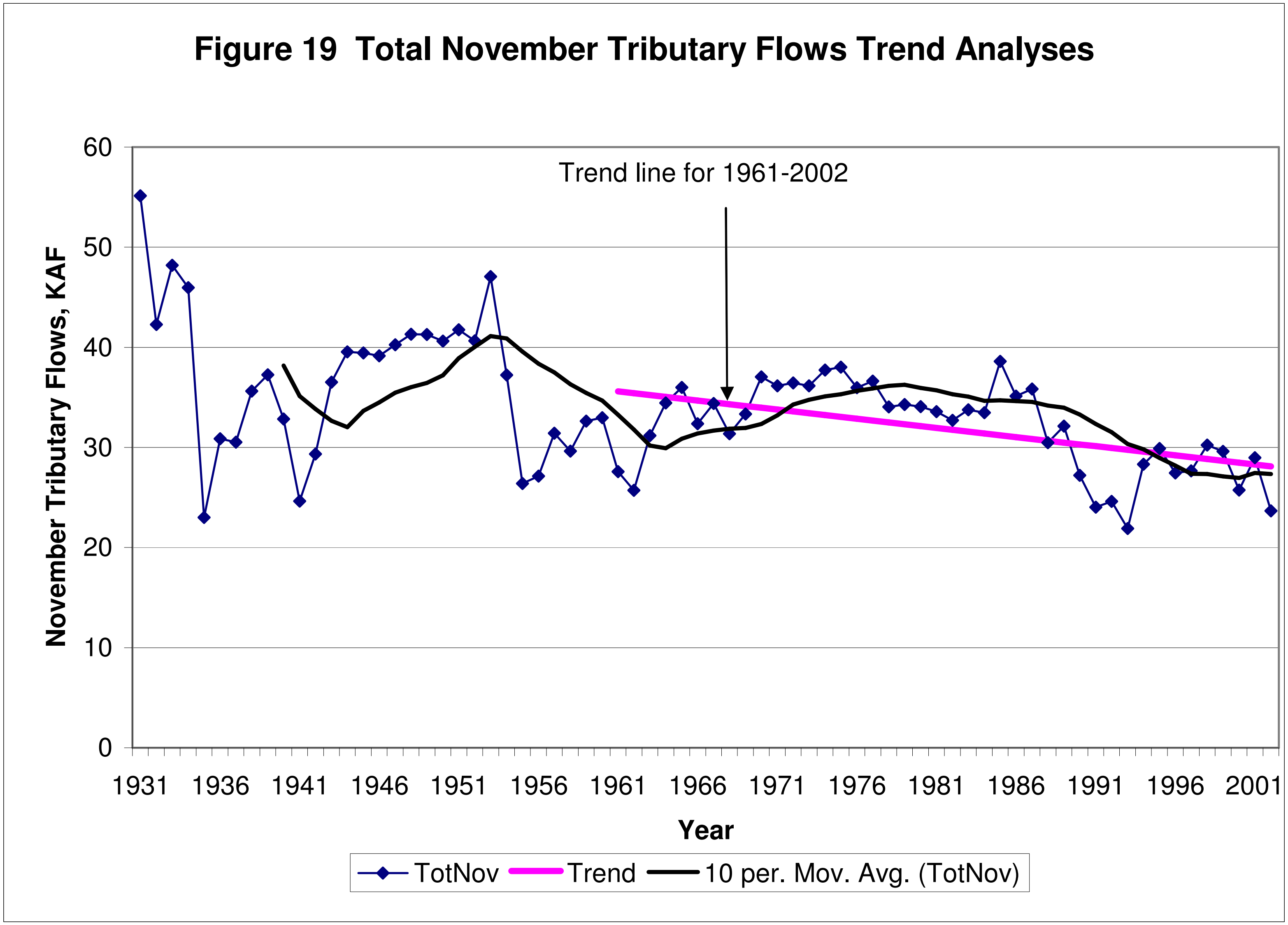


Figure 19 Total November Tributary Flows Trend Analyses
Trend line for 1961-2002
November Tributary Flows, KAF
60
50
40
30
20
10
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
TotNov
Trend
10 per. Mov. Avg. (TotNov)

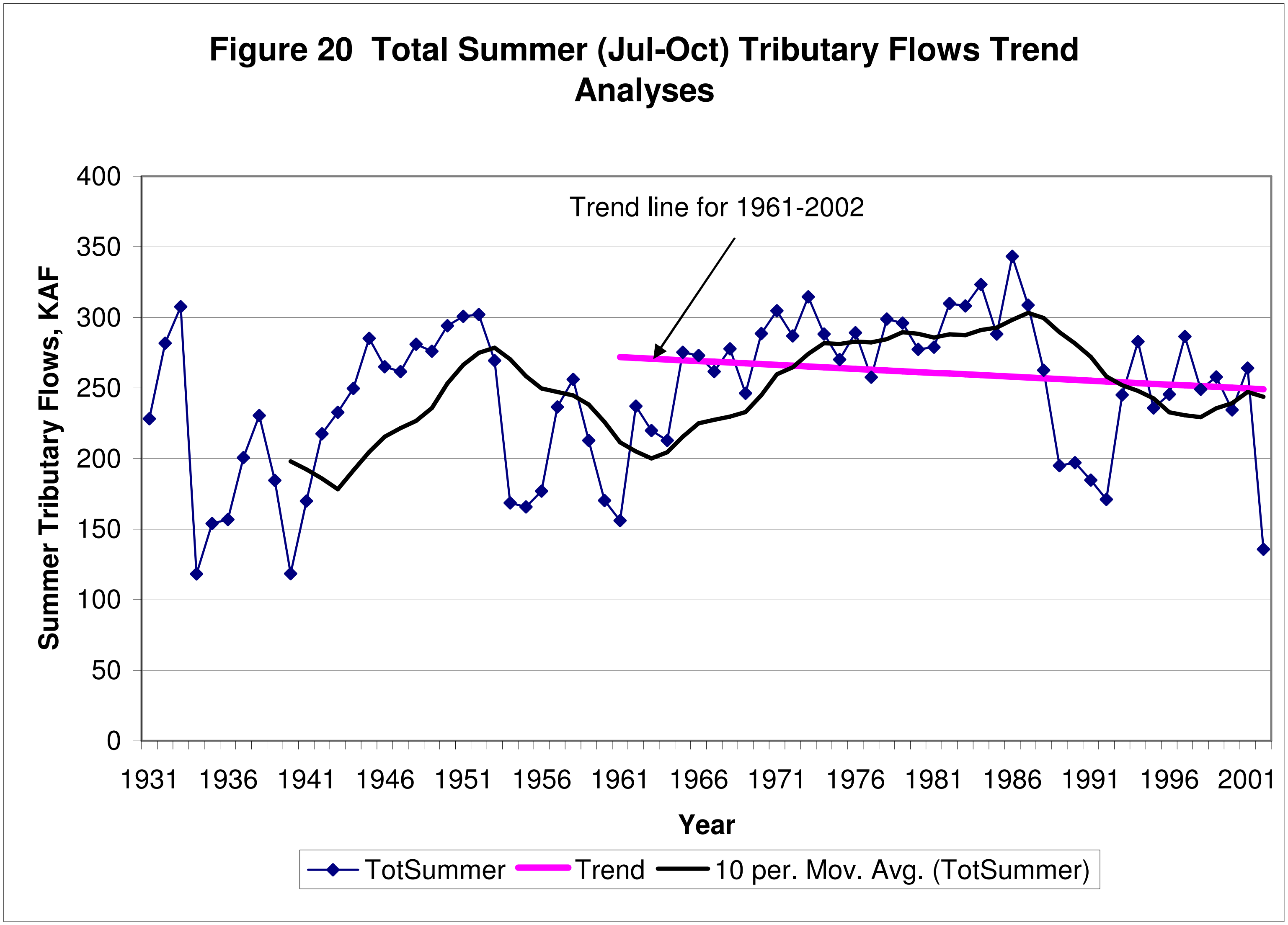


Figure 20 Total Summer (Jul-Oct) Tributary Flows Trend Analyses
Trend line for 1961-2002
Summer Tributary Flows, KAF
400
350
300
250
200
150
100
50
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
TotSummer
Trend
10 per. Mov. Avg. (TotSummer)

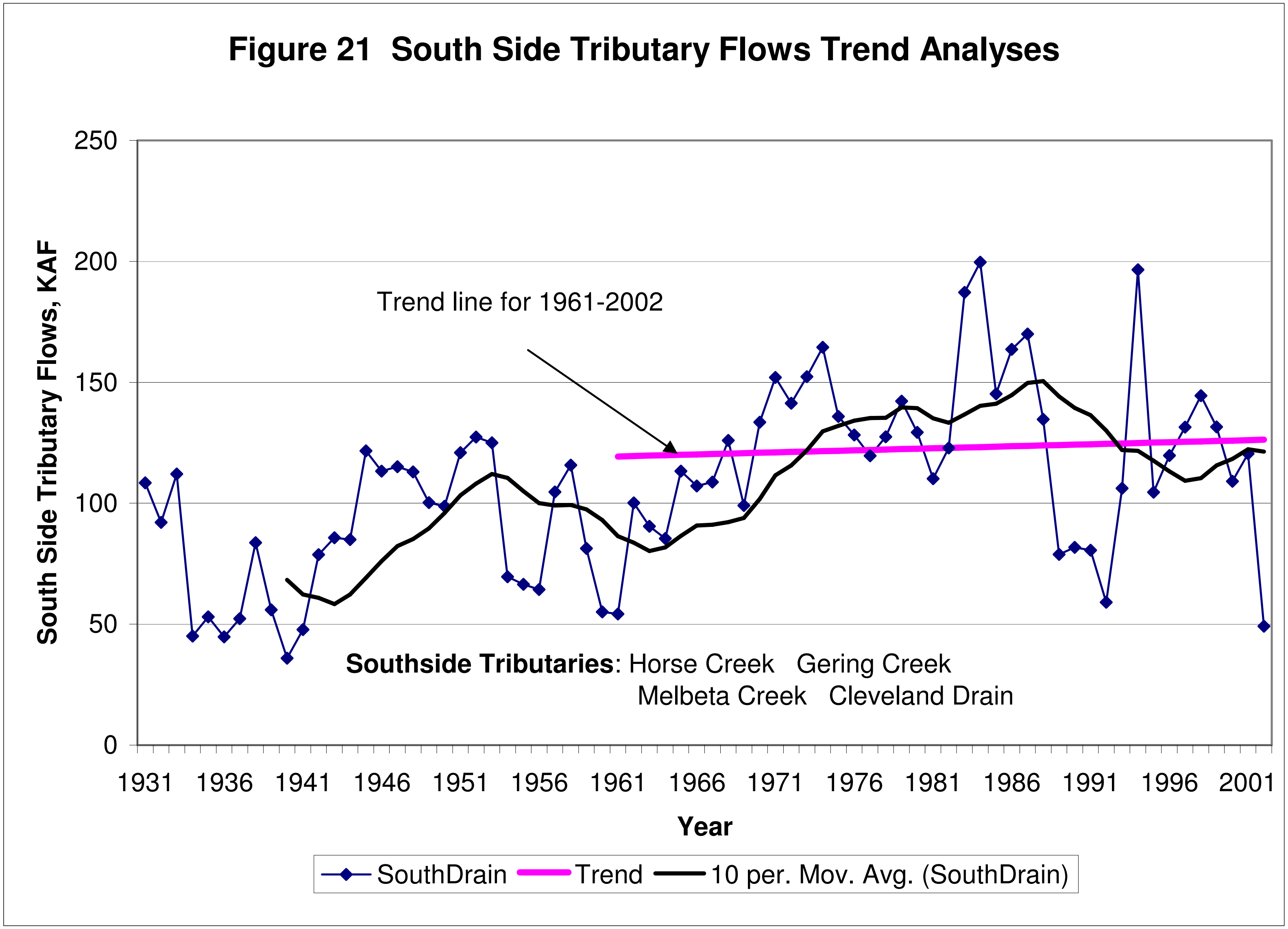


Figure 21 South Side Tributary Flows Trend Analyses
250
200
150
100
50
0
South Side Tributary Flows, KAF
Trend line for 1961-2002
Southside Tributaries: Horse Creek Gering Creek
Melbeta Creek Cleveland Drain
1931 1936 1941 1946 1951 1956 1961 1966 1971 1976 1981 1986 1991 1996 2001
Year
SouthDrain
Trend
10 per. Mov. Avg. (SouthDrain)

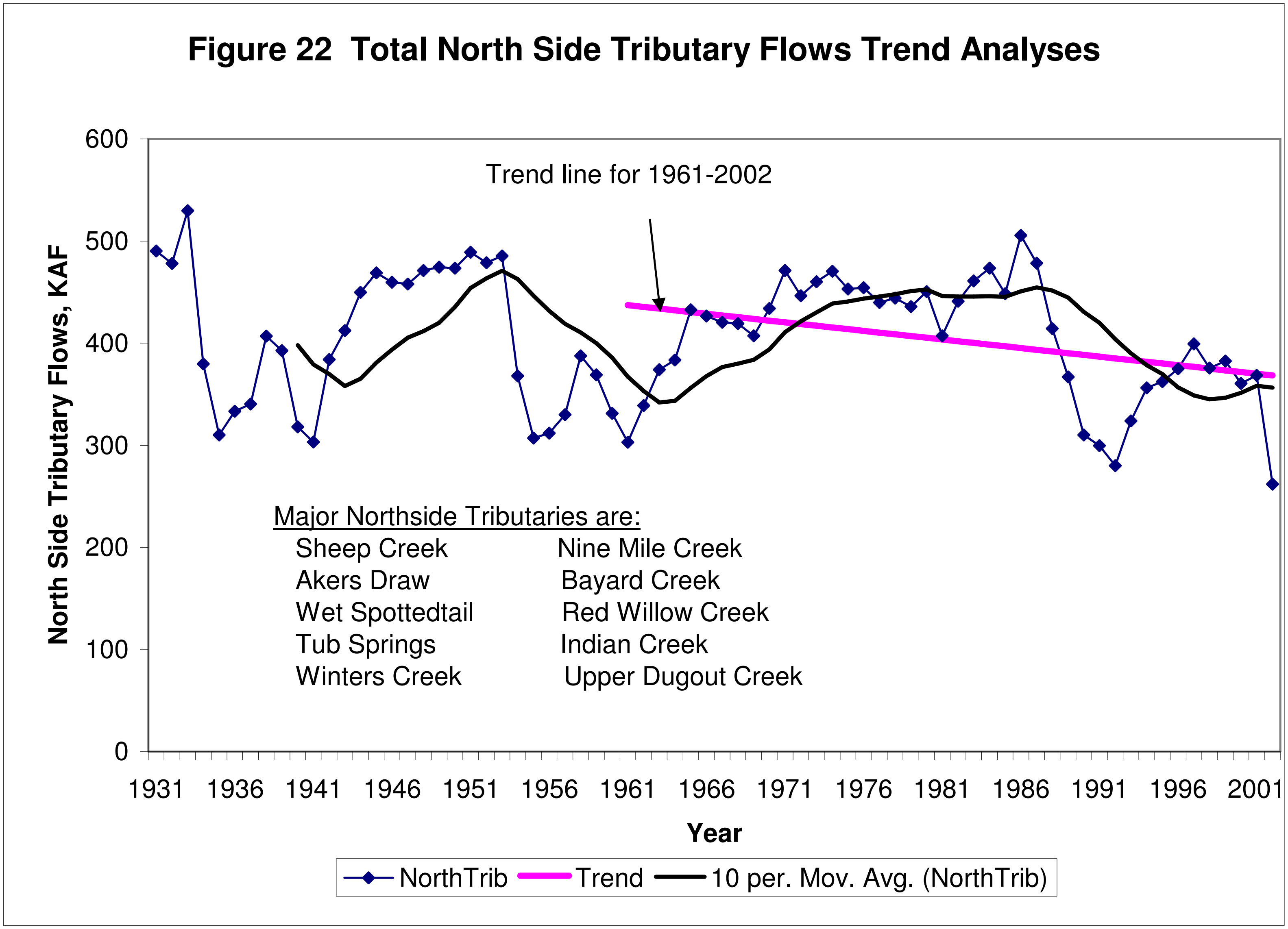


Figure 22 Total North Side Tributary Flows Trend Analyses
North Side Tributary Flows, KAF
600
500
400
300
200
100
0
Trend line for 1961-2002
Major Northside Tributaries are:
Sheep Creek
Akers Draw
Wet Spottedtail
Tub Springs
Winters Creek
Nine Mile Creek
Bayard Creek
Red Willow Creek
Indian Creek
Upper Dugout Creek
1931 1936 1941 1946 1951 1956 1961 1966 1971 1976 1981 1986 1991 1996 2001
Year
NorthTrib
Trend
10 per. Mov. Avg. (NorthTrib)

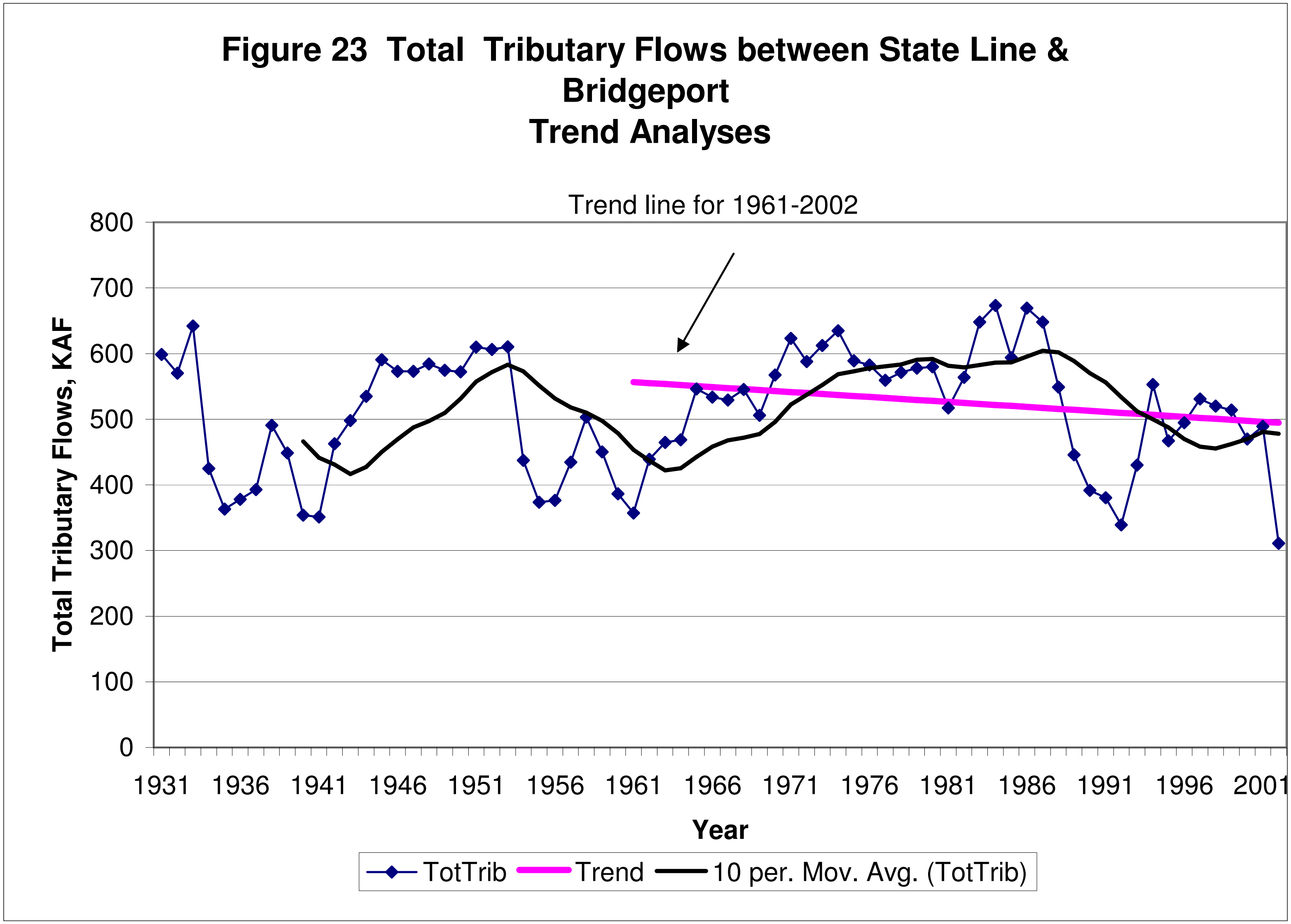


Figure 23 Total Tributary Flows between State Line & Bridgeport
Trend Analyses
Trend line for 1961-2002
800
700
600
500
400
300
200
100
0
Total Tributary Flows, KAF
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
TotTrib
Trend
10 per. Mov. Avg. (TotTrib)

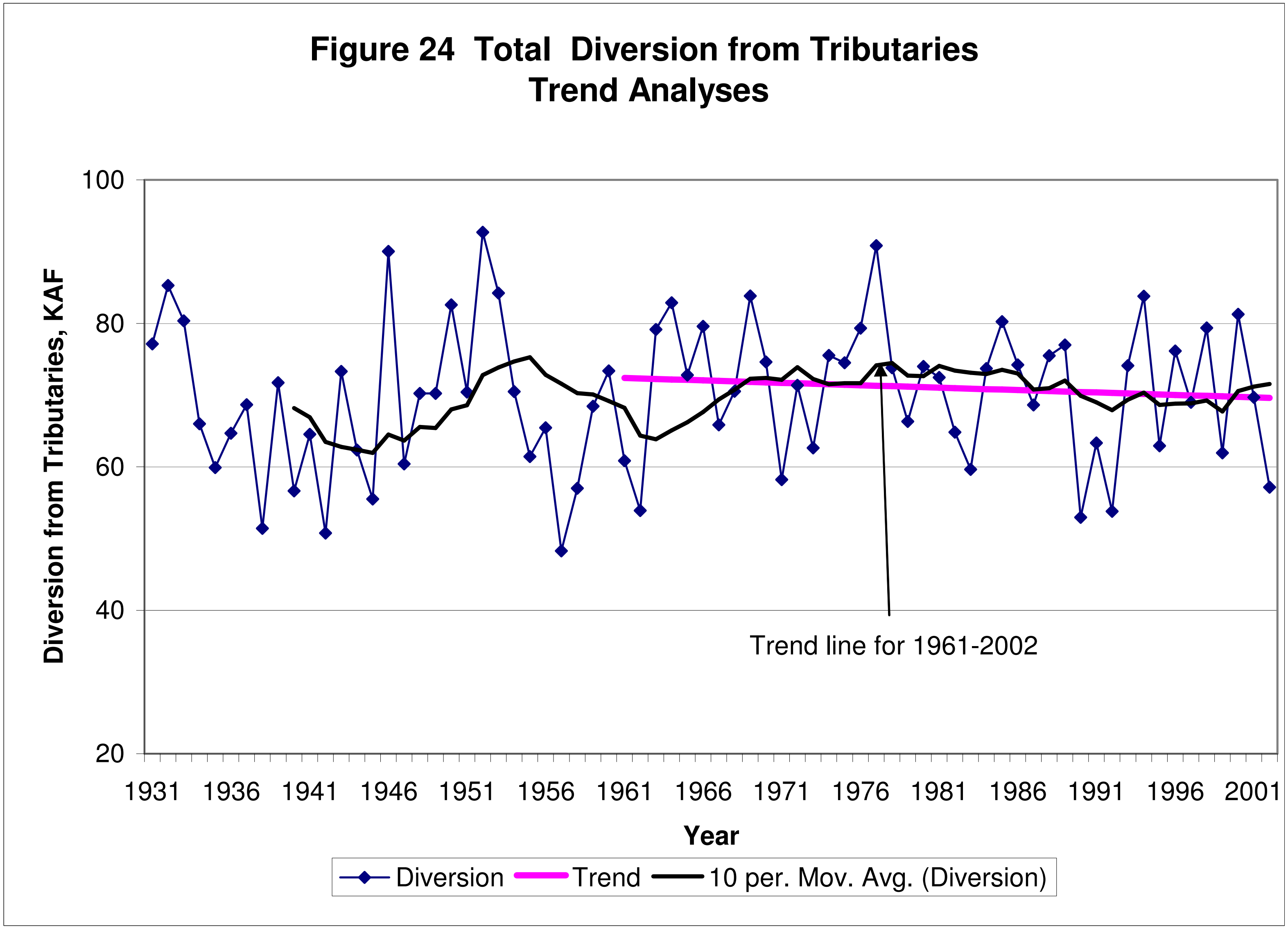


Figure 24 Total Diversion from Tributaries
Trend Analyses
Diversion from Tributaries, KAF
100
80
60
40
20
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Trend line for 1961-2002
Diversion
Trend
10 per. Mov. Avg. (Diversion)

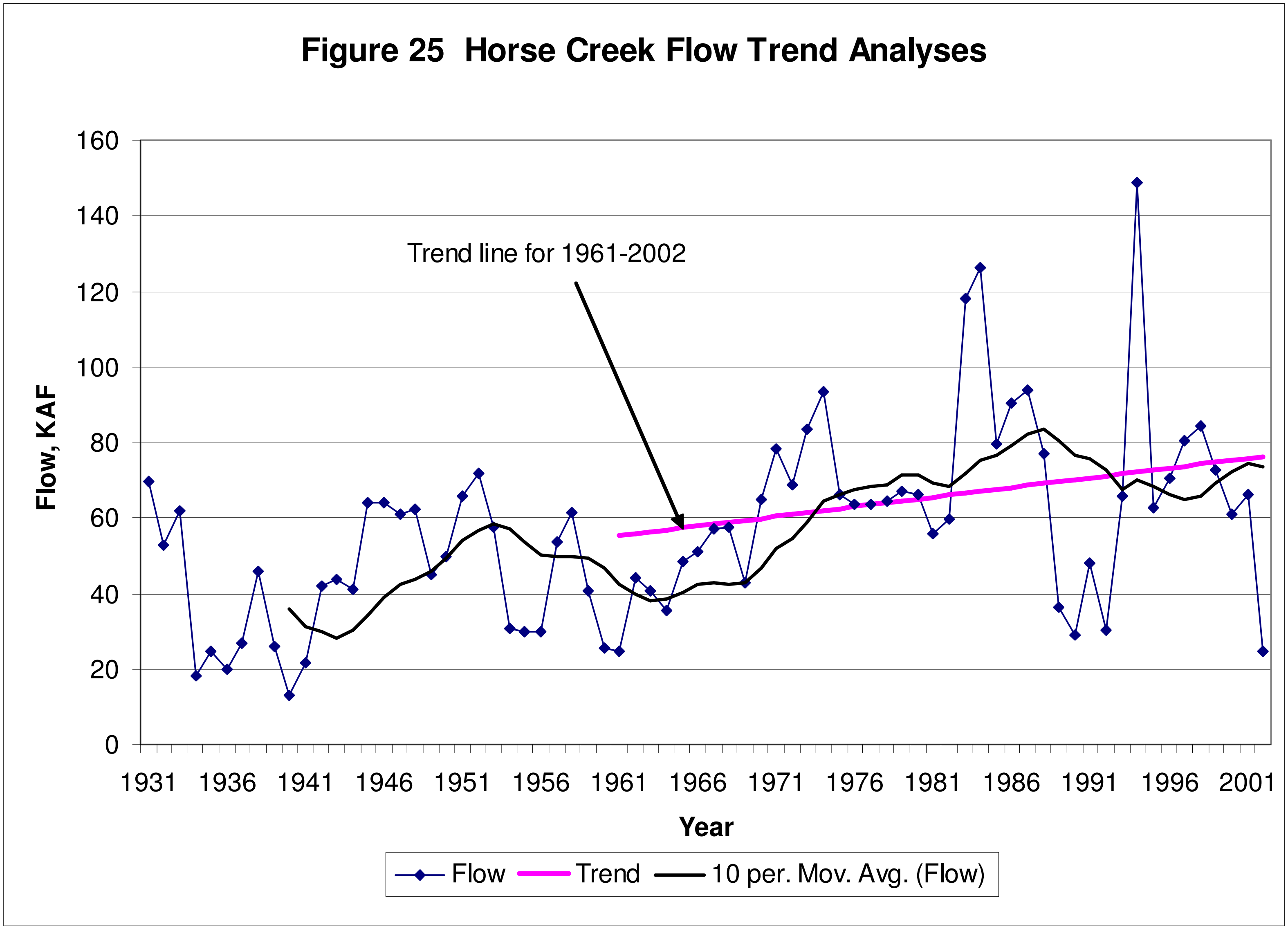


Figure 25 Horse Creek Flow Trend Analyses
Trend line for 1961-2002
Flow, KAF
160
140
120
100
80
60
40
20
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

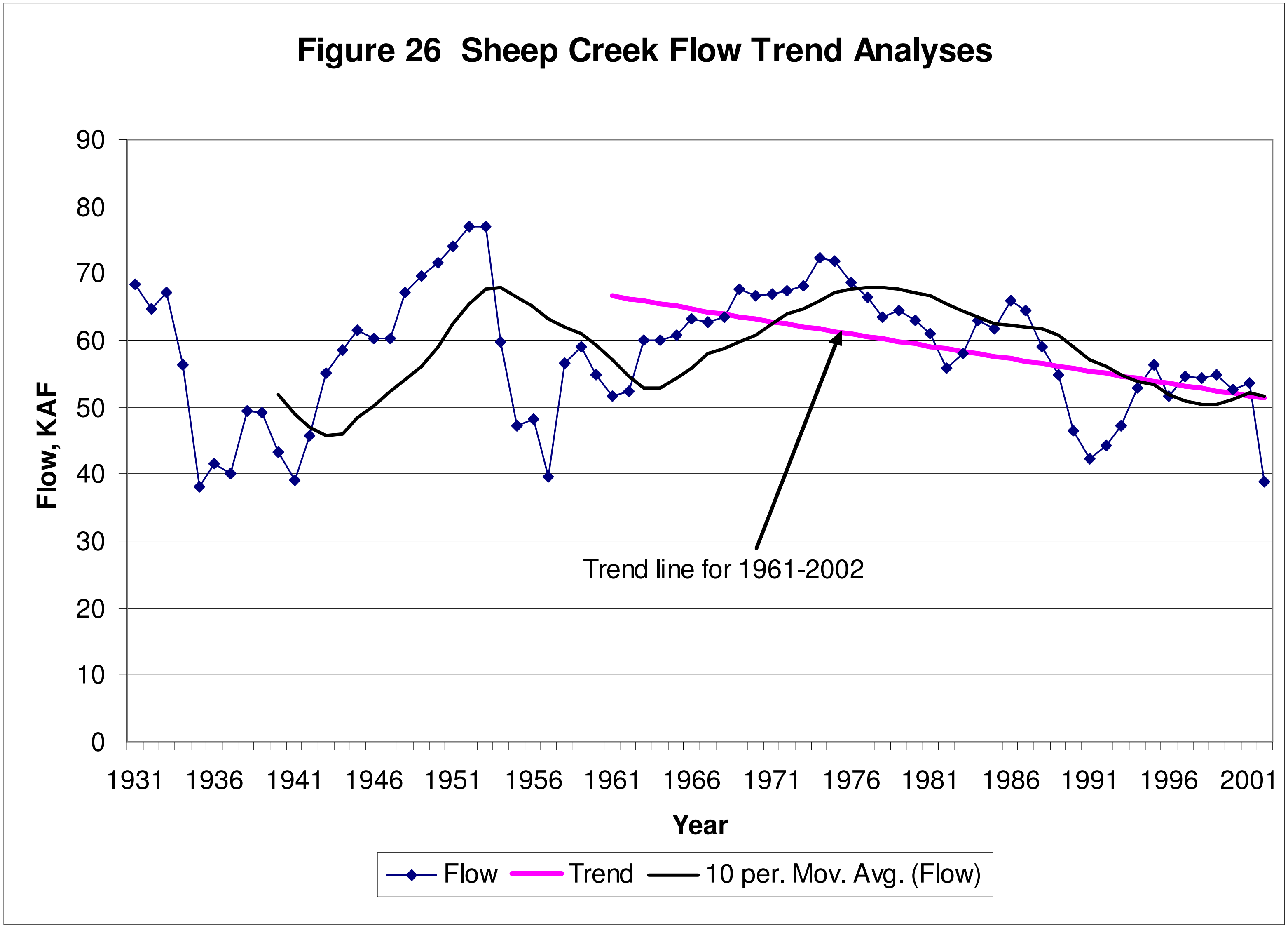


Figure 26 Sheep Creek Flow Trend Analyses
90
80
70
60
50
40
30
20
10
0
Flow, KAF
Trend line for 1961-2002
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

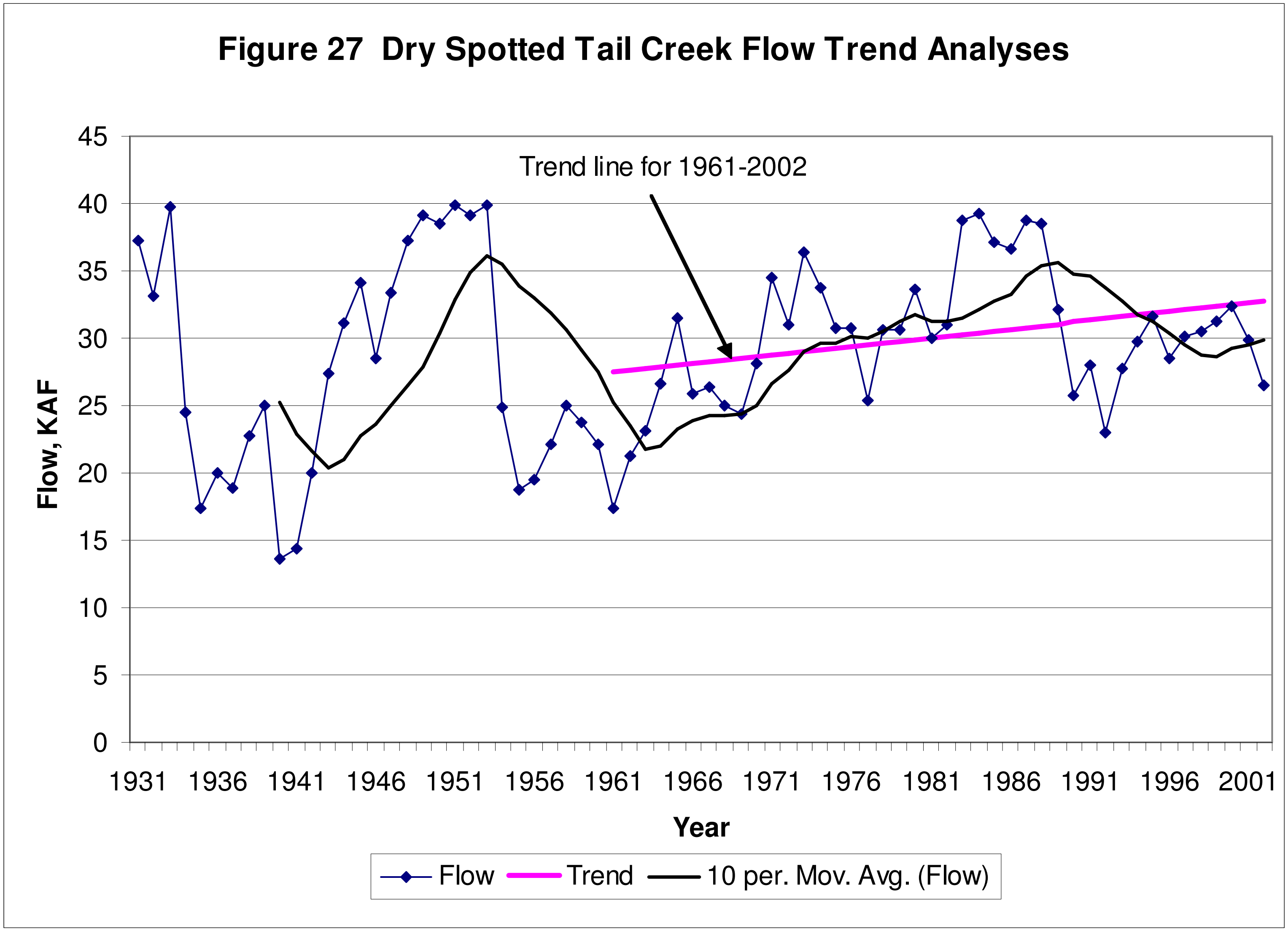


Figure 27 Dry Spotted Tail Creek Flow Trend Analyses
Trend line for 1961-2002
Flow, KAF
Year
45
40
35
30
25
20
15
10
5
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Flow
Trend
10 per. Mov. Avg. (Flow)

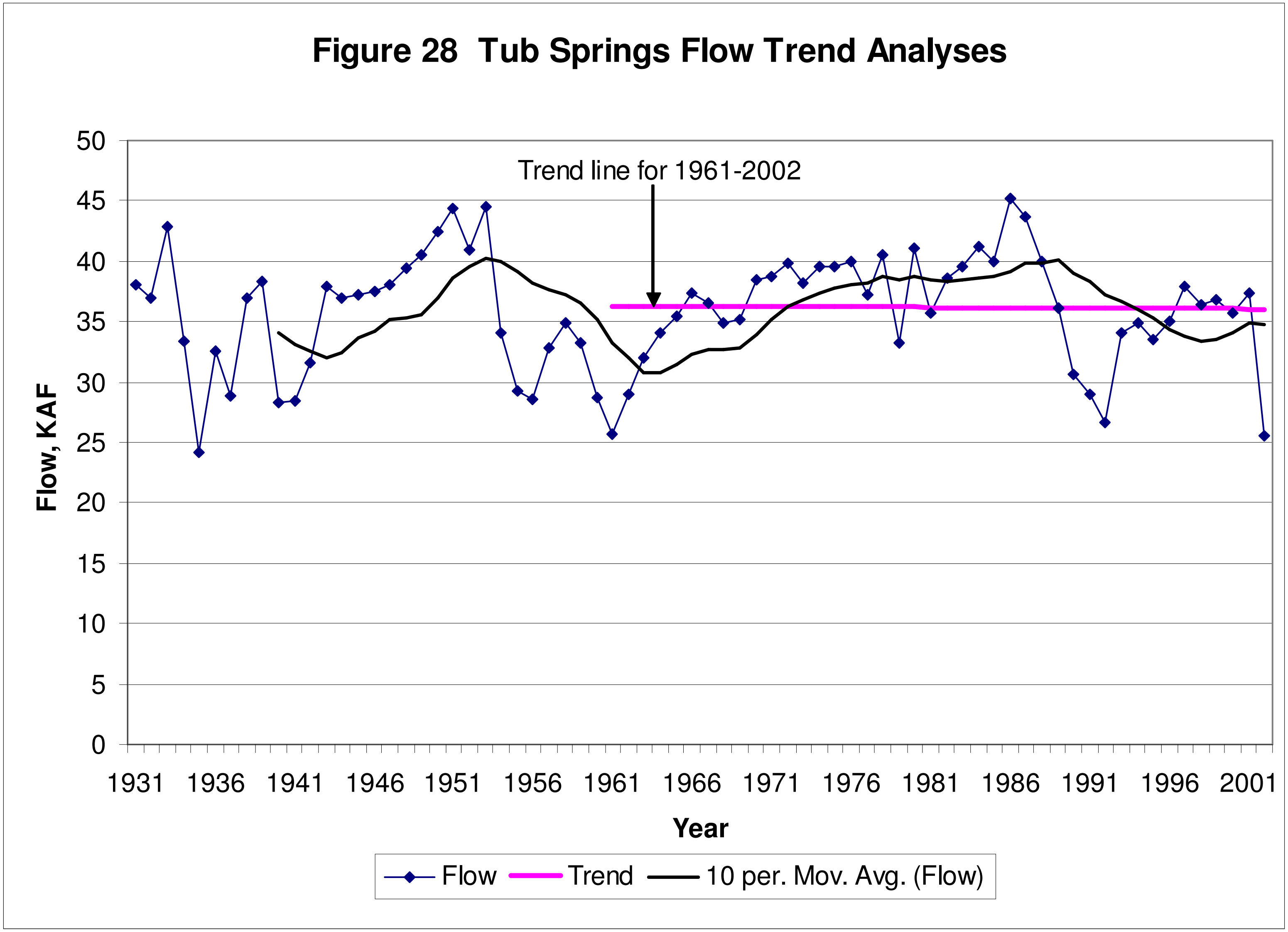


Figure 28 Tub Springs Flow Trend Analyses
Trend line for 1961-2002
50
45
40
35
30
25
20
15
10
5
0
Flow, KAF
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

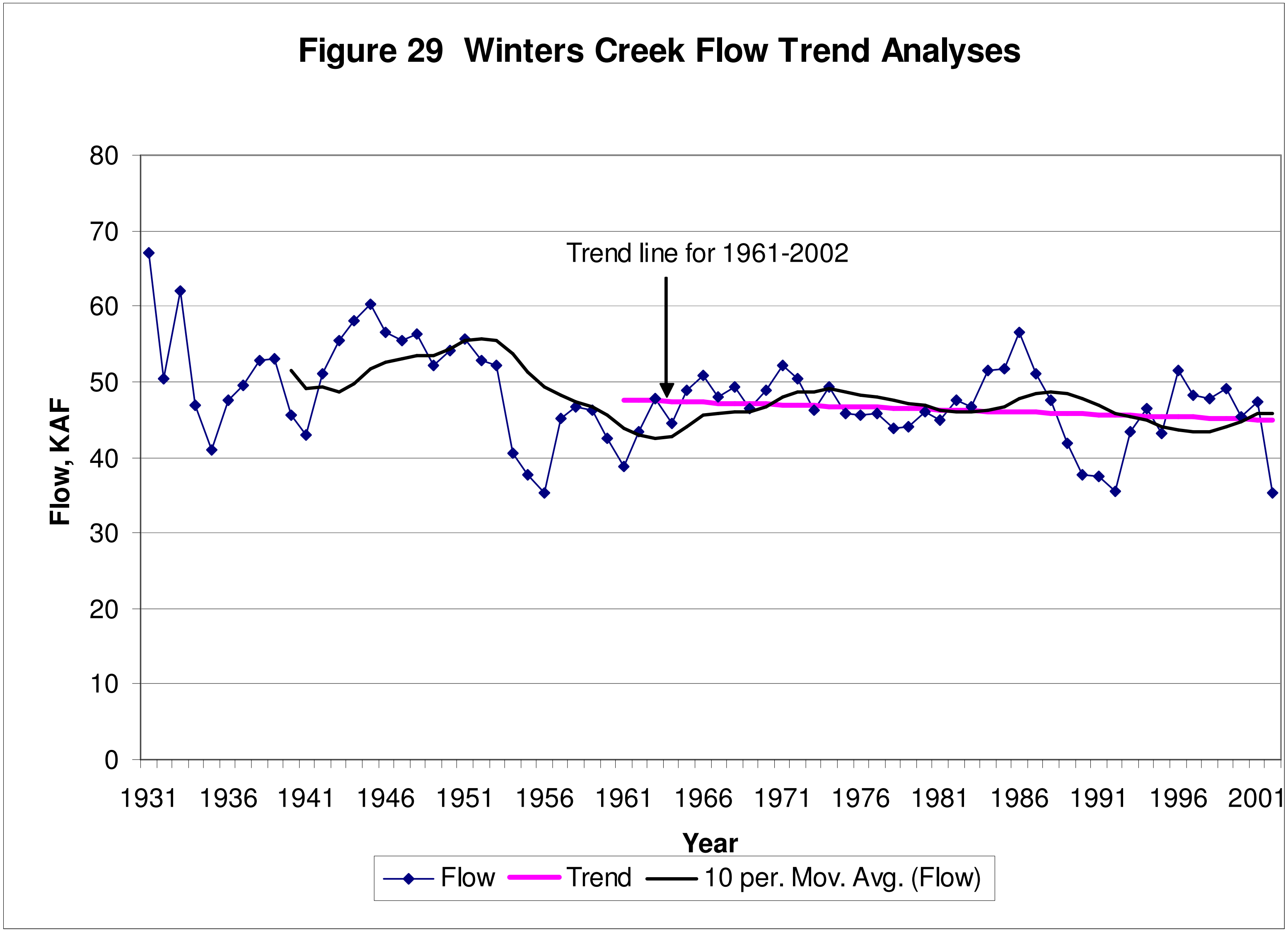


Figure 29 Winters Creek Flow Trend Analyses
Trend line for 1961-2002
Flow, KAF
80
70
60
50
40
30
20
10
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

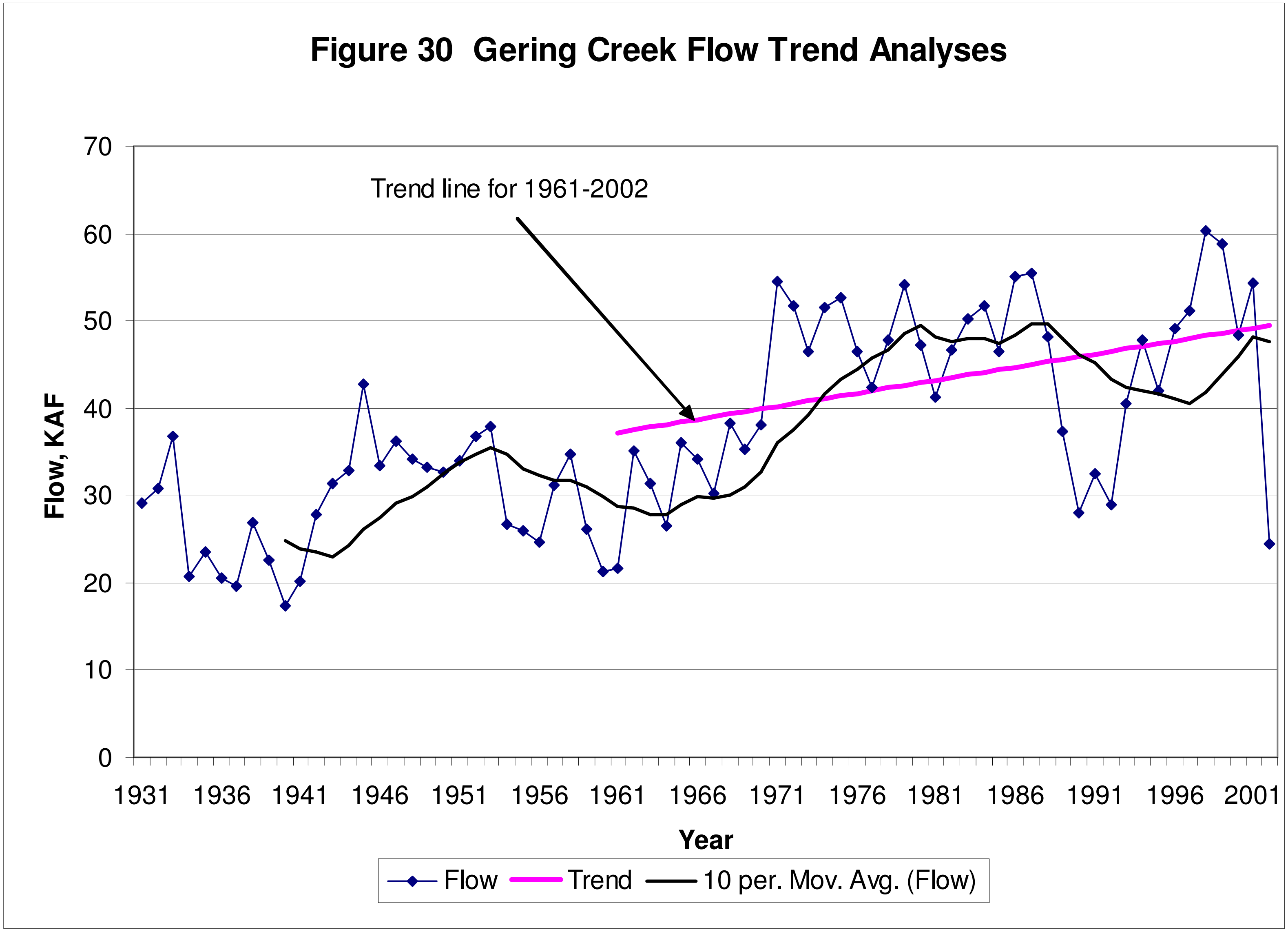


Figure 30 Gering Creek Flow Trend Analyses
Trend line for 1961-2002
70
60
50
40
30
20
10
0
Flow, KAF
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

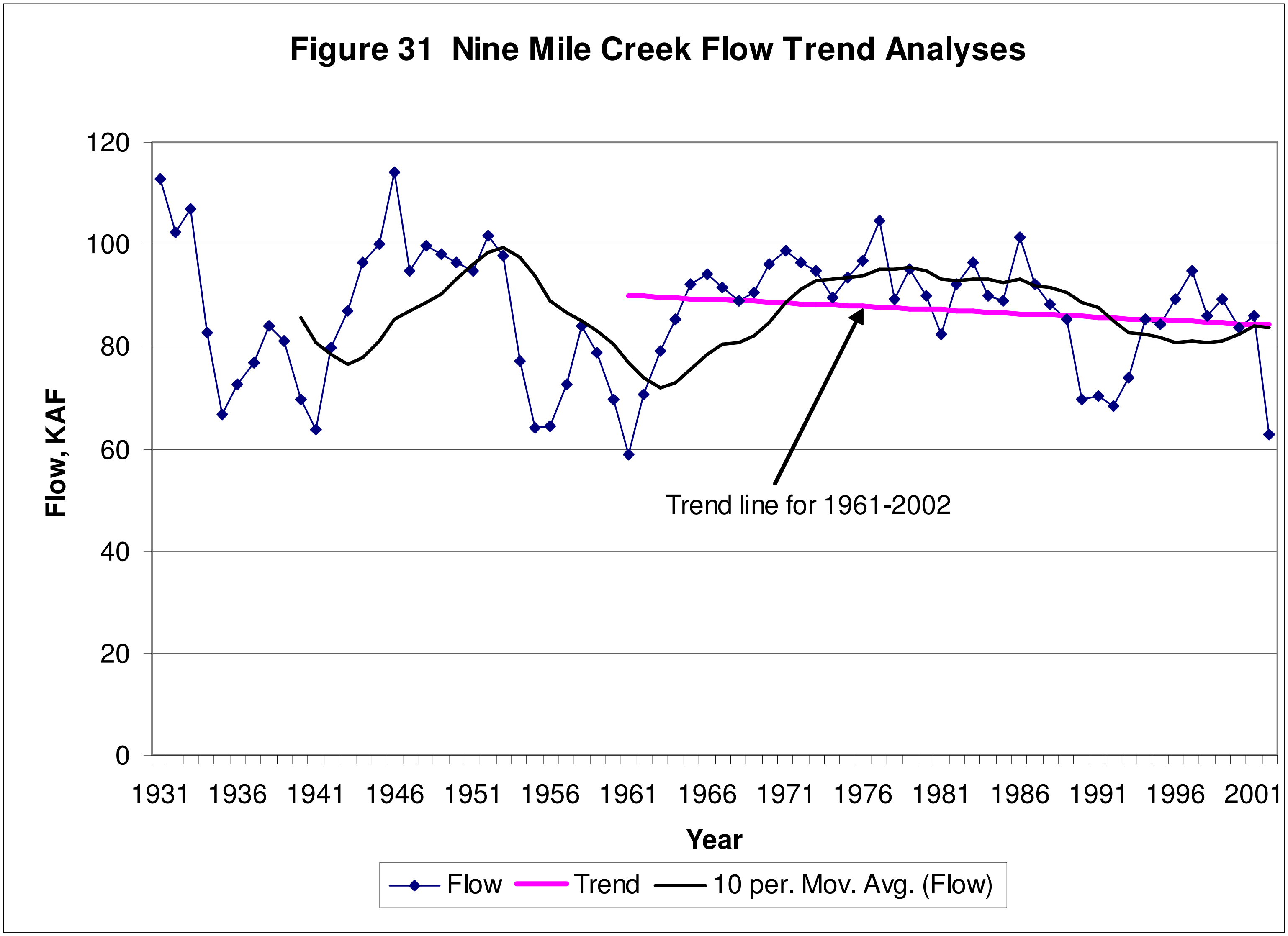


Figure 31 Nine Mile Creek Flow Trend Analyses
120
100
80
60
40
20
0
Flow, KAF
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Trend line for 1961-2002
Flow
Trend
10 per. Mov. Avg. (Flow)

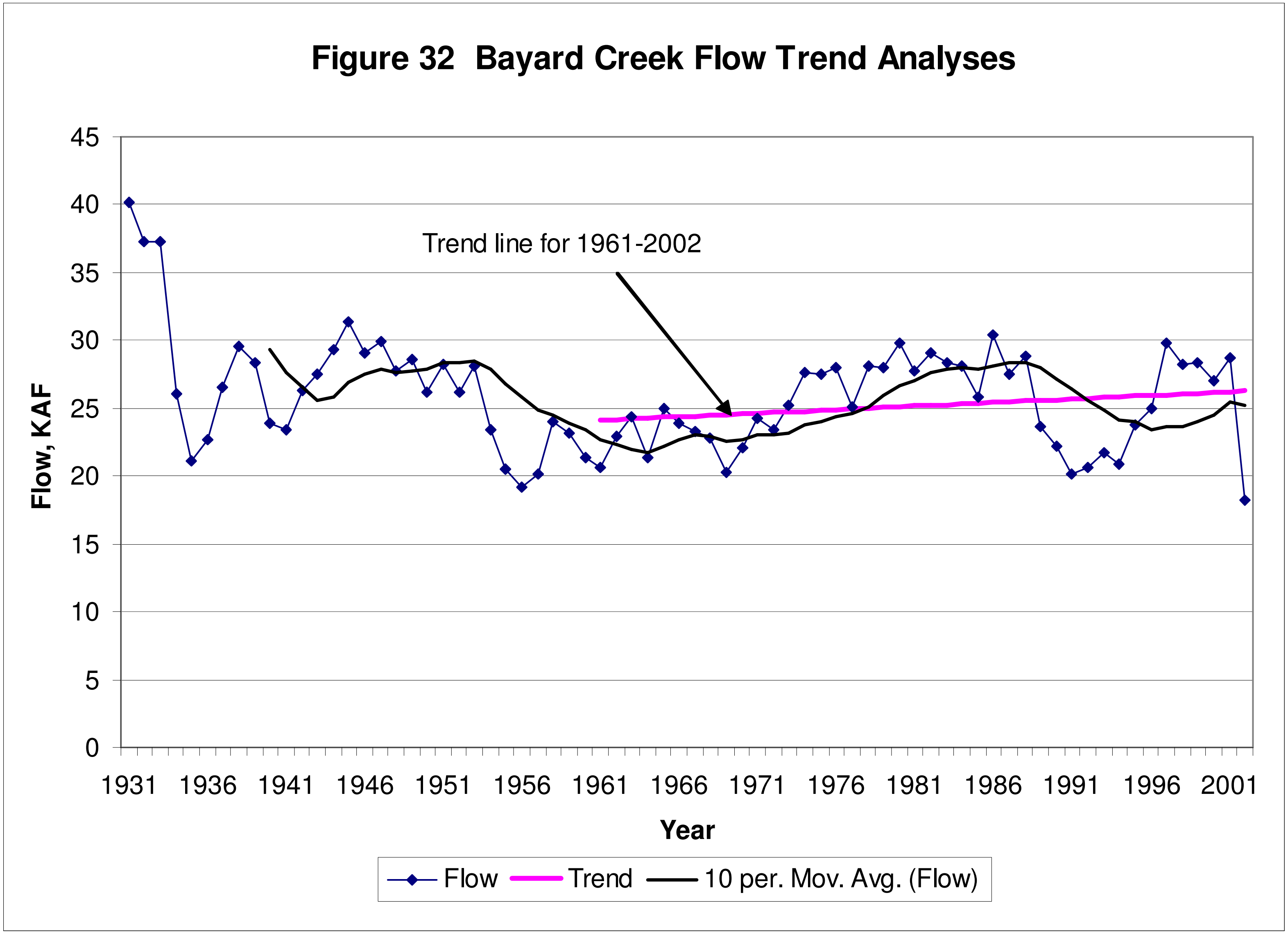


Figure 32 Bayard Creek Flow Trend Analyses
Trend line for 1961-2002
Flow, KAF
45
40
35
30
25
20
15
10
5
0
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

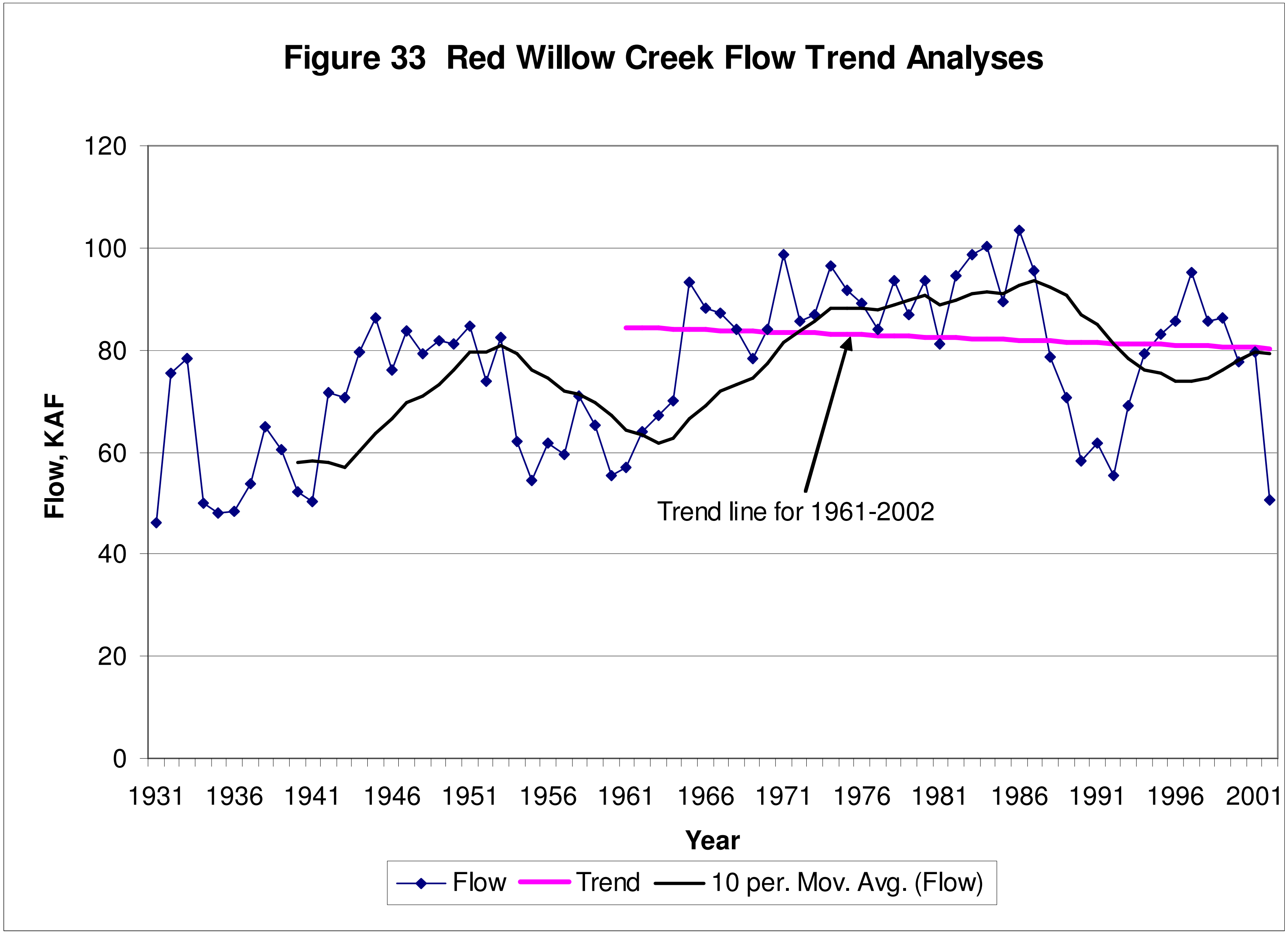


Figure 33 Red Willow Creek Flow Trend Analyses
120
100
80
60
40
20
0
Flow, KAF
1931
1936
1941
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
Trend line for 1961-2002
Flow
Trend
10 per. Mov. Avg. (Flow)

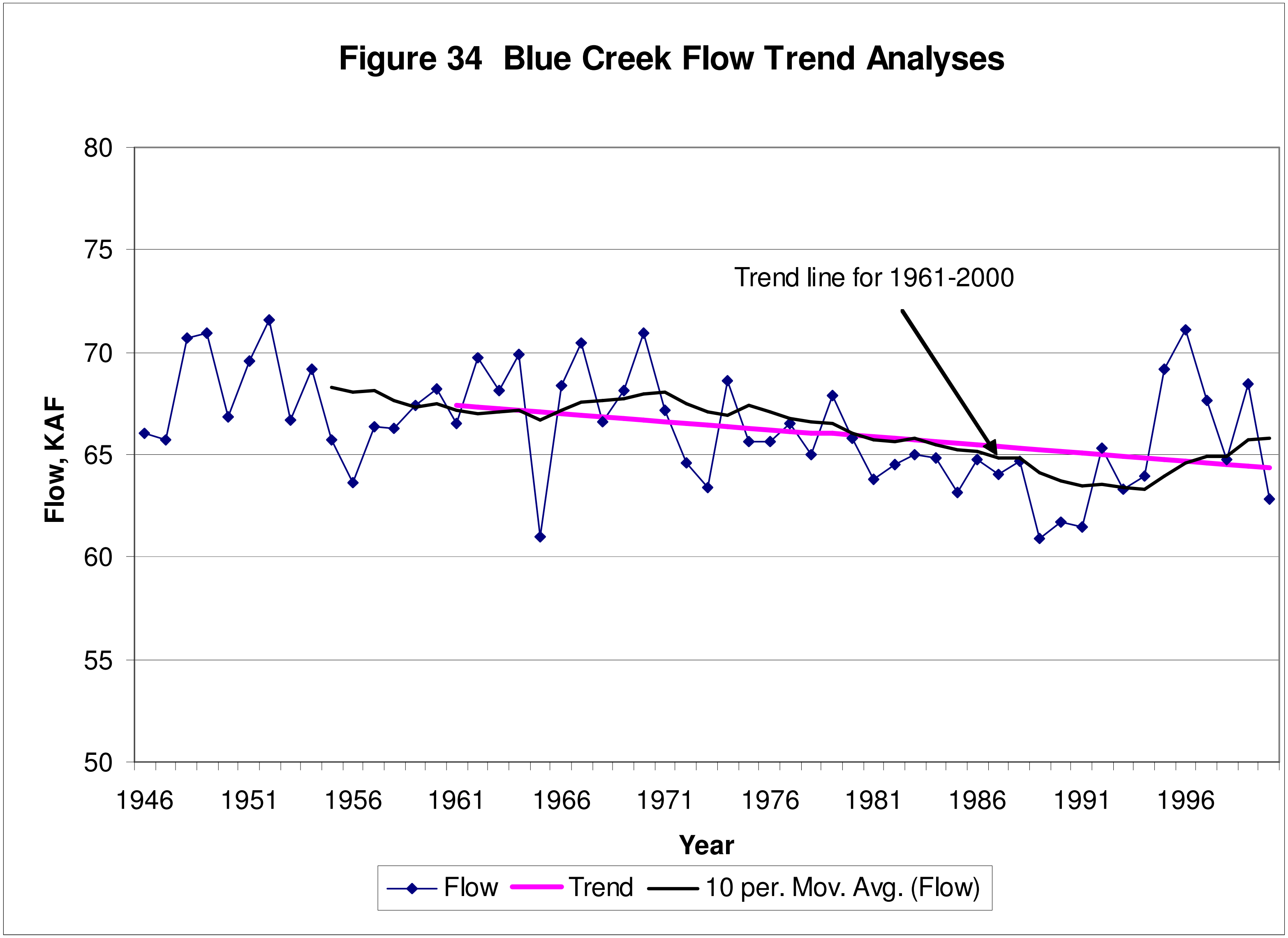


Figure 34 Blue Creek Flow Trend Analyses
80
75
70
65
60
55
50
Flow, KAF
Trend line for 1961-2000
1946
1951
1956
1961
1966
1971
1976
1981
1986
1991
1996
Year
Flow
Trend
10 per. Mov. Avg. (Flow)

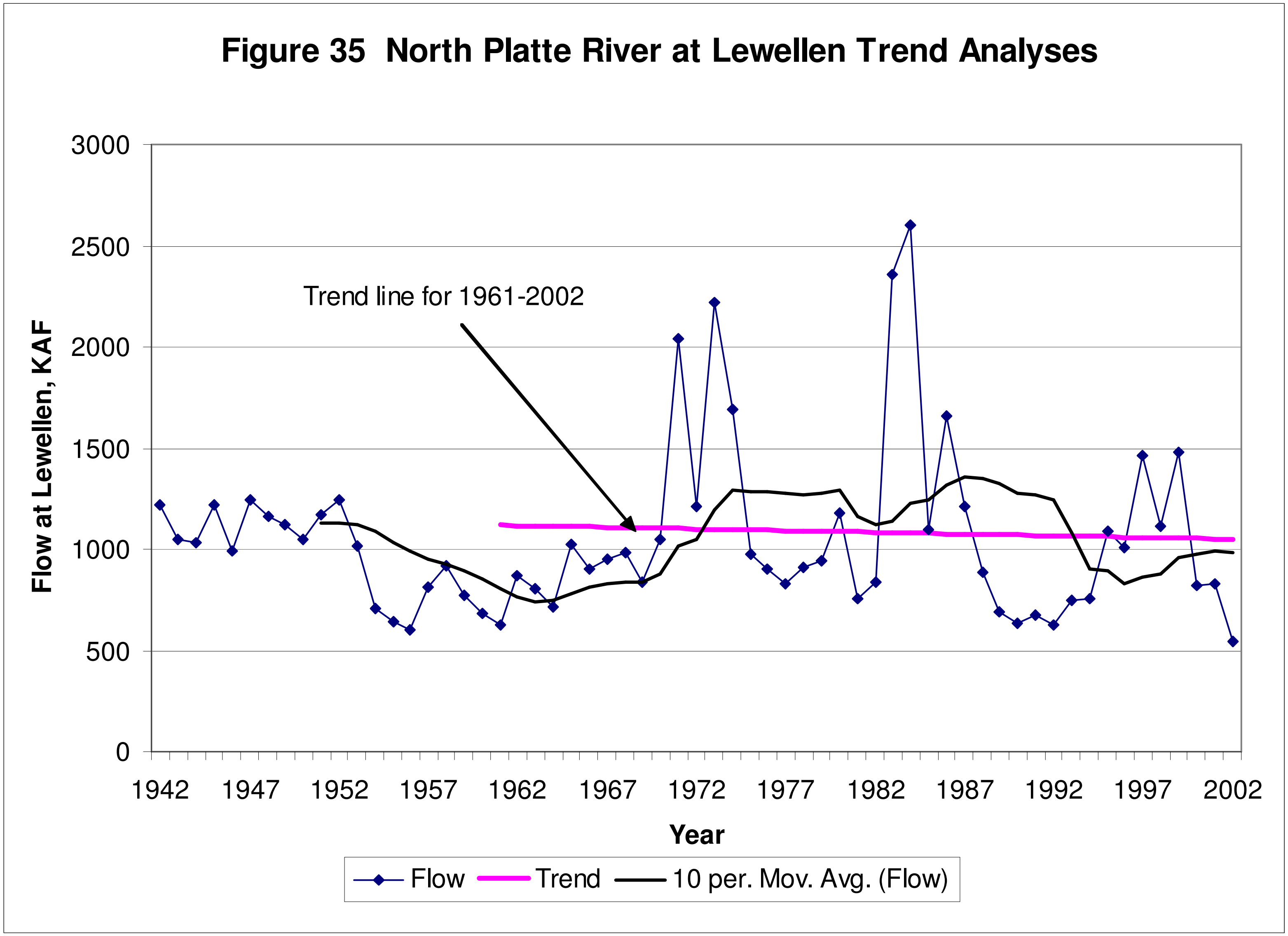


Figure 35 North Platte River at Lewellen Trend Analyses
Trend line for 1961-2002
Flow at Lewellen, KAF
Year
0
500
1000
1500
2000
2500
3000
1942
1947
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
Flow
Trend
10 per. Mov. Avg. (Flow)

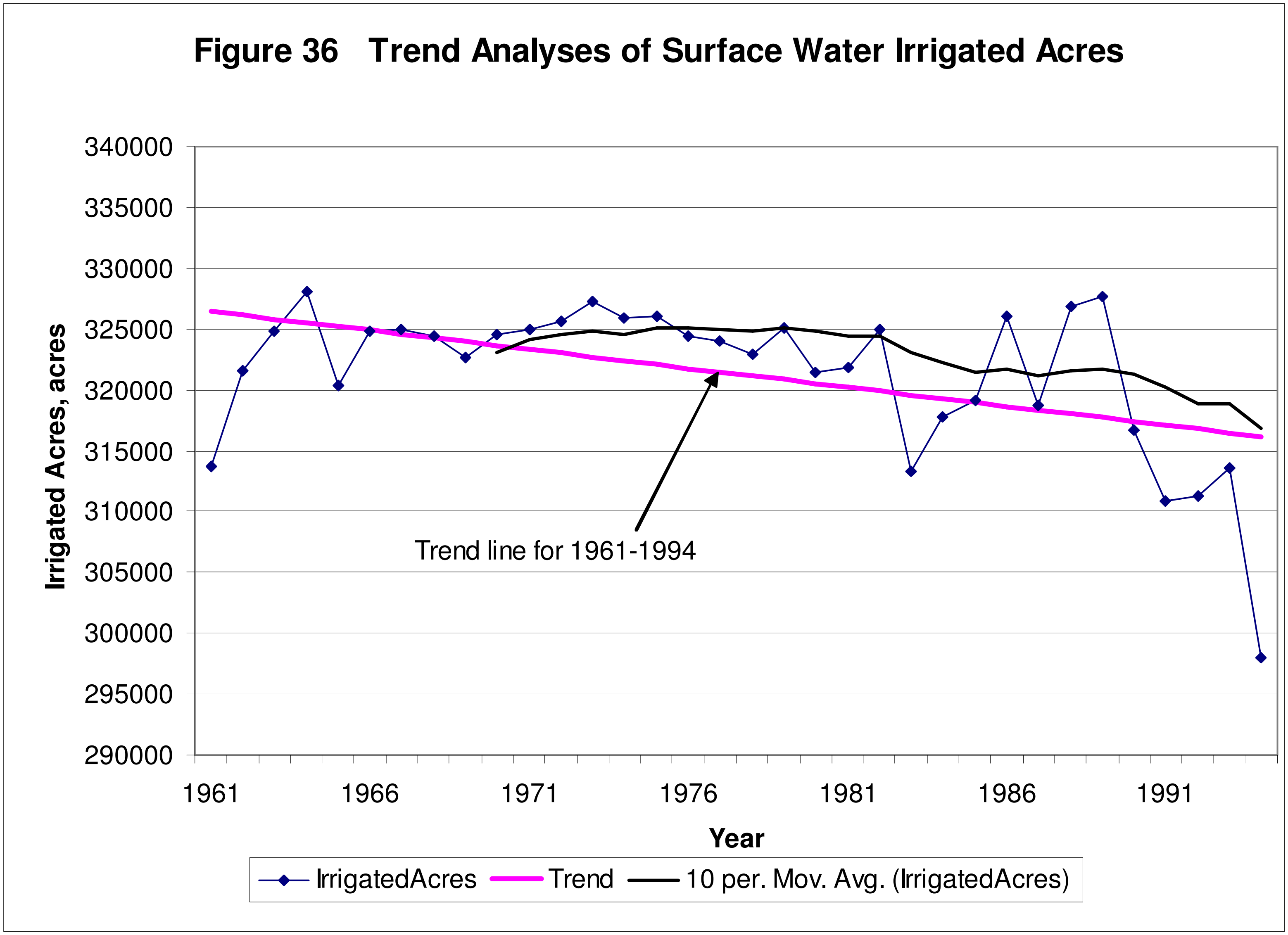


Figure 36 Trend Analyses of Surface Water Irrigated Acres
Irrigated Acres, acres
340000
335000
330000
325000
320000
315000
310000
305000
300000
295000
290000
1961
1966
1971
1976
1981
1986
1991
Year
Trend line for 1961-1994
IrrigatedAcres
Trend
10 per. Mov. Avg. (IrrigatedAcres)

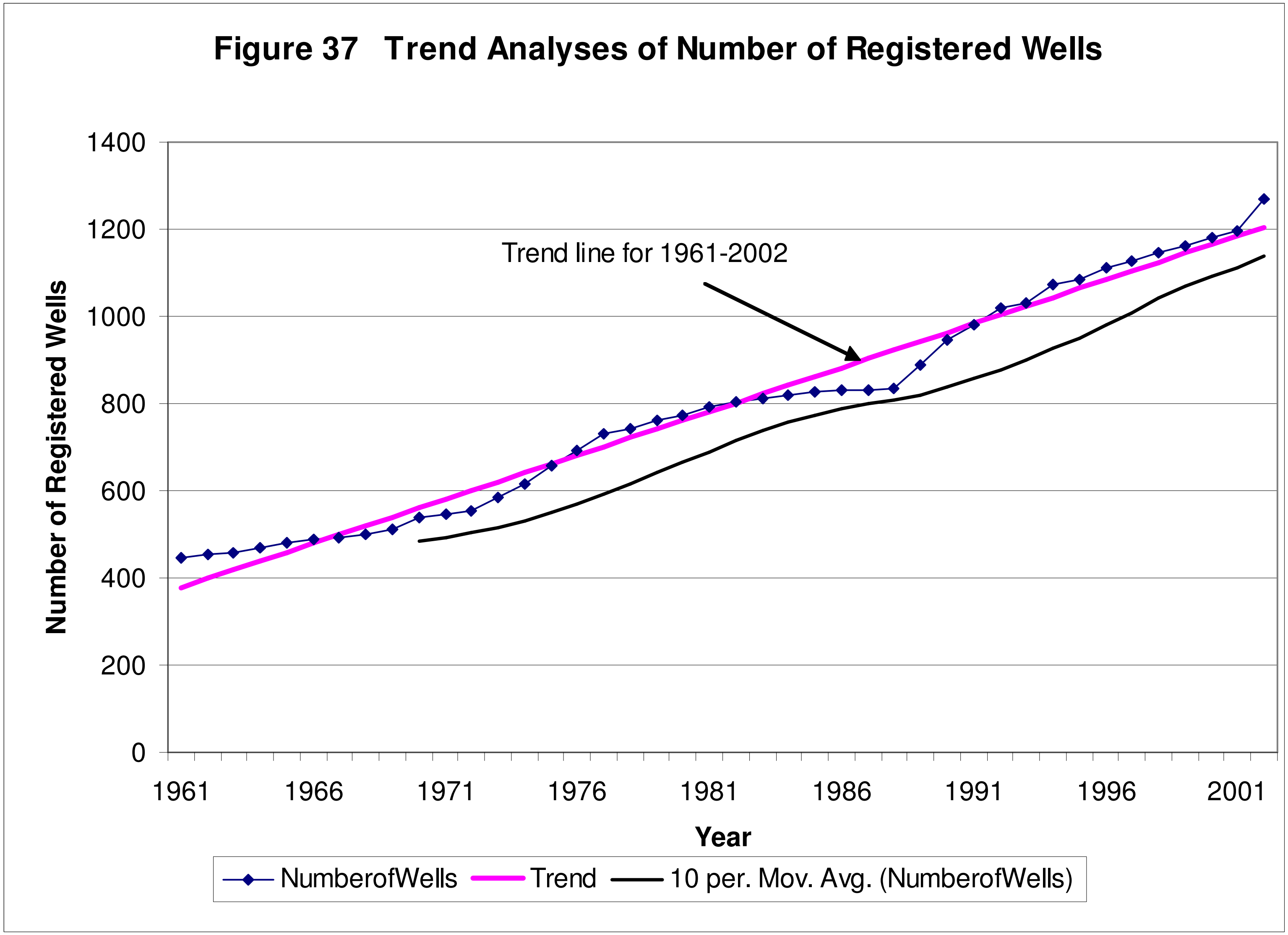
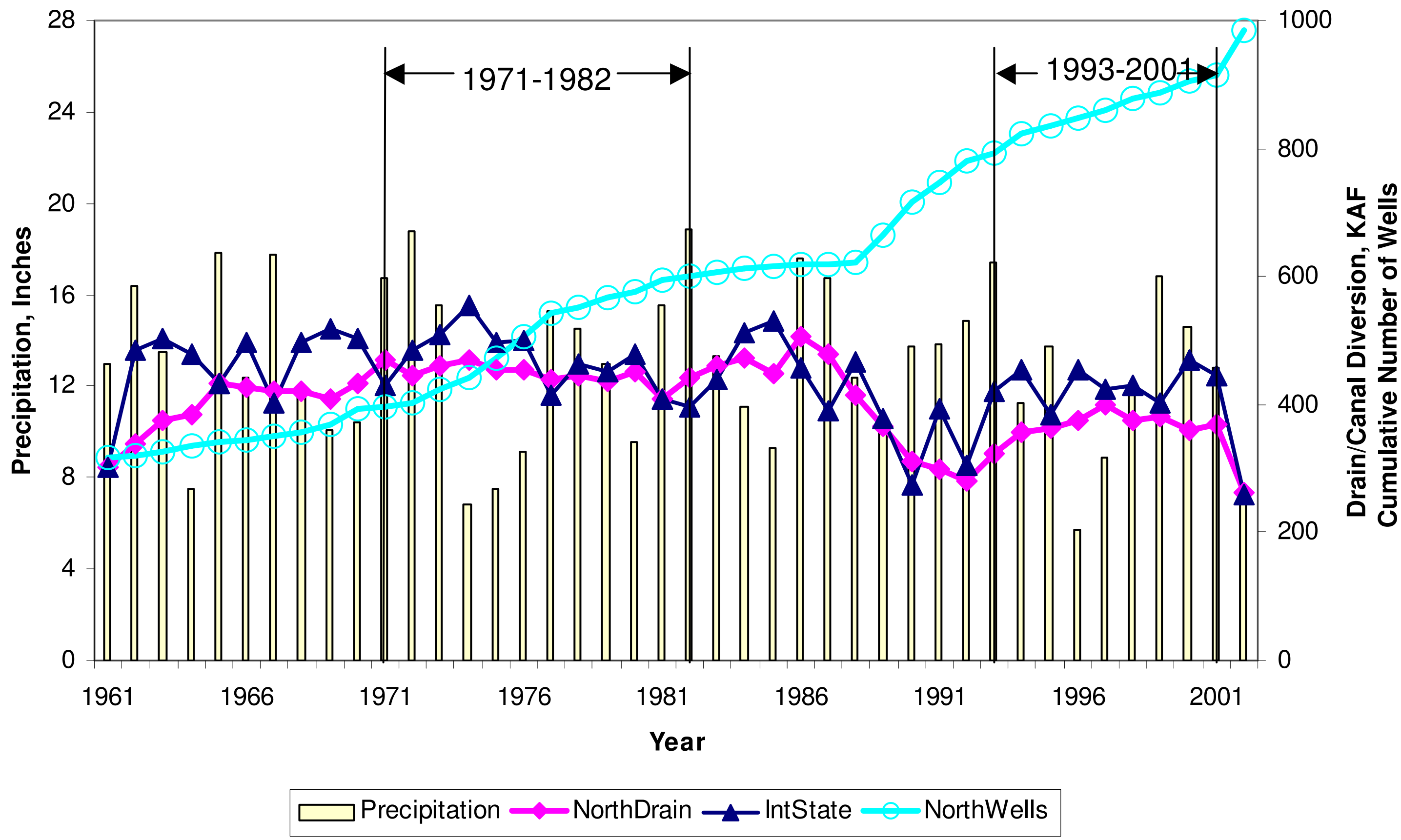
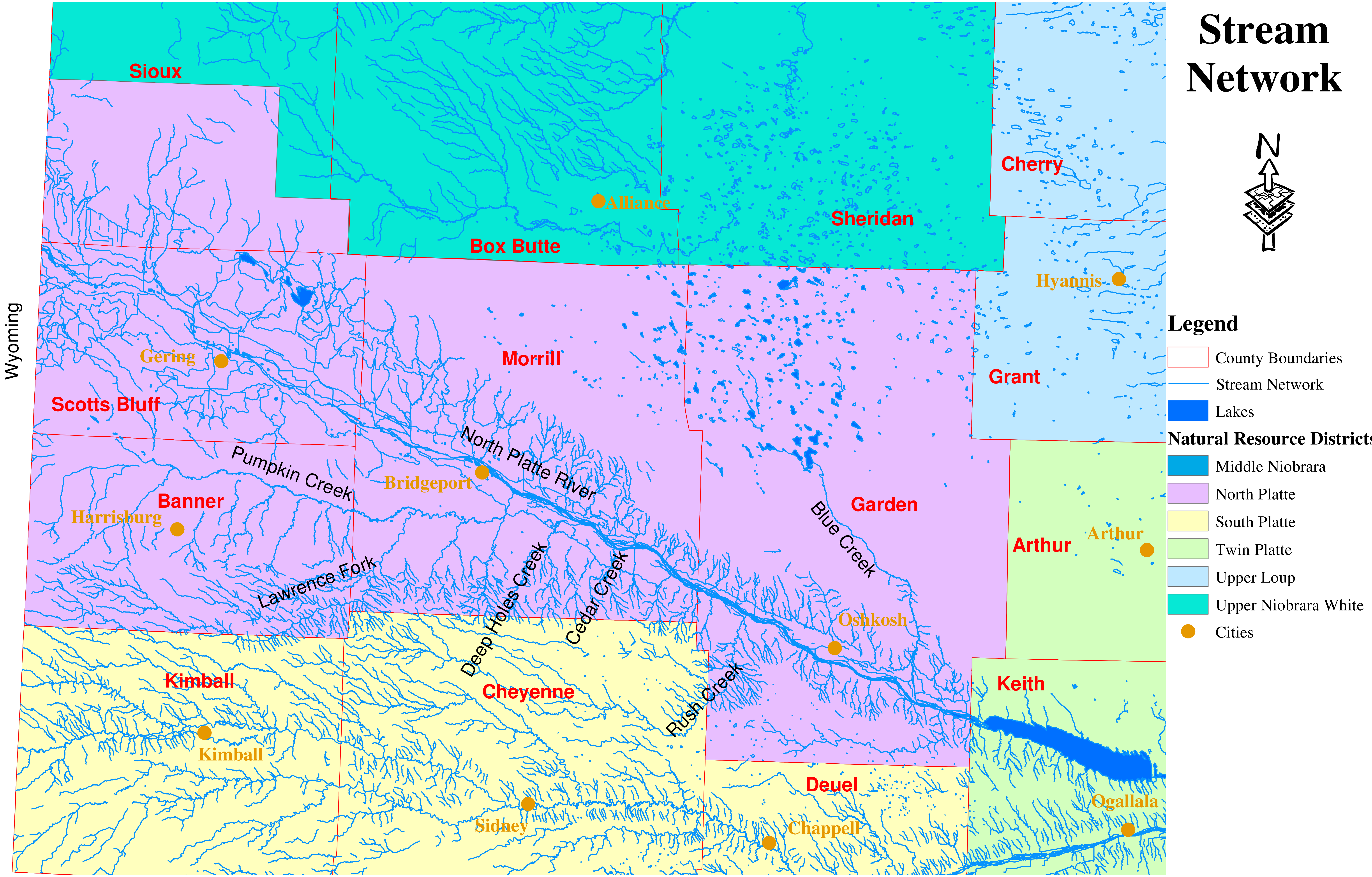


Figure 37 Trend Analyses of Number of Registered Wells
Number of Registered Wells
0
200
400
600
800
1000
1200
1400
Trend line for 1961-2002
1961
1966
1971
1976
1981
1986
1991
1996
2001
Year
NumberofWells
Trend
10 per. Mov. Avg. (NumberofWells)

Figure 38 North Side Drain vs. Precipitation, Interstate Canal Diversion, and Cumulative Number of Wells on the North Side



Appendix III


Stream Network
N
Wyoming
Sioux
Box Butte
Sheridan
Cherry
Alliance
Hyannis
Grant
Morrill
Gering
Scotts Bluff
Banner
Harrisburg
Bridgeport
Pumpkin Creek
North Platte River
Garden
Blue Creek
Arthur
Arthur
Lawrence Fork
Deep Holes Creek
Cedar Creek
Oshkosh
Kimball
Kimball
Cheyenne
Rush Creek
Keith
Deuel
Ogallala
Sidney
Chappell
Legend
County Boundaries
Stream Network
Lakes
Natural Resource Districts
Middle Niobrara
North Platte
South Platte
Twin Platte
Upper Loup
Upper Niobrara White
Cities
Figure 1

Topographic Regions

A digitized version of the 1:1,000,000 map of topographic regions of Nebraska.
The map was published in 1951. Digitized from 1:1,000,000 mylar source.
Conservation and Survey Division, University of Nebraska - Lincoln , 1997.
http://csd.unl.edu/csd/specials/gisdata.html

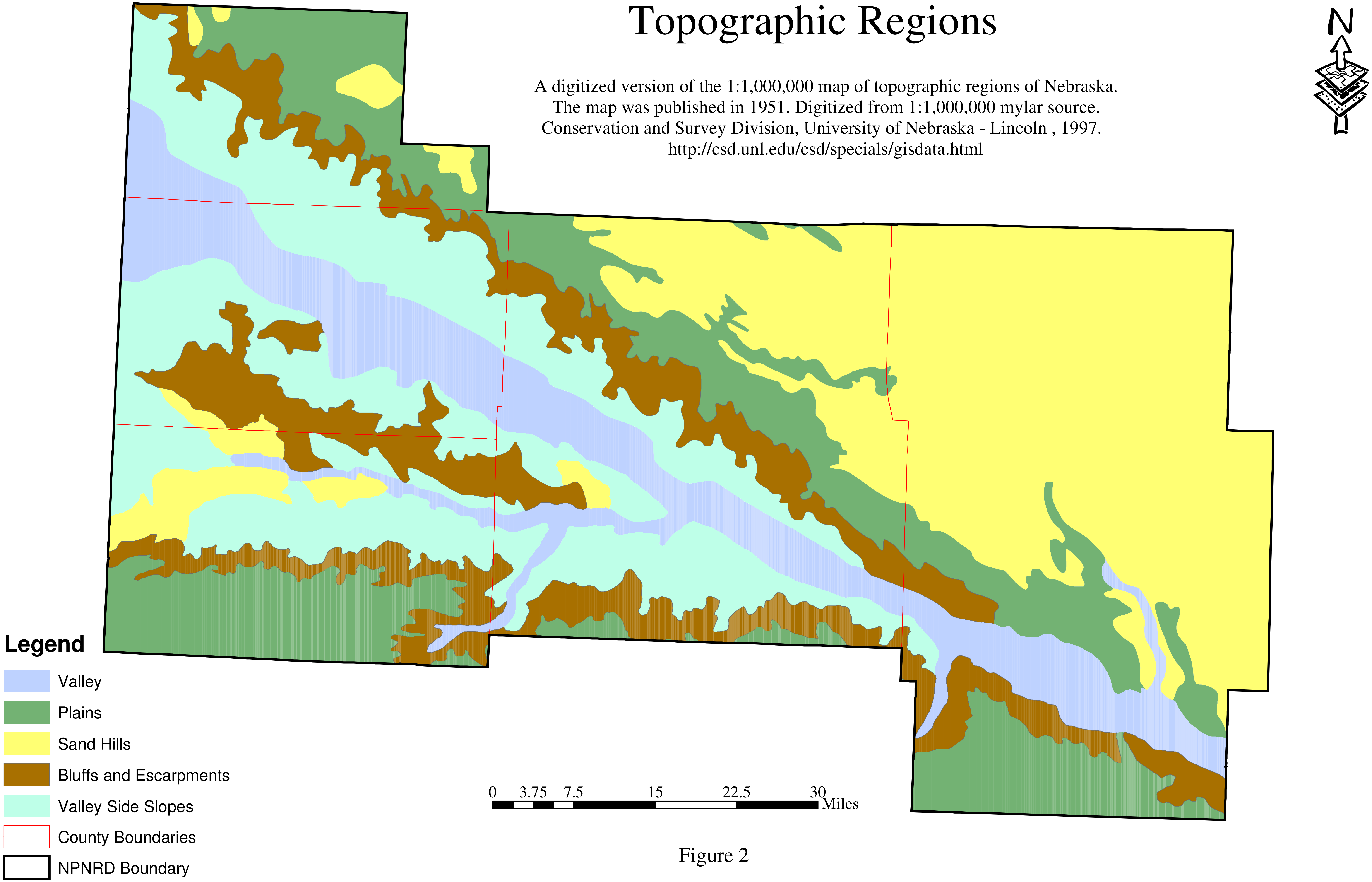


Figure 2

Digital Elevation Model and Canal Network in the NPNRD

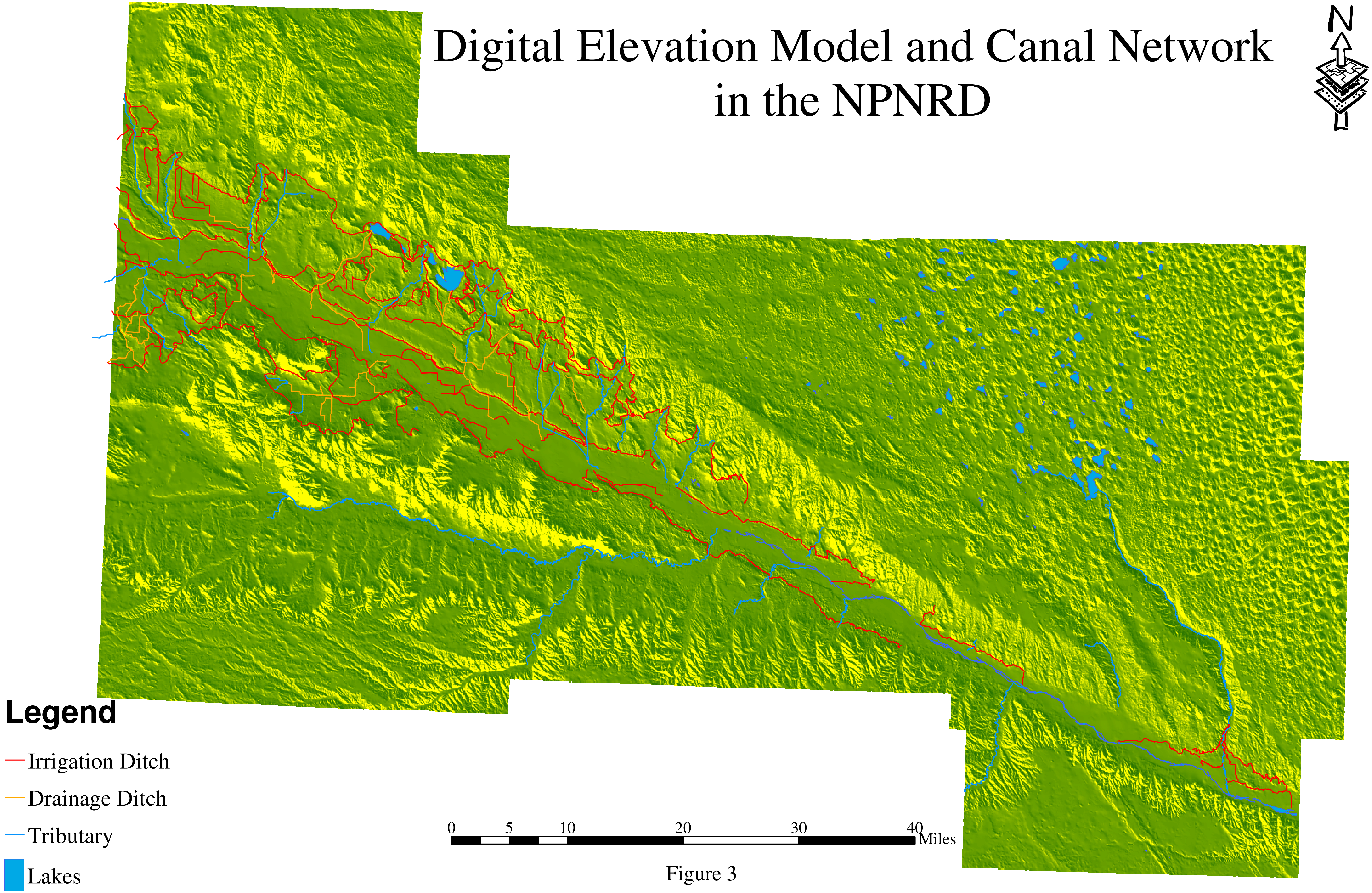


Figure 3

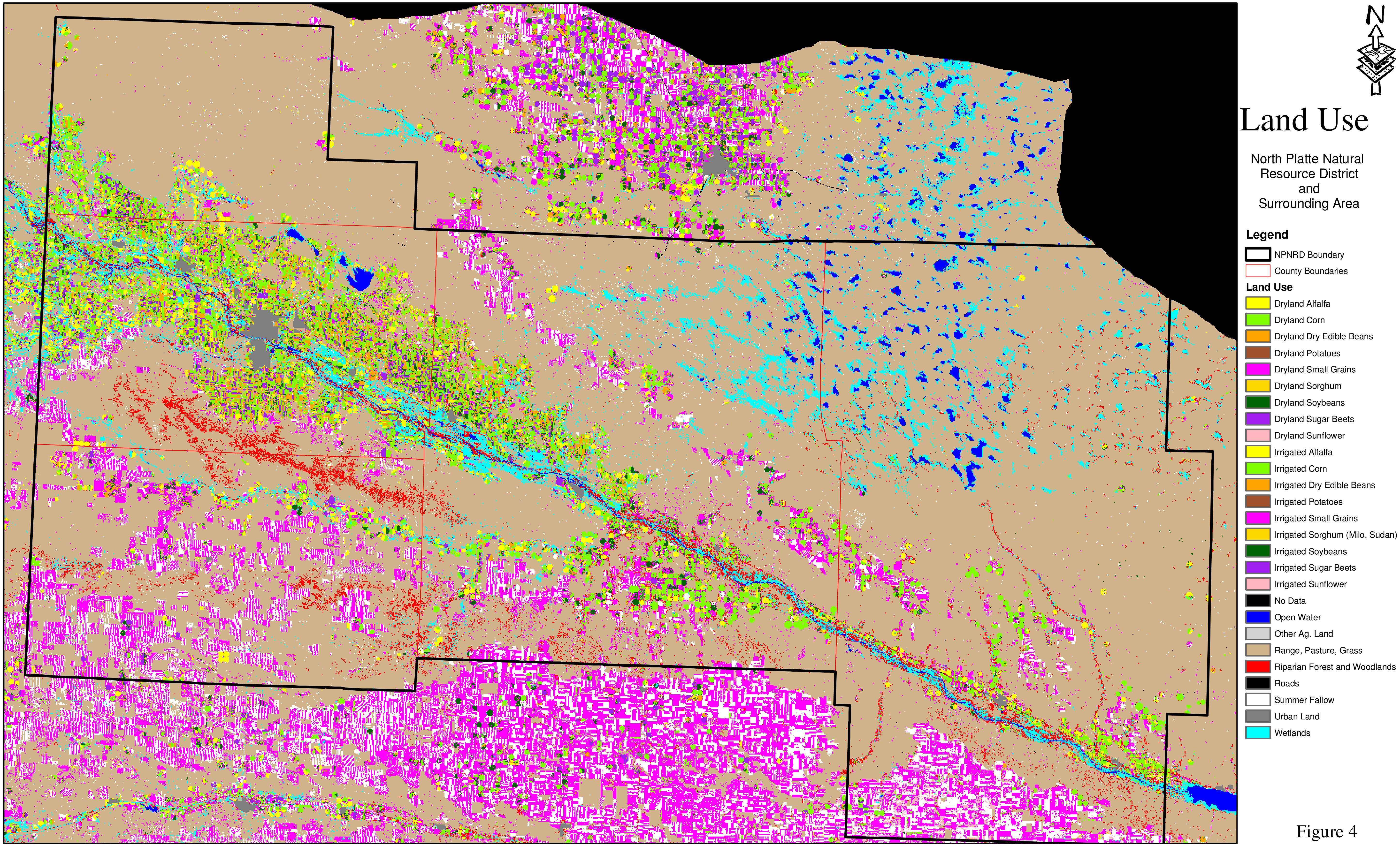

N
Land Use
North Platte Natural Resource District and Surrounding Area
Legend
NPNRD Boundary
County Boundaries
Land Use
Dryland Alfalfa
Dryland Corn
Dryland Dry Edible Beans
Dryland Potatoes
Dryland Small Grains
Dryland Sorghum
Dryland Soybeans
Dryland Sugar Beets
Dryland Sunflower
Irrigated Alfalfa
Irrigated Corn
Irrigated Dry Edible Beans
Irrigated Potatoes
Irrigated Small Grains
Irrigated Sorghum (Milo, Sudan)
Irrigated Soybeans
Irrigated Sugar Beets
Irrigated Sunflower
No Data
Open Water
Other Ag. Land
Range, Pasture, Grass
Riparian Forest and Woodlands
Roads
Summer Fallow
Urban Land
Wetlands

Figure 4

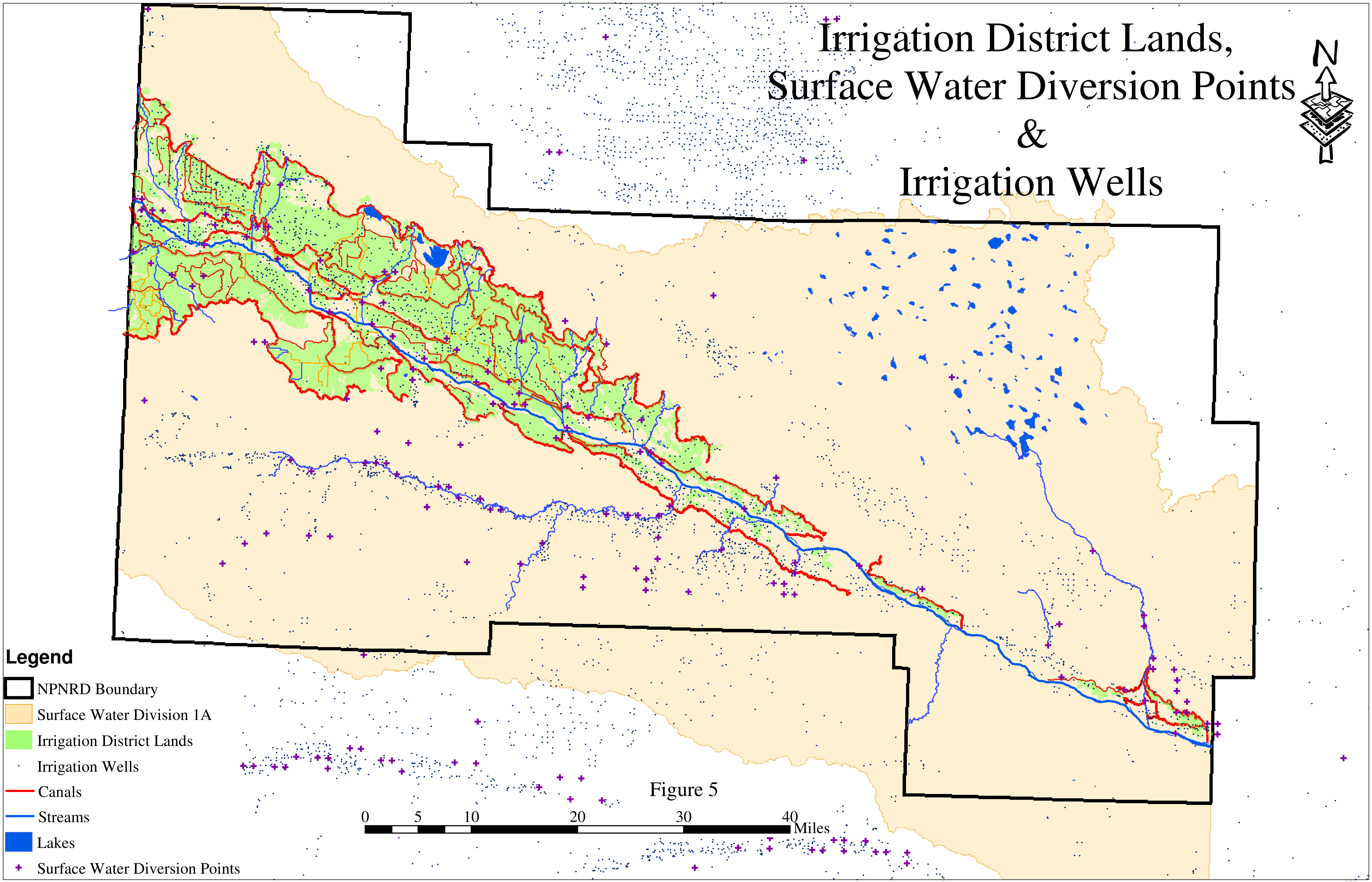
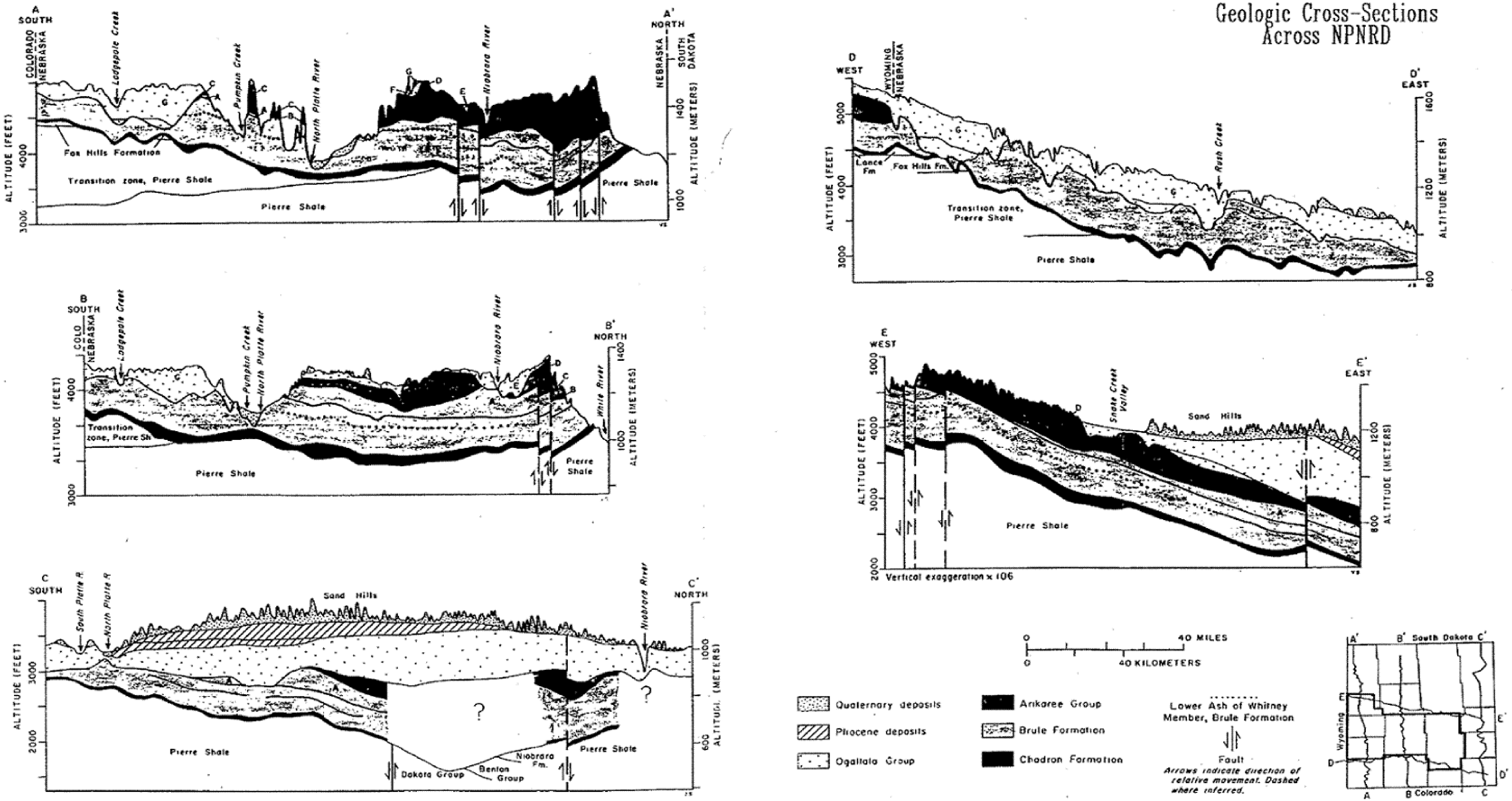

Irrigation District Lands,
Surface Water Diversion Points
&
Irrigation Wells
N
Legend
NPNRD Boundary
Surface Water Division 1A
Irrigation District Lands
Irrigation Wells
Canals
Streams
Lakes
Surface Water Diversion Points
0
5
10
20
30
40
Miles

Figure 5

Geologic Cross-Sections Across NPNRD



Geologic sections across study area. Brule Formation, Arikaree Group and Ogallala Group are subdivided in selected areas as follows:

A-Brown Siltstone beds; B-Gering Formation; C-Monroe Creek-Harrison formations; D-Upper Harrison beds; E-Runningwater Formation; F-Sheep Creek and Olcott formations; G-Ash Hollow Formation.

Figure 6.

Ground Water Regions

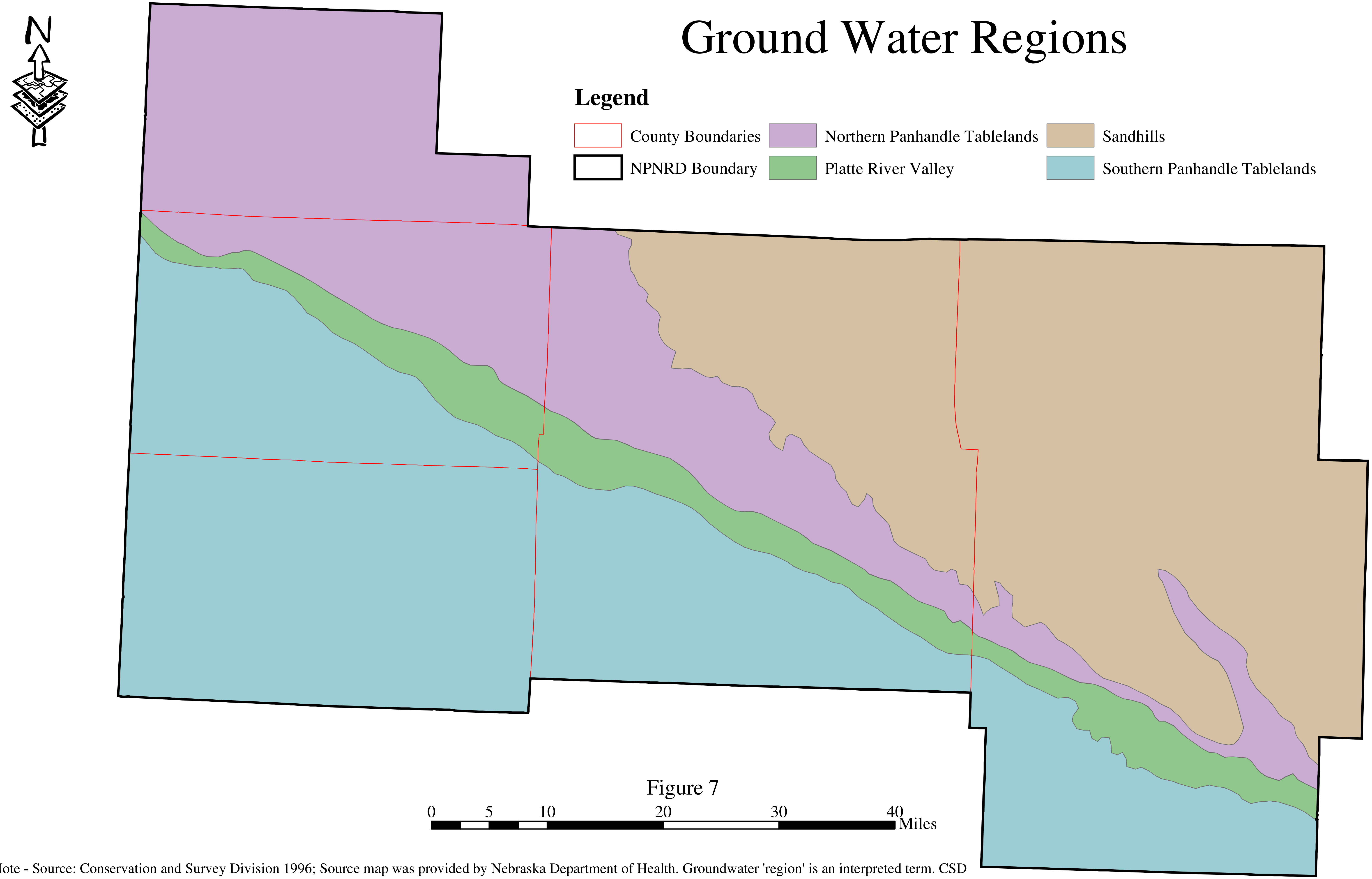
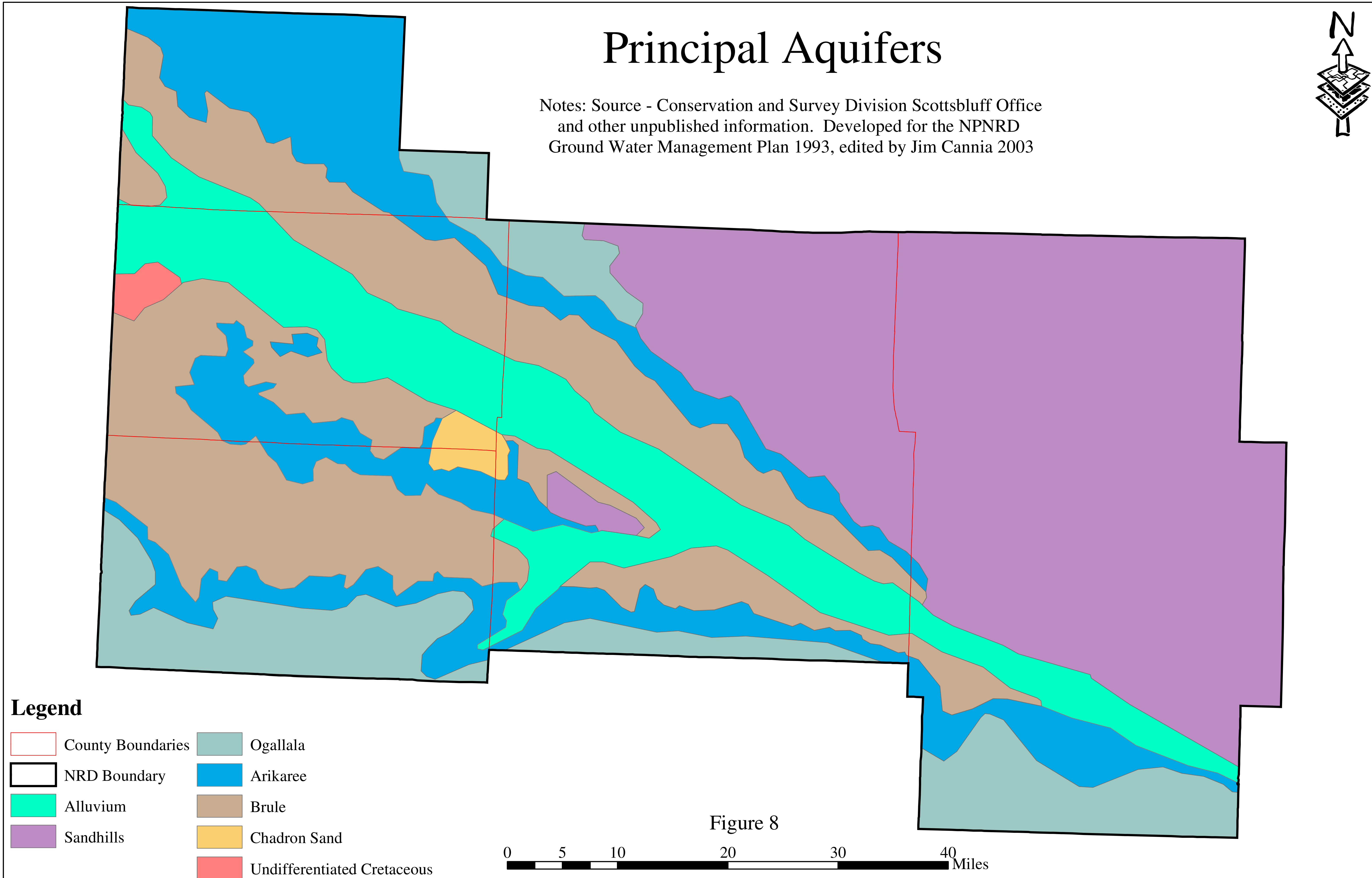
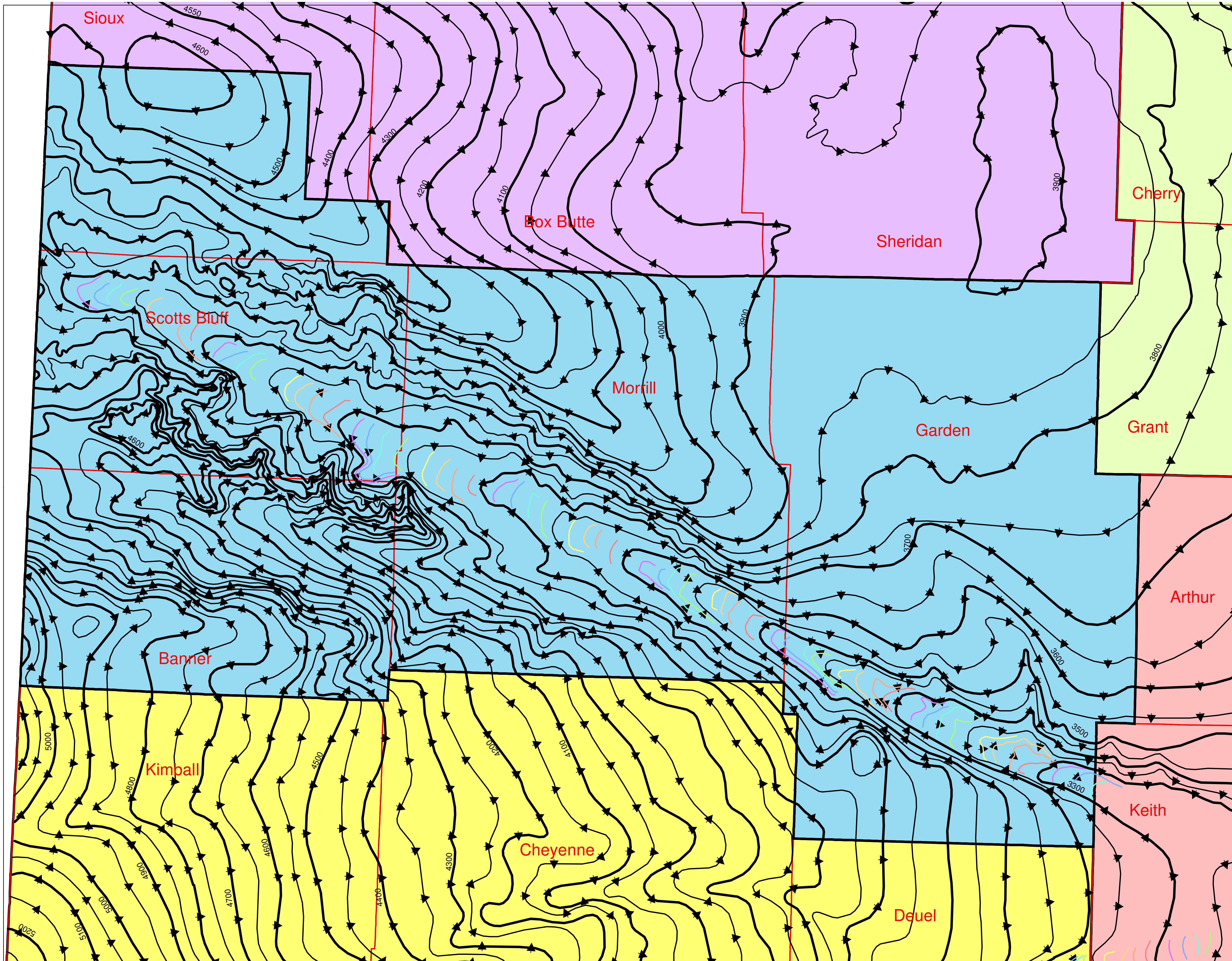


Figure 7

Note - Source: Conservation and Survey Division 1996; Source map was provided by Nebraska Department of Health. Groundwater 'region' is an interpreted term. CSD has a similar map done in 1968 by Eugene Reed at 1:500,000. The Conservation and Survey Division has produced this product using what is thought to be the most reliable information available or reproduced the material as provided. The detail and precision of the interpretations made are according to accepted professional standards and are dependant upon the techniques, hardware, and/or software utilized. http://csd.unl.edu/csd/specials/gisdata.html


Principal Aquifers
Notes: Source - Conservation and Survey Division Scottsbluff Office
and other unpublished information. Developed for the NPNRD
Ground Water Management Plan 1993, edited by Jim Cannia 2003
N
Legend
County Boundaries
NRD Boundary
Alluvium
Sandhills
Ogallala
Arikaree
Brule
Chadron Sand
Undifferentiated Cretaceous
0
5
10
20
30
40
Miles
Figure 8



Water Table Contours

Conservation
&
Survey Division

Spring 1995

Legend

Water Table Contours

- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- Flow Direction

Natural Resouce Districts

- NORTH PLATTE
- SOUTH PLATTE
- TWIN PLATTE
- UPPER LOUP
- UPPER NIOBRARA WHITE
- County Boundaries
- NRD Boundary

Figure 9

Existing Ground Water Management Areas

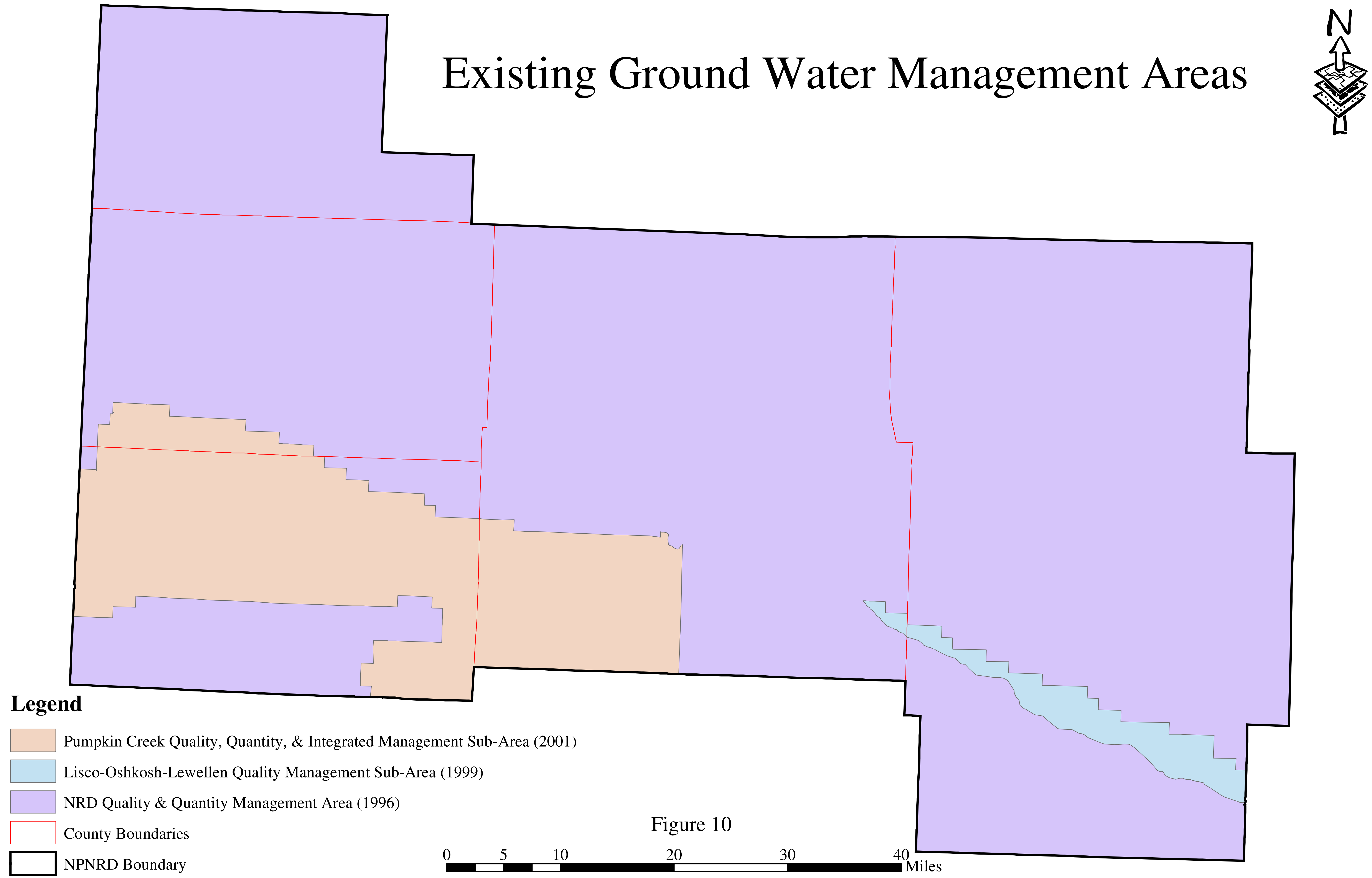


Figure 10

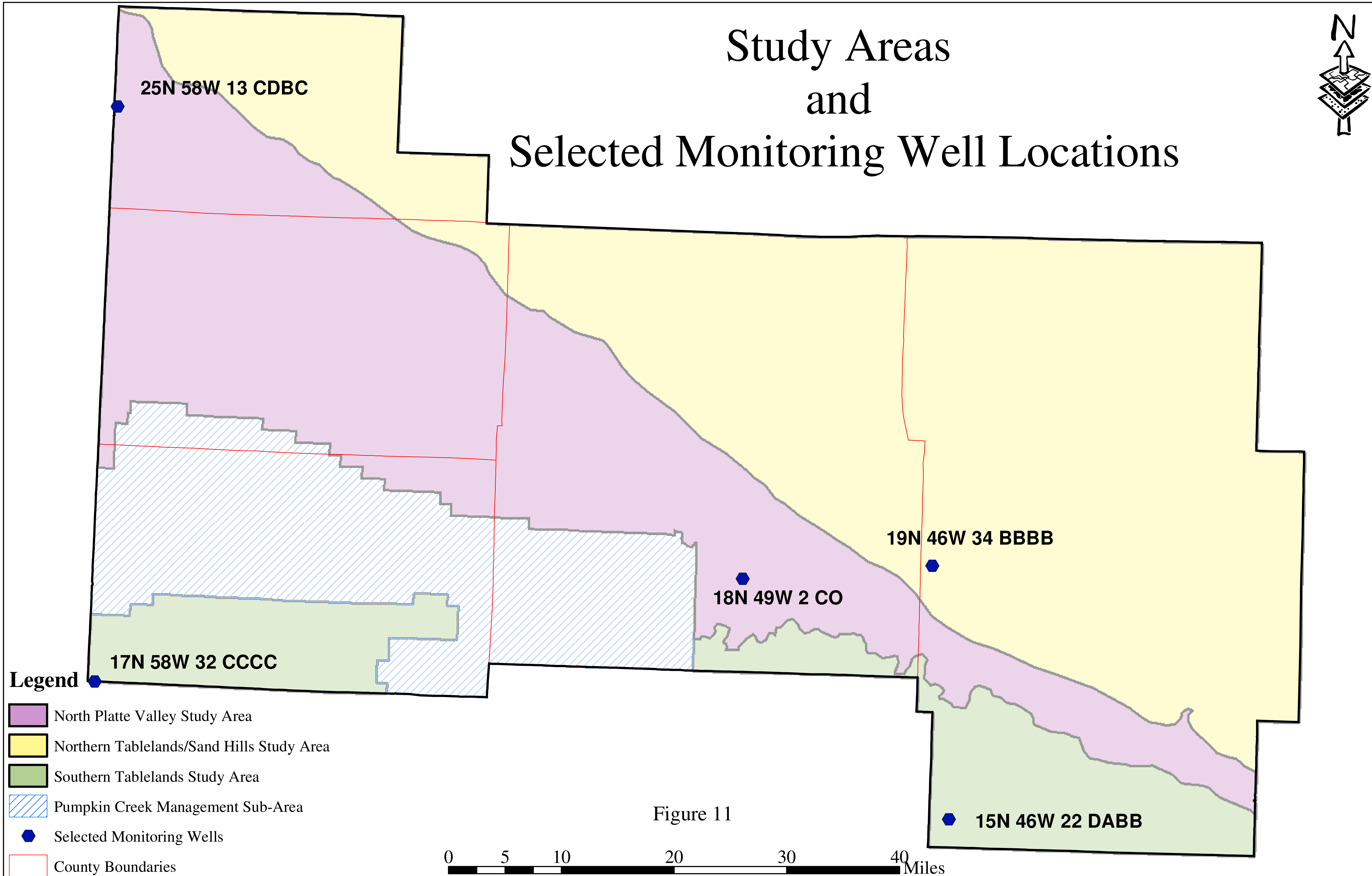

Study Areas
and
Selected Monitoring Well Locations
N
25N 58W 13 CDBC
19N 46W 34 BBBB
18N 49W 2 CO
17N 58W 32 CCCC
15N 46W 22 DABB
Legend
North Platte Valley Study Area
Northern Tablelands/Sand Hills Study Area
Southern Tablelands Study Area
Pumpkin Creek Management Sub-Area
Selected Monitoring Wells
County Boundaries
0
5
10
20
30
40
Miles

Figure 11

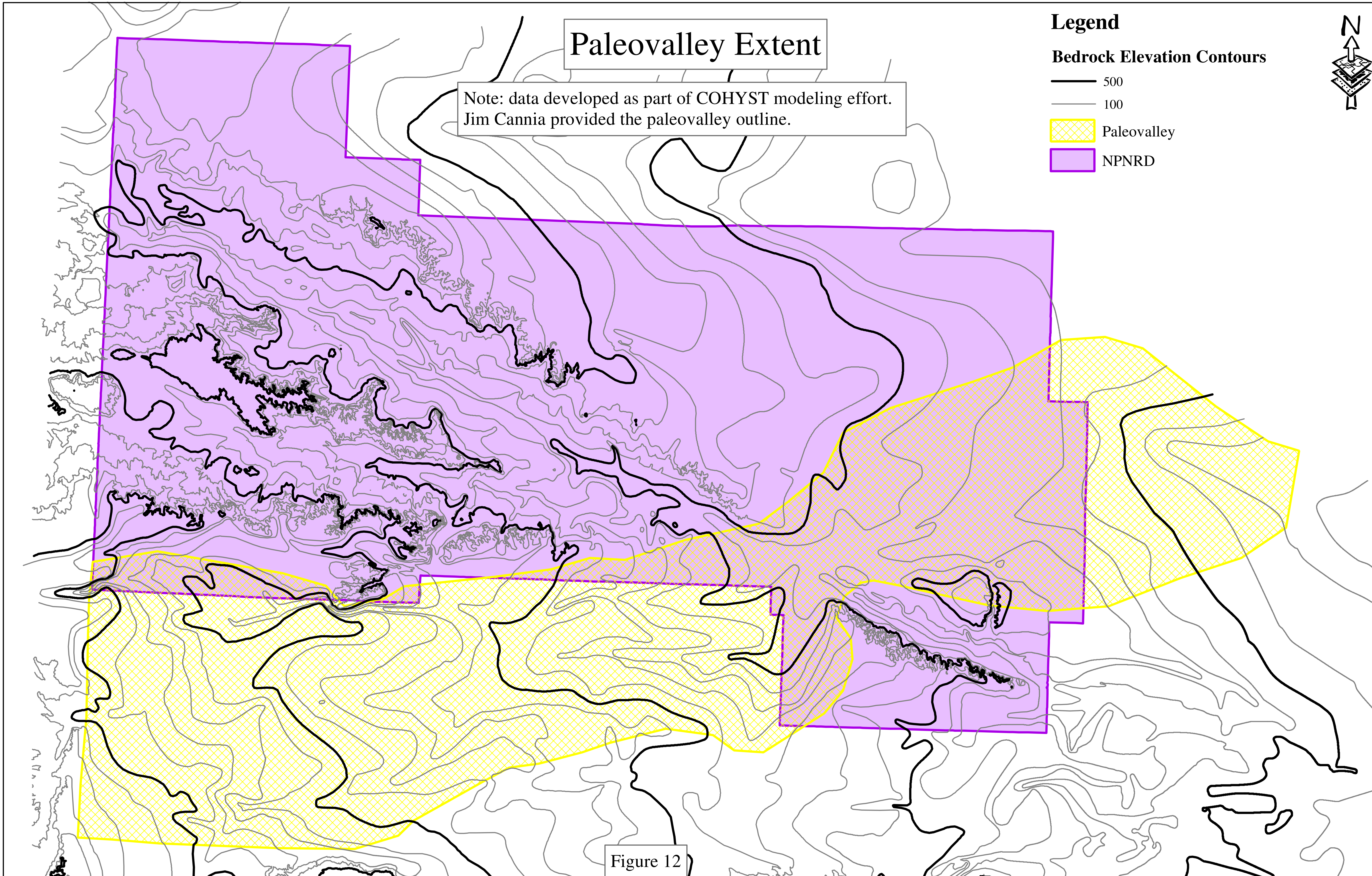

Paleovalley Extent
Note: data developed as part of COHYST modeling effort.
Jim Cannia provided the paleovalley outline.
Legend
Bedrock Elevation Contours
500
100
Paleovalley
NPNRD
N

Figure 12

Appendix IV

Surface Water Rights in the North Platte Natural Resources District

Application	Annotation	Carrier	Priority Date	Use[1]	Grant[2]	Rate[3]	Sec	Twn	Rng	County
ASH CREEK										
A 3305	R P-300	PUMP	10 22 1940	1	0.43	70	10	16	42 W	Garden
A 9628		GILLARD CANAL	6 17 1958	1	0.16	70	3	16	42 W	Garden
A 5900		GILLARD CANAL	1 25 1954	1	0.96	70	3	16	42 W	Garden
D 812		GILLARD CANAL	12 31 1890	1	1.43	70	3	16	42 W	Garden
A 14710		PUMP	2 14 1977	1	0.46	70	10	16	42 W	Garden
CAMP CLARK SEEP										
A 14244		O'NEAL CANAL	5 28 1976	1	2.22	70	9	20	51 W	Morrill
FARMERS CANAL SEEP										
A 1769	D-918	WARNER CANAL	9 16 1887	1	1.63	70	12	23	57 W	Scotts Bluff
GLENN SPRINGS										
A 2324		GLENN CANAL	5 29 1933	1	0.16	70	3	23	58 W	Scotts Bluff
GRANDSTAFF SPRING										
A 9865		GRANDSTAFF LATERALS	9 22 1960	1	0.5	70	10	23	57 W	Scotts Bluff
HORSE CREEK										
A 994		STATE LINE CANAL	4 21 1910	1	2	80	33	23	58 W	Scotts Bluff
A 407		STATE LINE CANAL	9 10 1897	1	3.07	70	33	23	58 W	Scotts Bluff
HUNTINGTON SPRINGS										
A 778		CARD CANAL	12 23 1904	1	1.43	70	9	20	58 W	Scotts Bluff
KIOWA CREEK										
A 880	R P-332	PUMP	11 29 1907	1	0.06	70	2	22	58 W	Scotts Bluff
NEALY SPRINGS, NORTH										
A 2454		NEALY CANAL	8 3 1934	1	0.38	70	11	23	58 W	Scotts Bluff
NEALY SPRINGS, SOUTH										
A 9777		PUMP	12 1 1959	1	1.01	70	11	23	58 W	Scotts Bluff
A 2311		PUMP	3 27 1933	1	0.06	70	11	23	58 W	Scotts Bluff
A 10097		PETSCH CANAL	8 30 1962	1	0.33	70	11	23	58 W	Scotts Bluff
NORTH PLATTE RIVER										
D 920	U-31, M-1	ENTERPRISE CANAL	3 28 1889	19	18.2		27	23	57 W	Scotts Bluff
A 365	R U-29	CENTRAL CANAL	8 17 1992	22	0		27	22	55 W	Scotts Bluff
A 365	R P-476B	CENTRAL CANAL	8 17 1992	1	0.09	70	27	22	55 W	Scotts Bluff
D 926		CENTRAL CANAL	6 23 1890	1	24.4	70	27	22	55 W	Scotts Bluff
D 952	U-30	WINTERS CREEK CANAL	10 18 1888	19	27.6		17	22	55 W	Scotts Bluff
D 920	M-1	ENTERPRISE CANAL	3 28 1889	1	115	43	27	23	57 W	Scotts Bluff
D 952		WINTERS CREEK CANAL	10 18 1888	1	14.4	70	17	22	55 W	Scotts Bluff

Application	Annotation	Carrier	Priority Date	Use[1]	Grant[2]	Rate[3]	Sec	Twn	Rng	County
A 1398	R D-918	TRI-STATE CANAL	9 16 1887	1	0.14	70	10	23	58 W	Scotts Bluff
A 1176	R T-211	TRI-STATE CANAL	9 16 1887	1	0.46	70	10	23	58 W	Scotts Bluff
D 945	R P-469	TRI-STATE CANAL	3 20 1893	1	0.74	70	10	23	58 W	Scotts Bluff
A 365		GERING CANAL	3 15 1897	1	15.6	70	4	23	58 W	Scotts Bluff
D 926	U-29	CENTRAL CANAL	6 23 1890	19	8.79		27	22	55 W	Scotts Bluff
D 918	T-250	TRI-STATE CANAL	9 16 1887	1	861	70	10	23	58 W	Scotts Bluff
A 660		TRI-STATE CANAL	4 14 1902	1	591	70	10	23	58 W	Scotts Bluff
A 768	R P-414	TRI-STATE/NORTHPORT CANAL	9 19 1904	1	230	70	10	23	58 W	Scotts Bluff
NORTH PLATTE RIVER, TRIB. TO										
A 11951		LIPPINCOTT RESERVOIR	6 1 1970	2	16.3 AF		10	22	57 W	Scotts Bluff
A 10427		CHILDS RESERVOIR	8 24 1964	2	3.62 AF		3	23	58 W	Scotts Bluff
A 10951		PUMP	9 14 1966	1	0.14	70	3	23	58 W	Scotts Bluff
OWL CREEK										
A 881	R P-423&424	PUMP	11 29 1907	1	0.57	70	7	22	57 W	Scotts Bluff
A 879	R P-422	PUMP	11 29 1907	1	1.14	70	7	22	57 W	Scotts Bluff
A 13052		PUMP	6 26 1974	1	0.3	70	16	22	57 W	Scotts Bluff
A 13309		STRATTON RESERVOIR	12 11 1974	2	15 AF		16	22	57 W	Scotts Bluff
A 411	R P-418&419	PUMP	9 17 1897	1	0.79	70	7	22	57 W	Scotts Bluff
A 770	R P-420&421	PUMP	10 10 1904	1	1.14	70	7	22	57 W	Scotts Bluff
PATHFINDER RESERVOIR										
A 768	D-918	TRI-STATE CANAL	9 19 1904	6	0		10	23	58 W	Scotts Bluff
A 768	D926,U29	CENTRAL CANAL	9 19 1904	22	0		27	22	55 W	Scotts Bluff
A 768	A-660	TRI-STATE CANAL	9 19 1904	6	0		10	23	58 W	Scotts Bluff
A 768	A-768R	TRI-STATE CANAL	9 19 1904	6	0		10	23	58 W	Scotts Bluff
A 768	R P477,U29	CENTRAL CANAL	9 19 1904	22	0		27	22	55 W	Scotts Bluff
PETSCH SPRINGS										
A 9866		PETSCH LATERAL NO. 2	9 28 1960	1	0.23	70	12	23	58 W	Scotts Bluff
ROGERS SPRING										
A 9867		PETSCH CANAL	9 28 1960	1	1.47	70	10	23	58 W	Scotts Bluff
SCHUPPE CREEK, EAST										
A 3918		SCHUPPE CANAL NO. 2	6 17 1946	1	0.02	70	3	23	58 W	Scotts Bluff
SCHUPPE CREEK, WEST										
A 3917		SCHUPPE CANAL NO. 1	6 17 1946	1	0.01	70	3	23	58 W	Scotts Bluff
SHEEP CREEK										
A 871		WEST FORK CANAL	9 21 1907	1	5.14	70	1	26	58 W	Sioux
SPOTTED TAIL CREEK, DRY										
A 16725		BOVE FISH PONDS	12 1 1988	2	8.05 AF		28	24	56 W	Sioux
D 920	P236,M1	DRY SPOTTED TAIL CREEK LATERAL	3 28 1889	1	0		20	23	56 W	Scotts Bluff

Application	Annotation	Carrier	Priority Date	Use[1]	Grant[2]	Rate[3]	Sec	Twn	Rng	County
A 1241	D-918	ROBERTS CANAL	9 16 1887	1	1.28	70	16	23	56 W	Scotts Bluff
D 918	P-195	ROBERTS CANAL	9 16 1887	1	0.46	70	16	23	56 W	Scotts Bluff
A 16983		RAINBOW CHANNEL 2	5 3 1990	7	1		28	24	56 W	Sioux
A 1582		MITCHELL FACTORY	3 24 1920	3	15		20	23	56 W	Scotts Bluff
A 16724		BOVE FISH PONDS	12 1 1988	7	3		28	24	56 W	Sioux
A 16984		RAINBOW CHANNEL 2 PONDS	5 3 1990	2	5 AF		28	24	56 W	Sioux
SPOTTED TAIL CREEK, WET										
A 16902		BOVEE FISH PONDS	12 7 1989	7	4		15	23	56 W	Scotts Bluff
D 920	P498,M1	ENTERPRISE CANAL	3 28 1889	1	0		35	23	56 W	Scotts Bluff
A 743	T-706	STEWART-BROWN CANAL AND PUMPSITES	3 2 1904	1	1.59	211	26	24	56 W	Sioux
A 1072	T-831	STEWART-BROWN CANAL AND PUMPSITES	3 17 1911	1	2.28	147	26	24	56 W	Sioux
A 16901		BOVEE FISH PONDS	12 7 1989	2	3.6 AF		15	23	56 W	Scotts Bluff
SPRINGS										
A 10046		VANDEL CANAL	4 24 1962	1	0.12	70	21	22	54 W	Scotts Bluff
A 16912		PUMP	1 16 1990	4	0.11		19	21	52 W	Scotts Bluff
STRATTON RESERVOIR										
A 13310	A-13052	PUMP	12 11 1974	6	0		16	22	57 W	Scotts Bluff
TUB SPRINGS										
D 920	P234,M1	ENTERPRISE CANAL	3 28 1889	1	0		33	23	55 W	Scotts Bluff
ELDRED LAKE										
A 16382		ELDRED DIVERSION	5 17 1985	23	13		16	21	45 W	Garden
MORRILL DRAIN										
A 1290	D920,T521	ENTERPRISE CANAL	3 28 1889	1	10	497	14	23	57 W	Scotts Bluff
BAYARD SUGAR FACTORY DRAIN										
A 1776	U-22	ALLIANCE CANAL	12 26 1892	19	4.91		5	20	52 W	Morrill
A 17240	A-1776	ALLIANCE CANAL	1 11 1993	1	0		4	20	52 W	Morrill
A 1429	R T-280	ALLIANCE CANAL	12 26 1892	1	0.22		5	20	52 W	Morrill
A 1776		ALLIANCE CANAL	12 26 1892	1	31	70	5	20	52 W	Morrill
BIG HORN CREEK										
A 6803		MUHR RESERVOIR	11 2 1954	2	38 AF		25	19	54 W	Banner
A 4027		BIG HORN CANAL	1 24 1947	1	1.03	70	25	19	54 W	Banner
BROWN RESERVOIR										
A 4878		BROWN CANAL	11 8 1950	5	0		17	19	53 W	Banner
FAWCUS SPRINGS										
A 2317		OLIVER CANAL	4 17 1933	1	2.71	70	24	20	52 W	Morrill
GEBAUER LAKE										
A 2138		GEBAUER CANAL	4 25 1930	1	0.8	70	28	20	50 W	Morrill

Application	Annotation	Carrier	Priority Date	Use[1]	Grant[2]	Rate[3]	Sec	Twn	Rng	County
GERING DRAIN, TRIB. TO										
A 10799		GERING VALLEY RESERVOIR A	3 15 1966	2	62.4 AF		3	20	55 W	Scotts Bluff
A 11752		GERING VALLEY RESERVOIR G-LOWER	7 18 1969	2	20.4 AF		10	21	56 W	Scotts Bluff
A 10683		GERING VALLEY RESERVOIR G-UPPER	8 26 1965	2	21 AF		9	21	56 W	Scotts Bluff
GOOSENECK CREEK										
A 15141		EAST GERING DRAIN RES.	11 14 1977	2	5.4 AF		21	21	54 W	Scotts Bluff
HOTH DRAW										
A 1473	D-918	O'HALLOREN CANAL	9 16 1887	1	1.07	70	28	21	52 W	Morrill
A 1593		BAYARD FACTORY	10 4 1920	3	15		34	21	52 W	Morrill
INDIAN CREEK, TRIB. TO										
A 11979		HALL RESERVOIR	6 22 1970	2	13.1 AF		8	20	50 W	Morrill
AIREDALE RESERVOIR NO. 3										
A 4981	A-698R	PUMPS	3 28 1951	6	0		1	19	55 W	Banner
A 4981	A-1133R	PUMPS	3 28 1951	6	0		1	19	55 W	Banner
A 4981	A-1380R	PUMPS	3 28 1951	6	0		1	19	55 W	Banner
A 4981	A-699R	PUMPS	3 28 1951	6	0		1	19	55 W	Banner
A 4981		PUMPS	3 28 1951	5	0		1	19	55 W	Banner
MUHR RESERVOIR										
A 9632	A-4027	BIG HORN CANAL	11 2 1954	6	0		25	19	54 W	Banner
NINE MILE CREEK										
A 2502 R	U-28	PUMP	1 14 1888	19	0		4	21	53 W	Scotts Bluff
A 1431	D-925	NINE MILE CANAL	12 6 1893	1	37.8	91	10	21	53 W	Scotts Bluff
A 2502 R	D919,T55	PUMP	1 14 1888	21	1.02	70	4	21	53 W	Scotts Bluff
A 1431	U-25	NINE MILE CANAL	12 6 1893	19	39.2		10	21	53 W	Scotts Bluff
NORTH PLATTE RIVER										
D 828 A		BELMONT CANAL	12 19 1889	1	90.2	70	18	20	51 W	Morrill
D 946		SHORT LINE CANAL	5 1 1893	1	42.5	74	25	21	53 W	Scotts Bluff
D 844	U-27	CHIMNEY ROCK CANAL	12 3 1890	21	60	70	1	20	53 W	Scotts Bluff
D 1031	D-844,U27	CHIMNEY ROCK CANAL	12 3 1890	21	0		1	20	53 W	Scotts Bluff
A 2190	U-27	CHIMNEY ROCK CANAL	2 2 1931	21	0.67	70	1	20	53 W	Scotts Bluff
D 858 R	P-NONE	EMPIRE CANAL	6 25 1891	1	28.6	75	18	20	51 W	Morrill
A 866		EMPIRE CANAL	7 20 1907	1	0.31	75	18	20	51 W	Morrill
D 857		BROWNS CREEK CANAL	1 20 1892	1	59.9	70	29	20	50 W	Morrill
D 828 B		EMPIRE CANAL	12 19 1889	1	0.18	70	18	29	51 W	Morrill
D 1033	D-857	BROWNS CREEK CANAL	1 20 1892	1	0		29	20	50 W	Morrill
A 16128		PUMP	7 14 1982	1	0.19	70	34	20	50 W	Morrill
D 919	U-28	MINATARE CANAL	1 14 1888	19	20.1	70	32	22	54 W	Scotts Bluff
D 921	U-26	CASTLE ROCK CANAL	4 18 1889	19	0.09	70	3	21	54 W	Scotts Bluff

Application	Annotation	Carrier	Priority Date	Use[1]	Grant[2]	Rate[3]	Sec	Twn	Rng	County
D 925	R U-25	NINE MILE CANAL	12 6 1893	19	39.2		18	21	53 W	Scotts Bluff
D 919	A R T-303	NINE MILE CANAL	1 14 1888	1	0.02		18	21	53 W	Scotts Bluff
A 350	A R U-26	CASTLE ROCK CANAL	7 22 1896	19	0.07		3	21	54 W	Scotts Bluff
A 350	A R T300/301	CASTLE ROCK CANAL	7 22 1896	1	0.29	372	3	21	54 W	Scotts Bluff
A 350	R U-26	CASTLE ROCK CANAL	7 22 1896	19	0.09		3	21	54 W	Scotts Bluff
A 186	A R U-26	CASTLE ROCK CANAL	10 22 1895	19	0.09		3	21	54 W	Scotts Bluff
D 925	R P-481	NINE MILE CANAL	12 6 1893	1	66.2	71	18	21	53 W	Scotts Bluff
A 186	A R T286/293	CASTLE ROCK CANAL	10 22 1895	1	0.19	568	3	21	54 W	Scotts Bluff
D 919	R P-452	NINE MILE CANAL	1 14 1888	1	2.26	70	18	21	53 W	Scotts Bluff
D 946	U-23	SHORT LINE CANAL	5 1 1893	19	10.5	70	25	21	53 W	Scotts Bluff
D 857	U-18	BROWNS CREEK CANAL	1 20 1892	19	27.6	70	29	20	50 W	Morrill
D 919		MINATARE CANAL	1 14 1888	1	95.9	70	32	22	54 W	Scotts Bluff
D 921		CASTLE ROCK CANAL	4 18 1889	1	82.5	70	3	21	54 W	Scotts Bluff
A 186	R P-255&309	CASTLE ROCK CANAL	10 22 1895	1	3.05	70	3	21	54 W	Scotts Bluff
A 350	R P-255&309	CASTLE ROCK CANAL	7 22 1896	1	0.4	70	3	21	54 W	Scotts Bluff
A 186	R U-26	CASTLE ROCK CANAL	10 22 1895	19	1.51		3	21	54 W	Scotts Bluff
NORTH PLATTE RIVER, TRIB. TO										
A 10167		ZEMANEK RESERVOIR	4 4 1963	2	1.39 AF		18	21	52 W	Scotts Bluff
A 10255		HUFFMAN-GRIMM RESERVOIR	10 28 1963	2	14.8 AF		28	20	53 W	Banner
PATHFINDER RESERVOIR										
A 768	D-857	BROWNS CREEK CANAL	9 19 1904	6	0		29	20	50 W	Morrill
A 768	D-844,U27	CHIMNEY ROCK CANAL	9 19 1904	22	0		1	20	53 W	Scotts Bluff
A 768	D1031,U27	CHIMNEY ROCK CANAL	9 19 1904	22	0		1	20	53 W	Scotts Bluff
A 768	D-1033	BROWNS CREEK CANAL	9 19 1904	6	0		29	20	50 W	Morrill
PUMPKINSEED CREEK										
A 1133	R P-294	PUMPS	10 26 1911	1	1.48	70	6	19	54 W	Banner
D 913		PETERS CANAL	7 1 1902	1	1.14	70	2	19	56 W	Banner
A 711		SCOTT RESERVOIR	6 24 1903	9	1.31	70	7	19	55 W	Banner
D 902		LOGAN CANAL	7 16 1890	1	4	70	7	19	55 W	Banner
A 4832		AIRDALE RESERVOIR NO. 3	3 28 1951	2	31 AF		1	19	55 W	Banner
A 699	R P-293	PUMPS	1 24 1903	1	3.22	70	6	19	54 W	Banner
A 3864		WRIGHT CANAL	1 8 1946	1	1.41	70	5	19	54 W	Banner
A 3859		PUMP	11 6 1945	1	0.82	70	18	19	53 W	Banner
A 3863		RODGERS CANAL	1 8 1946	1	0.26	70	9	19	54 W	Banner
A 1380	R P-295	PUMP	9 4 1914	1	0.51	70	5	19	54 W	Banner
A 3777		RODGERS CANAL	10 23 1944	1	1.8	70	9	19	54 W	Banner
A 4448		PUMP	3 10 1949	1	9.76	70	9	19	54 W	Banner
A 698	R P-292	PUMPS	1 24 1903	1	5.52	70	6	19	54 W	Banner

Application	Annotation	Carrier	Priority Date	Use [1]	Grant [2]	Rate [3]	Sec	Twn	Rng	County
PUMPKINSEED CREEK, TRIB. TO										
A 4763		BROWN RESERVOIR	11 8 1950	2	30 AF		17	19	53 W	Banner
A 8278		DOWNER BROS. RESERVOIR	12 6 1955	2	30 AF		9	18	55 W	Banner
A 16250		LOVER'S LEAP RESERVOIR	10 27 1983	2	155 AF		7	18	55 W	Banner
RED WILLOW CREEK										
A 1429	U-22	ALLIANCE CANAL	12 26 1892	19	8.93		6	20	51 W	Morrill
A 1432		ALLIANCE CANAL	2 28 1912	1	1.11	70	6	20	51 W	Morrill
A 1432	U-22	ALLIANCE CANAL	2 28 1912	19	0.89		6	20	51 W	Morrill
A 1429		ALLIANCE CANAL	12 26 1892	1	42.7	70	6	20	51 W	Morrill
A 17239	1429,1432	ALLIANCE CANAL	1 11 1993	1	0	70	6	20	51 W	Morrill
RED WILLOW CREEK, TRIB. TO										
A 11804		LOOMIS RESERVOIR	9 24 1969	2	16.7 AF		1	21	51 W	Morrill
SCOTT RESERVOIR										
A 711	A-711	SCOTT CANAL	6 24 1903	6	0		7	19	55 W	Banner
WEST WATER CREEK										
A 13760		WEST WATER CREEK RES.	8 25 1975	2	45.5 AF		29	22	51 W	Morrill
WILDHORSE CREEK, WEST										
A 11164		WILDHORSE RESERVOIR 14-A	6 7 1967	2	440 AF		3	21	52 W	Morrill
WILLOW CREEK, TRIB. TO										
A 10826		CROSS GROUP RESERVOIR	4 8 1966	2	75.9 AF		9	18	56 W	Banner
A 11544		ANDERSON GROUP RESERVOIR	8 15 1968	2	31.6 AF		18	18	56 W	Banner
A 5889		BRAUER RESERVOIR	1 22 1954	2	99 AF		26	18	57 W	Banner
WINTERS CREEK										
D 923 B		PUMP	8 17 1889	1	0.02	70	4	22	54 W	Scotts Bluff
A 2409	U-31, M-1	WINTERS CREEK LATERAL	3 28 1889	19	0.19		8	22	54 W	Scotts Bluff
A 1446 B		WINTERS CREEK CANAL	10 18 1888	1	34.4	70	19	22	54 W	Scotts Bluff
A 1446 B	U-30	WINTERS CREEK CANAL	10 18 1888	19	11.2		19	22	54 W	Scotts Bluff
A 1592		SCOTTSBLUFF FACTORY	10 4 1920	3	15		19	22	54 W	Scotts Bluff
A 1446 A	D-952	WINTERS CREEK CANAL	10 18 1888	1	5.68	70	19	22	54 W	Scotts Bluff
A 2409	D920,M-1	WINTERS CREEK LATERAL	3 28 1889	1	2.24	51	8	22	54 W	Scotts Bluff
D 923 C		PUMP	8 17 1889	1	0.27	70	4	22	54 W	Scotts Bluff
D 923 A		PUMP	8 17 1889	1	0.17	70	3	22	54 W	Scotts Bluff
A 1446 A	U30,D-952	WINTERS CREEK CANAL	10 18 1888	19	1.81		19	22	54 W	Scotts Bluff
MELBETA CREEK										
A 186 R	T-414	GATCH CANAL	10 22 1895	1	1.28	70	25	21	54 W	Scotts Bluff
A 937 A		GATCH CANAL	3 19 1909	1	0.61	70	25	21	54 W	Scotts Bluff
A 1220		GATCH CANAL	8 21 1912	1	0.86	70	25	21	54 W	Scotts Bluff
A 937 C		BOTT CANAL	3 19 1909	1	0.06	70	24	21	54 W	Scotts Bluff

Application	Annotation	Carrier	Priority Date	Use[1]	Grant[2]	Rate[3]	Sec	Twn	Rng	County
A 186	R T-217	BOTT CANAL	10 22 1895	1	0.66	70	24	21	54 W	Scotts Bluff
A 186	R T-238	BOTT CANAL	10 22 1895	1	0.88	70	24	21	54 W	Scotts Bluff
A 937 B		GATCH CANAL	3 19 1909	1	0.17	70	25	21	54 W	Scotts Bluff
MELBETA CREEK, TRIB. TO										
A 16476		BUFFALO CREEK WILDLIFE MANAGEMENT AREA	3 11 1986	2	87.1 AF		19	20	54 W	Banner
A 15194		DARRELL J ROBERTS RES.	3 3 1978	2	13.8 AF		27	20	54 W	Banner
CLEVELAND DRAIN										
A 1448		LIEBHARDT LATERAL	3 1 1916	1	2.92	70	6	20	52 W	Morrill
BLUE CREEK										
D 763		UNION CANAL	5 16 1890	1	15.2	70	18	16	42 W	Garden
D 781	P-470	BLUE CREEK-HOOPER CANAL	9 7 1893	1	12.0		33	17	42 W	Garden
A 515		PAISLEY CANAL	7 14 1899	1	1.37	70	28	17	42 W	Garden
A 15809		PETERSON'S PLANT	3 26 1981	11	49.2		4	18	43 W	Garden
A 16819		BLUE CREEK CANAL	6 12 1989	1	0.14	70	33	17	42 W	Garden
A 1154		BLUE CREEK CANAL	1 4 1912	1	0.43	70	33	17	42 W	Garden
D 795		BLUE CREEK CANAL	9 27 1894	1	5	70	33	17	42 W	Garden
A 11292		PUMP	12 18 1967	1	0.85	70	5	17	42 W	Garden
D 785		BLUE CREEK CANAL	12 27 1893	1	32.8	70	33	17	42 W	Garden
D 788	R P-535	BLUE CREEK CANAL	4 2 1894	1	11.2	70	33	17	42 W	Garden
A 16995		BLUE CREEK CANAL	6 4 1990	1	0.1	70	33	17	42 W	Garden
A 1738		PAISLEY CANAL	2 25 1924	1	2.19	70	28	17	42 W	Garden
D 800		PAISLEY CANAL	11 20 1894	1	11.8	70	28	17	42 W	Garden
BLUE CREEK, TRIB. TO										
A 10387		DELATOUR RESERVOIR	6 23 1964	2	4.93 AF		8	17	42 W	Garden
CEDAR CREEK										
A 11676		PUMP	3 24 1969	1	2.28	70	14	18	48 W	Morrill
A 1397	D-828	CEDAR CREEK FEEDER	12 19 1889	1	2.3	70	23	18	48 W	Morrill
CEDAR CREEK, EAST FORK										
A 12376		FAIRCHILD RESERVOIR	9 9 1971	2	78.4 AF		35	18	48 W	Morrill
CEDAR CREEK, SOUTH FORK										
D 1034 B	T-123T177	RADCLIFF CANAL NO. 2	7 1 1885	1	0.6	205	34	18	48 W	Morrill
CEDAR CREEK, WEST FORK										
D 1034 C	D1034A	PUMP	2 14 1890	1	0.76	410	27	18	48 W	Morrill
D 1034 B	R D-1034A	PUMP	7 1 1885	1	0.63	494	27	18	48 W	Morrill
A 15153		ARROWHEAD RESERVOIR	12 22 1977	2	19.8 AF		28	18	48 W	Morrill
D 1034 A	T520,P501	PUMP	6 1 1882	1	2.39	130	27	18	48 W	Morrill
COLD WATER CREEK										
D 796	U-17	COLD WATER CANAL	9 29 1894	21	4.29	70	26	18	46 W	Garden

Application	Annotation	Carrier		Priority Date	Use[1]	Grant[2]	Rate[3]	Sec	Twn	Rng	County
DEEP HOLES CREEK											
A 14042		PUMP		2 19 1976	1	0.33	70	31	18	49 W	Morrill
A 11339		PUMP		2 19 1968	1	3.27	70	10	18	49 W	Morrill
DUGOUT CREEK, LOWER											
A 1238		HAGARTY CANAL		10 26 1912	1	1	70	4	19	48 W	Morrill
D 872		COOPER CANAL		8 15 1892	1	0.86	70	4	19	48 W	Morrill
A 1547		KLONDYKE RESERVOIR		7 11 1919	2	33.5 AF		4	19	48 W	Morrill
A 4274		HAGERTY CANAL		5 28 1948	1	0.29	70	4	19	48 W	Morrill
GREENWOOD CREEK											
D 890		CAPRON CANAL		1 1 1893	1	2	70	15	18	50 W	Morrill
A 9537		MEGLEMRE CANAL		7 24 1957	1	0.57	70	3	18	50 W	Morrill
A 12310		BOYD RESERVOIR		7 1 1971	2	0.79 AF		28	18	50 W	Morrill
A 294		MEGLEMRE CANAL		5 6 1896	1	0.57	70	3	18	50 W	Morrill
A 9536		CAPRON CANAL		7 24 1957	1	0.31	70	15	18	50 W	Morrill
A 853		MEGLEMRE CANAL		3 11 1907	1	1.14	70	3	18	50 W	Morrill
A 1551	P-495	TRINNIER CANAL	NELSON CANAL	8 18 1919	1	1.5	70	28	18	50 W	Morrill
D 845		NELSON CANAL		4 1 1892	1	3	81	33	18	50 W	Morrill
D 849	P-495	TRINNIER CANAL	NELSON CANAL	4 6 1891	1	3.99	70	28	18	50 W	Morrill
HACKBERRY CREEK, TRIB. TO											
A 11772		JOHNSON'S POND		8 20 1969	2	9.6 AF		22	18	53 W	Banner
KINGSLEY RESERVOIR											
A 16519	D-787R	LISCO CANAL		8 21 1986	6	29.1 AF		14	18	47 W	Morrill
A 17256	D787R	LISCO CANAL		3 24 1993	6	429 AF		14	18	47 W	Morrill
A 16519	A-991	LISCO CANAL		8 21 1986	6	93.9 AF		14	18	47 W	Morrill
A 16519	D-796	LISCO CANAL		8 21 1986	6	134 AF		14	18	47 W	Morrill
A 16519	D-856	LISCO CANAL		8 21 1986	6	581 AF		14	18	47 W	Morrill
A 16519	A-243R	LISCO CANAL		8 21 1986	6	272 AF		14	18	47 W	Morrill
LAWRENCE FORK											
A 550		NIEHUS CANAL		3 23 1900	1	0.22	70	11	18	52 W	Morrill
A 669	R P-374	SPRING BRANCH CANAL		5 27 1902	1	0.23	70	11	18	52 W	Morrill
A 550	R P-392	PUMP		3 23 1900	1	0.64	70	11	18	52 W	Morrill
D 893	R P-373	SPRING BRANCH CANAL		5 1 1893	1	0.5	70	11	18	52 W	Morrill
D 862	R P-372	SPRING BRANCH CANAL		10 23 1891	1	1	70	11	18	52 W	Morrill
A 1100		RANDAL CANAL		5 15 1911	1	2.4	70	21	18	52 W	Morrill
LOST CREEK											
A 10409		ROBINSON RESERVOIR		7 29 1964	2	2.7 AF		23	17	44 W	Garden
LOST CREEK, TRIB. TO											
A 15006		DORMAN RESERVOIR		7 1 1977	2	32.2 AF		12	17	44 W	Garden

Application	Annotation		Carrier	Priority Date			Use[1]	Grant[2]	Rate[3]	Sec	Twn	Rng	County
MIDDLE CREEK													
A 2646			LOWER CANAL	10	19	1936	1	0.85	70	28	18	51 W	Morrill
A 2646			UPPER CANAL	10	19	1936	1	0.56	70	33	18	51 W	Morrill
NORTH PLATTE RIVER													
A 1742		D-800	MIDLAND-OVERLAND CANAL	11	20	1894	1	1.25	75	2	16	44 W	Garden
D 789	R	P-260	MIDLAND-OVERLAND CANAL	6	9	1894	1	8.77	70	2	16	44 W	Garden
A 243	R	U-17	LISCO CANAL	2	24	1896	19	2.74		14	18	47 W	Morrill
A 991		U-17	LISCO CANAL	4	6	1910	21	3	70	14	18	47 W	Morrill
A 243	R	P-NONE	LISCO CANAL	2	24	1896	1	8.69	70	14	18	47 W	Morrill
D 887			BEERLINE CANAL	10	13	1894	1	14.2	70	24	19	49 W	Morrill
D 856		U-17	LISCO CANAL	7	1	1893	19	1.3		14	18	47 W	Morrill
D 787	R	U-17	LISCO CANAL	3	27	1894	19	12.4		14	18	47 W	Morrill
D 856		T-236	LISCO CANAL	7	1	1893	1	18.6	70	14	18	47 W	Morrill
D 791	R	P-260	MIDLAND-OVERLAND CANAL	8	14	1894	1	14.4	70	2	16	44 W	Garden
D 787	R	P-NONE	LISCO CANAL	3	27	1894	1	2.97	70	14	18	47 W	Morrill
NORTH PLATTE RIVER, TRIB. TO													
A 14275			JACKSON-PAISLEY-ROBINSON RESERVOIR	6	17	1976	2	27.1 AF		11	16	43 W	Garden
PATHFINDER RESERVOIR													
A 768		A-768	BEERLINE CANAL	9	19	1904	5	0		24	19	49 W	Morrill
A 768		D-887	BEERLINE CANAL	9	19	1904	6	0		24	19	49 W	Morrill
PUMPKINSEED CREEK													
A 11439			PUMP	6	3	1968	1	1.02	70	23	19	53 W	Banner
A 11526			PUMP	8	6	1968	1	1.77	70	23	19	53 W	Banner
D 883	A		LAST CHANCE CANAL	4	12	1894	1	1.19	70	27	19	50 W	Morrill
D 883	C		LAST CHANCE CANAL	4	12	1894	1	1.28	70	27	19	50 W	Morrill
A 4689			PUMP	6	3	1950	1	0.2	70	29	19	50 W	Morrill
A 2315			COURT HOUSE ROCK CANAL	4	11	1933	1	0.08	70	30	19	50 W	Morrill
A 2117			PUMP	12	20	1929	1	1.68	70	25	19	53 W	Banner
A 6811			NIELSEN CANAL	11	16	1954	1	2.57	70	30	19	52 W	Morrill
A 851	R	P-123	COURT HOUSE ROCK CANAL	2	28	1907	1	0.43	70	30	19	50 W	Morrill
D 883	B		LAST CHANCE CANAL	4	12	1894	1	0.09	70	27	19	50 W	Morrill
A 9051			NIELSEN CANAL	12	21	1956	1	1.6	70	30	19	52 W	Morrill
D 842	B		SMITH-WHEELER NORTH CANAL	6	1	1896	1	0.71	70	26	19	51 W	Morrill
D 876			MEREDITH-AMMER CANAL	2	20	1893	1	4.8	70	23	19	50 W	Morrill
A 15831			HASS RESERVOIR	4	7	1981	2	29.4 AF		23	19	50 W	Morrill
D 842	A		SMITH-WHEELER SOUTH CANAL	10	16	1890	1	1.57	70	26	19	51 W	Morrill
D 840			COURT HOUSE ROCK CANAL	10	6	1890	1	19.1	70	30	19	50 W	Morrill

Application	Annotation	Carrier	Priority Date	Use[1]	Grant[2]	Rate[3]	Sec	Twn	Rng	County
PUMPKINSEED CREEK, TRIB. TO										
A 14315		DARNALL FISH POND	7 12 1976	2	4.2 AF		21	19	53 W	Banner
SCHUETZ SPRINGS										
D 881		SCHUETZ CANAL	5 10 1892	1	0.21	70	28	18	50 W	Morrill
GREENWOOD CREEK, TRIB. TO										
A 15300		LAKE OGARD	7 21 1978	2	18.6 AF		20	18	50 W	Morrill
ASH CREEK										
A 4403		CLARK RESERVOIR	12 16 1948	2	19 AF		34	16	42 W	Garden
A 13446		LOBNER GROUP NO. 70 RES.	2 26 1975	2	33.1 AF		35	17	42 W	Garden
A 17023		BUZZELL RESERVOIR	10 1 1990	2	2.8 AF		22	16	42 W	Garden
BLUE CREEK										
D 763	R P-458	UNION CANAL	5 16 1890	1	0.71	70	18	16	42 W	Garden
CLARK RESERVOIR										
A 4745	A-4403	PUMP	12 16 1948	5	19 AF		34	16	42 W	Garden
NORTH PLATTE RIVER, TRIB. TO										
A 15611		WES CLARK RESERVOIR	1 18 1980	2	54.9 AF		30	16	41 W	Garden
PLUM CREEK										
A 15622		BRISCOE RESERVOIR	2 22 1980	2	62.9 AF		23	16	42 W	Garden
A 1344	R P-145	PLUM CREEK RES. CANAL	1 12 1914	1	0.28	70	14	16	42 W	Garden
A 1344		PLUM CREEK RES. CANAL	1 12 1914	1	0.69	70	23	16	42 W	Garden

1 - Uses:
1 Irrigation from natural stream
2 Storage
3 Manufacturing
4 Domestic
5 Stor-only (irrigation from reservoir on lands not covered by natural flow approriation)
6 Supplemental Irrigation (irrig. from reservoir on lands also covered by Natural flow appr.)
7 Fish Culture
8 Supplemental Storage (An appropriation that has a prior appropriation for storage)
9 irrigation and storage (An appropriation which was approoved for both uses)
10 Supplemental power and incidental underground water storage
11 Power
...
19 Incidental underground storage
20 Storage and incidental underground storage
21 Irrigation and incidental underground storoage
22 Supplemental irrigation and incidental underground storage
23 Fish and wildlife

2 - Grant: The grant is listed in cubic feet per second (cfs) unless it is designated as acre-feet (af).

3 - Rate: The rate refers to the rate at which the applicant is allowed to withdraw water from a stream. Diversions from streams are limited by statute to a maximum of one cubic foot per second for every 70 acres of land.