Upper Mississippi River System
Flow Frequency Study

Hydrology and Hydraulics
Appendix F
Missouri River

U.S. Army Corps of Engineers
Omaha District

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of Engineers
Omaha District

UPPER MISSISSIPPI RIVER SYSTEM FLOW FREQUENCY STUDY
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INTRODUCTION

PURPOSE

The purpose of this appendix is to document the Hydrologic and Hydraulic analysis conducted by the Omaha District as part of the Upper Mississippi, Lower Missouri and Illinois Rivers Flow Frequency Study. Prior to this study, the discharge frequency relationships established for the Missouri River are those that were developed in 1962 and published in the Missouri River Agricultural Levee Restudy Program Hydrology Report.

This hydrology information was used for the water surface profiles and flood inundation areas that were developed for the Missouri River Flood Plain Study during the mid to late 1970's. Almost 40 years of additional streamflow data were available since the Missouri River Hydrology was last updated. Also, significant channel changes have occurred since the previous Hydraulic studies were completed.

SCOPE

This study was initiated by the Rock Island District with five Corps Districts participating in this study effort including Omaha, Kansas City, St. Paul, Rock Island, and St. Louis. Development of unregulated flows and regulated flows for a long-term period of record was a monumental task for the Missouri River because of the extensive water development that has occurred in the basin. Daily flow hydrographs were developed through model studies for both unregulated and regulated flow conditions. Adjustments or refinements were required to the simulated flow hydrographs based on judgment and past operating experience. Estimates of historical and current level depletions were developed by the US Bureau of Reclamation and incorporated into the analysis. Regulated flow conditions include the current level of water resources development and flood control regulation on the tributaries in addition to the regulation provided by the Missouri River Main Stem Reservoir system.

Water surface profiles were developed using the UNET unsteady flow routing model. Historical flood information was utilized to calibrate and verify the UNET model. The calibrated UNET model was used with period of record flows for both the observed and regulated flow data sets to develop a stage-flow relationship at each cross section location within the model. By combining the previously developed regulated flow-frequency with the period of record stage-flow relationship, updated stage-frequency profiles were determined.

OBJECTIVES

The main objective of the Upper Mississippi River and Lower Missouri River Flood Frequency Study is to update the discharge frequency relationships and water surface profiles on the Mississippi River above Cairo, Illinois, and the Missouri River downstream from Gavins Point Dam.

The primary objective of the hydrologic analysis is to establish the discharge frequency relationships for the Missouri River from Gavins Point Dam to the confluence with the Mississippi River near St. Louis. Establishing the discharge frequency relationships first involved extensive effort in developing unregulated flows and regulated flows for a long-term period of record at each of the main stem gaging stations. Once the unregulated and regulated hydrographs were developed, the annual peak discharges were selected for use in the discharge frequency analysis. The Corps Districts, HEC, Technical and Interagency Advisory Groups selected regional shape estimation methodology from among available statistical methods for estimating the unregulated annual peak flood distributions from the unregulated flow values (see Hydrologic Engineering Center, 1999 and 2000, and Appendix F-A of this report). The regulated frequency curve was obtained by transforming the unregulated frequency curve using a regulated versus unregulated relationship determined from a comparison of the derived unregulated and regulated curves.

PREVIOUS STUDIES

308 Report (1932).

In 1931 and 1932, studies of federal agricultural levees on the main stem of the Missouri River were made. This effort resulted in a plan for 15 levee units between St. Joseph and Boonville to protect 157,720 acres of agricultural lands. Design discharges for those levee units were based on the maximum discharges reached for the June 1903 flood. Discharge frequency relationships were also developed during this study. A comparison of the design discharges and the one percent chance exceedance flood peaks at various control points are listed in Table F-1.

Table F-1
Missouri River Discharges (1932 Study)

Location	1903 Flood Peak	1% Chance Flood Peak
Sioux City	---	325,000
St. Joseph	252,000	400,000
Kansas City	548,000	512,000
Boonville	612,000	603,000
St. Charles	730, 000	634,000

Flood Control Act of 1941.

The Flood Control Act of 1941 approved a plan providing for erosion protection works in the vicinity of Sioux City, Iowa. It also provided for levee protection against floods of the approximate magnitude of the flood of July 1938 for agricultural lands along both banks of the Missouri River between Sioux City and Kansas City. It established a floodway 3,000 to 4,000 feet in width except at isolated restricted points.

Flood Control Act of 1944.

The Flood Control Act of 1944 authorized a series of levees and appurtenant works along both sides of the Missouri River from the vicinity of Sioux City, Iowa to the vicinity of the mouth of the Missouri River. Proposed floodway widths were recommended in the report that would vary from a minimum of 3,000 feet from Sioux City, Iowa to Kansas City, Missouri to 5,000 feet from Kansas City, Missouri to the mouth. Also proposed in the report, were earthfill agricultural levees with two feet of freeboard above the design flood after settlement.

Missouri River Levees, Definite Project Report (1947).

During 1946-1947 a comprehensive hydrologic study of the Missouri River agricultural levees were made as part of the Definite Project Report (DPR). This DPR presented a plan for protection of about 1.5 million acres of agricultural land between Sioux City and the mouth of the Missouri River by a system of levees, supplemented by reservoirs, to protect the area against floods at least equal to or in excess of the highest floods of past record. Design flows for the levees above St. Joseph were based on studies of critical combinations of flows from past floods, runoff from transposed storms, and moderate releases from the main stem reservoir system. At and below St. Joseph the levee design flows were based on the expected one percent chance flood, assuming tributary reservoirs were in place, but without the reservoirs on the main stem of the Missouri. The initially recommended design flows are listed in Table F-2.

Table F-2
Missouri River Design Flows (1947 Study)

Station	Drainage Area (sq mi)*	Design Discharge (cfs)
Sioux City	314,617	150,000
Decatur	316,140	167,000
Omaha	322,820	250,000
Nebraska City	414,420	295,000
Rulo	418,905	310,000
St. Joseph	424,340	325,000
Kansas City	489,162	431,000
Waverly	491,230	437,000
Boonville	505,710	475,000
Hermann	528,200	529,000

* Note that drainage area revision since the 1947 study has revised tabulated values.

Floodway widths between levees varied from 3,000 feet at Sioux City to 5,000 feet at Hermann. Levee freeboard of two feet was used for the design of agricultural levees.

Mississippi Basin Model Studies.

A number of model studies have been conducted for the Missouri River below Sioux City, Iowa by the Waterways Experiment Station (WES) using the Missouri River portion of the Mississippi Basin Model (MBM). In general, model studies were conducted to assist in evaluating the effect of levee confinement on flood peaks and water surface profiles, freeboard requirements for dynamic effects, travel time of flood peaks, water surface profiles for various flood and floodway conditions, the effects of railroad and highway fills on flood heights, the effects of channel cutoffs on water surface profiles, and the timing and magnitude of flood peaks and probable areas of flooding for assisting flood fighting operations. Results of these studies are contained in numerous MBM reports prepared by WES.

Main Stem Flood Control Benefits Re-evaluation (1956).

In 1950, investigations and studies were initiated which led to the preparation of the Re-evaluation of Main Stem Flood Control Benefits Report, Missouri River dated February 1956. This report presented the results of the studies used to determine the flood damages on the bottom lands of the main stem of the Missouri River from Fort Peck Dam in Montana to the confluence with the Mississippi River at St. Louis, Missouri. In general, this report re-evaluated the flood damages that would result under several conditions of reservoir and levee construction and allocated the resulting benefits to the various features of the flood control program. A comprehensive reanalysis of streamflow probabilities was made using available stream discharge or stage data which extended back into the 1870's for the key gaging stations in the reach of the Missouri River between Sioux City and the mouth.

Missouri River Agricultural Levee Restudy Program (1962).

This study developed hydrologic data, flood damages and benefits for the Missouri River Agricultural Levee Restudy Program which was directed in September 1959 by the Chief of Engineers to determine which levee units, or group of physically interrelated levee units would provide benefits equal to or in excess of their costs. The hydrologic studies covered the entire reach from Sioux City, Iowa to the mouth of the Missouri River. Hydrologic data developed as part of this study included flow hydrographs, annual peak discharge probability curves, stage-discharge rating curves, evaluation of levee confinement effects, and effects of reservoir control. These data were developed for nine key stream gaging stations on the main stem of the Missouri River from Sioux City, Iowa to Hermann, Missouri. The discharge frequency relationships derived for this study are shown in Table F-3. Although eight different conditions were analyzed as part of this study, the values shown in the table are for condition VI. Condition VI represents existing and near future reservoirs (except Grand River reservoirs) in operation, Federal Agricultural levees constructed above Kansas City, and a 3,000 foot minimum floodway between levees below Kansas City.

Table F-3
Missouri River Discharge-Frequency Based on 1962 Study

LOCATION	50 %	10 %	2%	1%
Sioux City	44,000	65,000	82,000	90,000
Omaha	74,000	125,000	170,000	190,000
Nebraska City	108,000	160,000	200,000	220,000
Rulo	117,000	170,000	220,000	241,000
St. Joseph	120,000	187,000	246,000	270,000
Kansas City	150,000	270,000	375,000	425,000
Waverly	158,000	285,000	395,000	445,000
Boonville	195,000	365,000	495,000	550,000
Hermann	220,000	405,000	555,000	620,000

REPORT FORMAT

The report is organized into a main report that gives a general overview of the Mississippi River Basin and study approach including flood distribution selection, quality assurance/quality control, public involvement and coordination. Each of the five COE Districts within the Upper Mississippi River Basin (MVP, MVR, MVS, NWO and NWK) will have an appendix summarizing their hydrologic and hydraulic analysis. Appendix A is developed by the Hydrologic Engineering Center (HEC) and provides a detailed summary of the technical procedures adopted for the study and the efforts made to assure regional consistency of the frequency relationships and flood profiles between the districts.

ACKNOWLEDGEMENTS

The Corps of Engineers and the Omaha District would like to thank the numerous Federal, State, and Local government agencies for their involvement and the public for their support and comments throughout the course of this very complex and comprehensive investigation. Without your support this study would not have been successful.

BASIN DESCRIPTION

The Missouri River rises along the Continental Divide in the northern Rocky Mountains and flows generally easterly and southeasterly to join the Mississippi River near St. Louis Missouri. The river drains approximately 9,700 square miles of Canada and 513,300 square miles or one-sixth of the contiguous United States. Its headwaters begin near Three Forks, Montana where the Madison River, the Jefferson River and the Gallatin River join to form the Missouri River. From there it travels 2,315 miles to its confluence making it the longest river in the United States. Basin topography varies from the 56,000 square miles in the Rocky Mountain area in the west, where many peaks exceed 14,000 feet in elevation, to the approximately 370,000 square mile Great Plains area in the heartland of the basin, to the 90,000 square mile Central Lowlands in the lower basin where the elevation is 450 NGVD near the mouth at St. Louis, Missouri. The Black Hills in South Dakota and the Ozarks in Missouri, consisting of 13,000 square miles, are isolated dome like uplifts that have been eroded into a hilly and mountainous topography. Stream slopes vary from about 200 feet per mile in the mountains to about 0.9 foot per mile in the Great Plains and Central Lowlands.

Major Missouri River tributaries are the Yellowstone River, which drains an area of 70,000 square miles, joining the Missouri River near the Montana-North Dakota border; the Platte River with a 90,000 square mile drainage area entering the Missouri River in eastern Nebraska; and the Kansas River which empties into the Missouri River in eastern Kansas and drains an area of approximately 60,000 square miles. A prominent feature in the drainage pattern of the upper portion of the basin is that every major tributary, with the exception of the Milk River, is a right bank tributary flowing to the east or to the northeast. Only in the extreme lower basin, below the mouth of the Kansas River, is there a fair balance reached between left and right bank major tributaries. The direction of flow of the major tributaries is of particular importance from the standpoint of the potential concentration of flows from storms that typically move across the basin in an easterly direction. It is also important in another respect on the Yellowstone River, since early spring temperatures in the headwaters of the Yellowstone and its tributaries are normally from 8 to 12 degrees Fahrenheit higher than along the northern most reach of the Missouri near the Yellowstone confluence. This ordinarily results in ice breakup on the Yellowstone prior to the time the ice goes out of the Missouri River, thereby contributing to ice jam floods along the Missouri River downstream from the confluence to near Williston, North Dakota.

The broad range in latitude, longitude, and elevation of the Missouri River basin and its location near the geographical center of the North American Continent results in a wide variation in climatic conditions. The climate of the basin is produced largely by interactions of three great air masses that have their origins over the Gulf of Mexico, the northern Pacific Ocean, and the northern polar regions. They regularly invade and pass over the basin throughout the year, with the Gulf air tending to dominate the weather in summer and the polar air dominating in winter. This seasonal domination by the air masses and the frontal activity caused by their collisions produce the general weather regimens found within the basin. As is typical of continental-interior plains area, the variations from normal climatic conditions from season to season and from year to year are extreme. The outstanding climatic rarity in the basin was the severe drought of the 1930's when excessive summer temperatures and subnormal precipitation continued for more than a decade.

Streams having their source in the Rocky Mountains are fed by snowmelt. They are clear flowing and have steep gradients with cobble-lined channels. Stream valleys often are narrow in the mountains onto the outwash plains. Flood flows in this area are generally associated with the snowmelt runoff period occurring in May and June. Occasionally, summer rainfall floods having high, sharp peaks occur in the lower mountainous areas, such as the Rapid City flood in June 1972 and the Big Thompson River flood in July 1976.

Streams flowing across the plains area of Montana, Wyoming, and Colorado have variable characteristics. The larger streams with tributaries originating in the mountain areas carry sustained spring and summer flows from mountain snowmelt, and they have moderately broad alluvial valleys. Streams originating locally often are wide, sandy-bottomed, and intermittent, and they are subject to high peak rainfall floods.

In the plains region of North and South Dakota, Nebraska, and Kansas with the exception of the Nebraska sand hills area, streams generally have flat gradients and broad valleys. Except for the Platte River, most of the streams originate in the plains area and are fed by snowmelt in the early spring and rainfall runoff throughout the warm season. Stream flow is erratic. Stream channels are small for the size of the drainage areas, and flood potentials are high. When major rainstorms occur in the tributary area, streams are forced out of their banks onto the broad flood plains.

In the regions east of the Missouri River, streams have variable characteristics. Those in the Dakotas, such as the Big Sioux and James Rivers, are meandering streams with extremely flat gradients and very small channel capacities in relation to their drainage areas. These areas are generally covered with glacial drift and contain many pothole lakes and marshes. Rainfall in the spring often combines with the annual plains snowmelt to produce floods that exceed channel capacities and spread onto the broad flood plains.

Streams in the Ozark Highlands of Missouri resemble mountain streams with their clear, dependable base flows. Much of the area is underlain by limestone, and there are cavernous underground springs. The hilly terrain produces high peak runoff, which contributes to frequent floods with large volumes due to this area’s higher annual rainfall.

WATERSHED CHARACTERISTICS

Because the basin is so vast and was influenced by a variable geologic historical development, it is best to describe the basin in sections. There are three major physiographic divisions within the Missouri Basin -the Interior Highlands, the Interior Plains, and the Rocky Mountain System. The Rocky Mountain System division includes parts of the Northern Rocky Mountains, Middle Rocky Mountains, Wyoming Basin, and Southern Rocky Mountains provinces. The Interior Plains division includes parts of the Great Plains and Central Lowlands provinces. Sections and subsections within the Great Plains province include such distinct topographic features as the Black Hills in South Dakota and Wyoming, and the Sand Hills in Nebraska. The Interior Highlands division is characterized by the Ozark Plateaus province, but will not be discussed further here as it lies within Kansas City District.

The Rocky Mountain System forms the western boundary of the basin and reflects an exceptionally rugged topography, with numerous peaks surpassing 14,000 feet in elevation. The approximately 55,000-square-mile mountainous area is punctuated with many high valleys, but the peaks and mountain spurs dominate the physical features.

Extending eastward from the Rocky Mountain System division is the Interior Plains division that characterizes the major portion of the Missouri Basin. The Interior Plains division can be divided into two areas - the Great Plains and Central Lowlands provinces. The Great Plains province is a 360,000-square-mile area that forms the heartland of the basin. The eastern boundary of this province lies approximately along the 1500-foot contour, and the western boundary lies at the foot of the Rocky Mountain System, averaging about 5,500 feet in elevation. Average slopes from west-to-east are about 10 feet to the mile. South and west of the Missouri River the surface mantle and topography have been developed largely by erosion of a fluvial plain extending from the mountains. The alluvial outwash laid down a heterogeneous mixture of mantle material. Simultaneous and subsequent water and wind erosion of the mantle produced a variable topographic relief, dependent on variations in climate and erodibility of the mantle. That portion of the Great Plains province north and east of the Missouri River, and at places extending south of the river, has been influenced by continental glaciation. Here the topography was shaped mainly by erosion of the glacial drift and till. Morainic drift belts are in evidence and large boulders abound. Some relatively uneroded glacial debris remains as the ice left it, piled in hummocks without order and enclosing many shallow basins, ponds, and swamps.

Within the Great Plains province are isolated mountainous areas developed by erosion of dome-type uplifts. Principal among these are the Black Hills in western South Dakota and northeastern Wyoming, an elliptical-shaped area 60 miles wide and 125 miles long. Another distinctive area within the province is the Sand Hills in north-central Nebraska, covering about 24,000-square-miles.

The Central Lowlands province, within the Interior Plains division, borders the Great Plains province to the east, but generally there is no perceptible line of demarcation between them. This roughly 88,000-square-mile area extends between a line from Jamestown, North Dakota, to Salina, Kans., and the Mississippi River drainage divide. This entire area has been developed by erosion of a mantle of drift and till deposited by the continental glaciers. An abundance of rainfall and stream development has created a hilly topography in many places, but especially in the southern portion of the province.

CLIMATOLOGY

The climate within the basin is determined largely by the interaction of three great air masses that have their origins over the Gulf of Mexico, the northern Pacific Ocean, and the northern polar regions. They regularly invade and pass over the basin throughout the year, with the gulf air tending to dominate the weather in summer and the polar air dominating in winter. It is the seasonal domination of the air masses and the frontal activity caused by their colliding with each other that produces the general weather regimens found within the basin.

A major factor affecting the climate is the remoteness of the basin from the source areas of the air masses. This means that the air masses have to cross vast areas before they reach the basin. In crossing these areas they leave much of their available precipitation, and their air temperatures are changed considerably by radiation from the land surface.

Primarily because of its midcontinental location, the basin experiences weather that is known for fluctuations, extremes, and variability within the basin. Winters are relatively long and cold over much of the basin, while summers are fair and hot. Spring is cool, moist and windy; autumn is cool, dry and sunny. Weather tends to fluctuate widely around annual averages, with the occurrence and degree of the fluctuations being unpredictable. Thus the climatic averages have to be thought of as generalizations of the more common occurrences over a period of time.

Average annual precipitation varies from over 40 inches in parts of the Rocky Mountains and southeastern parts of the basin, to as low as 6 to 12 inches immediately east of the Rocky Mountains. Complicating the annual variations, there is a wide variation in the basinwide pattern of monthly precipitation.

Precipitation received from November through March generally is in the form of snowfall. Thunderstorms are prevalent in May through August and often are localized, with high-intensity rainfall. Prolonged droughts and lesser periods of deficient moisture may be interspersed with periods of abundant precipitation.

There are periods of extremely cold winter and hot summer temperatures in the basin. Extremes range from winter lows of - 60 F. in Montana to summer highs of up to 120 F. in Nebraska, Kansas, and Missouri. The basin regularly experiences over 100-degree temperatures in summer and below-zero temperatures in winter over most of its area.

Winds in the basin are the rule rather than the exception, particularly in the plains area. Average wind velocities of 10 miles per hour are prevalent over much of the basin. In the plains area strong winds accompanied by snow sometimes create "blizzard" conditions. High winds occasionally prevail during periods of high temperatures and deficient moisture that can destroy crops and desiccate rangeland within a few days.

FLOOD HISTORY

Prior to development of flood control reservoirs on the upper Missouri River basin, the Missouri River was a source of frequent flooding. In the plains areas of the upper basin, almost all large floods are caused by snowmelt. Rainfall becomes progressively a greater factor in flooding as the focus shifts from northern and western to southern and eastern drainage areas. Following is a narrative of some of the significant floods in the Missouri River basin.

Flood of 1844.

The flood of 1844 was of great magnitude throughout practically the entire Missouri River basin. Very little is known of the exact behavior of the flood except that it was caused by abnormally high rainfall over that portion of the basin lying in the humid zone, coincident with an extraordinary June rise from the upper part of the basin. The crest exceeded flood stage at various points from 12 to 17 feet. Estimated peak discharges were St. Joseph 350,000 cfs, Kansas City 625,000 cfs, Boonville 710,000 cfs, and Hermann 892,000 cfs. These discharges were the greatest ever estimated at Kansas City and Hermann.

Flood of 1881.

Following a wet year in 1880, the winter of 1880-1881 was marked by below normal temperatures and heavy snows, resulting in an exceedingly heavy snow blanket over the plains area of the upper Missouri River Basin by spring and resulting in river ice thickness of 24 to 32 inches in the vicinity of Yankton and Omaha. Spring thaws and ice breakup began in the upper basin while the lower river was still frozen, resulting in huge ice gorges in the Dakotas. The jam near Yankton were especially devastating, as the jam was estimated to be over 30 miles in length and produced a peak stage 15 feet higher than any other flood at Yankton. The April 1881 peak discharge from Sioux City to St. Joseph was the highest of record until 1952 when it was exceeded by another plains snowmelt flood. Estimated peak discharge at St Joseph was 370,000 cfs; the volume of the flood was estimated at over 40 million acre-feet at Sioux City, Iowa.

Flood of 1903.

The flood of 1903 was caused by prolonged and heavy rainfall over the lower Kansas River basin coinciding with the June rise from the upper Missouri basin. Tributary inflow below Kansas City materially increased the discharges, but the principal tributaries, such as the Grand, Osage, and Gasconade, were considerably below the maximum stages of record. Very little overflow occurred between St. Joseph, Missouri, and Atchison, Kansas. Below Atchison the flooding was more general, and below Kansas City, Missouri, the flood waters extended from bluff to bluff. Approximately 615,000 acres of agricultural land were inundated. Estimated peak discharges were St Joseph 252,000 cfs, Kansas City 548,000 cfs, Boonville 612,000 cfs, and Hermann 676,000 cfs.

Flood of 1951

The spring and summer of 1951 was a period of excessive rainfall over the Kansas River basin which culminated in an exceptionally heavy downpour during the 4-day period 9-13 July. The Kansas River crest fortunately coincided with a low flow out of the upper Missouri River, and there was no flooding, except from backwater, on the Missouri River above Kansas City. Several of the Federal levee units at Kansas City were overtopped. Below Kansas City, the entire Missouri River valley was flooded to depths up to 20 feet. The peak discharge at Kansas City of 573,000 cfs was the highest since the 1844 flood.

Flood of 1952.

The following spring, in March-April 1952, a flood of exceptional magnitude and severity on both the Missouri River itself and most of its plains area tributaries at and above Sioux City, Iowa, was generated from rapid snowmelt over the plains areas of the upper basin. On the Missouri River, flooding was continuous from the Yellowstone River in Montana to the mouth. Between Williston, North Dakota, and St. Joseph, Missouri, with the exception of isolated localities where past ice jams have occurred, this flood reached unprecedented heights.

The 1952 flood was caused exclusively by melting snow because rainfall over the basin prior to and during the flood was light. The winter of 1951 and 1952 produced one of the heaviest plains snow covers in history. Significant snow cover extended over almost all of the Dakotas and the Yellowstone river basin in Montana. Snow surveys taken in March indicated a 2.4 inch water content over 10,000 square miles of the Yellowstone River basin. Water equivalents as high as 3.6 inches were reported in the Grand River basin of North and South Dakota. Up to 6.0 inches of water content was present in the lower Grand, lower Moreau, and eastern Big Sioux River basins. The great magnitude of the flood can be attributed to the unusual areal cover of the accumulated snow cover, the high water content of the snowpack, the rapidity at which the snow melted, and the presence of an ice layer under the snow which allowed for rapid runoff. At and below Kansas City, because little water was being added from tributary areas, the flood, although still severe, became less than the maximum of record. Peak discharges at Sioux City 441,00 cfs, Omaha 396,000 cfs, Nebraska City 414,000 cfs, Rulo 358,000 cfs and St Joseph 397,000 cfs were the highest discharges ever recorded. The 1952 flood caused an estimated $200 million in damages.

Flood of 1967.

The flood of 1967 is of particular interest within the Missouri River basin because it was the first major flood occurring after the initial filling of the main stem reservoir system. The reservoirs did help reduce flooding during the flood of 1960, but the reservoir system was not full, and system operations as we see them today did not begin until 1967. Above normal runoff originated from three primary sources during 1967, plains snowmelt, mountain snowmelt, and intense summer rainfall.

In the Missouri River headwaters of Montana and Wyoming, mountain snows accumulated at a greater than normal rate. While the mountain snows were accumulating, flood discharges occurred in March and April resulted from rapid plains snowmelt caused by a sustained period of warm temperatures over a large portion of the basin. Water content over much of the upper basin was high and combined with frozen saturated soils; therefore, little infiltration occurred as the snowpack melted. Snowpack water content in the lower basin was somewhat less, but soil conditions were similar and melting snows produced discharges higher than those normally expected. By May of 1967 many mountain snow courses were reporting record high-water contents. During late May and early June, heavy upper basin rainfall coinciding with mountain snowmelt resulted in the third highest May through June runoff volume above Sioux City, Iowa. During June of 1967, intense rains over Nebraska, Kansas, and Missouri caused severe flooding along many tributaries and the Missouri River from the Platte River confluence downstream to the mouth.

However, operation of the main stem system reduced the flood peak at Sioux City, Iowa, by almost 200,000 cfs and eliminated Missouri River flood damages from Fort Peck Dam in Montana to the mouth of the Platte River in Nebraska. Flooding primarily occurred on the Missouri River within the Omaha District from Omaha downstream to Rulo, Nebraska. The volume of Missouri River inflow into the main stem system was the highest of record for the month of March since 1898. It was estimated that the main stem system reduced flood peaks by as much as 10 feet in the lower Missouri River.

Flood of 1984.

The flood of 1984 had its beginnings in late spring when heavy, wet snow and rain fell over a large area of southern South Dakota through Nebraska, Kansas, and Missouri. Persistent rains continued through April producing the highest April runoff volumes upstream from Sioux City since record keeping began in 1889. The weather pattern that caused the record and near record flooding in the lower Missouri River basin in 1984 consisted of warm moist air from the Gulf of Mexico funneled into the central United States by a strong ridge of high pressure located over the east coast. A series of upper air disturbances coupled with polar cold fronts and warm Gulf air produced a series of intense rainfall events covering much of the lower Missouri River basin. This intense rainfall fell over a wide area already saturated from heavy April and May rainfall.

During early June, the heaviest rainfall occurred in the lower basin over northwest Missouri and southeast Nebraska. Average rainfall amounts of 3 to 4 inches on the night of June 12 were reported over a large area of eastern and central Nebraska, with localized areas reporting as high as 7 to 8 inches. This storm caused record floods on many of the smaller tributaries and produced the highest stages since 1952 on the Missouri River from the confluence of the Platte River to St. Joseph, Missouri. During mid and late June, the intense rainfall pattern shifted north over the Dakotas. Rainfall amounts exceeded 7 inches over South Dakota on June 18 and 19 with an additional 4 inches on June 20. This rainfall produced record and near record stages on many southeast South Dakota tributaries and produced the highest Missouri River stages since 1952 from Sioux City, Iowa to Omaha, Nebraska.

Flood of 1993

Much of the eastern and southern Missouri River basin in Iowa, Nebraska, South Dakota, Kansas and Missouri had soil moisture conditions wetter than normal going into the summer of 1993. This was primarily due to the above average precipitation received in the last half of 1992 and the spring of 1993. Much of the late winter, including the 2-week period prior to the warmup that started the spring flooding in Nebraska was dominated by an upper level atmospheric pattern that favored storms followed by cold weather. The subpolar jet generally ran from northwest to southeast across the Rockies and the southern Plains.

During January and February, occasional polar outbreaks of bitterly cold air invaded the central Plains as the polar jet stream was forced south into the Plains by strong low pressure in the upper atmosphere over Hudson Bay. A strong overrunning pattern from the eastern Pacific brought ample upper level moisture to the Midwest to feed the surface storms moving off the central Rockies, often producing freezing rain in the cold air below. At the end of February the subpolar jet stream ran from west to east across the southern states.

By March 1, a vigorous cutoff low formed over New Mexico and moved northeastward, setting the stage for the additional precipitation that fell over the Platte River basin in Nebraska just prior to the melt. By March 5, the subpolar jet began to shift east and lift north as a weak high pressure ridge began to build in the upper atmosphere off the coast of California. This pattern edged the storm track north of Nebraska and began the thaw. High temperatures warmed from the 30's to the 40's and clouds gave way to sunshine between March 2 and 7. On March 8, the jet stream ran directly over eastern Nebraska on its eastward journey, allowing warmer air to pour across the frozen watersheds. High pressure built over the Rockies, strengthening the warmup. On March 9, daytime high temperatures pushed into the upper 40's and low 50's across the region, with nighttime lows near freezing. The snow continued to melt rapidly, until much of east and central Nebraska had lost its snow cover with only an inch or two remaining in extreme northeast Nebraska by March 10.

By early June a stationary high pressure system was located over the southeast United States and a stationary low pressure system was located over the northwest. The location of these two systems created a boundary or convergence zone where the jet stream, which dipped to the south over the western United States, was forced in a northeasterly direction through the Midwest. The thunderstorms that persisted in the Midwest through July were caused by the mixing of warm moist tropical air with unseasonably cool, dry air from Canada in this convergence zone. Chain reacting tropical storms off the western coast of Mexico during this period funneled moisture into the jet stream aimed at the Midwest. This convergence zone moved back and forth from the Dakotas, Minnesota, and Wisconsin to Kansas, Missouri, and Illinois producing more than twice the normal rainfall in much of the Missouri River basin east of the 100th meridian.

The precipitation was not only very heavy but also very persistent. Rain fell somewhere in the Missouri River basin every day from March 14 through July 29. During the period of June 1 to July 27, rainfall occurred on 34 out of 57 days at Omaha, Nebraska. The most severe flooding since 1952 occurred on the Missouri River from the confluence of the Platte River to the mouth. Within this reach, record or near record peak discharges were experienced during the period of July 23-31. On July 23-24, a record crest of the Missouri River overtopped federal levee L-550 near Brownville, Nebraska. On July 24, the St. Joseph Airport Levee Unit R-471-460 overtopped. On July 26, levee units L-400 and L-246 overtopped.

Flood of 1997

Runoff in the Missouri River basin upstream from Sioux City totaled 49.6 million acre-feet during calendar year 1997, the highest annual runoff in 100 years of record. This is nearly double the average of 24.8 million acre-feet and nearly 20 percent higher than the previous record runoff that occurred in 1978.

Record flooding occurred on the main stem of the Missouri River upstream from Canyon Ferry Reservoir and downstream of Canyon Ferry Reservoir to the confluence with the Sun River. In addition, the highest flows since the main stem reservoir system went into operation were experienced below Oahe Reservoir, Fort Randall Reservoir and Gavins Point Reservoir. Below Garrison the second highest releases on record occurred, while at Fort Peck, the releases reached the fourth highest on record.

Above Canyon Ferry Reservoir at Toston, Mt, the peak stage of 12.22 feet on June 12, exceeded the previous record stage that occurred in 1948 by about 0.5 feet. The estimated peak discharge of 33,300 cfs was also the highest on record. Downstream from Canyon Ferry Reservoir at Ulm, the peak stage of 15.20 feet exceeded the previous record stage that occurred in 1981 by about 0.2 feet. The estimated peak discharge at Ulm of 27,900 cfs was the second highest on record.

Upstream from Fort Peck Reservoir at Virgelle, the peak stage of 12.29 feet on June 16 was more than 11 feet below the record stage set in 1953. Downstream from Fort Peck at Culbertson, the peak stage of 17.52 feet on March 31 was about 2 feet below the record set in 1979. Upstream from Garrison Reservoir at Williston, the peak stage of 26.1 feet on June 26 was within 0.5 feet of the record stage set in 1994. With the second highest releases of 59,000 cfs from Garrison Reservoir, the peak stage climbed to 14 feet at Bismarck on July 25, within 0.8 foot of the highest stage experienced since construction of Garrison Dam, but well below the pre-dam record stage of 27.9 feet set in 1952. Record releases of 59,500 cfs from Oahe Dam pushed the peak stage at Pierre to almost above 12.5 feet during parts of April, July and August but below the peak ice-affected stage of 12.9 feet that occurred on January 10. At Yankton, the highest discharge since the construction of the main stem dams of 70,000 cfs was experienced through much of the fall during October, November and early December while evacuating the flood storage resulting from the Missouri River Main Stem Reservoir System.

At Sioux City and Omaha, the Missouri River remained well below flood stage. However, low lying agricultural areas adjacent to the river experienced flooding and drainage problems throughout the spring, summer and fall. Without the Missouri River Main Stem Reservoirs, the peak stage at Omaha of 26.4 feet on April 15 would have been about 13.1 feet higher which would have been only 0.7 feet below the record stage set in 1952. Below the confluence of the Platte River, the Missouri River exceeded flood stage for much of the April through July period. At Nebraska City, the peak stage of 21.06 feet occurred on April 18. This stage was about 3 feet above flood stage. Without the main stem reservoirs, the peak stage would have been about 10 feet higher, which would have exceeded the record stage set in 1952 by more than 3 feet.

Record floods also occurred on the James River in North and South Dakota, the upper Big Sioux River, the upper Yellowstone River, and the Moreau River as a result of melting of the unusually heavy snowpacks in those basins. Most tributaries in Montana, North Dakota, and South Dakota experienced stages exceeding flood stage. Record pool elevations occurred at the Fort Randall, Pipestem and Jamestown projects.

Flood fight efforts and Advance Measures projects constructed by the corps prevented $100 million in flood damages. The Missouri River Main Stem Reservoirs prevented $ 5.2 billion in flood damages. Other Corps Projects prevented over $ 300 million in flood damages.

There are many other notable floods in the upper Missouri River basin that are confined to smaller areas of the basin, but did not have a large impact on the mainstem. Their omission from this report in no way minimizes the impact or severity of these floods.

WATER RESOURCES DEVELOPMENT

Water resources development in the Missouri River basin has been dramatic over the past 150 years. Significant periods of development were prior to 1910 and since 1949. Early water resource developments were oriented largely towards single-purpose improvements to meet specific needs without substantial regard for other potential functions. However, as the region's demand for water resources grew, and technology improved, multi-purpose programs became more prevalent.

Flood Control Reservoirs

Numerous reservoirs and impoundments constructed by different interests for flood control, irrigation, power production, recreation, water supply, and fish and wildlife are located throughout the basin. The Bureau of Reclamation and the Corps of Engineers have constructed the most significant of these structures. Although primarily constructed for irrigation and power production, the projects constructed by the Bureau of Reclamation do provide some limited flood control in the upper basin. Six main stem dams constructed by the Corps are the most significant authorized flood control projects within the basin, providing a combined capacity in excess of 73.5 million acre-feet of which more than 16 million acre-feet is for flood control. These six projects were completed in 1964 and provide flood protection by controlling runoff from the upper 279,000 square miles of the Missouri River basin.

The flood control storage zones in the Missouri River main stem reservoirs were designed in a series of Detailed Project Reports in the mid-1940's to provide control of the severe 1881 flood, with maximum releases of about 100,000 cfs from all projects other than Fort Peck and with maximum pools at or near the top of the exclusive flood control storage space. The 1881 flood inflows were based on estimates of what actually occurred, without reduction to allow for operational effects of upstream tributary reservoirs or for consumptive use by upstream irrigation and other purposes. If the flood runoff were to recur today, its severity as far as the main stem reservoir designs are concerned would be significantly reduced by these factors. On the other hand, regulation criteria used in the 1881 reservoir design studies were based largely on hindsight, with little regard for downstream runoff conditions. Releases of approximately 100,000 cfs were assumed to be made from mid-April to mid-July from the five lowermost reservoirs, without any requirement for reducing releases to desynchronize with downstream flood peaks.

Regulation of the main stem reservoir system follows a repetitive annual cycle. Winter snows and spring and summer rains produce most of the year’s water supply, which results in rising pools and increasing storage accumulation. After reaching a peak, usually during July, storage declines until late winter when the cycle begins anew. A similar pattern may be found in rates of releases from the system, with the higher levels of flows from mid-March to late November, followed by low rates of winter discharge from late November until mid-March, after which the cycle repeats.

Two primary high-risk flood seasons are the plains snowmelt season extending from late February through April and the mountain snowmelt period extending from May through July. Overlapping the two snowmelt flood seasons is the primary rainfall flood season, which includes both upper and lower basin regulation considerations. The highest average power generation period extends from mid-April to mid-October with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August). The power needs during winter are supplied primarily with Fort Peck and Garrison releases and the peaking capacity of Oahe and Big Bend.

During the spring and summer period, releases are geared to navigation and flood control requirements and primary power loads are supplied using the four lower dams. During the fall when power needs diminish, Fort Randall pool is drawn down to permit generation during the winter period when the pool is refilled by Oahe and Big Bend peaking power releases. The major maintenance period for the main stem power facilities extends from mid-February through May and from September to mid-November which normally are the lower demand and off-peak energy periods. The exception is Gavins Point where maintenance is performed after the end of the navigation season since all three power facilities are normally required to provide navigation flow needs.

Normally, the navigation season extends from April 1 through December 1 during which time reservoir releases are increased to meet downstream target flows in combination with downstream tributary inflows. Much of the increased flow for navigation comes from the large carryover storage in Oahe Reservoir. Winter releases after the close of navigation season are much lower and vary depending on the need to conserve or evacuate main stem storage volumes, downstream ice conditions permitting. Minimum release restrictions and pool fluctuations for fish spawning management generally occur from April 1 through July. Endangered and threatened species including the interior least tern and piping plover nesting occurs from early May through August. During this period, special release patterns are made from Garrison, Fort Randall, and Gavins Point to avoid flooding nesting sites on low-lying sandbars and islands downstream from these projects.

Overall, the general regulation principles presented above provide the backbone philosophy for main stem system regulation. Detailed operation plans are developed, followed and adjusted as conditions warrant periodically as the system is monitored day-to-day. Beginning in 1953, projected operation of the Missouri River main stem reservoir system for the year ahead was developed annually as a basis for advance coordination with the various interested Federal, State, and local agencies and private citizens. These regulation schedules are prepared by the Reservoir Control Center, Missouri River Region, Northwest Division, Corps of Engineers.

In addition to the six main stem projects operated by the Corps, 65 tributary reservoirs operated by the Bureau of Reclamation and the Corps provide over 15 million acre-feet of flood control storage. Tables F-4 and F-5 list the mainstem and tributary flood control projects operated by the Corps of Engineers and the Bureau of Reclamation. The Bureau of Reclamation operates many additional reservoirs for irrigation and power production, which provide incidental flood control benefits.

Additional storage can be found in many other reservoirs throughout the Omaha District. However, only a few have significant enough storage as to impact flow peaks downstream of Gavins Point Dam. Hebgen Lake, Gibson Reservoir, Fresno Reservoir, Angostura Reservoir, and North Platte reservoirs in aggregate are the only reservoirs with significant non-flood control storage to be considered for this study.

Table F-4. Corps of Engineers Reservoirs in Missouri Basin.

Project Name	River or Stream Located On	Date of Closure	Total Storage Volume, acre-feet	Flood Control Storage, acre-feet
Fort Peck	Missouri River	June 24, 1937	18,688,000	3,692,000
Garrison	Missouri River	April 15, 1953	23,821,000	5,711,000
Oahe	Missouri River	August 3, 1958	23,137,000	4,303,000
Big Bend	Missouri River	July 24, 1963	1,859,000	177,000
Fort Randall	Missouri River	July 20, 1952	5,494,000	2,301,000
Gavins Point	Missouri River	July 31, 1955	492,000	152,000
Bowman-Haley	North Fork Grand River	August 1966	91,482	72,717
Cold Brook	Cold Brook	September 1952	7,200	6,680
Cottonwood Springs	Cottonwood Springs Creek	May 1969	8,385	7,730
Cedar Canyon	Deadmans Gulch	1959	136	123
Bull Hook Scott Coulee	Bull Hook Creek	1955	6,500	6,500
Pipestem	Pipestem Creek	July 1973	146,880	137,010
Papio Creek (10 dams)	Papillion Creek	1972-1984	42,237	31,323
Cherry Creek	Cherry Creek	October 1948	135,647	122,842
Chatfield	South Platte River	August 1973	235,098	206,945
Bear Creek	Bear Creek	July 1977	30,684	28,757
Kelly Road	Westerly Creek	1953	360	360
Westerly Creek	Westerly Creek	1991	4,150	4,150
Salt Creek (10 dams)	Salt Creek	1963-1973	189,933	139,462
Harlan County	Republican	1951	825,782	496,718
Milford	Republican	1964	1,145,485	756,669
Tuttle Creek	Big Blue	1959	2,257,185	1,922,085
Wilson	Saline	1963	772,732	530,204
Kanopolis	Smoky Hill	1946	418,752	369,278
Perry	Delaware	1966	725,509	515,961
Clinton	Wakarusa	1965	397,538	268,367
Smithville	Little Platte	1976	243,443	101,777
Longview	Little Blue	1983	46,944	24,810
Blue Springs	Little Blue	1986	26,557	15,715
Long Branch	Little Chariton	1976	64,516	30,327
Rathbun	Chariton	1967	545,621	345,791
Melvern	Osage	1970	360,258	208,207
Pomona	Osage	1962	243,102	176,460
Hillsdale	Osage	1980	159,840	83,570
Stockton	Osage	1968	1,650,943	776,066
Pomme De Terre	Osage	1960	644,177	406,821
Harry S Truman	Osage	1977	5,209,353	4,005,949
Total COE Project Storage			90,127,429	28,135,374

Irrigation Development

Irrigation first appeared in the Missouri Basin about 1650 by the Taos Indians along Ladder Creek in northern Scott County, Kansas. 'Modern' irrigation appeared in the basin in the 1860s, and water use for irrigation and other uses grew rapidly through the remainder of the 19th century and into the early 20th century as agricultural uses of water grew, especially in the more arid western plains. Estimates of irrigation and other use depletions by the U.S. Bureau of Reclamation range as high as 9,000,000 acre-feet by 1920 upstream of Rulo, Nebraska. Irrigation development leveled off for the next 30 years but since has been steadily increasing. According to USBR estimates, irrigation and other depletions have reached 13.5 million acre-feet by the mid-1990s above Rulo, Nebraska. Approximately 60% of the depletions in the Omaha District occur upstream of Sioux City, Iowa.

Table F-5. Bureau of Reclamation Projects Operated for Flood Control.

Project Name	River or Stream Located On	Date of Closure	Total Storage Volume, acre-feet	Flood Control Storage, acre-feet
Clark Canyon	Beaverhead River	June 1964	257,150	79,090
Canyon Ferry	Missouri River	December 1951	2,051,520	99,460
Tiber	Marias River	1952	1,555,960	400,900
Boysen	Wind River	October 1951	952,400	150,400
Yellowtail	Bighorn River	November 3, 1965	1,328,360	258,330
Heart Butte	Heart River	October 4, 1949	223,600	147,900
Shadehill	Grand River	July 1, 1950	357,400	218,300
Keyhole	Belle Fourche River	February 12, 1952	334,200	140,500
Pactola	Rapid Creek	August 1956	99,029	43,057
Jamestown	James River	February 1954	221,000	185,400
Glendo	North Platte River	October 17, 1957	789,400	271,900
Enders	Frenchman Creek	1950	74,520	30,040
Hugh Butler	Red Willow Creek	1961	86,630	48,854
Bonny	S. Fk. Republican	1950	170,160	128,820
Swanson	Republican	1953	246,291	134,077
Harry Strunk	Republican	1949	88,420	52,715
Keith Sebelius	Prairie Dog Creek	1964	134,740	98,805
Lovewell	White Rock Creek	1957	92,150	50,450
Kirwin	N. Fk. Soloman	1955	314,550	215,115
Webster	S. Fk. Soloman	1956	260,740	183,370
Waconda	Soloman	1967	963,775	722,315
Cedar Bluff	Smoky Hill	1950	418,752	191,860
Total USBR Project Storage			11,020,747	3,851,658

Navigation Channel

The Missouri River has served as a form of transportation for centuries. Early fur traders used the river and its tributaries as a means of bringing in goods and exporting their furs. As the westward expansion of the country progressed, the Missouri River was used to transport goods and people to the river towns which served as gateways for wagon routes to the west. As railroads became more prevalent, use of the river for transportation dwindled.

The first river navigation development work consisted of snagging and clearing to remove obstructions which hindered early steamboat traffic. In 1912, Congress authorized a 6-foot channel between Kansas City and the mouth, as well as improvements and maintenance from Kansas City to Fort Benton, Montana. In 1927, Congress authorized the extension of the navigation channel to Sioux City, as well as a study to determine the feasibility of a nine-foot channel. In 1945, Congress finally authorized the nine-foot channel to be constructed to Sioux City. In 1981, the navigation channel project was officially declared finished, with the terminus of the project at River Mile 734.8 at Sioux City.

Levees

The Federal Government had no official role in the construction of flood control projects on the Missouri River during the 19th century. However, landowners, municipalities and the railroads built dikes and levees to protect their properties. After floods of the early 1900s, States in the Missouri River basin authorized local drainage districts to construct flood protection works. Some of the drainage districts came to the Corps of Engineers for assistance in their flood control efforts.

The Missouri River levee system was authorized by the Flood Control Acts of 1941 and 1944 to provide protection to agricultural lands and communities from Sioux City, Iowa to the mouth at St. Louis, Missouri. No Federal levees have been constructed from Gavins Point Dam to the Omaha, Nebraska-Council Bluffs, Iowa, area due to the significant protection afforded this reach by the Missouri River mainstem reservoirs and due to gradual channel degradation through much of this reach. This reach does have non-Federal levees providing varying degrees of protection.

The Federal levee system begins in the Omaha-Council Bluffs metropolitan area, protecting a large urban area. Downstream of Omaha to Rulo, Nebraska, the Federal levee system protects agricultural lands and several small towns. All of these levee units were designed to operate in conjunction in with the six mainstem reservoirs to reduce flood damages. Most Federal levees were constructed in the 1950s and are generally set back from the riverbank 500 to 1500 feet. Federal levees provide left bank protection from river mile 515.2 to 619.7. Right bank levees are intermittent, as the river is often near the bluff. There are a total of 191 levee miles from Omaha, Nebraska to Rulo, Nebraska, of which 133.5 miles are along the Missouri River and 57.5 miles are levee tiebacks.

Following construction of the Federal levee system, farming of the lands riverward of the Federal levees became more extensive. Farmers constructed secondary levees at or near the riverbank to prevent crop damages caused by normal high flows on the Missouri River. Private levees have also been built in those areas where Federal levees were not built. For example, the left bank reach from river mile 515.5 to 498.1 is protected solely by private levees.

HYDROLOGIC ANALYSIS

The hydrologic analysis performed for this study was composed of many steps. In order to provide a homogenous data set from which frequency analysis can be performed, effects of reservoir regulation and stream depletions had to be removed. This produced the data set referred to as the "unregulated flow" data set. A homogeneous "regulated flow" data set was then developed by extrapolating reservoir and stream depletions to current use level over the period of record. A relationship between the annual unregulated and regulated flow peaks was established in order to determine the regulated flow frequency at various points. A more detailed description of the analysis methodology is contained herein.

METHODOLOGY

The following is a brief description of the work performed to estimate the flow frequency for points along the Missouri River.

The existing stream flow data for mainstem gaging stations were extended by converting stage records to discharge through use of old rating curve information at each gage prior to the establishment of USGS gaging records. Discharges had to be estimated or interpolated based on other stations during periods of no stage records at some stations. This extended the period of record for the study back to 1898.

Estimates of historic and current level irrigation water use and other consumptive uses (otherwise referred to as depletions, in sum) were developed by the USBR. The historic level depletions were utilized in estimating the unregulated flow data set, while the current level depletions were used in developing the regulated flow data set.

Historic evaporation and precipitation records were researched and compiled for inclusion in the input data set to the unregulated flow model.

Reservoir regulation data were compiled for inclusion in the input data set to the unregulated flow model.

The unregulated flow computer model was run, using data developed by both Omaha and Kansas City Districts, to determine a daily record of unregulated flows from Yankton, South Dakota to Hermann, Missouri covering the period from January 1, 1898 to December 31, 1997.

Flow frequency analyses were performed on the annual peaks using procedures found in Bulletin #17b. The results indicated the use of a mixed distribution of spring and summer peaks above the Kansas River and the use of annual peaks downstream of the Kansas River.

The regulated flow computer model was run, using data developed by both Omaha and Kansas City Districts, to determine a daily record of regulated flows from Gavins Point Dam to Hermann, Missouri covering the period from January 1, 1898 to December 31, 1997.

The regulated flow frequency curve is determined by transforming the unregulated curve using an unregulated versus regulated relationship. To determine this relationship, annual peaks for regulated and unregulated flows were compared, the regulated flow data being determined at each station by routing studies. The annual peaks from the regulated and unregulated data sets were then paired against each other in descending order. A relationship between regulated and unregulated flow frequencies could then be established at each station.

Volume-duration-probability relationships were determined at each gage using procedures found in this report. The results indicated the use of a mixed distribution for durations up to 30 days above the Kansas River, while an annual distribution was used for longer durations.

DATABASE

Stream flow Records

The first river stage station on the Missouri River was established on January 1, 1872 at Fort Leavenworth, Kansas, which is currently located in the Kansas City District. Within the current boundaries of the Omaha District, the first stage gage on the Missouri River was established on April 10, 1872 at Omaha, Nebraska. Other river stage gages were established at Plattsmouth, Nebraska on April 19, 1873; at Nebraska City on August 1, 1878; and at Sioux City, Iowa on September 2, 1878. These river stage stations were operated by the Corps of Engineers from the date of their establishment to December 31, 1899. On January 1, 1900, the work of securing a record of river stages was taken over by the United States Weather Bureau, who maintained daily river stage records until 1930. At that time, the USGS had taken over the responsibility of collecting and recording river gage records. Available records at key stations are shown in Table F-6.

Gage Description

Descriptions of each gage in the Omaha District used for this study are listed in Appendix F-B, along with descriptions of how flow data were derived from stage data.

Meteorological Records

Meteorological records such as precipitation and evaporation were need for determining unregulated flows, as precipitation and evaporation affect the amount of water in reservoir storage.

Evaporation from large flood control reservoirs is a major loss of water from the basin and must be accounted for in determining unregulated flows. Precipitation on reservoir surfaces must also be accounted for. Since the reservoir surfaces are so much larger than the original channel, precipitation that used to fall on soil and infiltrate into the soil now runs directly into the reservoir, thereby increasing the amount of water in the basin system.

Table F-6. Missouri River Main Stem Streamgage Records

LOCATION	RIVER MILE	DRAINAGE AREA (SQ MI)	GAGE DATUM NGVD	FLOOD STAGE (FT)	CURRENT GAGE OWNER	STAGE	DISCHARGE
Yankton, SD	805.8	279,500	1139.7	32	USGS	1921 – date	1930 - 1995
Sioux City, Ia	732.3	314,600	1057.0	36	USGS	1878 – date	1928-1931 1938 - date
Decatur, Ne	691.0	316,200	1010.0	35	COE	1987-date	None
Blair, Ne	648.3	321,400	987.3	19	COE	1881-1899 1905-date	None
Omaha, Ne	615.9	322,800	948.2	29	USGS	1872-date	1928-date
Plattsmouth, Ne	591.5	323,500	938.8	16	COE	1872-1928 1932-date	None
Nebraska City, Ne	562.6	410,000	905.4	18	USGS	1878-1900 1929-date	1929-date
Rulo, Ne	498.0	414,900	837.2	17	USGS	1929-date	1949-date
St. Joseph, Mo	448.2	420,300	788.2	17	USGS	1873-date	1928--date
Kansas City, Mo	366.1	489,200	706.4	32	USGS	1873-date	1928-date
Waverly, Mo	293.4	491,200	646.0	20	USGS	1879-1900 1915-date	1929-date
Boonville, Mo	197.1	505,700	565.4	21	USGS	1875-date	1925-date
Hermann, Mo	97.9	528,200	481.6	21	USGS	1873-date	1928-date
St. Charles, Mo	28.2	529,200	413.6	25	COE	1878-1899 1917-date	None

Precipitation

Precipitation records were drawn from NWS records available on CD-ROM. Records were drawn from the closest and/or most reliable nearby precipitation station for each reservoir project. The table below shows the data source used to estimate precipitation at each reservoir project.

Table F-7. Precipitation Data Sources Used in UFDM

Project	Date of Closure	Precip Data Source		
		NWS ID	Station	Years
Clark Canyon	1964	2409	Dillon WMCE	1964-97
Hebgen	1915	2409 8857 4038	Dillon WMCE W. Yellowstone Hebgen Dam	1915-24 1925-48 1949-97
Canyon Ferry	1953	1465 1470 4055	Canyon Ferry Canyon Ferry Helena WSO	1953-56 1957-96 1997
Gibson	1929	0364 3489	Augusta Gibson Dam	1929-47 1948-97
Tiber	1950	8236 8233	Tiber Lake Tiber Dam	1950-52 1953-97
Fort Peck	1937	3557 3175 3176	Glasgow Fort Peck Fort Peck PP	1937-47 1948-56 1957-97
Fresno	1939	3994 3996	Havre WB Havre WSO	1939-60 1961-97
Bull Lake	1938	7760	Riverton	1938-97
Boysen	1951	1000	Boysen Dam	1951-97
Buffalo Bill	1908	 1840 1175	(none) Cody Buffalo Bill	1908-14 1915-48 1949-97

Project	Date of Closure	Precip Data Source		
		NWS ID	Station	Years
Yellowtail	1966	9240	Yellowtail Dam	1966-97
Garrison	1953	7585 3376	Riverdale Garrison 1NW	1953-81 1982-97
Heart Butte	1949	0136 4091	Altmont 7W Heart Butte	1949-83 1984-87
Bowman-Haley	1966	0995	Bowman Ct Hs	1966-97
Shadehill	1950	7567 4864	Shadehill Dam Lemmon	1950-77 1978-97
Keyhole	1952		Keyhole Dam Devil's Tower	1952-58 1959-97
Pactola	1956	6427	Pactola Dam	1956-97
Angostura	1949	0217 6304	Angostura Oral	1949-71 1972-97
Oahe	1958	6597 6170	Pierre FAA AP Oahe Dam	1958-59 1960-97
Big Bend	1963	1690 0649 4766	Chamberlain Big Bend Dam Lake Sharpe	1963-64 1965-71 1972-97
Fort Randall	1952	6574	Pickstown	1952-97
Gavins Point	1955	9502 3165 9502	Yankton 2E Gavins Point Yankton 2E	1955-60 1961-95 1996-97
Pipestem	1973	4413	Jamestown AP	1973-97
Jamestown	1953	4413	Jamestown AP	1953-97

Missing precipitation records were filled in with the average monthly precipitation computed from available records. For each day with a missing precipitation record, the average monthly values were divided by the number of days in the month and used to replace the missing record. Average monthly precipitation values used for each project are shown in the following table.

Table F-8. Precipitation Data Used To Fill In Missing Records

Project	Precip Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oahe	Oahe	.19	.36	.68	1.53	2.26	2.81	2.01	1.38	1.17	.72	.34	.30
Big Bend	Oahe	.19	.36	.68	1.53	2.26	2.81	2.01	1.38	1.17	.72	.34	.30
Fort Randall	Pickstown	.41	.58	1.42	2.40	3.26	3.62	2.75	2.52	2.27	1.45	.82	.57
Pactola	Pactola	.27	.45	.86	2.21	3.76	3.91	3.11	1.99	1.34	1.17	.55	.38
Gavins Pt	Gavins Pt	.44	.55	1.61	2.34	3.42	3.71	3.18	2.96	2.37	1.73	.87	.66
Angostura	Angostura	.34	.50	.88	1.51	2.77	3.11	2.24	1.17	1.30	.74	.39	.37
Shadehill	Lemmon	.53	.50	.93	1.79	2.65	3.33	2.50	1.86	1.36	.99	.63	.53
Garrison	Garrison	.47	.37	.60	1.22	1.86	3.06	2.36	1.72	1.37	.85	.50	.43
Jamestown	Jamestown	.66	.50	.86	1.41	2.34	3.37	3.28	1.98	1.66	1.10	.62	.54
Pipestem	Jamestown	.66	.50	.86	1.41	2.34	3.37	3.28	1.98	1.66	1.10	.62	.54
Bowman-Haley	Bowman	.45	.35	.61	1.34	2.34	3.45	2.13	1.48	1.28	.99	.45	.33
Heart Butte	Altmont	.44	.39	.69	1.65	2.27	3.52	2.10	2.12	1.38	.93	.46	.39
Fort Peck	Fort Peck PP	.33	.28	.38	.96	1.77	2.22	1.97	1.28	1.10	.72	.30	.25
Gibson Dam	Gibson Dam	1.01	.76	.99	1.56	3.02	3.18	1.57	1.59	1.46	1.01	1.01	.90
Clark Canyon	Dillon	.57	.49	.88	1.36	2.35	2.23	1.29	1.14	1.21	.79	.61	.52
Canyon Ferry	Canyon Ferry	.48	.33	.54	.94	1.84	1.95	1.30	1.24	1.12	.67	.48	.48
Tiber	Tiber Dam	.32	.23	.43	.84	1.71	2.25	1.28	1.17	.84	.51	.34	.29
Yellowtail	Yellowtail	.95	.69	1.33	2.28	2.99	2.57	1.48	1.06	1.87	1.63	.96	.83
Fresno	Fort Peck	.33	.28	.38	.96	1.77	2.22	1.97	1.28	1.10	.72	.30	.25

Evaporation

Evaporation records were drawn from NWS records available on CD-ROM. Records were drawn from the closest and/or most reliable nearby evaporation station for each reservoir project. The table below shows the data source used to estimate evaporation at each reservoir project.

Table F-9. Evaporation Data Sources Used in UFDM

Project	Date of Closure	Evaporation Data Source		
		NWS ID	Station	Years
Clark Canyon	1964	2409	Dillon WMCE	1964-97
Hebgen	1915		(Average)	1915-49
		2409	Dillon WMCE	1950-97
Canyon Ferry	1953	1044	Bozeman MSU	1953
		1465	Canyon Ferry	1954-56
		1470	Canyon Ferry	1957-96
		1047	Bozeman EF	1997
Gibson	1929		(Average)	1929-47
		1044	Bozeman MSU	1948-53
		1465	Canyon Ferry	1954-56
		1470	Canyon Ferry	1957-96
		1047	Bozeman EF	1997
Tiber	1950	3110	Ft Assinniboin	1950-97
Fort Peck	1937		(Average)	1937-47
		3175	Fort Peck	1948-56
		3176	Fort Peck PP	1957-78
		MRADS	Fort Peck PP	1979-97
Fresno	1939		(Average)	1939-48
		3110	Ft Assinniboin	1949-97
Bull Lake	1938		(Average)	1938-50
		6470	Morton	1951-68
		1000	Boysen Dam	1969-76
		4411	Heart Mtn	1977-97
Boysen	1951	1000	Boysen Dam	1951-76
		4411	Heart Mtn	1977-97
Buffalo Bill	1908		(Average)	1908-49
		4411	Heart Mtn	1950-97
Yellowtail	1966	9240	Yellowtail Dam	1967-68
		1044	Bozeman MSU	1969
		9240	Yellowtail Dam	1970-97
Garrison	1953	7585	Riverdale	1953-80
		9430	Williston	1981-97
Heart Butte	1949	5479	Mandan	1949-97
Bowman-Haley	1966	5479	Mandan	1966-97
Shadehill	1950	5479	Mandan	1950-97
Keyhole	1952	5137	Keyhole Dam	1952-58
		8160	Sheridan Field	1959-97
Pactola	1956	6427	Pactola Dam	1956-97
Angostura	1949	0217	Angostura	1948-70
		6304	Oral	1971-97
Oahe	1958		(Average)	1958-59
		6170	Oahe Dam	1960-97
Big Bend	1963	6170	Oahe Dam	1963-67
		0649	Big Bend Dam	1968-71
		4766	Lake Sharpe	1972-78
		6170	Oahe Dam	1979-97

Project	Date of Closure	Evaporation Data Source		
		NWS ID	Station	Years
Fort Randall	1952	6574	Pickstown	1952-97
Gavins Point	1955	6474	Pickstown	1955-97
Pipestem	1973	4413	Jamestown	1973-97
Jamestown	1953	4413	Jamestown	1953-97

Evaporation records generally are not as extensive as those for precipitation, nor do they cover as long a timeframe. Several reservoirs, such as Hebgen, Fresno, Bull Lake, and Buffalo Bill, antecede evaporation records, so the daily average from the period of record at each station was used to estimate evaporation records at these reservoirs prior to the period of record. Additionally, some stations do not report evaporation records during winter months, so monthly average values, taken from NWS 34 (NWS, 1982b), were used at these stations. As evaporation is minimal during winter, it was felt that the average values would suffice. Evaporation estimates for the Huron station were used to fill in missing records at Oahe, Big Bend, Fort Randall, and Gavins Point. Values from Rapid City were used to fill in missing records at Angostura and Pactola. Estimates at Bismarck were used for Pipestem, Jamestown, Garrison, Heart Butte and Bowman-Haley. Missoula evaporation estimates were used to fill in missing data at Dillon, while Helena estimates were used for Canyon Ferry. At Fort Peck, missing records were based on average values observed at Fort Peck. For missing evaporation records at Yellowtail Dam, estimates at Billings were used.

The evaporation records needed to be adjusted, as the published values are pan evaporation records. Annual pan evaporation coefficients were taken from NWS 33 (NWS, 1982a) and applied to the pan evaporation data to obtain the final evaporation values for the USBR and smaller COE reservoirs. Pan evaporation coefficient values for the six mainstem reservoirs were taken from (NWS, 1982b) and applied to the mainstem evaporation records. The table below shows the pan evaporation coefficients used to obtain lake evaporation at each reservoir project.

Table F-10. Pan Evaporation Coefficients

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fort Peck	1.28	0.70	0.60	0.11	0.22	0.32	0.39	0.64	1.21	1.32	2.57	4.22
Garrison	0.70	0.70	0.70	0.14	0.20	0.21	0.26	0.64	1.13	1.44	3.74	5.04
Oahe	0.73	0.56	0.49	0.13	0.16	0.18	0.22	0.50	0.89	1.19	2.22	3.42
Big Bend	0.63	0.63	0.54	0.47	0.35	0.39	0.53	0.70	0.82	1.05	1.52	1.36
Fort Randall	0.70	0.70	0.63	0.19	0.32	0.37	0.42	0.78	1.31	1.42	1.62	1.39
Gavins Point	0.70	0.70	0.62	0.53	0.53	0.53	0.56	0.70	0.93	0.97	1.59	1.57
Boysen									0.72 (annual)			
Fresno, Bowman-Haley, Heart Butte, Keyhole, Shadehill									0.73 (annual)			
Canyon Ferry, Tiber, Pactola									0.74 (annual)			
Hebgen, Clark Canyon, Yellowtail									0.75 (annual)			
Gibson, Buffalo Bill, Bull Lake									0.76 (annual)			
Pipestem, Jamestown									0.77 (annual)			

UNREGULATED FLOW

The unregulated flow data set was developed through use of the Unregulated Flow Development Model (UFDM), utilizing data sets for discharge, reservoir inflow and outflow or storage change, evaporation, precipitation, area-storage relationships, depletion data, and routing parameters. The following sections describe the UFDM model and its inputs.

Hydrologic Model Description (UFDM)

The UFDM is a computer model developed by the U.S. Army Corps of Engineers Reservoir Control Center at the Missouri River Region Office (MRR-RCC) to determine unregulated flows for a base level of water resource development in the basin. The model is used to assist in determining flood control benefits for the mainstem reservoir system as well as to determine the amount of runoff from the upper Missouri River basin.

Model Philosophy

Reliable runoff or flow data are a continuing need for purposes of efficient utilization of the available water supply in the Missouri Basin. With these data the nature and distribution of the supply becomes apparent, long term normals are defined more precisely, effects of basin water resources development can be estimated, and reservoir regulation effects on downstream flood flows or low water conditions may be developed.

In basic terms, the model determines reservoir holdouts and adds these holdouts to irrigation and other water-use depletions to obtain total holdouts in each mainstem reservoir reach. The total holdouts are routed through the system of reservoirs and then downstream to each gage, with the holdouts added to observed flow at each gage to determine unregulated flow. A more detailed description of the UFDM modeling philosophy may be found in USACE (1973).

Modifications to UFDM

The UFDM model, as developed by MRR-RCC, is written in FORTRAN source code and is set up to determine one year of flow record downstream to St. Joseph, with output directed to a text file, as well as a MRADS database. The model also only considers holdouts and depletions above Sioux City in developing unregulated flows. Several modifications to the program source code were necessary for the purposes of this study.

Period of record simulation. The UFDM, as originally programmed, was set to run one year of data at a time. In order to simplify data processing, an additional program loop was added that gives the user the option of running as many years of data as desired at one time. The program does not, however, carry over data from year to year. In other words, the initial reservoir storage values and other initial values are reset at the beginning of every year so that any errors that may accrue in computed reservoir storage do not compound from year-to-year.

Routing one stretch (OAHE-BEND). The outflows from Oahe to Big Bend and Big Bend to Fort Randall were routed by regression coefficients, rather than by lag-average method, as the travel time is so short. However, upon investigation of the code algorithm for computing the Big Bend and Fort Randall holdouts, it was discovered that the computed holdout at Big Bend and Fort Randall was dependent upon today's and yesterday's values. However, yesterday's value was already modified, so the computed value for today's holdout was incorrect. The code algorithm was changed so that today's computed holdout used yesterday's actual inflow, rather than the modified inflow.

Choice of routing method. The UFDM was programmed to route flows from station to station using the lag-average method. This method is somewhat simplistic, but has the advantage over most other routing methods in that flow volumes are preserved. However, the computer model used for the regulated flow data set uses regression routing from station to station (which also preserves flow volumes) below Gavins Point Dam. In order to have the ability to maintain consistent routing methodology, the UFDM code was altered to give the user the option of choosing lag-average routing or regression routing at gage stations downstream of Gavins Point Dam; a subroutine that routes flows with regression routing was also added to the UFDM code. Routing downstream of Gavins Point was also altered, as the UFDM originally routed holdouts above Gavins Point to each station from Gavins Point; the code was altered so that holdouts are routed from station to station below Gavins to be consistent with the routing methodology in the regulated flow model. The model input allows different lag-average values to be input for different years, while the regression routing uses constant values for the entire period of simulation. However, the program code could be altered to allow different regression values for different years, if desired. The tributary holdouts downstream of Gavins Point are routed from station to station using the regression routing only.

Output to DSS. The UFDM output capability was limited to the MRADS database and a text file for each year. Since HEC-DSS is more widely used within COE as a database, the program was changed so that all output that was sent to text files was also written to a DSS file. A new subroutine to the program was developed to handle the output to DSS.

Auxiliary programs for input and output. Due to the size and complexity of the data input and output required for this program, several auxiliary programs were developed or modified to streamline some of the input and output processes. These auxiliary programs, along with descriptions, are presented in Appendix F-D.

Depletions and depletion level. The UFDM used USBR estimates of depletions adjusted to 1949 levels of development in data input files. However, use of a 1949 level of depletion development would not have met the definition of unregulated flow for this study. Therefore, the code and input file format were modified to use historic levels of depletions, as determined by the USBR. The UFDM also did not include estimates of Platte or Kansas River depletions, so additional code was written to allow the inclusion of Platte and Kansas River basin depletions so as to determine their effect on observed flows. The Platte River estimates of depletions included reservoir holdouts, as well as irrigation and other uses. The Kansas River depletion data did not include reservoir holdouts. The Kansas River depletion data was added to the Kansas River basin reservoir holdouts for model input purposes.

Additional Flood Control Reservoirs The UFDM originally did not include several flood control reservoirs used in this study (Jamestown, Pipestem, Bowman-Haley, Kansas City District reservoirs). In order to more accurately reflect unregulated flow conditions, the model was altered to allow the impacts of these reservoirs on observed flows to be modeled. The addition of Bowman-Haley to the model did not require much change in programming, other than increasing some array sizes and increasing some variable counters. However, adding the other reservoirs to the model required changes in the way routing was done, as the model routed all mainstem and tributary holdouts from Gavins Point to each station individually. In order to route Jamestown, Pipestem and the Kansas City District reservoirs, their individual holdouts had to be routed with regression routing from station to station by means of a new subroutine and using regression coefficients that corresponded to those used in the DRM.

Input Data Development

Copious amounts of data were required for input to the UFDM model. The development of the various parameters is discussed below.

Area-Capacity Relationships

Area-capacity relationships at each reservoir are important for determining how much water is lost to evaporation and how much water is gained from precipitation at each reservoir. Survey data was gathered for each reservoir modeled in the UFDM, either from the USBR, COE, or dam operator. Even though each reservoir has suffered from sedimentation, the area-capacity relationship has remained amazingly stable over time. Because of this, it was decided to use one area-capacity relationship over the period of record of reservoir operation, rather than trying to interpolate the relationship between survey dates and having a slightly different relationship each year. The table below lists each reservoir and the dates from which survey data was available.

Table F-11. Dates of Available Area-Capacity Surveys

Reservoir	Date(s) of Survey Availability
Clark Canyon	1963
Hebgen	1962
Canyon Ferry	1946, 1964, 1983
Gibson	1929, 1965, 1975, 1996
Tiber	1950, 1963
Fort Peck	1937, 1946, 1961, 1972, 1986
Fresno	1953
Bull Lake	1965
Boysen	1946, 1966, 1996
Buffalo Bill	1970, 1986, 1992
Yellowtail	1946, 1963, 1982
Garrison	1954, 1964, 1969, 1979, 1988
Heart Butte	1944, 1992
Bowman-Haley	1966, 1984
Shadehill	1950, 1993
Keyhole	1946, 1966, 1978
Pactola	1956, 1965, 1988
Angostura	1945, 1966, 1979
Oahe	1950, 1968, 1976, 1989
Big Bend	1971, 1975, 1979, 1991
Fort Randall	1950, 1962, 1967, 1973, 1981, 1986, 1996
Gavins Point	1953, 1965, 1970, 1975, 1979, 1985, 1995
Pipestem	1971, 1973, 1990
Jamestown	1948

Reservoir Hydrologic Data

In order to accurately estimate how much each reservoir is affecting flows through holdouts, it is necessary to have accurate records of reservoir inflow and outflow and/or reservoir storage, precipitation at or near the reservoir, and evaporation at or near the reservoir. Data for inflow, outflow and storage is available from the USBR, COE and USGS for federal reservoirs, and from private companies for the privately owned reservoirs. Data for inflow must be in daily values. Storage data can be either daily or monthly; the UFDM automatically translates monthly data to daily data in a linear manner for modeling purposes. Precipitation and evaporation data was gathered from National Weather Service sources and can be either daily or monthly, as the UFDM will translate monthly values to daily values in a linear manner for modeling purposes.

The following table shows the period of record for which various data were available for modeling purposes, and whether the data was daily or monthly.

Table F-12. Reservoir Hydrologic Data Availability

Project	Date of Initial Storage	Inflow	Outflow	Storage	Evaporation	Precipitation
Clark Canyon	8/28/1964	Daily: 9/1/64-12/31/97	Daily: 9/1/64-12/31/97	Daily: 9/1/64-9/30/98	Daily: 1/1/63-12/31/97	Daily: 1/1/60-12/31/97
Hebgen	1914	Daily: 1/1/31-9/30/98	Daily: 1/1/31-9/30/98	Monthly: 6/14-12/29 Daily: 1/1/31-9/30/98	Daily: 1/1/50-12/31/97	Daily: 1/1/15-12/31/97
Canyon Ferry	3/1953	Daily: 3/28/53-12/31/97	Daily: 3/28/53-12/31/97	Daily: 3/27/53-9/30/98	Daily: 1/1/54-12/31/97	Daily: 1/1/48-12/31/97
Gibson	1929	Daily: 1/1/73-9/30/98	Daily: 1/1/30-9/30/98	Monthly: 12/29-9/95 Daily: 10/1/38-9/30/49 & 1/1/73-9/30/98	Daily: 1/1/54-12/31/97	Daily: 1/1/28-12/31/97
Tiber	10/28/1955	Daily: 1/1/56-4/3/98	Daily: 1/1/56-4/3/98	Daily: 1/1/56-9/30/98	Daily: 1/1/54-12/31/97	Daily: 1/1/48-12/31/97
Fort Peck	1937	Daily: 1/1/38-12/31/97	Daily: 1/1/38-12/31/97	Monthly: 9/37-8/98	Daily: 1/1/48-12/31/97	Daily: 1/1/37-12/31/97
Fresno	1939	Daily: 1/1/48-7/22/98	Daily: 1/1/48-7/22/98	Monthly: 12/39-9/50 Daily: 1/1/48-7/22/98	Daily: 1/1/49-12/31/97	Daily: 1/1/38-12/31/97
Bull Lake	10/1937	Daily: 12/1/68-9/17/98	Daily: 12/1/68-9/17/98	Monthly: 10/37-8/98 Daily: 12/1/68-9/17/98	Daily: 1/1/51-12/31/97	Daily: 1/1/37-12/31/97
Boysen	10/1951	Monthly: 3/52-6/66 Daily: 3/1/52-12/31/97	Daily: 3/1/52-12/31/97	Monthly: 10/51-8/98 Daily: 3/1/52-9/30/98	Daily: 1/1/49-12/31/97	Daily: 8/1/48-12/31/97
Buffalo Bill	5/1909	Daily: 4/1/52-12/31/97	Daily: 3/24/52-12/31/97	Monthly: 04/09-8/98 Daily: 3/23/52-9/30/98	Daily: 1/1/50-12/31/97	Daily: 1/1/15-12/31/97
Yellowtail	11/3/1965	Daily: 11/1/65-4/3/98	Daily: 10/1/65-4/3/98	Daily: 11/1/65-9/30/98	Daily: 1/1/65-12/31/97	Daily: 1/1/62-12/31/97
Garrison	11/1953	Daily: 12/1/53-12/31/97	Daily: 12/1/53-12/31/97	Monthly: 10/53-8/98	Daily: 1/1/49-12/31/97	Daily: 1/1/48-12/31/97
Heart Butte	9/29/1949	Daily: 10/1/49-4/3/98	Daily: 10/1/49-4/3/98	Daily: 10/1/49-9/30/98	Daily: 1/1/49-12/31/97	Daily: 1/1/48-12/31/97
Bowman-Haley		Daily: 3/2/67-12/31/97	Daily: 1/1/67-12/31/97	Daily: 3/31/67-12/31/97	Daily: 1/1/67-12/31/97	Daily: 1/1/60-12/31/97
Shadehill	7/1/1950	Daily: 4/1/52-4/3/98	Daily: 4/1/52-4/3/98	Monthly: 7/50-3/52 Daily:	Daily: 1/1/50-12/31/97	Daily: 1/1/50-12/31/97

Project	Date of Initial Storage	Inflow	Outflow	Storage	Evaporation	Precipitation
				4/1/52-9/30/98		
Keyhole	2/12/1952	Daily: 4/1/52-4/3/98	Daily: 4/1/52-4/3/98	Daily: 4/1/52-9/30/98	Daily: 1/1/52-12/31/97	Daily: 11/1/49-12/31/97
Pactola	8/22/1956	Daily: 8/22/56-4/3/98	Daily: 8/22/56-4/3/98	Daily: 8/22/56-9/30/98	Daily: 1/1/55-12/31/97	Daily: 1/1/55-12/31/97
Angostura	10/3/1949	Daily: 4/1/52-9/17/98	Daily: 4/1/52-9/17/98	Monthly: 10/49-3/52 Daily: 4/1/52-9/17/98	Daily: 1/1/48-12/31/97	Daily: 1/1/48-12/31/97
Oahe	8/1958	Daily: 8/3/58-12/31/97	Daily: 8/3/58-12/31/97	Monthly: 7/58-8/98	Daily: 1/1/60-12/31/97	Daily: 1/1/57-12/31/97
Big Bend	7/1963	Daily: 8/1/63-12/31/97	Daily: 8/1/63-12/31/97	Monthly: 6/63-8/98	Daily: 1/1/68-12/31/97	Daily: 1/1/62-12/31/97
Fort Randall	12/1952	Daily: 1/1/53-12/31/97	Daily: 1/1/53-12/31/97	Monthly: 11/52-9/98	Daily: 1/1/51-12/31/97	Daily: 1/1/48-12/31/97
Gavins Point	7/1955	Daily: 8/1/55-12/31/97	Daily: 8/1/55-12/31/97	Monthly: 6/55-9/98	Daily: 1/1/55-12/31/97	Daily: 1/1/54-12/31/97
Pipestem	7/1973	Daily: 3/1/74-3/31/98	Daily: 3/1/74-3/31/98	Daily: 2/14/78-3/31/98 Lots of daily values missing	Daily: 1/1/73-12/31/97	Daily: 1/1/48-12/31/97
Jamestown	10/1/1953	Daily: 2/2/54-4/3/98	Daily: 2/2/54-4/3/98	Monthly: 10/53-2/54 Daily: 2/1/54-4/3/98	Daily: 1/1/48-12/31/97	Daily: 1/1/48-12/31/97

Storage values were used only in the absence of daily inflow and outflow records, which was often the case in the first month or two of reservoir operation.

As can be seen above, not all reservoirs have evaporation or precipitation records extending back to the beginning of regulation at that dam site. In this instance, the monthly averages from the period of record for evaporation and precipitation were computed, then used for the missing months. The monthly data was then distributed evenly over each day of the month. All the reservoirs for which this was done, with the exception of Fort Peck, are fairly small and it was felt that precipitation and evaporation from these reservoirs had very little impact on annual peaks, especially considering the smaller number of reservoirs in operation prior to evaporation records being kept.

Hebgen Reservoir had one year of storage/flow records missing, as there was no storage or flow data available for 1930 from the Montana Power Company. The total change in storage from 12/31/29 to 1/1/31 was computed, and then monthly volume changes were patterned after long-term monthly storage changes to achieve the proper annual storage change at Hebgen.

Historic Depletion Estimates

In order to properly develop unregulated flows, an accurate accounting of streamflow depletions by irrigation, reservoir holdouts, and other consumptive uses was needed. The USBR was contracted with to provide estimates of streamflow depletions for the period 1898-1996 for the Missouri River upstream of Hermann, Missouri. The methodologies and results of the USBR are presented as Appendix F-C.

The values provided by the USBR were by month, and included historic (actual) level of depletions and current-use level depletions. The UFDM as originally coded used 1949 levels of depletion. This program code was modified to use the actual depletions. The monthly values are read into the UFDM program, and the program automatically prorates the monthly values to daily values at each appropriate node in the model. The historic depletion data provided by the USBR included reservoir holdouts at USBR projects that were already modeled in the UFDM, so those reservoir projects were subtracted out of the depletion data before input to the UFDM model.

The Platte (NE) River depletions were converted from monthly values to daily values by patterning the depletions after the observed daily hydrograph on the Platte River at either the Ashland gage (1928-1953) or the Louisville gage (1953-1997). This was done by computing the mean monthly flow on the Platte River and computing the ratio of monthly depletions to monthly Platte River flows. The daily Platte River flows were then multiplied by the monthly ratio to determine daily depletions. The computed daily depletions were then smoothed by use of a 3-day moving average. The monthly depletion values were prorated on a daily basis for data prior to 1928.

Routing Parameters

Parameters for the lag-average routing were taken from existing model input files used by MRR-RCC and from USACE (1973). However, there was concern that with channel changes, there would be differences in the routing parameters with time.

Work was done to determine if these parameters changed with time. Two methods were used to determine the lag and the average values for each of the reaches. The first method was to optimize the lag and the average for each yearly high flow period using HEC-1 and the optimization function. The second method attempted to determine the lag and the average by minimizing the total yearly negative incremental inflows.

Observed flows at Sioux City and Omaha were configured in an HEC-1 model with the optimization function. Because mean daily flows on the Missouri River were used in the analysis, the average value and the lag values were derived using a time step of 1-day. Optimized values were based on the high flow event for each year. The average flow optimized at two flow values for the majority of the years. However, the lag optimized almost equally between 1 day and 2 days for any given year. To derive the incremental inflow, two DSSMATH models were configured using an average flow based on 2-days of flow values for both models and lag of 1-day for the first model and 2-days for the second.

When the calculated incremental inflows for the period of record were analyzed, it was observed that there were numerous negative inflows. The negative incremental inflows are likely caused by errors in the flows used in the analysis. Mean daily flows are being used with a 1-day time step for the averaging and lag. In addition, some of the flow data at the gages were derived from stage records for part of the period of record or reconstituted using nearby streamflow data when there was no flow of stage data available for that gage.

With the construction of the navigation channel and bank stabilization works on the Missouri River, the length of the river channel has been reduced. This may have the effect of altering the lag and average. Based on the first method used, a second calibration method used was an iterative process where the lag and average values were varied and the negative incremental inflows for the year accumulated and compared to each other with the objective of minimizing negative inflows. DSSMATH was used for the analysis. This process was performed for each reach between the main stem gages. The yearly negative totals were observed to determine if the chosen lag and average changed, and if they were the least over time. No significant change was found over the period of record, so the lag and average were not altered over the period of record for each reach. Lag-average parameters for the Kansas City District also showed little change over time, so no changes were made over the period of record.

Lag-average parameters had to be added for the reservoirs that were added into the UFDM program. The lag value was based on the average travel time for moderate to high flows, as published in other reports. For reservoirs with insufficient downstream streamgage records, the number of days to average was based on values for other reservoirs already in the UFDM model, or in the case of the James River reservoirs, the number of days to average was taken as one day less than the travel time, due to the sluggish nature of the James River.

The lag-average parameters used for this study are shown in Table F-13.

Table F-13. Lag-Average Parameters Used

Routing Reach	Days Average	Days Lag
Clark Canyon	5	8
Hebgen	4	8
Canyon Ferry	4	7
Gibson	3	6
Tiber	3	6
Fort Peck Inflow To Fort Peck Dam	1 1	3 (if elev, > 2200 msl)[a] 2 (if elev < 2200 msl)[a]
Fort Peck To Garrison	3	6
Fresno	5	10
Bull Lake	5	8
Boysen	5	7
Buffalo Bill	5	7
Yellowtail	3	6
Garrison Inflows To Garrison Dam	1 1 1	3 (if elev > 1800 msl)[a] 2 (if elev >1750 msl & < 1800 msl)[a] 1 (if elev < 1750 msl)[a]
Garrison To Oahe	3	4
Heart Butte	3	5
Bowman Haley	3	5
Shadehill	3	4
Keyhole	3	5
Pactola	2	4
Angostura	2	4
Oahe Inflow To Oahe Dam	1 1 1 1	4 (if elev > 1600 msl)[a] 3 (if elev > 1550 msl & < 1600 msl)[a] 2 (if elev > 1500 msl & < 1550 msl)[a] 1 (if elev < 1500 msl)[a]
Oahe To Big Bend	1	1
Big Bend Inflow To Big Bend Dam	1	1
Big Bend To Ft Randall	2	1
Fort Randall Inflow To Fort Randall Dam	1 1	2 (if elev >1345 msl)[a] 1 (if elev < 1345 msl)[a]

Routing Reach	Days Average	Days Lag
Fort Randall To Gavins Point	1	1
Gavins Point Inflow To Gavins Point Dam	1	1
Gavins Point To Yankton	2	1
Gavins Point To Sioux City	2	1
Fort Peck Q To Garrison Headwaters	3	5
Garrison Q To Oahe Headwaters	2	3
Oahe Release To Big Bend Headwaters	0.1 [b]	0.9[b]
Big Bend Q To Ftr Headwaters	0.1 [b]	0.9[b]
Ft Randall Q To Gavins Headwater	1	1
Sioux City To Decatur	2	2
Sioux City To Omaha	2	2
Sioux City To Nebraska City	2	3
Sioux City To Rulo	2	3
Sioux City To St. Joseph	2	4
Fort Peck To Wolf Point	2	1
Fort Peck To Culbertson	2	3
Garrison To Bismarck	2	2
Pipestem To Sioux City	67	66
Jamestown To Sioux City	67	66
Gavins Point To Kansas City	3	4
Gavins Point To Waverly	3	4
Gavins Point To Boonville	3	5
Gavins Point To Hermann	4	5
Gavins Point To Mouth	4	6
Platte River Louisville To Nebraska City	2	1
Platte River (Missouri) To Kansas City	2	1
Kansas River To Kansas City	1	1
Chariton River To Boonville	2	1
Osage River To Hermann	2	1

[a] Elevation refers to the computed elevation of the reservoir.

[b] Because of the very short travel distances from Oahe to Big Bend and from Big Bend to Fort Randall, flows were routed using regression coefficients, rather than lag-average.

Model Calibration/Verification

Traditionally, hydrologic computer models are calibrated to observed events to obtain some degree of confidence in the model parameters. However, as this model's purpose is to obtain hypothetical flows, the model cannot be calibrated to observed flows. However, the model was tested using zero reservoir holdouts and zero depletions to ensure the model output at each of the mainstem gages matched the observed flow.

One means to verify the accuracy of the model output is to compare it to various hydrologic and climatological data. Since the 1898-1928 period appears to have some differences (whether in mean or variance) with the rest of the period of record, the climatological record was investigated for differences. One readily available measure of climatological conditions is the Palmer Drought Severity Index. The

Palmer Drought Severity Index uses temperature and rainfall data to measure long-term dryness. The data is available on a monthly basis for regions within each state for the period 1895-present from the National Climate Data Center.

Data for regions within the Missouri River basin were collected. Monthly regional values within each state were averaged to obtain a statewide monthly average, as regions within each state are roughly equal in area. However, only those regions within the Missouri River basin were used. The monthly statewide drought values were weighted by each month's percent of mean annual flow (i.e., 2.3%-Jan, 3.2%-Feb., 7.6%-Mar., 10.9%-Apr, 11.2%-May, 19.6%-Jun, 19.2%-Jul, 10.3%-Aug, 6.0%-Sep, 4.3%-Oct, 3.3%-Nov, 2.2%-Dec for Sioux City) to obtain an annual drought index for each state. The annual drought index for each state was then weighted by drainage area upstream of the gage in question to obtain an overall basin drought index.

The annual drought index and annual unregulated flow at Sioux City, Nebraska City, Kansas City, and Hermann were analyzed using linear regression. The period 1929-1997 showed a fairly strong correlation, while the data for 1898-1928 showed a fair correlation but within the scatter of the 1929-1997 data. The results of the regression are shown on Plates F-1 to F-4. Plates F-5 to F-8 show the annual time-series for both the annual flow and annual drought index. The trend in both parameters can be seen to follow quite closely. On the basis of this analysis, it appears that the period 1898-1928 may have been wetter above Sioux City than the period 1929-1997. The annual flow volumes appear reasonable for Sioux City as computed with a single rating curve.

A similar analysis was performed to determine the correlation between mean annual reach inflow and the drought index from Sioux City to Nebraska City, Nebraska City to Kansas City, and Kansas City to Hermann to determine if the annual mean incremental flow is reasonable. Again, the period 1929-1997 showed a strong correlation, while the data for 1898-1928 showed a fair to poor correlation. The Sioux City to Nebraska City reach shows the poorest correlation and greatest scatter for the pre-1928 period, while the Kansas City to Hermann reach appears consistently low (see Plates F-9 to F-11). On the basis of the above information, it is likely that the annual flow volumes at Sioux City, Nebraska City, and Kansas City are reasonable for the 1898-1928 period, while the values at Hermann may be slightly low. In all, the comparison between annual flow and annual drought index supports the mean annual flows as reasonable for the pre-USGS gaging period.

An analysis of annual stream flows tends to further support this position. In order to further verify the reasonableness of the historic flows derived for the period of 1898-1928, the following procedures were used. First the average annual historic flows for the period 1898-1928 were compared to the average flows for various other periods measured by the USGS. Results of this comparison are shown in Table F-14.

Table F-14. Comparison of Average Annual Flows

Period	Average Annual Flow (million acre-feet per year)		
	Sioux City	Omaha	Nebraska City
1898-1928	32.9	35.8	43.7
1929-1942	16.4	17.0	20.7
1943-1952	26.4	27.8	33.0
1953-1968	16.9	18.0	22.4
1969-1992	22.8	25.6	30.2
1993-1997	29.1	34.4	39.2

Although the 1898-1928 estimated flows are higher than any other period during the historical record, they are reasonable when considering the effects of droughts, depletions, and reservoirs. Since 1898, basin depletions for irrigation and other uses (not including reservoirs) upstream from Sioux City have increased from about 2 million acre-feet to over 8 million acre-feet per year and Platte River basin depletions have increased by about 4 million acre-feet per year. In addition, construction of the main stem and tributary reservoirs has added 2 to 3 million acre-feet per year in evaporation losses. The period of 1929-1942 was affected by the 1930's drought, the most severe recorded drought in the Missouri River basin, and the filling of Fort Peck Reservoir. Runoff during the 1943-1952 period was also affected by the 1930's drought during the recovery of basin groundwater and pothole storage. Many large tributary irrigation and flood control reservoirs also came online during this period including Tiber, Boysen, Keyhole, and Heart Butte reservoirs. The 1953-1968 period was affected by a drought during the mid-50's and the filling of the main stem reservoir system. During the 1969-1992 period, the late 1980s drought resulted in reduced runoff conditions. Recorded flows during the 1993-1997 period, a relatively wet period, compare favorably to the estimated flows during the 1898-1928 period when considering the increased basin depletions due to irrigation, reservoir evaporation and other water uses.

The USGS prepared estimates of monthly flows at Sioux City for the period 1897 through 1928 based on the recorded discharge at Williston, North Dakota and weather records. Results of that study, published in USGS Circular 108 (USGS), indicate that the average annual flow at Sioux City from 1898-1928 was 27.8 million acre-feet per year. That estimate appears low when compared to recorded flows at Sioux City during the post main-stem reservoir filling period (1968-1997) which averaged 23.9 million acre-feet per year. Considering basin depletions and reservoir evaporation upstream from Sioux City (approximately 6 to 8 maf/yr), the USGS estimate of flows during the 1898-1928 period equate to about 20 million acre-feet per year adjusted for present level of development conditions.

Results of this verification indicate that the estimates of annual discharges for the period of 1898-1928 prepared for this study may be overestimated by about 1 to 2 million acre-feet per year. This would be equivalent to an average of about 1,400 to 2,800 cfs throughout the year. Because the discharges were estimated by use of a single rating curve derived from measurements made primarily during the summer months, it is believed that the majority of the overestimation would occur during late fall and winter periods, when flows were at their lowest. Therefore, it is concluded that high flows and peak flows estimated for the period 1898-1928 are reasonable and adequate for peak flow frequency and high flow volume investigations. If the flows for the low flow periods developed for this study are to be used in future study, additional adjustment to those flows may be required.

Period of Record Simulation

Once all input data were compiled, the model was run, covering the period of January 1, 1898 to December 31, 1997. Annual daily peaks were extracted from the output data and are compiled in Table FA-1. Various other data extracted from the output data are compiled in Tables FA-2 and FA-3.

Sensitivity Analysis

The model accuracy was assessed by testing the sensitivity of simulated values to a reasonable range of input parameter values.

Sensitivity to Routing Method

The UFDM allows for two routing methods to be employed below Gavins Point for routing reservoir holdouts. Output from the UFDM using the lag-average method was compared to the output used for the regression routing method. The following table compares the statistics of the two methods.

Table. F-15. Comparison of annual statistics for regression and lag-average routing methods

Location	(1)	(2)	(3)	(4)	(5)	(6)
Yankton	5.2026	0.1372	0.0552	5.2027	0.1358	0.0509
Sioux City	5.2120	0.1323	-0.0244	5.2127	0.1322	-0.0323
Decatur	5.2132	0.1312	-0.0575	5.2135	0.1307	-0.0726
Omaha	5.2302	0.1329	-0.0661	5.2307	0.1334	-0.0805
Nebraska City	5.3203	0.1177	-0.0474	5.3187	0.1165	-0.0797
Rulo	5.3266	0.1220	-0.0533	5.3270	0.1217	-0.0703
St. Joseph	5.3398	0.1218	0.0670	5.3386	0.1211	0.0652

(1) Mean of annual max instantaneous log-flows, regression routing
(2) Standard deviation of annual max instantaneous log-flows, regression routing
(3) Skew of annual max instantaneous log-flows, regression routing
(4) Mean of annual max instantaneous log-flows, lag-average routing
(5) Standard deviation of annual max instantaneous log-flows, lag-average routing
(6) Skew of annual max instantaneous log-flows, lag-average routing

As can be seen, there is little difference in the mean or standard deviation. The following table compares the difference between the 1%-flood for both routing methods at each gage using mixed distribution methodology.

Table F-16. Difference in 1%- and 0.2%-flood for regression and lag-average routings.

Location	% Difference	
	1% Flood	0.2% Flood
Yankton	-0.4%	-0.4%
Sioux City	-0.2%	-0.2%
Decatur	+0.1%	+0.2%
Omaha	-0.4%	-0.6%
Nebraska City	-0.8%	-0.2%
Rulo	-0.2%	+0.3%
St. Joseph	-0.6%	+0.1%

As can be seen, the effect on the 1%- and 0.2%-flood is minimal, as differences are less than 1%, and generally much lower. These differences are insignificant.

Sensitivity to Reservoir Precipitation and Evaporation

To verify how sensitive the model is to the values of precipitation and evaporation at reservoirs, a run was made with no precipitation or evaporation data input. The following table shows the difference in station statistics with and without the precipitation and evaporation data.

Table F-17. Comparison of annual statistics with and without reservoir precipitation and evaporation data

Location	(1)	(2)	(3)	(4)	(5)	(6)
Yankton	5.2026	0.1372	0.0552	5.2061	0.1358	0.0589
Sioux City	5.2120	0.1323	-0.0244	5.2152	0.1314	-0.0187
Decatur	5.2132	0.1312	-0.0575	5.2165	0.1304	-0.0581
Omaha	5.2302	0.1329	-0.0661	5.2335	0.1323	-0.0683

Nebraska City	5.3203	0.1177	-0.0474	5.3228	0.1179	-0.0249
Rulo	5.3266	0.1220	-0.0533	5.3292	0.1225	-0.0345
St. Joseph	5.3398	0.1218	0.0670	5.3423	0.1223	0.0690

(1) Mean of annual max instantaneous log-flows, precipitation and evaporation data included
(2) Standard deviation of annual max instantaneous log-flows, precipitation and evaporation data included
(3) Skew of annual max instantaneous log-flows, precipitation and evaporation data included
(4) Mean of annual max instantaneous log-flows, precipitation and evaporation data not included
(5) Standard deviation of annual max instantaneous log-flows, precipitation and evaporation data not included
(6) Skew of annual max instantaneous log-flows, precipitation and evaporation data not included

As can be seen, there is little difference in the station parameters. The following table compares the difference between the 1%- and 0.2%-flood for both methods at each gage using mixed population methodology.

Table F-18. Difference in 1%- and 0.2%-flood for with and without precipitation and evaporation data.

Location	% Difference	
	1% Flood	0.2% Flood
Yankton	+0.2%	+0.4%
Sioux City	+0.2%	+0.4%
Decatur	0%	+0.1%
Omaha	0%	+0.1%
Nebraska City	+0.2%	-0.4%
Rulo	+1.0%	+0.3%
St. Joseph	+1.0%	+0.4%

As can be seen, the 1%- and 0.2% floods remain the same or slightly increase by ignoring precipitation and evaporation data. These differences are insignificant.

Sensitivity to Depletions

The 1962 study (USACE, 1962) did not include the effects of historic depletions in determining the regulated flow frequency. To evaluate how sensitive the results of this study are to depletion data, a run was performed with no depletion data entered. The following table shows the difference in station statistics with and without depletion data.

Table F-19. Comparison of annual statistics with and without depletion data

Location	(1)	(2)	(3)	(4)	(5)	(6)
Yankton	5.2026	0.1372	0.0552	5.1439	0.1821	-0.4204
Sioux City	5.2120	0.1323	-0.0244	5.1550	0.1743	-0.4467
Decatur	5.2132	0.1312	-0.0575	5.1552	0.1731	-0.4569
Omaha	5.2302	0.1329	-0.0661	5.1756	0.1715	-0.4588
Nebraska City	5.3203	0.1177	-0.0474	5.2258	0.1712	-0.6574
Rulo	5.3266	0.1220	-0.0533	5.2367	0.1693	-0.4993
St. Joseph	5.3398	0.1218	0.0670	5.2588	0.1612	-0.3319

(1) Mean of annual max instantaneous log-flows, depletion data included
(2) Standard deviation of annual max instantaneous log-flows, depletion data included

(3) Skew of annual max instantaneous log-flows, depletion data included
(4) Mean of annual max instantaneous log-flows, depletion data not included
(5) Standard deviation of annual max instantaneous log-flows, depletion data not included
(6) Skew of annual max instantaneous log-flows, depletion data not included

As can be seen, the mean decreases significantly, the standard deviation increases significantly, and skew becomes significantly more negative. The following table compares the difference in the 1%- and 0.2%-floods for with and without depletions using mixed distribution methods at each gage.

Table F-20. Difference in 1%- and 0.2%-flood for with and without depletion data

Location	% Difference, 1%	% Difference, 0.2%
Yankton	+0.6%	+0.8%
Sioux City	+0.1%	+0.1%
Decatur	+0.1%	+0.1%
Omaha	-0.2%	-0.1%
Nebraska City	-2.8%	-0.1%
Rulo	-6.4%	-3.5%
St. Joseph	-9.5%	-7.2%

As can be seen, the elimination of depletion data only slightly impacts the 1- and 0.2%-floods, except at St. Joseph. Even though depletions can account for as much as 25% of the annual unregulated flow, depletions generally have a small impact on larger floods.

Limitation of Routing Method's Effect on Ice Jams

In the 1962 study (USACE, 1962), it was recognized that the lag-average routing method used was inadequate to accurately route the dynamic peaking of ice jam breakups in the development of the unregulated flow record; additionally, the construction of the mainstem reservoir system prevents this dynamic ice breakup from occurring. It was felt that this led to an underestimation of the instantaneous peak value at downstream stations. Accordingly, peak values were adjusted upwards in years following the closure of Fort Peck that were judged to have a reduced ice breakup due to the reservoirs. The following Table F-21 lists those years in which peaks were adjusted and by how much at Sioux City. However, there was little documentation as to how these values were derived.

Table F-21. Increases in Peak Flows at Sioux City Due to Reduced Ice Jam Breakup

Year	Increase in Peak Flow Value
1939	+31,000
1943	+25,000
1947	+45,000
1950	+11,000
1952	+38,000
1959	+54,000
1960	+58,000

In order to determine what impact this may have on the flow frequency results, flood years after 1960 were identified that may have had significant ice jam breakups on the Missouri River if the mainstem reservoirs were not in place – these were 1962, 1966, 1969, 1972, 1978, 1979, 1982, 1986, 1987, 1994, 1995, and 1997. These years were selected on the basis of climatic data and occurrence of ice jams on tributary streams. The unregulated spring flood peaks in these years were all increased by 40,000 cfs at Sioux City (roughly the average amount of the values in Table F-21), and a flow frequency analysis was performed (see the section on Mixed Population Analysis for further details on methodology) using these modified values.

The revised values with the ice jam adjustment show a sharp increase over the values determined without an ice jam adjustment. The following table shows the increase in discharges for various flow events at Sioux City. As can be seen, an adjustment to peak flows has a significant impact on the less frequent events.

Table F-22. Increase in Flow Frequency Caused by Adjustments to Peak Flows for Ice Jam Effects at Sioux City

Exceedance Probability	% Increase in Flow Estimate
0.5	1.48%
0.2	2.83%
0.1	5.24%
0.05	10.71%
0.02	15.23%
0.01	17.44%
0.005	19.81%
0.002	22.38%

However, a more careful examination of the record shows that an adjustment to flow may not be necessary. The 1881 flood resulted in a tremendous ice jam at Yankton, raising stages some 35 feet above flood stage and resulting in a tremendous volume of water being retained, if only for a short time. The effect of this ice jam may have been to reduce peak flows, and thus stages, downstream. The 1952 flood also had a tremendous ice jam upstream of Bismarck, North Dakota that released. The flood wave caused a significant increase in flow at Bismarck, but by the time the flood wave reached Pierre, South Dakota, the sharp peak in the Bismarck flood crest was attenuated.

It is recognized that the routing methods, and underlying assumptions, used in the unregulated analysis do not adequately account for ice jams that no longer occur on the Missouri mainstem. However, as demonstrated by the 1881 and 1952 floods, this may be a moot point, as the peaking effects of ice jams do not always propagate themselves downstream to the stations in question and they can actually reduce flows if the ice jam is large enough and stable enough to retain significant volumes of water. Therefore, it was deemed unnecessary to make any adjustments to the flow record to account for ice jam breakups on peak discharges through the study reach.

Sensitivity of Period Modeled to Monthly Volumes

There is some degree of uncertainty in the use of rating curves to develop flows for the period prior to USGS flow records. The Drought Series analysis appears to support that these flows are reasonable on an annual basis, and various statistical tests show that peak flows and volumes are stationary in nature throughout the period of record. In order to evaluate shorter time frames, monthly mean volumes can be compared for various periods to see if there is any significant difference.

The following Tables F-23 to F-28 list the computed monthly mean and standard deviation of flows at Yankton, Sioux City, Decatur, Omaha, Nebraska City and Rulo.

Table F-23. Mean Monthly Flows and Standard Deviations (1000 cfs), Yankton

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1898-1997												
Average	11.358	16.591	35.492	54.381	54.998	100.101	95.309	50.750	30.064	21.336	16.881	10.803
St Dev	5.22	7.51	17.15	31.99	16.93	23.33	27.84	14.49	8.64	8.73	7.11	5.45
1898-1928												
Average	14.961	19.755	39.267	59.443	65.389	112.537	103.301	62.069	37.551	28.192	23.275	14.164
St Dev	5.62	9.07	17.41	24.61	13.73	14.61	20.00	13.65	8.96	9.63	7.46	5.54
1929-1966												
Average	9.111	12.997	28.584	52.148	46.823	90.210	84.865	42.430	24.828	16.249	11.693	7.030
St Dev	3.31	5.20	10.85	36.07	14.78	22.50	27.18	8.98	5.85	5.61	4.38	3.45
1967-1997												
Average	10.508	17.831	40.184	52.057	54.629	99.788	100.120	49.629	28.997	20.715	16.847	12.067
St Dev	4.94	6.49	20.60	33.60	17.07	25.98	31.91	13.65	5.50	6.19	3.37	4.61
1929-1997												
Average	9.739	15.169	33.795	52.107	50.330	94.513	91.719	45.665	26.701	18.255	14.008	9.293
St Dev	4.15	6.26	16.88	34.73	16.21	24.42	30.16	11.79	6.03	6.25	4.70	4.71

Table F-24. Mean Monthly Flows and Standard Deviations (1000 cfs), Sioux City

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1898-1997												
Average	11.692	17.892	39.281	60.283	58.573	104.033	99.749	53.461	31.658	22.444	18.011	11.487
St Dev	5.42	7.79	18.43	35.54	18.87	24.80	28.99	15.61	9.36	9.11	7.39	5.80
1898-1928												
Average	15.281	21.381	43.332	63.781	69.217	117.303	107.934	65.277	39.817	29.479	24.510	14.899
St Dev	5.66	8.83	17.44	24.87	14.39	15.57	20.52	14.23	9.44	9.65	7.52	5.73
1929-1966												
Average	9.233	13.749	31.577	57.047	49.070	92.420	87.808	44.336	26.063	17.113	12.639	7.210
St Dev	3.40	5.57	12.38	39.74	15.92	23.32	28.20	9.75	6.34	6.02	4.87	3.62
1967-1997												
Average	11.118	19.481	44.674	60.750	59.578	104.998	106.202	52.830	30.357	21.944	18.099	13.317
St Dev	5.41	6.87	22.48	39.70	20.57	27.61	32.85	15.31	6.31	6.99	3.75	4.84
1929-1997												
Average	10.080	16.324	37.461	58.711	53.791	98.071	96.072	48.152	27.992	19.283	15.092	9.954
St Dev	4.48	6.78	18.69	39.47	18.77	25.92	31.52	13.16	6.64	6.87	5.16	5.18

Table F-25. Mean Monthly Flows and Standard Deviations (1000 cfs), Decatur

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1898-1997												
Average	11.973	18.463	39.984	61.385	59.029	104.839	100.796	54.195	32.068	22.616	18.022	11.621
St Dev	5.48	7.96	18.79	35.85	19.08	25.20	29.17	15.83	9.37	9.02	6.96	5.71
1898-1928												
Average	15.733	22.393	44.270	65.638	69.730	118.652	109.612	66.479	40.237	29.278	23.787	14.756
St Dev	5.45	8.75	18.03	25.10	14.50	16.21	20.38	14.02	9.27	9.49	6.73	5.11
1929-1966												
Average	9.280	13.986	32.031	57.538	49.245	92.725	88.331	44.735	26.323	17.228	12.771	7.273
St Dev	3.41	5.65	12.47	39.95	15.99	23.45	28.36	9.90	6.43	6.02	4.88	3.63
1967-1997												
Average	11.512	20.020	45.449	61.846	60.321	105.874	107.261	53.508	30.942	22.559	18.694	13.814
St Dev	5.57	7.03	22.75	40.06	20.85	27.75	32.89	15.47	6.40	7.17	3.93	5.10
1929-1997												
Average	10.283	16.697	38.059	59.474	54.222	98.633	96.836	48.676	28.398	19.623	15.432	10.212
St Dev	4.62	6.95	18.93	39.76	19.02	26.12	31.70	13.35	6.78	7.04	5.34	5.42

Table F-26. Mean Monthly Flows and Standard Deviations (1000 cfs), Omaha

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1898-1997												
Average	13.211	21.124	43.424	66.867	61.221	108.603	106.100	57.954	33.969	23.199	17.744	12.032
St Dev	7.37	10.21	21.56	37.92	21.32	28.50	31.72	18.59	10.80	9.89	6.55	5.96
1898-1928												
Average	17.978	27.377	48.907	74.897	71.823	124.632	117.750	72.576	42.226	28.068	19.637	13.647
St Dev	8.74	11.84	24.17	28.56	18.89	23.21	24.94	17.99	12.00	11.82	6.39	4.29
1929-1966												
Average	9.421	15.032	34.085	59.785	49.796	93.744	90.837	46.648	27.491	17.616	13.283	7.531

St Dev	3.52	6.15	13.10	40.98	16.49	24.16	29.23	10.83	6.96	5.97	4.91	3.79
1967-1997												
Average	13.091	22.339	49.388	67.517	64.623	110.789	113.159	57.190	33.652	25.174	21.319	15.935
St Dev	6.79	8.28	23.66	41.57	22.69	29.53	34.02	16.99	7.57	8.44	5.37	6.09
1929-1997												
Average	11.070	18.315	40.960	63.259	56.457	101.402	100.866	51.385	30.259	21.011	16.894	11.307
St Dev	5.52	8.01	19.98	41.12	20.74	27.84	33.18	14.80	7.82	8.07	6.49	6.47

Table F-27. Mean Monthly Flows and Standard Deviations (1000 cfs), Nebraska City

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1898-1997												
Average	17.737	28.646	59.946	80.945	83.736	136.694	129.560	78.181	44.291	28.229	21.893	16.049
St Dev	9.39	12.48	23.90	39.23	25.03	32.01	33.86	22.22	13.11	11.75	7.56	7.20
1898-1928												
Average	22.680	34.421	75.877	92.880	100.524	154.670	142.212	96.177	52.977	32.795	22.845	16.473
St Dev	12.24	15.06	19.13	21.65	18.26	20.96	22.55	21.17	14.63	14.55	7.75	5.97
1929-1966												
Average	13.340	21.958	45.552	71.399	68.652	120.342	112.376	63.477	36.332	22.372	17.431	11.313
St Dev	4.20	7.90	16.17	43.92	19.23	27.64	30.67	12.00	8.13	7.46	6.01	4.67
1967-1997												
Average	18.185	31.069	61.659	80.712	85.440	138.763	137.971	78.211	45.361	30.842	26.411	21.430
St Dev	8.35	10.61	25.86	44.35	26.37	36.38	38.76	19.87	10.61	10.17	6.04	7.07
1929-1997												
Average	15.517	26.052	52.788	75.583	76.194	128.618	123.875	70.096	40.389	26.177	21.466	15.858
St Dev	6.80	10.22	22.41	44.04	24.06	32.93	36.59	17.52	10.30	9.69	7.48	7.72

Table F-28. Mean Monthly Flows and Standard Deviations (1000 cfs), Rulo

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1898-1997												
Average	18.157	29.346	58.513	80.822	83.329	137.568	131.691	78.644	45.808	29.460	23.333	16.736
St Dev	9.10	11.62	22.44	40.44	25.17	32.84	36.30	21.00	12.78	11.60	7.68	7.82
1898-1928												
Average	21.975	33.436	66.329	86.395	92.456	151.031	139.894	92.152	52.496	32.908	23.956	15.966
St Dev	11.19	11.77	17.29	25.63	19.78	24.22	26.71	18.81	12.75	12.48	5.81	5.45
1929-1966												
Average	13.781	22.831	46.634	73.014	70.423	122.440	115.161	65.395	38.137	23.510	18.493	11.876
St Dev	4.17	8.25	16.87	45.23	20.56	28.59	31.61	12.62	8.80	7.97	6.48	4.81
1967-1997												
Average	19.703	33.245	65.257	84.822	90.023	142.648	143.752	81.377	48.521	33.305	28.643	23.464
St Dev	9.20	11.69	26.89	45.71	28.90	38.22	42.85	22.07	12.34	11.71	7.07	8.15
1929-1997												
Average	16.442	27.509	55.001	78.319	79.228	131.519	128.006	72.575	42.803	27.911	23.053	17.082
St Dev	7.46	11.16	23.68	45.50	26.36	34.52	39.48	19.12	11.68	10.92	8.41	8.69

These monthly values can be compared using a simple two-sided hypothesis testing and checking the statistical significance of the parameters to see if the various periods are significantly different or not. The following table lists the various periods compared and those stations that differ at the 0.01 significance level by month.

Table F-29. Stations with Differences Between Monthly Means at 0.01 Significance Level

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1898-1928 vs. 1929-1997												
Yankton	✓				✓	✓		✓	✓	✓	✓	✓
Sioux City	✓	✓			✓	✓		✓	✓	✓	✓	✓
Decatur	✓	✓			✓	✓		✓	✓	✓	✓	✓
Omaha	✓	✓			✓	✓	✓	✓	✓	✓		
Nebraska City	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Rulo			✓		✓	✓		✓	✓			
St. Joseph												
1898-1928 vs. 1929-1966												
Yankton	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Sioux City	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Decatur	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Omaha	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
Nebraska City	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Rulo	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
St. Joseph	✓	✓						✓	✓	✓	✓	
1898-1928 vs. 1967-1997												
Yankton	✓				✓			✓	✓	✓	✓	
Sioux City	✓							✓	✓	✓	✓	
Decatur	✓							✓	✓	✓	✓	
Omaha								✓	✓			
Nebraska City								✓				✓
Rulo											✓	✓
St. Joseph			✓								✓	✓
1929-1966 vs. 1967-1997												
Yankton		✓	✓						✓	✓	✓	✓
Sioux City		✓	✓					✓	✓	✓	✓	✓
Decatur		✓	✓					✓	✓	✓	✓	✓
Omaha	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓
Nebraska City	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓
Rulo	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓
St. Joseph	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓

A check mark indicates a statistically significant difference between periods compared

As can be seen, the mean monthly flows at most stations for most months differ significantly for the periods 1898-1928 and 1929-1997. However, it appears that this difference may be due to the period 1929-1966 being lower. The periods 1898-1928 and 1967-1997 both differ significantly from the period 1929-1966 in most months. It is also interesting to note that most months for the periods 1898-1928 and 1967-1997 do not differ significantly. This further verifies that the flow values for the period 1898-1928 are likely reasonable. One thing to note is that the monthly values for the period 1898-1928 shown above differ from monthly flow values published by the USGS. However, the USGS values were based on rainfall-runoff characteristics of the basin in the late 1930s and early 1940s, and observed differences in the rainfall-runoff characteristics over various periods may account for the differences in the monthly flow volumes derived for this report and those published by the USGS for 1898-1928.

REGULATED FLOW

The regulated flow data set was developed through use of the Daily Routing Model (DRM), utilizing data sets for discharge, reservoir inflow and outflow, and depletions. The following sections describe the DRM and its inputs.

Hydrologic Model Description (DRM)

Model Philosophy

The DRM was not developed for this study; rather, it was developed for use in the Missouri River Master Water Control Manual Update Study to evaluate flood control, interior drainage, and groundwater levels along the Missouri River and navigation contributions to the Mississippi River.

The DRM contains 20 nodes including the six mainstem reservoirs and 14 gaging stations – Wolf Point and Culbertson, Montana; Williston and Bismarck, North Dakota; Sioux City, Iowa; Omaha, Nebraska City, and Rulo, Nebraska; and St. Joseph, Kansas City, Waverly, Boonville, and Hermann, Missouri on the Missouri River and St. Louis, Missouri on the Mississippi River.
The model utilizes two sets of input data. The first set of input files contains historic reach inflow and streamflow depletion data, and the second contains the various constants and variable parameters that define regulation decisions.

The historic data is organized in yearly files that contain daily data for each of the reservoir and gage locations and includes annual evaporation values for the six mainstem reservoirs. Monthly incremental inflow for each node and depletions that adjust historic monthly inflow to current water year uses are also included. Each yearly file contains 14 months of data – December of the previous year through January of the following year.

The second set of data contains five files that establish the variables and constants to define the capacity and operational limits of the river and reservoirs and to establish the guide curves and operating limits of a particular run. Program considerations include (1) reductions in historic inflows to reflect current levels of water uses; (2) reductions in reservoir volumes to reflect continued sediment accumulation from the date of the last sediment survey to the date of the study; (3) reductions in tailwater levels due to degradation; (4) reductions in inflow due to reservoir evaporation; (5) factors for determining the amount of tributary inflow that is available for meeting navigation targets; and (6) seasonal flow limits for flood control, navigation, hydropower, water supply, irrigation, endangered species, and evacuation of excess water during high runoff years.

Navigation guidelines are based on system storage on March 15 and July 1. Four navigation flow target gages are used: Sioux City, Omaha, Nebraska City, and Kansas City. System storage on March 15 determines whether navigation flows from April 1 to July 1 will be full service or minimum service or some intermediate level (where minimum service is 6000 cfs less than full service). The length of the navigation season is based on the system storage on July 1. Winter release rates are based on system storage on September 1. If system storage drops below 19.6 MAF, navigation will not be supported, so as to prevent system storage from dropping below permanent pool storage of 18 MAF.

The model uses a set of flow factors that are applied to incremental inflow between gaging stations to assign the amount of the inflow that is applicable on a monthly basis for navigation purposes, as not all local inflow can be considered usable for navigation.

Releases from Oahe, Garrison, and Fort Peck are checked and adjustments made for flood control, environmental, fish reproduction, irrigation, recreation, power, safety, and other considerations. The last check before saving each period's data is a routine to adjust releases for terns and plovers. After any final release adjustments are made, individual reservoir storages are recomputed, downstream flows are rerouted, and hydropower is adjusted as necessary. The program goes through the same process for each period, and the data is stored in arrays. The data is output to a file after completing the last period of each year. The program halts after processing all of the data or when the system storage limits are exceeded which necessitates adjusting parameters and restarting.

The DRM also has a supplemental program named ROUTE.EXE. This program is designed for analysis of daily data, but can also be used for graphing monthly data. More detailed information on the background and use of the DRM can be found in USACE (1998).

Modifications to DRM

The source code for the DRM was not modified for this study. The model does however continue to go through various periods of refinement for the Missouri River Master Water Control Manual Study.

Input Data Development

Virtually all input data required for the DRM was previously developed for the unregulated flow analysis or developed for previous studies utilizing the DRM. Input data at gaging stations includes incremental reach inflow, observed gage flow data, and incremental reach depletion data. Input for the six mainstem reservoirs includes reservoir inflow, reservoir outflow, incremental reach inflow, evaporation, and storage. The remaining data sets are the rule curves which dictate the operation of the reservoirs given various parameters. Data that was not modified included the rule curves and reservoir data. The gage data and reach inflow developed for the unregulated analysis were put into the DRM input files. Additionally, depletion data developed by the USBR was used for all depletion data in the model.

Current Depletion Estimates

The USBR developed estimates of current level depletions for the period 1898-1996. The DRM uses depletion data by adjusting historic flows to present day consumptive water uses. The depletion data input to the DRM is actually the difference between historic and current level depletions. This necessitated a slight adjustment to the depletion data used in the UFDM, as the UFDM modeled the USBR reservoirs that operate for flood control upstream of Sioux City, and hence the depletion data for these reservoirs was taken out of the depletion data used in the UFDM to eliminate duplicity. For the DRM, both the current and historic depletion data sets included all reservoir depletions (exclusive of the six mainstem reservoirs). Tables A-20 to A-35 list the historic and current level depletions used for the DRM.

Routing Parameters

The DRM uses routing coefficients for routing flows from one gage to the next (i.e. does not include incremental inflows, as they are routed separately). The routing coefficients used in the model had previously been calibrated for the period 1967-1997. Since one of the study assumptions was to use existing conditions, these values were used in this study, and are the same as used for the UFDM regression routing option. The table below lists the coefficients used.

Table F-30. Routing Coefficients Used in DRM Model

Reach	A_1	A_2	A_3
Gavins Point to Sioux City	0.17532	0.53734	0.28734
Sioux City to Omaha	0.16794	0.72176	0.11030
Omaha to Nebraska City	0.58790	0.41210	0.0
Nebraska City to Rulo	0.58837	0.41163	0.0
Rulo to St. Joseph	0.77547	0.22453	0.0
St. Joseph to Kansas City	0.42647	0.44863	0.12490

Reach	A_1	A_2	A_3
Kansas City to Waverly	0.47605	0.52395	0.0
Waverly to Boonville	0.35420	0.61748	0.02832
Boonville to Hermann	0.38146	0.43382	0.18472

Regression routing equation: $Q_{ds} = Q_{us}(d)*A_1 + Q_{us}(d-1)*A_2 + Q_{us}(d-2)*A_3$

Where:
Q_{ds} = Flow at downstream station
Q_{us} = Flow at upstream station
d-1 = yesterday, d= today, d+1 = tomorrow, etc.
A_1, A_2, A_3 = regression routing coefficients

Model Calibration/Verification

The output for the DRM can be compared to observed data for a relatively good check on the validity of model results. The mainstem reservoir system reached operational volume in 1967, so results from 1968 to 1997 can be compared to see how well the model reproduces the observed hydrograph. The Table F-31 below compares the observed and modeled annual peaks at each of the stations within Omaha District. As can be seen, some modeled peaks are higher, while some modeled peaks are lower.

Table F-31. Comparison of Simulated and Observed Peak Regulated Flows.

Year	Observed Daily Mean Max-Calendar					Simulated Daily Mean Max-calendar				
	Yankton	Sioux City	Omaha	Nebraska City	Rulo	Yankton	Sioux City	Omaha	Nebraska City	Rulo
1968	38400	38300	47000	62600	71500	41200	40200	48200	64800	73300
1969	55700	76400	99500	103000	106000	58700	77100	99400	103300	103400
1970	46100	45600	47200	57300	62000	56300	53900	53900	56800	55900
1971	54500	69800	79700	112000	125000	55000	72000	80600	125000	131800
1972	51200	54100	66800	80800	91300	52400	57100	69400	81000	89000
1973	33800	40900	52400	82200	122000	42100	41300	45500	82500	121200
1974	37400	40000	47900	75000	87800	39400	39300	46500	72600	86100
1975	63400	66200	73900	76700	81800	61500	62000	66300	71100	82300
1976	41700	41100	47000	61600	69100	50300	53000	52700	60800	65800
1977	36700	37800	43900	58600	77700	34500	36100	42400	54300	71000
1978	53500	61200	81200	154000	160000	60500	67100	86100	154100	164300
1979	43900	50100	82800	114000	135000	44400	55900	80300	109400	135100
1980	38500	42000	47000	64300	73600	35500	40300	47400	64400	72700
1981	36300	37000	47200	57400	56100	38100	36200	46300	56800	55200
1982	44600	49900	58000	97500	121000	56800	62800	72100	99200	124700
1983	39100	44000	80500	119000	121000	48100	57100	93800	136100	139200
1984	47800	103000	114000	180000	216000	48300	116300	125800	198200	231000
1985	41200	49500	68800	79100	85600	34500	46200	65000	75900	81500
1986	50300	56600	76300	99700	128000	64000	69400	88900	124100	150100
1987	34400	46600	58800	119000	140000	40100	39500	52800	109800	129700
1988	38900	38400	42200	48100	50700	36000	36500	41700	48200	51200
1989	32700	33500	44500	81600	114000	32200	32600	40600	78400	110400
1990	33400	36700	71700	114000	118000	31500	33600	72300	111800	116300
1991	32100	32600	74100	89200	94600	33000	35200	76800	91500	99100
1992	29100	37100	52500	54700	79800	31500	41800	51300	59300	120300
1993	24300	71300	113000	188000	289000	31500	89300	120500	201200	299500
1994	32400	49200	62100	86600	90400	34500	45700	53900	79900	85200

Year	Observed Daily Mean Max-Calendar					Simulated Daily Mean Max-calendar				
	Yankton	Sioux City	Omaha	Nebraska City	Rulo	Yankton	Sioux City	Omaha	Nebraska City	Rulo
1995	56100	65300	80300	108000	118000	65000	95500	109400	136700	148500
1996	55000	79900	116000	139000	146000	57300	96800	137100	136000	137600
1997	70100	97400	108000	113000	121000	70000	106000	109500	114600	121000

Table F-32 shows the average difference between simulated and observed annual peaks, as well as the standard deviation of those annual differences. As can be seen, the modeled peaks are a few thousand cfs higher on average. However, for the highest flow year (1997), the simulated and observed peaks are nearly identical.

Table F-32. Average Annual Difference Between Simulated and Observed Peak Regulated Flows.

	Yankton	Sioux City	Omaha	Nebraska City	Rulo
Average	3053	4810	3073	2727	3347
St. Dev.	4963	8342	8530	9176	11505

Some difference can be expected between observed and simulated, as the actual and current level of depletion differ somewhat; therefore it should be expected that the simulated values are slightly higher than the observed.

Another way to compare the accuracy of the computer simulation is to compare observed and computed system storage in the mainstem reservoirs. A table of computed and observed end-of-month storage is shown in Table FA-37. The mainstem reservoir system reached operating capacity in 1967, so a graph showing end of month storage as observed and as computed by the DRM was plotted and is shown in Figure F-1. As can be seen, there is sometimes a significant difference between observed and computed until the mid-1980s. However, most of this difference is due to depletions. If the difference between computed and observed end-of-month storage is plotted, it can be shown that the difference between computed and observed decreases by about 117,000 acre-feet per year. If the differences between observed and current level depletions are compared, it can be seen that depletions increased on average by about 82,000 acre-feet per year from 1967 through the 1990s. This indicates that about 70% of the difference between observed and computed end-of-month storage is due to increasing depletions throughout the upper basin. There have also been some minor differences in reservoir operation over the years. The monthly computed storage trends do track the trends in observed, so that indicates that the model is doing a good job of modeling reservoir operation over the period of record.

The final check of model validity is to compare the computed daily discharge versus observed daily discharge at Gavins Point. As pointed out above, some difference in discharge can be expected due to differences between actual and current level depletions. Daily observed and computed releases are available electronically. In several years, however, there are significant differences at various times of the year. Most often this is due to the model being unable to more accurately forecast future inflows in order to step up or step down releases.

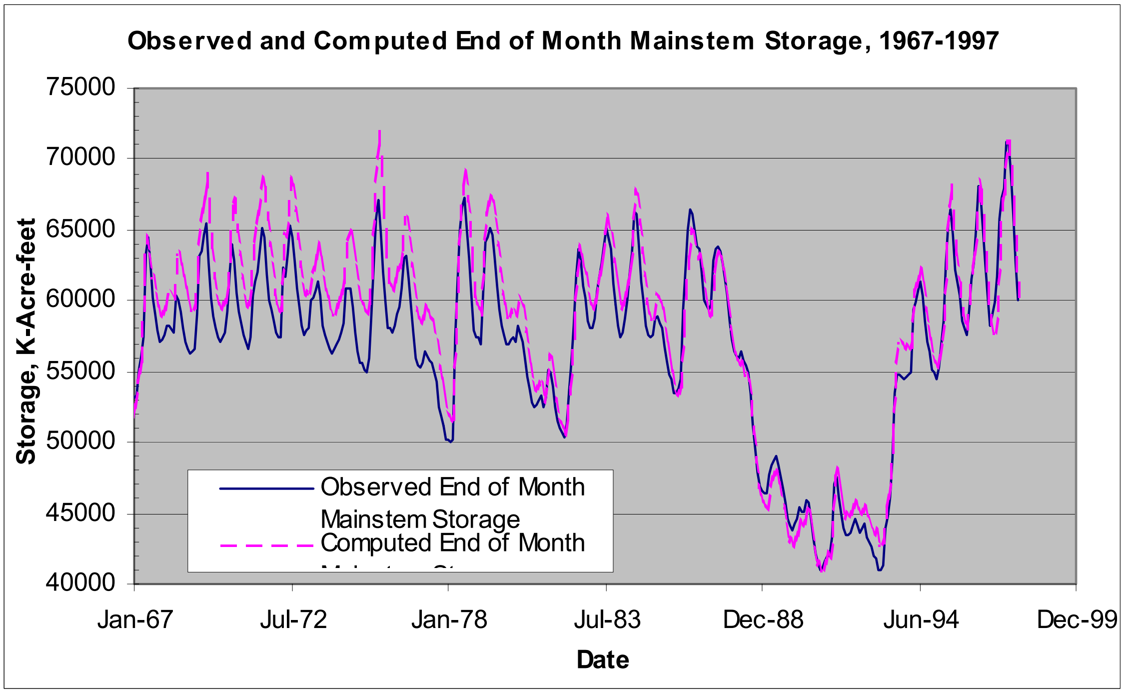


Figure F-1. Observed and Computed End of Month Mainstem Storage, 1967-1997

Period of Record Simulation

Once all input data was compiled, the model was run, covering the period of January 1, 1898 to December 31, 1997. Annual peaks were extracted from the output data and are compiled in Table FA-19.

Sensitivity Analysis

To see the model's sensitivity to depletion data, a comparison can be made between the results of this study and of that done by the RCC. All input data should be the same, except for some slight differences in depletion data. Table F-33 compares the results for the simulated Gavins Point peak outflow. As can be seen, there is little difference in most years, but in other years there can be a difference in excess of 10000 cfs. This shows that the model can be sensitive to depletion input. Presumably, the model would be equally sensitive to differences in input for observed flows at each gage or inflows to the mainstem reservoirs. As the simulations were continuous over the period of record, it is also possible that differences in storage carrying over from one year to the next may cause the model to hit a threshold for larger releases, thereby causing one data set to be higher than the other. This does point out that great care must be taken in using this model and interpreting its results.

Table F-33. Comparison of Simulated Annual Peaks with Different Depletion Data.

Year	RCC	NWO	Year	RCC	NWO	Year	RCC	NWO	Year	RCC	NWO
1898	61000	60500	1923	61850	62000	1948	45550	40800	1973	35770	42100
1899	61500	60000	1924	48720	61000	1949	40790	41200	1974	37120	39400
1900	34500	48300	1925	46820	56700	1950	60260	52800	1975	61390	61500
1901	40080	59500	1926	40780	36800	1951	59690	59700	1976	40540	50300
1902	34500	47200	1927	66500	65500	1952	65000	70800	1977	34500	34500
1903	36130	53800	1928	58430	66500	1953	41220	49300	1978	65000	60500

Year	RCC	NWO	Year	RCC	NWO	Year	RCC	NWO	Year	RCC	NWO
1904	48310	55300	1929	51560	51800	1954	38690	39300	1979	43430	44400
1905	34500	56400	1930	40120	42500	1955	39690	43800	1980	35250	35500
1906	33860	50400	1931	40860	43200	1956	36900	38100	1981	37180	38100
1907	66780	51600	1932	36880	36600	1957	33950	33000	1982	45550	56800
1908	61340	62000	1933	39450	41900	1958	30630	37400	1983	42080	48100
1909	67000	66500	1934	38460	38400	1959	33920	35300	1984	52260	48300
1910	39500	51900	1935	38540	39000	1960	41440	66100	1985	34500	34500
1911	41690	48800	1936	39320	47600	1961	30590	39300	1986	64000	64000
1912	59440	61000	1937	14370	15000	1962	37880	37800	1987	37590	40100
1913	55810	61000	1938	38030	43500	1963	39000	38600	1988	34500	36000
1914	53760	61500	1939	36920	51200	1964	36080	36500	1989	32820	32200
1915	67000	61500	1940	38500	40300	1965	56290	49600	1990	30530	31500
1916	62000	62000	1941	12050	20800	1966	37840	40000	1991	33200	33000
1917	61500	61800	1942	32610	38400	1967	44570	54700	1992	28790	31500
1918	49030	59900	1943	41550	49000	1968	38090	41200	1993	28500	31500
1919	34500	42400	1944	35950	40700	1969	53230	58700	1994	34500	34500
1920	44710	43700	1945	39550	37700	1970	57380	56300	1995	59820	65000
1921	34860	46400	1946	45200	41500	1971	52770	55000	1996	55660	57300
1922	40770	36200	1947	43900	42000	1972	52710	52400	1997	70000	70000

FREQUENCY ANALYSIS

A frequency analysis was performed on the unregulated flow data set at each gaging station. A relationship between regulated and unregulated peak annual flows was then developed at each station. The regulated-unregulated relationship was then used to derive the regulated flow frequency at each station. Volume-duration-probability relationships were developed at each gage, using durations of 1- to 181-days. Balanced flood hydrographs were then derived using the results of the volume-duration-probability relationships.

Unregulated Flow Frequency

Frequency analysis was performed on peak annual unregulated flows at each gage, using Bulletin 17B procedures. Outliers were examined, and historical flood information was considered for increasing the reliability of estimates of less frequent floods. A mixed distribution was evaluated for applicability to the flow data. In order to obtain regionally consistent frequency profiles, skew values were regionalized for final frequency estimates.

Methodology

The Technical Advisory Group/Interagency Advisory Group (TAG/IAG) recommended regional shape estimation to estimate the unregulated flow frequency curves (see HEC, 2000) This method differs from the standard Bulleting 17B guidelines in that a regional skew is used as the adopted skew value rather than the weighted skew recommended in the guidelines. Regional analyses were performed on the annual peak unregulated flow series at each gage to obtain the regional skew value. Results are tabulated in the following two tables:

Table F-34. Statistics of log-flows of Gages Above the Kansas River

Location	Drainage Area, sq. mi.	Mean	Standard Deviation	Computed Skew
Yankton	279500	5.2026	0.1372	0.0552
Sioux City	314580	5.2120	0.1323	-0.0244
Decatur	316200	5.2132	0.1312	-0.0575
Omaha	322800	5.2302	0.1329	-0.0661
Nebraska City	410000	5.3203	0.1177	-0.0474
Rulo	414900	5.3266	0.1220	-0.0532
St. Joseph	420300	5.3398	0.1218	0.0670

Table F-35. Unregulated Flow Frequency Relations for Annual Series of Gages in Omaha District.

Exceedance Probability	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo
0.002	400000	386000	381000	399000	448000	467000
0.005	363000	354000	349000	366000	414000	431000
0.01	335000	328000	325000	341000	388000	403000
0.02	307000	303000	301000	315000	362000	374000
0.05	269000	268000	267000	279000	325000	335000
0.1	239000	240000	240000	251000	295000	304000
0.2	208000	211000	211000	220000	263000	269000
0.5	159000	163000	164000	171000	210000	213000
0.8	122000	126000	127000	131000	167000	168000
0.9	106000	110000	111000	115000	147000	148000
0.95	95100	98400	98900	102000	133000	133000
0.99	77000	79500	79800	82000	110000	109000

Historical Flood Information

For all the gages upstream of the Kansas River, the 1952 flood was the highest of record since the 1881 flood. According to estimates of the peak flow at Omaha, the 1881 flood would be the 2nd largest flood of the unregulated flow series, if the period of record were extended. There were notations in some of the early stage record books that indicated that the 1844 flood at Omaha was 10 feet higher than the 1881 flood. However, further study found no credible evidence to support this, and a considerable amount of evidence to refute it. A consensus was reached among all Districts to not use historic floods to extend the period of record, as study area land use conditions become much more different as one goes back further than 1898.

Outliers

The 1952 flood is identified as a high outlier by the Bulletin 17B outlier test at all gages upstream of the Kansas River for an annual series analysis. Flow records are considered quite reliable for the 1952 flood, so it is unlikely that the observed flow data is greatly in error. As the flood occurred in the early spring, there are not many depletions or holdouts to drastically affect the computed peak discharge either. The 1881 flood could be added to the period of record, but it would not keep the 1952 flood from being considered a high outlier. Further analyses would show that the snowmelt season and rainfall season events have different distributions, and should therefore be treated as a mixed population.

Mixed Population Analysis

Downstream of Yankton, South Dakota, the Missouri River has historically been subject to two main annual flood events: a spring plains snowmelt period, and a summer mountain snowmelt and plains rainfall period. Each series of floods was examined to see if they were significantly different and if the two flood periods could be combined to better describe the flow frequency at each gage.

For purposes of analysis, the calendar year was divided into two seasons: spring (January 1 - April 30) and summer (May 1 - December 31). Virtually all plains snowmelt-related floods occur from mid-March through late-April, while all other floods occur from mid-May through late-July.

First, the top 10 floods in the annual series at each gage were examined to see if they were spring or summer floods. The following table lists the top 10 floods at each gage and notes whether a spring or summer event.

Table F-36. Top 10 Annual Flood Events at Each Gage and Season of Occurrence.

Rank	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo	St Joseph
1	1952 – S[1]	1952 - S	1952 – S	1952 – S	1952 – S	1952 – S	1952 – S
2	1943 – S	1997 – S	1997 – S	1997 – S	1960 – S	1993 – R	1993 – R
3	1953 – R[2]	1978 – S	1978 – S	1978 – S	1993 – R	1960 – S	1960 – S
4	1978 – S	1953 – R	1953 – R	1960 – S	1967 – R	1984 – R	1903 – R
5	1950 - S	1960 – S	1960 – S	1953 – R	1978 – S	1978 – S	1978 – S
6	1899 - S	1899 – S	1899 – S	1967 - R	1984 – R	1967 – R	1984 – R
7	1905 - R	1950 – S	1967 – R	1972 – S	1996 – R	1996 – R	1967 – R
8	1997 – S	1972 – S	1972 – S	1899 - S	1997 – S	1997 – S	1996 – R
9	1972 – S	1967 – R	1950 - S	1984 – R	1921 - R	1965 – R	1917 - R
10	1967 - R	1905 - R	1964 - R	1964 – R	1944 - R	1983 - R	1965 - R

[1] S=Plains snowmelt flood

[2] R=Summer rainfall/mountain snowmelt flood

As can be seen, the majority of large floods above the Platte River result from plains snowmelt floods, while between the Platte and Kansas Rivers, plains snowmelt floods are in the minority of top 10 floods, but constitute the majority of top 5 floods. Overall, plains snowmelt floods account for 16 of the top 25 annual and only 24 of the 100 annual peak floods at Yankton and 7 of the top 25 annual and only 16 of the 100 annual peak floods at St. Joseph. This suggests that plains snowmelt floods have an impact on the larger floods, and the impact decreases as one moves downstream, until the impact is negligible downstream of the Kansas River.

USACE (1993) suggests the use of mixed population analysis when there are two or more different, but independent, causative conditions, as exists on the upper Missouri basin. The plains snowmelt and mountain snowmelt can be considered independent of each other, or very nearly so, as plains snowpack typically peaks from February to late-March, and is non-existent by the end of April, while the mountain snowpack typically continues to accumulate until mid-May or later. Rainfall sometimes augments a plains snowmelt and sometimes a very late snowfall may occur in May over much of the upper basin. However, runoff characteristics differ greatly from early spring to late spring, with mostly frozen soil early in the spring resulting in much greater runoff than occurs later in the spring from the same volume of precipitation.

USACE (1993) prescribes that the frequency relation of each population be derived by analytical techniques and then combined to yield the mixed population frequency curve. The individual populations are combined by "probability of union," with the equation:

$P_c = P_1 + P_2 - P_1 * P_2$

where:
P_c = Annual exceedance probability of combined populations for a selected magnitude
P_1 = Annual exceedance probability of same selected magnitude for population series 1
P_2 = Annual exceedance probability of same sleected magnitude for population series 2

The largest flood event from the January-April and May-December time frame for each year was determined from the unregulated flow data set at each gage and examined to make sure each was either a plains snowmelt or mountain snowmelt/plains rainfall event per the time frame. In only a couple years did it appear that the plains snowmelt lasted into May, but the difference between late April and early May peaks was nominal, so the January-April data was not changed. In those years that snowmelt may have persisted into May, either a later peak surpassed it in magnitude, or the difference between later peaks was nominal (less than 10% difference), so the May-December data was not changed either. In no case did the floods in question rank in the top half of either population, so the impacts on computed frequency may be considered insignificant.

The following statistics were derived from the analysis of each population at each gage:

Table F-37. Seasonal Statistics of log-flows of Gages Above the Kansas River

Location	(1)	(2)	(3)	(4)	(5)	(6)
Yankton	5.000	0.256	-0.003	5.162	0.123	-0.416
Sioux City	5.014	0.249	-0.085	5.171	0.119	-0.475
Decatur	5.012	0.246	-0.067	5.173	0.119	-0.472
Omaha	5.031	0.243	-0.046	5.190	0.121	-0.344
Nebraska City	5.083	0.221	0.008	5.298	0.111	-0.183
Rulo	5.084	0.218	0.120	5.306	0.116	-0.092
St. Joseph	5.101	0.214	0.172	5.320	0.118	0.032

(1) Mean of annual max 1-day log-flows (January-April)
(2) Standard deviation of annual max 1-day log-flows (January-April)
(3) Skew of annual max 1-day log-flows (January-April)
(4) Mean of annual max 1-day log-flows (May-December)
(5) Standard deviation of annual max 1-day log-flows (May-December)
(6) Skew of annual max 1-day log-flows (May-December)

The above results in the following frequency relation at each gage for spring and summer populations, as well as the mixed distribution frequency relation.

Table F-38. At-Station Frequency Relations for Spring and Summer Populations and Mixed Distribution, Yankton to Omaha

(1)	Yankton			Sioux City			Decatur			Omaha		
	(2)	(3	(4)	(2)	(3	(4)	(2)	(3	(4)	(2)	(3	(4)
99	25000	69000	81000	26000	71000	83000	26000	71000	84000	29000	76000	87000
95	38000	89000	100000	40000	91000	103000	40000	92000	104000	43000	96000	108000
90	47000	100000	112000	49000	103000	115000	49000	104000	116000	52000	108000	120000
80	61000	115000	127000	64000	119000	131000	64000	119000	131000	67000	123000	136000
50	100000	148000	162000	104000	152000	165000	104000	153000	166000	107000	157000	172000
20	164000	185000	206000	168000	188000	207000	166000	189000	207000	172000	197000	217000
10	213000	206000	235000	214000	207000	235000	211000	208000	234000	219000	219000	247000
5	264000	224000	274000	261000	223000	270000	257000	224000	269000	269000	239000	283000
2	336000	244000	335000	325000	242000	327000	319000	243000	322000	338000	262000	335000
1	395000	258000	394000	375000	254000	378000	369000	255000	373000	393000	279000	387000
0.5	457000	271000	462000	428000	265000	438000	420000	266000	432000	452000	294000	449000
0.2	547000	287000	544000	501000	278000	507000	491000	279000	501000	535000	313000	521000

(1) Percent Chance Exceedance
(2) Spring Frequency Relation
(3) Summer Frequency Relation
(4) Mixed Distribution Relation

Table F-39. At-Station Frequency Relations for Spring and Summer Populations and Mixed Distribution, Nebraska City to St. Joseph

(1)	Nebraska City			Rulo			St. Joseph		
	(2)	(3	(4)	(2)	(3	(4)	(2)	(3	(4)
99	37000	106000	116000	39000	107000	116000	43000	111000	121000
95	53000	129000	138000	54000	129000	139000	58000	134000	143000
90	63000	143000	152000	64000	143000	153000	68000	148000	157000
80	79000	161000	170000	79000	162000	171000	83000	166000	176000
50	121000	200000	211000	120000	203000	214000	124000	209000	220000
20	186000	247000	260000	185000	253000	267000	190000	263000	277000
10	232000	274000	292000	232000	284000	301000	239000	296000	315000
5	279000	298000	325000	281000	311000	338000	291000	327000	355000
2	344000	326000	366000	349000	345000	383000	365000	365000	405000
1	395000	346000	406000	405000	369000	425000	426000	393000	449000
0.5	448000	365000	458000	463000	392000	481000	492000	420000	505000
0.2	523000	389000	527000	547000	422000	553000	587000	456000	578000

(1) Percent Chance Exceedance
(2) Spring Frequency Relation
(3) Summer Frequency Relation
(4) Mixed Distribution Relation

Regionalization of Statistics

In order to obtain regionally consistent frequency curves at each gage, it is necessary to regionalize the results of the flow frequency analysis. However, there is no guidance for regionalizing computed flow statistics in a mixed distribution, other than USACE (1993) stating, “If annual flood peaks have been separated by causative factors, a generalized skew must be derived for each separate series to apply the log-Pearson Type III distribution as recommended by Bulletin 17B.”

An examination of the station statistics, as shown in Table F-37, shows that there appears to be a flood regime change in computed values between Omaha and Nebraska City (see HEC, 2000). Therefore, it was decided to regionalize skew for the gages above the Platte River and for those between the Platte and Kansas Rivers. The following table shows the computed skew at each station, and the average skew for each region, by season.

Table F-40. Statistics for Regional Flow Frequency Analysis

	(1)	(2)	(3)	(4)	(5)	(6)
Yankton	4.9999	0.256	-0.003	5.1624	0.123	-0.416
Sioux City	5.0142	0.249	-0.085	5.1712	0.119	-0.476
Decatur	5.0118	0.246	-0.067	5.1735	0.119	-0.472
Omaha	5.0306	0.243	-0.046	5.1905	0.121	-0.345
Region Average			**-0.050**			**-0.427**
Nebraska City	5.0830	0.221	0.008	5.2982	0.111	-0.183
Rulo	5.0840	0.223	0.096	5.3057	0.117	-0.100
St. Joseph	5.1013	0.225	0.126	5.3200	0.121	0.013
Region Average			**0.077**			**-0.090**

(1) Log-mean of spring instantaneous peaks
(2) Standard deviation of spring 1-day means
(3) Computed skew of spring 1-day means
(4) Log-mean of summer instantaneous peaks
(5) Standard deviation of summer 1-day means
(6) Computed skew of summer 1-day means

Use of the above regional skew values results in the following frequency relationships at each gage (Tables F-41 to F-42).

Table F-41. Regional Frequency Relations for Spring and Summer Populations and Mixed Distribution, Yankton to Omaha

(4)	Yankton			Sioux City			Decatur			Omaha		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
99	24800	68900	80500	26600	72000	83700	27000	72400	84000	28600	74300	86800
95	37600	88300	100100	39900	91600	103400	40200	92000	103700	42500	94900	107400
90	46800	100000	111800	49400	103000	115200	49600	104000	115600	52300	107000	119700
80	61000	115000	127600	63800	119000	130800	63900	119000	131100	67200	123000	136200
50	100000	148000	162200	104000	151000	165100	103000	152000	165300	108000	158000	172100
20	164000	185000	205300	168000	187000	207500	166000	188000	207400	172000	197000	216200
10	212000	206000	234600	215000	208000	236300	212000	208000	235300	219000	218000	245200
5	261000	223000	272100	263000	225000	273200	259000	226000	270100	267000	236000	280200
2	330000	243000	330300	330000	244000	330200	324000	245000	324400	334000	257000	334400
1	386000	257000	385600	384000	257000	383800	376000	258000	376000	387000	271000	387000
0.5	444000	269000	450000	440000	269000	446000	431000	270000	436100	442000	284000	447700
0.2	526000	284000	526400	519000	284000	519500	507000	285000	507100	520000	300000	519600

(1) Spring Frequency Relation
(2) Summer Frequency Relation
(3) Mixed Distribution Relation
(4) Percent Chance Exceedance

Table F-42. Regional Frequency Relations for Spring and Summer Populations and Mixed Distribution, Nebraska City to St. Joseph

(4)	Nebraska City			Rulo			St. Joseph		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
99	38100	108000	116700	38200	106000	115700	38900	107000	117800
95	53000	130000	138700	53100	129000	138600	54400	131000	141800
90	63300	143000	152000	63500	143000	152600	65300	146000	156500
80	78700	160000	169800	78900	161000	171400	81400	165000	176400
50	120000	199000	210100	121000	203000	214200	125000	210000	222000
20	185000	247000	260900	186000	254000	268400	195000	264000	280100
10	233000	275000	293900	234000	285000	303000	246000	298000	317500
5	283000	300000	329100	283000	313000	340400	299000	328000	357700
2	352000	332000	374100	352000	347000	386200	374000	365000	406900
1	407000	354000	417600	408000	372000	429300	434000	392000	452800
0.5	466000	375000	473600	467000	396000	485200	498000	418000	511700
0.2	549000	403000	548700	551000	427000	557900	588000	452000	588400

(1) Spring Frequency Relation

(2) Summer Frequency Relation
(3) Mixed Distribution Relation
(4) Percent Chance Exceedance

The regionally computed values still maintain the slight decrease in discharge from Yankton to Decatur for the less frequent events (which appears to be due to the large amount of overbank storage available between Yankton and Omaha, leading to attenuation of large flood peaks). There is a slight difference between the at-station and the regionally computed frequency relationships. The following table shows the differences at each station for various floods.

Table F-43. Difference Between At-Station and Regionally Computed Frequency Curves

Percent Chance Exceedance	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo	St. Joseph
99	-0.6%	0.8%	0.0%	-0.2%	0.6%	-0.3%	-2.6%
95	0.1%	0.4%	-0.3%	-0.6%	0.5%	-0.3%	-0.8%
90	-0.2%	0.2%	-0.3%	-0.2%	0.0%	-0.3%	-0.3%
80	0.5%	-0.2%	0.1%	0.1%	-0.1%	0.2%	0.2%
50	0.1%	0.1%	-0.4%	0.1%	-0.4%	0.1%	0.9%
20	-0.3%	0.2%	0.2%	-0.4%	0.3%	0.5%	1.1%
10	-0.2%	0.6%	0.6%	-0.7%	0.7%	0.7%	0.8%
5	-0.7%	1.2%	0.4%	-1.0%	1.3%	0.7%	0.8%
2	-1.4%	1.0%	0.7%	-0.2%	2.2%	0.8%	0.5%
1	-2.1%	1.5%	0.8%	-0.1%	2.9%	1.0%	0.8%
0.5	-2.6%	1.8%	0.9%	-0.3%	3.4%	0.9%	1.3%
0.2	-3.2%	2.5%	1.2%	-0.3%	4.1%	0.9%	1.8%

Other methods for regionalizing the frequency curves were investigated. One method involved regression versus drainage area for the various quintiles. However, this method does not preserve the log-normal distribution of the flow populations. Another method involved factoring the regionalized Yankton curve by the ratio of annual peaks of each downstream station to the Yankton annual peaks; this method was applicable only to the reach above the Platte River. However, this method results in the more frequent events being overestimated due to the poor fit of annual peak ratios at lower discharges.

Conversion of Maximum Daily to Peak Flow

The UFDM model uses daily mean data for input and output. In order to convert the daily mean values to peak instantaneous values for purposes of frequency analysis, a relation between published USGS instantaneous and daily means was determined at each gage. A linear relation was selected at each station from Yankton to Nebraska City, forcing the line through the origin. The best-fit line was forced through the origin to preserve the standard deviation and skew of the daily means, as well as to prevent relationships with a slope of less than one. Some lower flood values were discarded as they had undue influence on the curve (the instantaneous value was significantly higher than daily mean). The following table lists the percentages which peak daily mean flows were increased by to obtain instantaneous values.

Table F-44. Conversion of Daily Means to Instantaneous Flows

Station	% Increase
Yankton	3.6%
Sioux City	2.3%
Decatur	3.1%
Omaha	3.9%
Nebraska City	4.2%

Unregulated Flow Frequency Profiles

Flow frequency profiles were developed to determine the various flood frequency relationships at points intermediate to the gaging stations. Values were determined by linearly interpolating between gages based on drainage area. Subsequent analysis determined that drainage area may not be suitable for flow distribution upstream of Sioux City. Refer to the cross section flow frequency section for further information. The following table lists the flow frequency relationships at various points along the Missouri River mainstem from Yankton to St. Joseph.

Table F-45. Unregulated Flow Frequency Profiles *

Location	1960 River Mile	Drainage Area, sq mi	Exceedance Probability											
			99	95	90	80	50	20	10	5	2	1	0.5	0.2
Gavins Point Dam	811.1	279400	80500	100100	111800	127600	162200	205300	234600	272100	330300	385600	450000	526400
Yankton, SD	805.8	279500	80500	100100	111800	127600	162200	205300	234600	272100	330300	385600	450000	526400
James River	797.7	279600	80500	100100	111800	127600	162200	205300	234600	272100	330300	385600	450000	526400
		301700	82500	102200	114000	129600	164000	206700	235700	272800	330200	384500	447500	522000
Vermillion River	771.9	302295	82600	102200	114000	129700	164100	206700	235700	272800	330200	384400	447400	521900
		304480	82800	102400	114200	129900	164300	206900	235800	272900	330200	384300	447200	521500
Big Sioux River	734.0	305110	82800	102500	114300	129900	164300	206900	235800	272900	330200	384300	447100	521400
		314680	83700	103400	115200	130800	165100	207500	236300	273200	330200	383800	446000	519500
Sioux City, IA	732.3	314600	83700	103400	115200	130800	165100	207500	236300	273200	330200	383800	446000	519500
Floyd River	731.3	314620	83700	103400	115200	130800	165100	207500	236300	273200	330100	383700	445900	519300
		315541	83900	103600	115400	131000	165200	207400	235700	271400	326800	379200	440200	512200
Decatur, NE	691.0	316200	84000	103700	115600	131100	165300	207400	235300	270100	324400	376000	436100	507100
Little Sioux River	669.2	316370	84100	103800	115700	131200	165500	207600	235600	270400	324700	376300	436400	507400
		320877	86000	106300	118500	134700	170100	213600	242300	277300	331500	383600	444300	516000
Soldier River	664.0	320900	86000	106300	118500	134700	170100	213700	242400	277300	331500	383600	444400	516000
		321345	86200	106600	118800	135100	170600	214300	243000	278000	332200	384300	445100	516800
Boyer River	635.2	321500	86200	106700	118900	135200	170800	214500	243300	278200	332400	384600	445400	517100
		322688	86800	107300	119600	136100	172000	216100	245000	280000	334200	386500	447500	519400
Omaha, NE	615.9	322800	86800	107400	119700	136200	172100	216200	245200	280200	334400	386700	447700	519600
Platte River	594.8	323530	87000	107700	120000	136500	172400	216600	245600	280600	334700	387000	447900	519800
		410020	116600	138600	151900	169700	209900	260700	293700	328900	373900	417500	473500	548600
Nebraska City, NE	562.6	410400	116700	138700	152000	169800	210100	260900	293900	329100	374100	417600	473600	548700
Nishnabotna River	542.1	410530	116700	138700	152000	169800	210200	261100	294200	329400	374400	417900	473900	549000
		413525	116000	138600	152400	170900	212900	266100	300200	336900	382500	425700	481700	555100
Little Nemaha	527.8	413525	116000	138600	152400	170900	212900	266100	300200	336900	382500	425700	481700	555100
		414366	115800	138600	152500	171200	213700	267500	301900	339100	384800	427900	483800	556800
Tarkio River	507.6	414366	115800	138600	152500	171200	213700	267500	301900	339100	384800	427900	483800	556800
		414900	115700	138600	152600	171400	214200	268400	303000	340400	386200	429300	485200	557900
Rulo, NE	498.0	414900	115700	138600	152600	171400	214200	268400	303000	340400	386200	429300	485200	557900

* Drainage area distribution method was revised upstream of Sioux City as described in the cross section flow frequency section of the hydraulic analysis.

Regulated-Unregulated Relationships

Frequency analysis of a regulated data set is not done by normal analytical methods. In order to determine an accurate regulated frequency relationship, it is necessary to determine the unregulated frequency relationship at the gage, and determine a relationship between regulated and unregulated peaks. The regulated-unregulated relationship is then applied to the unregulated frequency curve to determine the final regulated flow frequency relation. The following describes how the regulated-unregulated relationships were determined.

Methodology

The regulated-unregulated relationship is determined by pairing regulated and unregulated peak values with one another, and determining the best relationship that describes that pairing. Since the unregulated analysis relied upon a mixed distribution analysis, it was thought that perhaps the regulated-unregulated relationship could be derived by pairing the spring regulated and unregulated peaks and the summer regulated and unregulated peaks, determining the relationship for the spring and summer data, and combine the curves using the probability of union. However, this method proved unsatisfactory, as the spring and summer regulated values were not truly independent, making the combination of the curves extremely cumbersome.

Thus, it was decided to determine the regulated-unregulated relationship using annual peaks from the regulated and unregulated data sets. Data were first paired by year (year-ordered pairs), but this resulted in a great deal of scatter (see Plates F-25 to F-29). Each data set was then ordered by magnitude of flood, and then paired (rank-ordered pair). This pairing resulted in a relationship that plotted through the median of the year-ordered pair data (see Plates F-30 to F-34). However, development of a relationship between regulated and unregulated peaks is not possible through use of this data alone due to the relatively few infrequent events.

In order to develop a regulated-unregulated relationship with a greater degree of confidence, it was necessary to develop some "design" storms to synthesize data points to extrapolate the regulated-unregulated relationship. Several large floods were chosen that had roughly the same exceedance probability at 5 or more of the gages from Yankton to St. Joseph. The years chosen were 1960, 1978, 1984, 1993, and 1997. These floods were chosen as representative in terms of timing (i.e. spring snowmelt – 1960, 1978, 1997 vs. summer rainfall/mountain snowmelt – 1984, 1993, 1997) as well as areal distribution (i.e. mostly upstream of Gavins Point – 1978, 1997 mostly downstream of Gavins Point – 1984, 1993, or both upstream and downstream – 1960). These floods were factored by various percentages (25-, 50-, 75-, and 100%) to develop several synthetic floods. For the unregulated flow development, all the incremental inflows to each reservoir and between each gage were factored by the above percentages and put into the model. The data at each gage downstream of Gavins Point had to be adjusted to reflect the higher inflows between gages, assuming Gavins Point releases were the same. Gavins Point releases were not adjusted as the difference in Gavins releases would only be a small percentage of the flow downstream for unregulated flow, and also recognizing that releases would likely be cut back during periods of downstream flooding, or that releases would be curtailed during periods of high runoff into the reservoir to be released later, thus lagging the actual downstream flood. Irrigation and other depletions were assumed to be constant. Each of the 20 floods were then modeled using the UFDM, and annual peaks were extracted. The table below shows the resulting annual peaks for each synthetic flood.

Table F-46. Synthetic Unregulated Flood Annual Peaks (Mean Daily Peaks)

Flood Event	Flood Factor	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo
1960	Baseline	211600	250500	251900	263500	315600	347000
	25%	264200	312900	318800	329100	393100	438100
	50%	316300	374700	381900	394100	469100	523400

Flood Event	Flood Factor	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo
	75%	368400	436500	444800	459200	545200	608800
	100%	420500	498300	507900	524200	621300	694000
1978	Baseline	262000	274800	274700	276600	303400	317700
	25%	326100	341000	341000	343800	375400	392300
	50%	388500	406900	406600	410300	445900	466100
	75%	450900	472700	472000	476700	516700	539900
	100%	539100	538600	537600	543100	587600	613800
1984	Baseline	126200	215200	215200	226500	302700	345900
	25%	149500	259400	262300	276200	349100	415300
	50%	170800	303500	307100	323800	410900	481300
	75%	192500	347600	351800	371300	465300	547300
	100%	391600	391700	396800	419000	519700	613400
1993	Baseline	113000	166700	170900	207900	313800	395900
	25%	136000	206000	215900	249400	382200	485200
	50%	160100	241400	253800	292200	448400	574400
	75%	184100	276800	291700	335000	514500	663600
	100%	208100	312300	329600	378600	580600	752700
1997	Baseline	236800	283800	281100	282800	287500	296800
	25%	297500	356400	347300	355300	358100	368800
	50%	358200	429000	417900	427600	430400	443200
	75%	418900	501500	488600	500000	502700	517400
	100%	479700	574100	559300	572300	575000	591700

The new incremental flow data and gage flow data was then incorporated into the DRM input files, and the DRM model was run. Again, this approach only models the regulation of the mainstem reservoirs and assumes that any increase in inflow to all other reservoirs is matched by an equal percentage increase in outflow. This likely underestimates peak regulated values for the larger synthetic floods. The following table lists the annual regulated peaks for the synthetic storms.

Table F-47. Synthetic Regulated Flood Annual Peaks (Mean Daily Peaks)

Flood Event	Flood Factor	Yankton	Sioux City	Omaha	Nebraska City	Rulo
1960	Baseline	65500	90200	119900	174300	173300
	25%	62200	109000	149100	215700	216500
	50%	72800	130700	179300	258600	260400
	75%	84800	149600	212800	304500	301300
	100%	96800	175200	246300	349100	350500
1978	Baseline	60000	67100	86100	154100	164300
	25%	79100	81800	106800	199800	213400
	50%	150400	158400	159100	242700	257700
	75%	160000	170000	172000	284000	302000
	100%	162000	178000	181000	325000	346000
1984	Baseline	49300	116300	125800	198200	231000
	25%	60600	131300	146100	219400	265700
	50%	67000	170000	183000	274000	329000
	75%	97000	208000	228000	359000	426000
	100%	261000	337000	358000	435000	514000

Flood Event	Flood Factor	Yankton	Sioux City	Omaha	Nebraska City	Rulo
1993	Baseline	31500	89300	120500	201200	299500
	25%	31500	112400	152500	238900	371300
	50%	47900	127700	179600	291500	444200
	75%	98000	145800	198000	337300	515100
	100%	187900	199400	233400	380800	585300
1997	Baseline	70000	106000	109500	114600	121000
	25%	147500	191400	201000	212800	218400
	50%	205200	277800	285200	293300	302500
	75%	365000	383600	393000	354600	363100
	100%	423700	450900	464600	472800	469900

Volume-duration curves were also determined for each of the synthetic unregulated floods and compared to the volume-duration relation of the baseline unregulated flood (see section on volume-duration-probability relationships for more detail on development of volume-duration curves). Those floods that did not reasonably preserve the consistency of the volume-duration curve of the baseline flood were not used for extending the regulated-unregulated relationships. The remaining floods were then plotted with the year-ordered pairs and rank-ordered pairs to ensure they fell within the scatter of points (or as best could be extrapolated).

The following floods were judged to be reasonable estimates for extending the regulated-unregulated relationship at each gage.

Table F-48. Synthetic Floods Used for Extending the Regulated-Unregulated Relationship

Location	Synthetic Floods Used
Yankton	1960: 25-, 50-, 75-, 100%
Sioux City	1960: 25-, 50-, 75-, 100% 1978: 25-, 50% 1984: 25-, 50% 1997: 25%
Omaha	1960: 25-, 50-, 75-, 100% 1978: 25-, 50% 1984: 25-, 50% 1997: 25-, 50%
Nebraska City	1960: 25-, 50-, 75-, 100% 1978: 25-, 50% 1984: 25% 1993: 25-, 50% 1997: 25-, 50-, 75-, 100%
Rulo	1960: 25-, 50% 1978: 25-, 50% 1984: 25% 1993: 25% 1997: 25-, 50-, 75%

Adopted Relationships

Once the synthetic storms were picked, the values were combined with the rank-ordered pair data at each gage. A relationship was then derived that was determined to best fit the data points (see Plates F-35 to F-39). At each gage, the top rank-ordered pair deviated significantly from most of the synthetic flood data, with the adopted relation lying significantly above the top-ranked pair of simulated data. However, in the design of the mainstem reservoir system, a recurrence of the 1881 flood was estimated to have a Gavins Point release of 100,000 cfs; the estimated unregulated discharge at Yankton in 1881 was between 300,000 and 350,000 cfs. If these two estimated flow values are plotted on the Yankton regulated-unregulated relationship, the point lies well above the adopted relation, as well as much of the synthetic data at Yankton. It was therefore deemed appropriate that the adopted relationship at each gage was adequate.

Regulated Flow Frequency

In order to determine the final regulated flow frequency relationship at each gage, all that needs to be done is to apply the regulated-unregulated relationship described above to the unregulated frequency curves found in Tables F-41 to F-42. This results in the regulated flow frequency relationships found in the table below. It should be noted that subsequent analysis determined that drainage area may not be suitable for flow distribution upstream of Sioux City. Refer to the cross section flow frequency section for further information regarding distribution between gage stations.

Table F-49. Regulated Frequency Curves, Yankton to Rulo

Percent Chance Exceedance	Yankton	Sioux City	Omaha	Nebraska City	Rulo
99	27000	31200	34600	40600	44900
95	32100	34000	40700	53500	55800
90	34800	36100	44800	60500	62800
80	38300	39100	49900	70500	72600
50	45300	49500	64200	88000	94700
20	63000	66800	85300	118700	132300
10	65000	78300	123600	149800	160900
5	69100	93900	132700	189900	188600
2	74700	113800	147900	206400	217300
1	84900	133800	174700	236700	252200
0.5	98000	155000	204500	275900	296900
0.2	123500	185400	247900	345400	370700

* Flow Distribution between gage locations was refined during the hydraulic analysis.

Volume-Duration-Probability Relationships

Volume-duration-probability relationships are necessary for evaluating balanced hydrographs, as well as for evaluating the effectiveness of the mainstem reservoir system. The following describes the steps in determining the volume-duration-probability relationships for unregulated flow.

Methodology

The methodology followed closely mirrors that of the unregulated annual flow-probability relationship described above. Durations of 1-, 3-, 7-, 15-, 31-, 91, and 181-days were chosen for analysis.

Since the instantaneous data was best described using a mixed distribution-type analysis, it was decided to analyze the volume-duration-probability relationships using both an annual series and a mixed distribution. DSS macros were used to calculate the mean flow volume for these various durations, using a centered-moving average, over the entire period of record. Additional macros were used to extract the maximum value for each duration by year and by season, and an executable program was used to tabulate all the results.

In an effort to make a comparison between annual and mixed distributions, regional skew coefficients need to be incorporated into the analysis. Values recommended by Beard (Beard, 1962) for annual flood volume frequency computations were plotted, and the appropriate values were determined for each duration above. The following table lists the values used for regional skew values in the analysis.

Table F-50. Initial Regional Skew Values for Duration

Duration	Skew Coefficient
1 day	-0.04
3 days	-0.12
7 days	-0.195
15 days	-0.267
31 days	-0.322
91 days	-0.37
181 days	-0.388

Annual and mixed distribution results were computed using log-Pearson type III analysis, and the results were graphically compared. It was noted that, just like in the annual flow-probability relationships, the mixed distribution provided a better fit of the data than the annual series for durations of 31-days or less. There was virtually no difference between the annual or mixed results for the 91- or 181-day durations. It was decided to use the mixed distribution analysis for durations of 31-days and less, and to use annual series analysis for the 91- and 181-day durations. The following table lists the computed statistics for each distribution checked.

Table F-51. Statistics of Annual and Mixed Populations, Volume-Duration-Probability Analysis

Location	Duration	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Yankton	1 day	4.985	0.256	-0.008	5.147	0.123	-0.342	5.187	0.137	0.040
	3 days	4.947	0.256	0.099	5.132	0.123	-0.370	5.171	0.136	0.024
	7 days	4.890	0.254	0.159	5.109	0.121	-0.411	5.141	0.129	-0.070
	15 days	4.820	0.238	0.112	5.081	0.118	-0.402	5.099	0.120	-0.200
	31 days	4.744	0.211	0.043	5.044	0.114	-0.444	5.052	0.114	-0.413
	91 days	4.742	0.140	-0.264	4.934	0.105	-0.513	4.934	0.105	-0.513
	181 days	4.760	0.110	-0.340	4.813	0.107	-0.389	4.813	0.107	-0.389
Sioux City	1 day	5.004	0.249	-0.077	5.161	0.119	-0.386	5.202	0.132	-0.027
	3 days	4.973	0.252	0.003	5.149	0.120	-0.414	5.188	0.133	-0.040
	7 days	4.921	0.252	0.053	5.125	0.120	-0.466	5.158	0.130	-0.103
	15 days	4.856	0.240	0.019	5.097	0.118	-0.479	5.119	0.122	-0.251
	31 days	4.783	0.215	-0.020	5.061	0.114	-0.505	5.071	0.115	-0.479
	91 days	4.771	0.148	-0.306	4.954	0.109	-0.511	4.954	0.109	-0.511
	181 days	4.786	0.114	-0.395	4.837	0.112	-0.408	4.837	0.112	-0.408
Decatur	1 day	4.999	0.246	-0.062	5.160	0.119	-0.384	5.200	0.131	-0.055
	3 days	4.973	0.249	-0.009	5.150	0.120	-0.420	5.188	0.131	-0.075
	7 days	4.925	0.251	0.031	5.128	0.120	-0.464	5.161	0.129	-0.128
	15 days	4.861	0.241	-0.004	5.100	0.118	-0.481	5.122	0.122	-0.268
	31 days	4.789	0.216	-0.045	5.064	0.115	-0.510	5.074	0.115	-0.490
	91 days	4.776	0.149	-0.324	4.958	0.110	-0.513	4.958	0.110	-0.513

Location	Duration	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	181 days	4.791	0.115	-0.411	4.842	0.113	-0.421	4.842	0.113	-0.421
Omaha	1 day	5.014	0.243	-0.045	5.174	0.121	-0.287	5.214	0.133	-0.062
	3 days	4.993	0.246	-0.022	5.164	0.122	-0.336	5.203	0.133	-0.147
	7 days	4.951	0.250	-0.018	5.143	0.125	-0.399	5.178	0.132	-0.245
	15 days	4.891	0.244	-0.063	5.115	0.125	-0.393	5.139	0.128	-0.309
	31 days	4.820	0.222	-0.153	5.081	0.122	-0.424	5.091	0.121	-0.468
	91 days	4.797	0.158	-0.345	4.975	0.117	-0.418	4.975	0.117	-0.418
	181 days	4.814	0.125	-0.381	4.864	0.122	-0.384	4.864	0.122	-0.384
Nebraska City	1 day	5.065	0.221	0.001	5.280	0.111	-0.159	5.302	0.118	-0.046
	3 days	5.048	0.221	0.015	5.269	0.111	-0.221	5.292	0.116	-0.116
	7 days	5.013	0.221	0.035	5.243	0.111	-0.298	5.264	0.114	-0.150
	15 days	4.967	0.209	0.006	5.211	0.111	-0.345	5.226	0.114	-0.289
	31 days	4.917	0.188	-0.167	5.174	0.109	-0.404	5.180	0.110	-0.453
	91 days	4.914	0.138	-0.437	5.076	0.104	-0.462	5.076	0.104	-0.462
	181 days	4.923	0.111	-0.481	4.972	0.107	-0.457	4.972	0.107	-0.457
Rulo	1 day	5.060	0.223	0.074	5.287	0.117	-0.090	5.308	0.124	-0.059
	3 days	5.045	0.223	0.100	5.276	0.116	-0.118	5.297	0.122	-0.067
	7 days	5.012	0.223	0.122	5.251	0.115	-0.162	5.271	0.120	-0.069
	15 days	4.966	0.211	0.119	5.218	0.115	-0.205	5.233	0.119	-0.167
	31 days	4.915	0.188	-0.013	5.180	0.112	-0.247	5.186	0.113	-0.304
	91 days	4.912	0.136	-0.301	5.080	0.104	-0.337	5.080	0.104	-0.337
	181 days	4.925	0.109	-0.390	4.974	0.105	-0.349	4.974	0.105	-0.349
St. Joseph	1 day	5.078	0.225	0.099	5.307	0.121	0.005	5.328	0.125	0.033
	3 days	5.052	0.231	0.131	5.293	0.123	-0.026	5.314	0.127	0.002
	7 days	5.010	0.234	0.145	5.263	0.123	-0.010	5.283	0.127	-0.003
	15 days	4.958	0.223	0.167	5.226	0.121	-0.056	5.240	0.126	-0.055
	31 days	4.903	0.201	0.127	5.185	0.119	-0.028	5.192	0.120	-0.102
	91 days	4.901	0.142	0.017	5.081	0.109	-0.095	5.081	0.109	-0.095
	181 days	4.921	0.112	-0.077	4.971	0.106	-0.038	4.971	0.106	-0.038

(1) Computed Mean of annual max [duration] log-flows (January-April)
(2) Computed Standard deviation of annual max [duration] log-flows (January-April)
(3) Computed Skew of annual max [duration] log-flows (January-April)
(4) Computed Mean of annual max [duration] log-flows (May-December)
(5) Computed Standard deviation of annual max [duration] log-flows (May-December)
(6) Computed Skew of annual max [duration] log-flows (May-December)
(7) Computed Mean of annual max [duration] log-flows (annual)
(8) Computed Standard deviation of annual max [duration] log-flows (annual)
(9) Computed Skew of annual max [duration] log-flows (annual)

Regionalization of Statistics

Once the method of analysis was determined, further “smoothing”, or regionalization, of statistics was necessary to obtain regionally consistent results for all durations.
The skews were averaged the same as they were for the instantaneous peak analysis. The following tables show the individual skews, and the adopted skew for each region and duration.

Table F-52. Individual Skews and Regional Skews, Spring Flows

Duration, Days	Yankton	Sioux City	Decatur	Omaha	**Regional Average**	Nebraska City	Rulo	St. Joseph	**Regional Average**
1	-0.0083	-0.0774	-0.0623	-0.0447	**-0.048**	0.0008	0.0741	0.0989	**0.058**
3	0.0994	0.0026	-0.0086	-0.0216	**0.018**	0.0148	0.1002	0.1309	**0.082**
7	0.1594	0.0533	0.0309	-	**0.056**	0.0354	0.1217	0.1454	**0.101**

				0.0183					
15	0.1117	0.0192	-0.0036	-0.0627	**0.016**	0.0058	0.1185	0.1669	**0.097**
31	0.0430	-0.0202	-0.0451	-0.1528	**-0.044**	-0.1671	-0.013	0.1265	**-0.018**

Table F-53. Individual Skews and Regional Skews, Summer Flows

Duration, Days	Yankton	Sioux City	Decatur	Omaha	**Regional Average**	Nebraska City	Rulo	St. Joseph	**Regional Average**
1	-0.3419	-0.3862	-0.3837	-0.2870	**-0.350**	-0.1589	-0.0901	0.0048	**-0.081**
3	-0.3695	-0.4137	-0.4197	-0.3362	**-0.385**	-0.2213	-0.1176	-0.0261	**-0.122**
7	-0.4108	-0.4658	-0.4644	-0.3994	**-0.435**	-0.2979	-0.1624	-0.0095	**-0.157**
15	-0.4022	-0.4788	-0.4806	-0.3925	**-0.439**	-0.3450	-0.2045	-0.0564	**-0.202**
31	-0.4439	-0.5053	-0.5098	-0.4235	**-0.473**	-0.4035	-0.2470	-0.0275	**-0.226**

For the 91- and 181-day durations, the annual series values were used, and the individual stations were averaged to obtain regional skew coefficients as well. The following table summarizes the results.

Table F-54. Individual Skews and Regional Skews, Annual Flows

Duration, Days	Yankton	Sioux City	Decatur	Omaha	**Regional Average**	Nebraska City	Rulo	St. Joseph	**Regional Average**
91	-0.5131	-0.5106	-0.5128	-0.4182	**-0.489**	-0.4616	-0.3372	-0.0954	**-0.298**
181	-0.3887	-0.4077	-0.4214	-0.3838	**-0.400**	-0.4573	-0.3487	-0.0380	**-0.281**

However, regionalizing the skews was not enough to obtain consistent volume-duration-probability relationships at each station. For durations of 3- to 31-days, the means were not consistent, so they were smoothed by drainage area. The computed means for various durations can be found in Table F-51 above.

The computed standard deviations were also not consistent from station to station for various durations. Plots of mean vs. standard deviation were prepared for each station and duration. These plotted relationships were then graphically edited to provide relationships as smooth as possible at each station over the various durations and also from station to station. The computed values of standard deviation can be found in Table F-56 above.

Once the smoothed skews, means and standard deviations were determined, the results were put into the mixed distribution program for durations of 1- to 31- days to determine the volume-duration-probability curves, while the FFA program was used to determine the volume-duration-probability curves for 91- and 181-day durations. The following table lists the adopted means, standard deviations, and skews used for the final adopted relationships.

Table F-55. Adopted Mean, Standard Deviation, and Skew for Determination of Volume-Duration Frequency Curves

Location	Duration	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Yankton	1 day	4.985	0.256	-0.008	5.147	0.123	-0.342			
	3 days	4.947	0.256	0.099	5.132	0.123	-0.370			
	7 days	4.890	0.254	0.159	5.109	0.121	-0.411			
	15 days	4.820	0.238	0.112	5.081	0.118	-0.402			
	31 days	4.744	0.211	0.043	5.044	0.114	-0.444			
	91 days							4.934	0.105	-0.513
	181 days							4.813	0.107	-0.389
Sioux City	1 day	5.004	0.249	-0.077	5.161	0.119	-0.386			
	3 days	4.973	0.252	0.003	5.149	0.120	-0.414			
	7 days	4.921	0.252	0.053	5.125	0.120	-0.466			
	15 days	4.856	0.240	0.019	5.097	0.118	-0.479			
	31 days	4.783	0.215	-0.020	5.061	0.114	-0.505			
	91 days							4.954	0.109	-0.511
	181 days							4.837	0.112	-0.408
Decatur	1 day	4.999	0.246	-0.062	5.160	0.119	-0.384			
	3 days	4.973	0.249	-0.009	5.150	0.120	-0.420			
	7 days	4.925	0.251	0.031	5.128	0.120	-0.464			
	15 days	4.861	0.241	-0.004	5.100	0.118	-0.481			
	31 days	4.789	0.216	-0.045	5.064	0.115	-0.510			
	91 days							4.958	0.110	-0.513
	181 days							4.842	0.113	-0.421
Omaha	1 day	5.014	0.243	-0.045	5.174	0.121	-0.287			
	3 days	4.993	0.246	-0.022	5.164	0.122	-0.336			
	7 days	4.951	0.250	-0.018	5.143	0.125	-0.399			
	15 days	4.891	0.244	-0.063	5.115	0.125	-0.393			
	31 days	4.820	0.222	-0.153	5.081	0.122	-0.424			
	91 days							4.975	0.117	-0.418
	181 days							4.864	0.122	-0.384
Nebraska City	1 day	5.065	0.221	0.001	5.280	0.111	-0.159			
	3 days	5.048	0.221	0.015	5.269	0.111	-0.221			
	7 days	5.013	0.221	0.035	5.243	0.111	-0.298			
	15 days	4.967	0.209	0.006	5.211	0.111	-0.345			
	31 days	4.917	0.188	-0.167	5.174	0.109	-0.404			
	91 days							5.076	0.104	-0.462
	181 days							4.972	0.107	-0.457
Rulo	1 day	5.060	0.223	0.074	5.287	0.117	-0.090			
	3 days	5.045	0.223	0.100	5.276	0.116	-0.118			
	7 days	5.012	0.223	0.122	5.251	0.115	-0.162			
	15 days	4.966	0.211	0.119	5.218	0.115	-0.205			
	31 days	4.915	0.188	-0.013	5.180	0.112	-0.247			
	91 days							5.080	0.104	-0.337
	181 days							4.974	0.105	-0.349

(1) Adopted Mean of annual max [duration] log-flows (January-April)
(2) Adopted Standard deviation of annual max [duration] log-flows (January-April)
(3) Adopted Skew of annual max [duration] log-flows (January-April)
(4) Adopted Mean of annual max [duration] log-flows (May-December)
(5) Adopted Standard deviation of annual max [duration] log-flows (May-December)
(6) Adopted Skew of annual max [duration] log-flows (May-December)
(7) Adopted Mean of annual max [duration] log-flows (annual)
(8) Adopted Standard deviation of annual max [duration] log-flows (annual)
(9) Adopted Skew of annual max [duration] log-flows (annual)

Adopted Volume-Duration-Probability Relationships

The final adopted volume-duration-probability relationships for unregulated flows are shown in the following Tables F-56 to F-62.

Table F-56. Volume-Probability Relationship, 1-day Flow (cfs)

Exceedance Probability	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo
99	78300	82100	82400	83600	111700	111600
95	96800	100900	101000	103100	132700	133300
90	108000	112200	112300	114900	145500	146400
80	122900	127400	127100	130600	162700	164200
50	156400	161000	160000	165700	201600	204400
20	198800	203400	201200	209400	250700	255200
10	227900	232200	229100	238300	282700	287700
5	264200	267800	263100	272700	316400	322500
2	319800	321900	315300	322500	359000	364900
1	372800	373400	365300	372200	399600	404500
0.5	435200	433700	423800	431000	452200	455400
0.2	509200	505100	492900	500300	520600	522000

Table F-57. Volume-Probability Relationship, 3-day Flow (cfs)

Exceedance Probability	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo
99	74400	79200	79400	81500	108500	108800
95	92400	97500	97700	100500	129300	130100
90	103100	108500	108700	112000	141800	143000
80	117600	123200	123400	127300	158600	160400
50	149500	155300	155700	160900	196200	199400
20	189200	195000	195500	202500	243200	248400
10	215400	221400	221900	229700	273400	279300
5	248300	253700	254300	262900	305100	312600
2	299300	305100	305800	313100	345400	353700
1	351500	356100	356900	364400	384500	393100
0.5	414000	416700	417600	425500	435300	444900
0.2	489100	489100	490200	498600	504300	513700

Table F-58. Volume-Probability Relationship, 7-day Flow (cfs)

Exceedance Probability	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo
99	69900	74200	74700	76200	101800	102300
95	86800	91400	91900	94200	121400	122500
90	97000	101700	102300	105100	133200	134700
80	110600	115500	116300	119600	149000	151100
50	140100	145400	146400	151100	184000	187500
20	175700	181300	182400	188300	227200	232500
10	198300	204300	205500	211900	254000	260500
5	224600	231000	232300	238300	282600	290000
2	267100	274000	275300	277400	317600	325600
1	314300	320700	322100	323100	351900	359500
0.5	371600	376800	378600	379200	398100	404800
0.2	440900	444500	446500	446600	459800	465300

Table F-59. Volume-Probability Relationship, 15-day Flow (cfs)

Exceedance Probability	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo
99	65300	68600	69000	70600	93400	94500
95	80700	84500	85000	87300	111800	113200
90	89900	94000	94600	97300	122800	124500
80	102300	106600	107300	110600	137500	139500
50	128600	133800	134700	139200	169800	172500
20	158900	165000	166100	172200	208500	212300
10	176900	183800	185000	191800	232200	236600
5	195400	202900	204200	211600	255800	260800
2	219100	227600	228900	237000	283800	289500
1	243600	253900	255100	261600	307800	313800
0.5	281700	292500	293800	300700	339400	345900
0.2	328600	339900	341500	349300	384600	391800

Table F-60. Volume-Probability Relationship, 31-day Flow (cfs)

Exceedance Probability	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo
99	59700	62800	63200	64600	85500	86300
95	73600	77100	77600	79700	102100	103200
90	81800	85600	86200	88800	112100	113400
80	92600	96900	97500	100700	125300	126800
50	115600	120700	121600	126300	154100	156300
20	141100	147300	148300	154800	188000	191000
10	155400	162200	163300	170800	208000	211500
5	168400	176000	177200	185500	226800	230800
2	182500	191000	192200	201300	247600	252000
1	193400	203000	204300	213400	263300	268100
0.5	206300	216000	217300	227500	280600	285700
0.2	236700	237900	239000	258800	300300	306100

Table F-61. Volume-Probability Relationship, 91-day Flow (cfs)

Exceedance Probability	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo
99	43800	46900	46900	47400	64300	64800
95	54500	58900	59000	59700	78200	78900
90	60800	65900	66100	67000	86300	87200
80	68900	75000	75200	76400	96900	98000
50	85500	93800	94200	95900	119000	121000
20	103000	114000	115000	117000	145000	147000
10	113000	125000	126000	128000	159000	161000
5	121000	134000	135000	138000	171000	174000
2	129000	144000	145000	148000	185000	188000
1	135000	151000	152000	155000	195000	198000
0.5	140000	157000	158000	161000	204000	207000
0.2	146000	164000	165000	169000	215000	219000

Table F-62. Volume-Probability Relationship, 181-day Flow (cfs)

Exceedance Probability	Yankton	Sioux City	Decatur	Omaha	Nebraska City	Rulo
99	34300	37000	37100	37400	50900	51600
95	42100	45700	46000	46400	61500	62400
90	46700	50900	51100	51800	67800	68800
80	52500	57600	57800	58700	76000	77000
50	64800	71600	71900	73300	93200	94500
20	78100	86900	87300	89300	113000	114000
10	85400	95400	95800	98100	124000	125000
5	91500	102000	103000	106000	133000	135000
2	98500	111000	111000	114000	144000	146000
1	103000	116000	117000	120000	152000	154000
0.5	107000	121000	122000	125000	159000	161000
0.2	113000	127000	128000	132000	167000	170000

HYDROLOGIC SUMMARY

Hydrologic analysis was conducted by the Omaha District as part of the Upper Mississippi, Lower Missouri and Illinois Rivers Flow Frequency Study. Prior to this study, the discharge frequency relationships established for the Missouri River are those that were developed in 1962 and published in the Missouri River Agricultural Levee Restudy Program Hydrology Report. This hydrology information was used for the water surface profiles and flood inundation areas that were developed for the Missouri River Flood Plain Study during the mid to late 1970's. Almost 40 years of additional streamflow data were available since the Missouri River Hydrology was last updated. Also, significant channel changes have occurred since the previous hydraulic studies were completed.

The hydrologic analysis performed for this study was composed of many steps. In order to provide a homogenous data set from which frequency analysis can be performed, effects of reservoir regulation and stream depletions had to be removed. This produced the data set referred to as the "unregulated flow" data set. A homogeneous "regulated flow" data set was then developed by extrapolating reservoir and stream depletions to current use level over the period of record. A relationship between the annual unregulated and regulated flow peaks was established in order to determine the regulated flow frequency at various points.

The existing stream flow data for mainstem gaging stations were extended by converting stage records to discharge through use of old rating curve information at each gage prior to the establishment of USGS gaging records. Discharges had to be estimated or interpolated based on other stations during periods of no stage records at some stations. Historic records for evaporation and precipitation were collected. Estimates of historic and current level irrigation water use and other consumptive uses (otherwise referred to as depletions, in sum) were developed. The assembled data was used with an unregulated flow computer model to determine a daily record of unregulated flows from Yankton, South Dakota to Hermann, Missouri.

Flow frequency analyses were performed on the annual peaks using procedures found in Bulletin #17b. The results indicated the use of a mixed distribution of spring and summer peaks above the Kansas River and the use of annual peaks downstream of the Kansas River.

A regulated flow computer model was run, using data developed by both Omaha and Kansas City Districts, to determine a daily record of regulated flows from Gavins Point Dam to Hermann, Missouri. The regulated flow frequency curve is determined by transforming the unregulated curve using an unregulated versus regulated relationship. To determine this relationship, annual peaks for regulated and unregulated flows were compared, the regulated flow data being determined at each station by routing studies. The annual peaks from the regulated and unregulated data sets were then paired against each other in descending order. A relationship between regulated and unregulated flow frequencies was then established at each station. The hydraulic analysis employed the regulated flow frequency values determined at each gage location.

HYDRAULIC ANALYSIS

GEOGRAPHIC COVERAGE.

The Omaha District performed hydraulic modeling along the Missouri River. The hydraulic model extends from Gavins Point Dam, at river mile (RM) 811.1, downstream to Rulo, NE, at RM 498.0. Rulo, NE, corresponds with the Omaha District boundary with the Kansas City District. The Omaha District hydraulic model includes 313 miles of the Missouri River and 211 miles of tributaries. Within the model limits, the Missouri River drainage area increases from 279,500 square miles at Gavins Point Dam to 414,900 square miles at Rulo. Shown in Figure F-2 is a schematic of the modeled area. The schematic illustrates the Missouri River gaging stations on the main stem, tributaries that are included as routing reaches, lateral inflows to the model, and the river mile location of hydrologic features. In order to provide an accurate downstream boundary, the hydraulic model also includes geometry between Rulo, NE and St. Joseph, MO. This adds an additional Missouri River length of 49.9 miles to the hydraulic model. All features pertaining to the Missouri River downstream of Rulo, NE, are described within the Kansas City District section of the report, appendix E. All river miles referenced in the Omaha District appendix use the 1960 mileage for the Missouri River.

BASIN DESCRIPTION.

The Missouri River originates in the northern Rocky Mountains along the continental divide and flows south and east to join the Mississippi River near St. Louis, Missouri. At 2,315 miles (1960 mileage), it is the longest river in the United States. The Omaha District encompasses approximately 414,900 square miles of the drainage basin upstream of Rulo, NE to the river headwaters in the Rocky Mountains. The Missouri River basin contains numerous reservoirs and impoundments constructed by different interests for flood control, irrigation, power production, recreation, and water supply.

Missouri River Mainstem Dams.

The most significant flood control projects constructed within the basin are the six main stem Missouri River Dams. The six dams, which were completed by 1964, provide flood protection by controlling runoff from the upper most 279,000 square miles of the drainage basin. The reservoir system has a total combined capacity in excess of 73 million acre-feet of which more than 16 million acre-feet is for flood control. Gavins Point Dam, located near Yankton, SD at river mile 811.1, forms Lewis and Clark Lake and is the most downstream of the projects.

Recreational River Reach.

The Gavins-to-Ponca reach (RM 811 to 752) of the Missouri river was designated a Recreational River pursuant to Section 707 of the National Parks and Recreation Act (PL 95-625) which amended the Wild and Scenic Rivers Act (PL 90-542). The river is channelized starting at the downstream end of the Recreational River, a segment known as "Kenslers Bend". Demonstration bank stabilization projects on the Missouri River were authorized under Section 32 of the Streambank Erosion Control Evaluation and Demonstration Act of 1974 (P.L. 93-251). Nine of these projects are located in the reach from Gavins Point Dam down to Ponca State Park.

The recreational river reach has been impacted by Gavins Point Dam including flow regulation and the capture of sediment. Within this reach, the riverbed has experienced significant degradation and the loss of high bank. Bank stabilization such as the Section 32 projects has greatly reduced the migration of the high banks. However, in many areas, the river is characterized by a dynamic channel with shifting islands and sand bars.

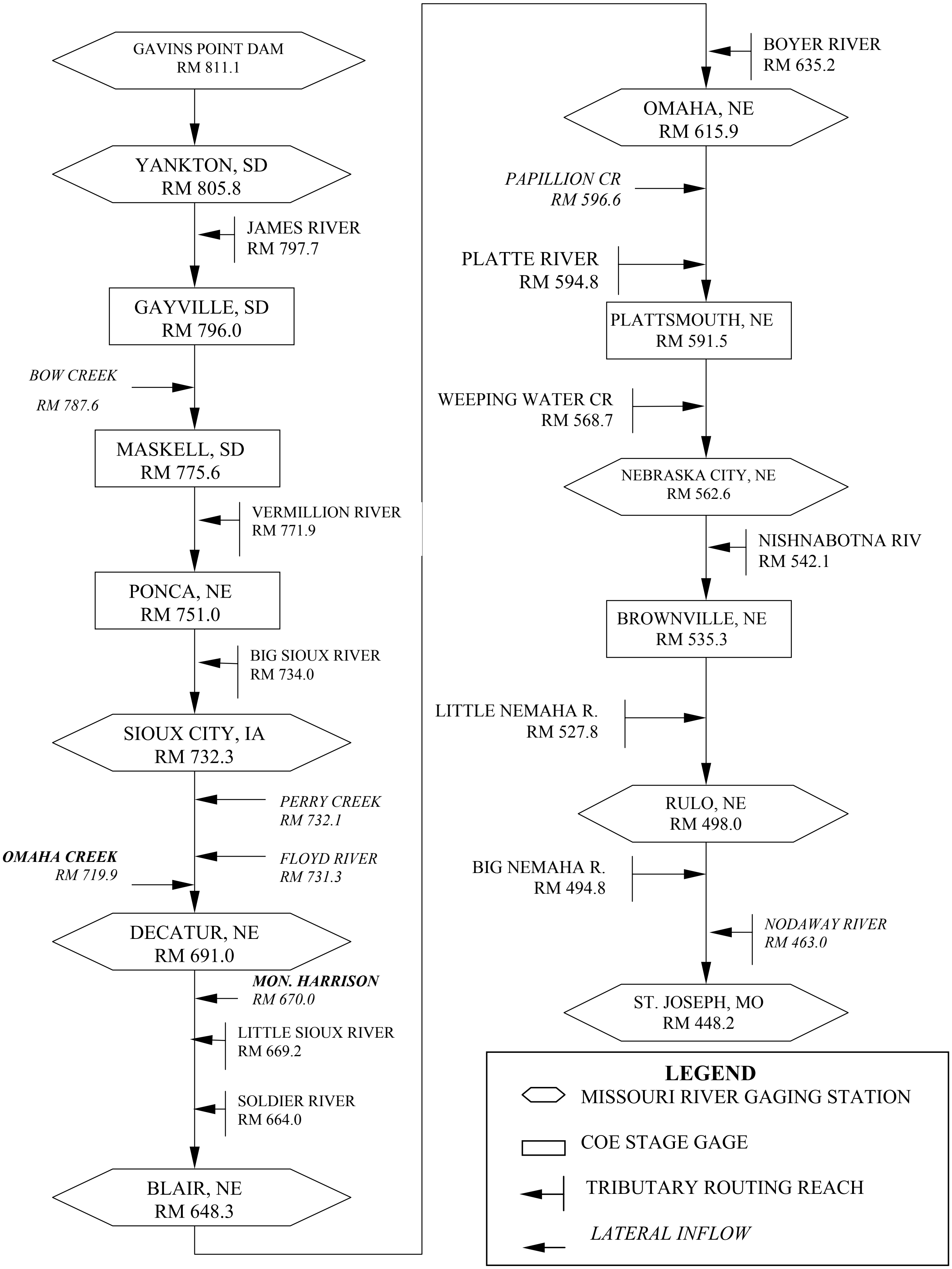

GAVINS POINT DAM
RM 811.1
YANKTON, SD
RM 805.8
JAMES RIVER
RM 797.7
GAYVILLE, SD
RM 796.0
BOW CREEK
RM 787.6
MASKELL, SD
RM 775.6
VERMILLION RIVER
RM 771.9
PONCA, NE
RM 751.0
BIG SIOUX RIVER
RM 734.0
SIOUX CITY, IA
RM 732.3
PERRY CREEK
RM 732.1
OMAHA CREEK
RM 719.9
FLOYD RIVER
RM 731.3
DECATUR, NE
RM 691.0
MON. HARRISON
RM 670.0
LITTLE SIOUX RIVER
RM 669.2
SOLDIER RIVER
RM 664.0
BLAIR, NE
RM 648.3
BOYER RIVER
RM 635.2
OMAHA, NE
RM 615.9
PAPILLION CR
RM 596.6
PLATTE RIVER
RM 594.8
PLATTSMOUTH, NE
RM 591.5
WEEPING WATER CR
RM 568.7
NEBRASKA CITY, NE
RM 562.6
NISHNABOTNA RIV
RM 542.1
BROWNVILLE, NE
RM 535.3
LITTLE NEMAHA R.
RM 527.8
RULO, NE
RM 498.0
BIG NEMAHA R.
RM 494.8
NODAWAY RIVER
RM 463.0
ST. JOSEPH, MO
RM 448.2
LEGEND
MISSOURI RIVER GAGING STATION
COE STAGE GAGE
TRIBUTARY ROUTING REACH
LATERAL INFLOW

Figure F-2

Navigation and Bank Stabilization.

There were seven acts of Congress that provided for the construction, operation and maintenance of a navigation channel and bank stabilization works on the Missouri River. The most recent was authorized in 1945 and provided for bank stabilization combined with a 9-foot deep and not less than 300 feet wide navigation channel. The authorized project for the Missouri River extends from its confluence with the Mississippi River at St Louis, MO to Sioux City, IA for a total distance of 734.2 river miles. This was accomplished through revetment of banks, construction of permeable dikes, cutoff of oxbows, closing minor channels, removal of snags and dredging. In order to achieve the project objectives of bank stabilization and navigation, the river was shaped into a series of smoothly curved bends of the proper radii and channel width. Stabilization of the bank along the concave alignment of the design curve was accomplished with pile and stone fill revetments. Dikes were constructed along the convex bank, approximately perpendicular to the flow. These dikes were designed to prevent bank erosion and to promote accretion, forcing the channel to develop and maintain itself along the design alignment. In areas where the natural river channel did not conform to the design alignment, canals were excavated and natural channels blocked in order to force the river to flow along the design alignment.

Levee System.

The Missouri River levee system was authorized by the Flood Control Acts of 1941 and 1944 to provide protection to agricultural lands and communities along the Missouri River from Sioux City, IA to the mouth at St. Louis, MO. The levees were designed to operate in accord with the six main stem dams. The extent of the levee system within the Omaha District consists of levee units on both banks from near Omaha, NE to near Rulo, NE. Although many federal levees were proposed north of Omaha, NE along the Missouri River, few have been built due to the significant contribution of the main stem dams in this reach and channel degradation that has occurred following dam closure. The majority of the area planned for protection by federal levees north of Omaha, NE is protected by private or non-federal levees with varying degrees of protection.

TRIBUTARY SYSTEM.

Numerous tributaries enter the Missouri River within the model reach. Refer to the model schematic shown in Figure F-2 for the location of significant tributaries. Major tributaries were included as separate routing reaches within the forecast model. Minor tributaries were included as lateral inflow to the model. Routing of the tributary flows from the gaging station location to the confluence with the Missouri River was found to increase the simulation accuracy. Tributary modeling efforts were of limited detail and intended for flow routing only. As a result of the coarse cross section data, computed stage information on the tributaries may not be accurate. Flow data from the USGS gaging station provides flow required for the tributary upstream model boundary. A drainage area accounting is provided in Plate F-52 that lists significant tributaries included in the model. A brief description of the tributaries included as separate routing reaches within the model is provided in the following sections.

James River - RM 797.7

The James River is a major left bank tributary that enters the Missouri River downstream of Yankton, SD at river mile 797.7. The basin has a drainage area of approximately 20,942 square miles and includes portions of South Dakota and North Dakota. Federal projects on the James River include Pipestem and Jamestown Dams located near Jamestown, ND. The James River has a large drainage basin but an extremely flat channel gradient. The USGS gaging station #06478500 at Scotland, SD, is the upstream model inflow boundary and is located over 50 river miles from the Missouri River.

Vermillion River - RM 771.9
The Vermillion River is a major left bank tributary that enters the Missouri River near Vermillion, SD. The basin has a drainage area of approximately 2302 square miles within east central South Dakota. The USGS gaging station #06479010 at Vermillion, SD, is the upstream model inflow boundary and is located 10.8 river miles from the Missouri River.

Big Sioux River - RM 734.0
The Big Sioux River is a left bank tributary that enters the Missouri River near Sioux City, IA at river mile 734.2. The basin has a drainage area of approximately 8424 square miles and includes portions of South Dakota, Minnesota and Iowa. The USGS gaging station #06485500 at Akron, IA, is the upstream model boundary and is located about 45 river miles measured along the channel from the Missouri River. The Big Sioux River floodplain length is slightly more than 30 miles measured from the Missouri River.

Little Sioux River - RM 669.2
The Little Sioux River is a left bank tributary to the Missouri River that drains approximately 3,526 square miles within northwest Iowa above its confluence with the Missouri River at river mile 669.2. Extensive systems of federal levees have been constructed in the lower basin on both the Little Sioux and its tributaries to protect primarily agricultural lands. The levee construction began in 1956 and was completed in 1966. The USGS gaging station #06607500 near Turin, IA, is the upstream model inflow boundary and is located 13.3 river miles from the Missouri River. During extreme events flow may be diverted between the Little Sioux River and the Monona-Harrison Ditch at the Missouri River confluence.

Soldier River - RM 664.0
The Soldier River is a small left bank tributary to the Missouri River located immediately to the north of the Boyer River Basin. It drains approximately 407 square miles of western Iowa and enters the Missouri River at river mile 664.0. The USGS gaging station #06608500 at Pisgah, IA, is the upstream model inflow boundary and is located 13.1 river miles from the Missouri River.

Boyer River - RM 635.2
The Boyer River is a small left bank tributary to the Missouri River at river mile 635.2. It drains approximately 871 square miles of western IA. Much of the lower portion of the Boyer River is protected by private levees with varying levels of protection. The USGS gaging station #06609500 at Logan, IA, is the upstream model inflow boundary and is located 15.8 river miles from the Missouri River.

Platte River - RM 594.8
The Platte River is a major right bank tributary to the Missouri River draining an area of approximately 85,370 square miles of northeast Colorado, southeast Wyoming and most of central Nebraska. The Platte River joins the Missouri River approximately 21 miles downstream of Omaha, NE at river mile 594.80. In eastern Nebraska, major tributaries to the Platte River are Salt Creek, the Elkhorn and Loup Rivers. The USGS gaging station #06805500 at Louisville, NE, is the upstream model inflow boundary and is located 16.5 river miles from the Missouri River.

Weeping Water Creek - RM 568.7
Weeping Water Creek is a right bank tributary to the Missouri River located in southeast Nebraska at river mile 568.70. It has a drainage area of approximately 241 square miles. The USGS gaging station #06806500 at Union, NE, is the upstream model inflow boundary and is located 6.2 river miles from the Missouri River.

Nishnabotna River - RM 542.1
The Nishnabotna River is a major left bank tributary to the Missouri River located approximately 20 miles downstream of Nebraska City, NE at river mile 542.1. It has a total drainage area of 2,806 square

miles. Major changes within the basin include the construction of federal levees, private agricultural levees, channel changes and drainage improvements. The Nishnabotna River has federal levees along the right bank from the Missouri River confluence to Highway 275 located upstream of Hamburg, IA. The left bank also has federal levees from the Missouri River confluence upstream to Highway 275. The USGS gaging station #06810000 near Hamburg, IA, is the upstream model inflow boundary and is located 13.8 river miles from the Missouri River.

Little Nemaha - RM 527.8.

The Little Nemaha River located in southeast Nebraska is a right bank tributary to the Missouri River. The basin has a drainage area of approximately 793 square miles and enters the Missouri River at river mile 527.80 near Nemaha, NE. The USGS gaging station #06811500 at Auburn, NE, is the upstream model inflow boundary and is located 10.4 river miles from the Missouri River.

ICE IMPACTS ON PEAK STAGE .

The flood history within the Missouri River basin provides documentation of numerous impacts of ice causing much higher stages than would normally occur for an open water condition. Refer to the flood history section of this report for a detailed discussion of ice impacts. The hydrologic analysis evaluated the requirement for an ice affected flow adjustment as described within the text and illustrated in Table F-21 and F-22.

The hydraulic analysis does not include any adjustment for ice. Typically, flood events in the early spring will include floating ice with the potential for ice jams to occur. Installation of the mainstem dams has altered the frequency of spring floods and the accompanying ice jams. However, extreme flood events in the upper reaches of the Missouri River may include ice conditions.

AGGRADATION AND DEGRADATION TRENDS.

Over the last 100 years, significant change has occurred in channel conveyance as a result of aggradation and degradation. Missouri River natural variability and construction including flood control projects, channel cutoffs, channel and bank stability projects have all contributed to conveyance change. Numerous studies have been conducted by the Omaha District to quantify the impact of Missouri River geometry changes on the stage-flow relationship (USACE, 2001).

Gavins Point Dam to Omaha, NE.

Downstream of the Missouri River main stem reservoir system, significant channel degradation has occurred. Degradation analysis and impacts have been outlined in several reports prepared by the Omaha District (USACE, 1981, 2001). Missouri River degradation is a complex issue with several contributing causes. Since construction of Gavins Point Dam (RM 811.05) in 1952, water surface elevations for a discharge of 30,000 cfs have decreased between 4 and 6 feet at Yankton, SD (RM 805.8), Sioux City, IA (RM 732.3), and Decatur, NE (RM 691.0). Many of the tributaries are also experiencing significant degradation. Data analysis indicates that future degradation rates are declining as the river elevation becomes more stable. Current data has generally been observed to indicate that Missouri River channel degradation dissipates prior to reaching Omaha, NE (RM 615.9).

Omaha, NE to Rulo, NE.

An assessment of the impact of aggradation and degradation trends on channel capacity was performed in the study *Missouri River Channel Capacity Study* (USACE, 1992). The reach between Omaha, NE (RM 615.) and Rulo, NE (RM 498.0) has illustrated general aggradational trends. Since 1955, thalweg elevations have increased by as much as 4 to 6 feet. Based on measured data for a low-flow continuous water surface profile, the increase in water surface elevations varies from 1 to 3 feet. Average bed slope has remained relatively constant at 0.8 to 1.1 foot per mile. An additional increase of 1 - 2 feet in water surface elevation is projected by the year 2020. Within the reach, aggradation at and downstream of the Platte River confluence indicates that the Platte River continues to deliver significant sediment quantities.

Sediment Deposition Factors.

Sediment deposition within the floodplain near the channel is a common occurrence. In many river systems, natural levees are formed when deposition occurs outside of a channel during high flows (mainly during flood recessions) because vegetation traps sediment and increases hydraulic roughness, reducing velocities and sediment transport capacities. Another general characteristic of this phenomenon is the deposition of the larger size sediment particles immediately adjacent to the channel with a lateral reduction in grainsize down to clay away from the channel.

A levee project can exacerbate the sediment deposition because overbank flows that once spread across a major portion of the floodplain are now confined to a relatively narrow zone adjacent to the river banks. Therefore, a given volume of sediment is deposited over a smaller surface area, resulting in increased deposit depths. Although the federal levees are generally set back from the river bank, many areas include private levee cells between the federal levee and the river bank. These cells act as sediment settling basins when the levee elevation is exceeded.

Field Reconnaissance.

Field reconnaissance was conducted by the Omaha District to evaluate sediment deposition patterns in the area between the Missouri River bank and the federal levee. The reconnaissance was conducted in September 1993 following the extensive summer 1993 flooding. Standing water and mud limited the reconnaissance to accessible areas. Material deposited near the levee base consisted entirely of silts and clays. Depths of deposition were determined by digging to the vegetation layer at several locations. Deposition depth averaged about one foot. Large sand deposits were observed immediately adjacent to the channel. These observations with sand deposits near the channel and silts and clays at a distance away are consistent with expected floodplain deposition patterns, as discussed in the preceding paragraph.

Another reconnaissance was conducted in April 1994. This reconnaissance confirmed the presence of sand deposits immediately adjacent to the channel. It was also noted at this time that lands experiencing the greatest volume of sand deposits were those riverward of failed agricultural levees. These agricultural levees run parallel to the river and are located inside of the federal tie-back levee. In all likelihood, these levees confined flows, resulting in increased channel velocities, allowing the sand sized particles to be transported through the reach. When they failed, the large concentrations of sand were deposited when the flow spread across the overbank and velocities were reduced.

Gage Stage Trends.

Data collected at Missouri River gaging stations demonstrates shifts in the stage-discharge relationship. The shift of the rating curve varies according to location with degradation in the upper reach and aggradation in the lower reach. Gage stage trends are illustrated on Plates F-53 thru F-55 for Sioux City, Omaha, and Nebraska City.

CONNECTIONS WITH OTHER DISTRICTS.

The Omaha District UNET model is the most upstream model for the Missouri River. Therefore, there is no connection with other Districts upstream. However, on the downstream end of the model the UNET model includes a portion of the Kansas City District from Rulo, NE, to St. Joseph, MO. The reach within the Kansas City District allows for a convergence reach at the downstream end of the model to smooth any computational instabilities that could result within the model near the downstream boundary condition. Computed results for the reach downstream of Rulo, NE, should be obtained from the Kansas City District hydraulic appendix and are not reported here.

UNET APPLICATION.

The Omaha District constructed an unsteady flow model of the Missouri River. UNET was employed as the unsteady flow model for the basin wide modeling tool. UNET is a one-dimensional unsteady flow program that includes the capability of simulating a complex network of open channels. Unsteady flow routing accounts for the variation in flow with both time and space. The UNET model has the ability to account for critical backwater effects in the routing and can directly simulate flows that spill over or breach a levee. Customized versions of UNET were developed as necessary via contracts with Dr. Barkau by several District offices involved in the Flow Frequency Study. The UNET model utilized for computational purposes was version 4.0, LAN version 1.0 executable date 9/12/2002. The UNET version contains additional capabilities developed by Dr. Robert L. Barkau that are not included in the normal UNET program distributed by the Hydrologic Engineering Center. The UNET model background and capability is only briefly described in this appendix. Refer to appendix A for a detailed description of UNET model features.

Model Geometry Development and Description

The geometry input file consists of the HEC-2 style cross sectional geometry developed by the user. Cross section data for the Missouri River was extracted from digital models developed from floodplain and hydrographic survey data. Federal levee areas are included within the model as storage cells. The UNET model also requires flow and stage hydrograph data to provide boundary conditions and inflow data. Figure F-3 illustrates a general plan view of the model features.

River Geometry.

River geometry within the UNET model is required to describe the Missouri River and all tributary routing reaches. River geometry is described in a cross section format using station-elevation data. Data is coded in a format similar to HEC-2 using X1 and GR cards (HEC, 1990).

Floodplain Topography.

Aerial photography, airborne global positioning system (GPS) control, ground survey control, and aero triangulation were used in development of a digital terrain model (DTM) and digital elevation model (DEM) of the project area for the Omaha District. The aerial photography for the DTM was taken in the fall of 1999. The DTM data is composed of mass points and break lines that adequately define elevated roads, railroads, levees (features that would impede flow) and other major topographic changes required for accurate DEM development. The aerial mapping is based on surveyed ground control points. These surveyed ground control points are very accurate, but the aerial mapping of well-defined features between the ground control points can vary by as much as 0.67 foot 67 percent of the time in accordance with the ASPRS Class I mapping standards. Ground surface elevations developed by the aerial mapping will be accurate to within 1.33 feet. A description of survey accuracy is included in Plate F-56.

Hydrographic Data.

Hydrographic survey data was collected in 1994 between Rulo, NE, and Ponca, NE (river mile 498 to 752). Hydrographic survey data from Ponca to Gavins Point Dam was collected in 1995 (river mile 752 to 811). Hydrographic data is collected in a cross section format at a spacing of approximately 500 feet. Accuracy of the hydrographic survey data equipment is approximately 0.5 for the elevations. However, it should be noted that the Missouri River has a high sediment concentration with notable bed variation.

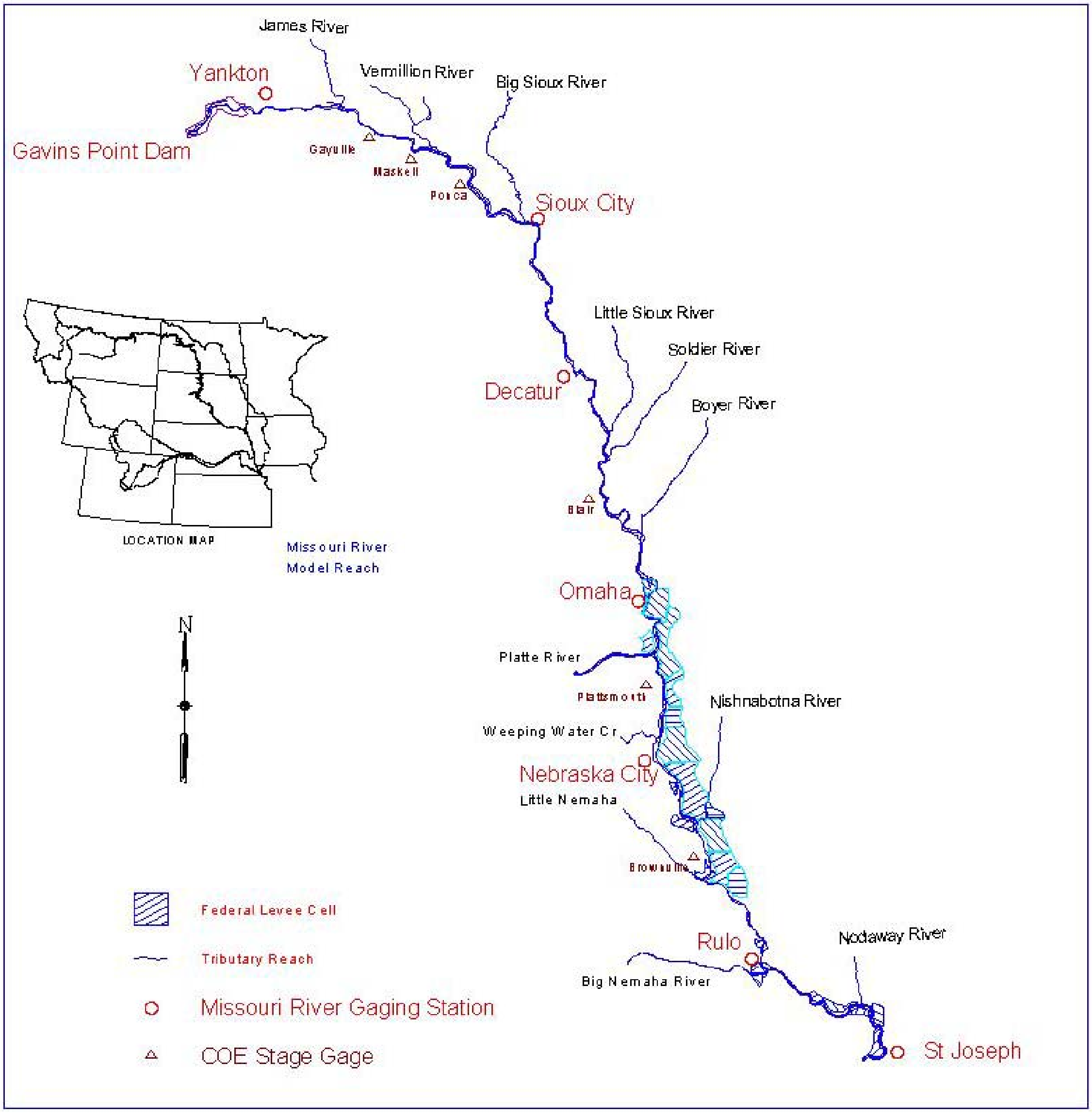


Figure F-3

Final DTM Data.

The final digital terrain model was formed by merging the hydrographic and floodplain topography and was furnished by the survey contractor. Since the hydrographic data was inserted as random points, cross section data extracted from the digital terrain model is only valid at the hydrographic survey locations.

Missouri River Sections.

New Missouri River sections were used in construction of the UNET model. Cross section location was limited to the location of hydrographic survey data. Using Arcview and digital images of the quadrangle maps and hydrographic survey location, shape files were created for the cross section locations, reach lengths, and bank stations. The shape files were submitted to the contractor. The contractor extracted the geo-referenced cross sections and provided the results in a .geo file suitable for importing into HEC-RAS.

Cross sections were extracted from the dtm model at an interval of roughly 2000 feet. Extracted cross sections extended from bluff to bluff within the river valley. The total number of cross sections is in excess of 800 through the model reach. A number of editing steps were performed within HEC-RAS prior to incorporating the new sections within the UNET model. These steps included checking reach lengths, correcting the river mile cross section identifier to 1960 river miles, removing storage from the effective section width, adding additional sections at bridge locations, adding effective flow area encroachments, inserting the horizontal roughness, etc. The program RAS2UNET, furnished by the Hydrologic Engineering Center, was used to translate the cross section data from RAS to UNET format.

Section Bank Stations and Effective Flow Areas.

Many steady flow analysis models require construction of separate models for different frequency events making it possible to vary the effective flow area within a cross section for different flow rates. The UNET model employs a single geometry for the entire period of record. Within the UNET model, bank stations and effective flow areas are specified at each cross section. The model included an encroachment at the bank station to confine all flow to the channel until the bank station is exceeded. An additional station was specified within the section to define ineffective flow within the model after the channel capacity is exceeded. Since the model was constructed to model a full range of flows, placement of a single encroachment station within the floodplain was usually based on higher flows. Starting with the original section width that extended from bluff to bluff, section width was reduced to eliminate ineffective flow areas. Section reduction was required to avoid double counting storage areas behind levees and to correctly model effective flow. An analysis of active top width at a specific flow determined that some inconsistencies occur. The single geometry for the cross section is a limitation of the UNET model.

Model Roughness.

Most cross sections within the model employed horizontal roughness variation to specify Manning n values. Roughness values were coded for the main channel, sand bars and light vegetation, farming areas, and trees or heavy vegetation. Model roughness is further discussed in section *UNET Calibration*.

Tributary River Sections.

Cross section geometry was included within the UNET model for all major tributaries for the reach from the confluence with the Missouri River upstream to the USGS gaging station location. Most tributary gaging stations are located approximately 10-15 river miles upstream of the confluence with the Missouri River. Tributary cross section data were taken from USGS 7.5 minute quadrangle topographic maps or the best available topographic information. Tributary cross section spacing varied from 5,000 to 20,000 feet. The assembled cross section data for each tributary is suitable for flow routing only. Accurate stage computation on the tributaries is not possible with the coarse data employed in the model.

UNET Model Geometry Assembly.

Further editing was required within UNET to complete UNET model assembly. The UNET editing steps included insertion of the tributary routing reaches within the Missouri River section data, specification of model connectivity, and setting UNET model parameters. Levee information was coded within an include file to describe stage-storage information and overtopping elevations for each levee cell and provide levee connection UNET data. Hydrograph information and calibration record cards were inserted at gage station locations.

Boundary Conditions

Flow and stage hydrographs for the Missouri River and tributaries are required for all boundary conditions and lateral inflow points. Daily hydrographs were employed for all UNET analysis. Historic hydrologic data was obtained from the USGS' Automated Data Processing System (ADAPS) that is part of the National Water Information System (NWIS). USGS and COE streamflow gages with their locations, gage identification numbers and other pertinent data are shown in Table F-63 for the tributaries and Table F-64 for the main stem Missouri River.

Table F-63
Tributary Stream Gaging Stations

Tributary Gage and Location	USGS Gage ID	Confluence River Mile (1960 River Miles)
Gavins Point Dam Flow Release	----	811.1
James River at Scotland, SD	06478500	797.7
Vermillion River nr Vermillion, SD	06479010	771.9
Big Sioux River at Akron, IA	06485500	734.0
Perry Creek at Sioux City, IA	06600000	732.1
Floyd River at James, IA	06600500	731.3
Monona Harrison Ditch at Turin, IA	06602400	670.0
Little Sioux River nr Turin, IA	06607500	669.2
Soldier River at Pisgah, IA	06608500	664.0
Boyer River at Logan, IA	06609500	635.2
Papillion Creek at Fort Crook, NE	Corps Gage	596.6
Platte River at Louisville, NE	06805500	594.8
Weeping Water Creek at Union, NE	06806500	568.7
Nishnabotna River above Hamburg, IA	06810000	542.1
Little Nemaha River at Auburn, NE	06811500	527.8
Big Nemaha River at Fall City, NE	06815000	494.8
Nodaway River at Graham, MO	06817700	463.0

Table F-64
Missouri River Gaging Station Locations

Missouri River Gage Location	USGS Gage ID	Gage Datum (feet 1929 NGVD)	River Mile Location (1960 RM)
Yankton, SD–5.2 Miles D/S of Gavins Point Dam	06467500	1139.7	805.8
Gayville, SD – 3.8 Miles S.W. of Gayville	Corps Stage Gage	1100	796.0
Maskell, SD – 3.0 Miles N.E. of Maskell	Corps Stage Gage	1100	775.6
Ponca, NE - Right Bank of Missouri River	Corps Stage Gage	1080	751.0
Sioux City, IA - 1.9 Miles D/S of Big Sioux River	06486000	1056.98	732.3
Decatur, NE – 0.1 Miles U/S of Hwy 175	06601200	1010	691.0
Blair, NE	Corps Stage Gage	977.28	648.3
Omaha, NE – 0.1 Miles D/S of I-480	06610000	948.24	615.9
Plattsmouth, NE - 3.2 Miles D/S of Platte River	Corps Stage Gage	928.31	591.5

Nebraska City, NE – 2.0 Miles U/S of Hwy 2	06807000	905.36	562.6
Brownville, NE - 6.8 Miles D/S of Nishnabotna River	Corps Stage Gage	860	535.3
Rulo, NE - D/S Hwy 159 and 3.2 Miles U/S of Big Nemaha River	06813500	837.23	498.0
St. Joseph, MO	06818000	788.2	448.2

Levees
Within the Omaha District, areas to the landward side of the federal levees were included within the UNET model by describing each area with a stage-storage relationship. Large overbank areas behind the federal levees will affect model timing and computed results if a significant amount of flow is conveyed into the levee cells. A levee interior acts as a storage cell, which interacts with the river through a breach or breaches in the embankment, until the interior area is filled to overflowing. At this point flow may be transmitted to adjacent levee cells or the river. For extreme floods, the flow transfer between adjacent levee cells continues until all levee areas have been filled and the transfer of flow between cells begins to approximate floodplain conveyance.

Therefore, the UNET program must simulate the following situations. First, the active flow area is confined between the levees and the area behind a levee acts as a storage cell. Secondly, the Missouri River water surface elevation exceeds the levee top elevation and water is flowing into the storage area behind the levee. Next, the levee storage area is filled and water begins to spill to the adjacent levee cell or back to the Missouri River as dictated by computed water elevations. In this manner, flow is transferred down the levee system parallel to the main channel for extreme events. The routing between levee cells is similar to level pool routing common to hydrologic models. Both a high peak flow and sufficient volume are required to maintain cascading flow between the levee cells. As the flood hydrograph starts to recede, the river flow and water level falls to the point that the area behind the levee reverses flow direction and the levee cell is drained. Finally, when the flood hydrograph recedes below the specified levee cell elevation, the levee cell is no longer connected to the river and the levee is repaired. These situations can occur simultaneously up and down the river. During an extreme event a combination of all events may occur simultaneously with some levees intact, some levees filling, and other levee filled and transferring flow to adjacent levee cells or back to the Missouri River.

Levee overflow from the main channel into the adjacent overbank requires additional coding of data within the UNET model as described in section *UNET Levee Modeling Parameters.*

Federal Levees.
A system of federal levees exists from Omaha, NE, to near Rulo, NE. Levees were constructed as part of local flood protection projects in the larger metropolitan areas of Omaha, NE and Council Bluffs, IA. The remainder of the federal levees were constructed as part of the Missouri River basin Comprehensive Plan to protect smaller communities and agricultural lands. All of the levee units on the Missouri River were designed to operate in conjunction with the six main stem dams to reduce flood damages as part of the Pick-Sloan plan. Previous studies, including a levee adequacy study, have identified a declining level of protection for the federal levee system (USACE, 1986).

Federal levees were constructed in the 1950's and are usually set-back from the river bank a distance of 500-1500 feet. Levee top elevation was extracted from the 1999 aerial topography. Federal levees cover the left bank from river mile 515.2 to river mile 619.7. Levees on the right bank are intermittent since the river is often near the bluff. Total federal levee length is estimated as 191 miles in the reach from Omaha, NE (RM 615.9) to Rulo, NE (RM 498.0). The 191 levee miles may be subdivided as 133.5 miles along the main stem Missouri River and 57.5 miles of levee tiebacks. Table F-65 provides a summary of the federal levees within the Omaha District. Plate F-57 illustrates the location of federal levee cells and the separation between levee cells that was used for the UNET modeling.

Table F-65
Missouri River Levee Summary
Extracted from Table III-2, Adequacy of Missouri River Levee System (USACE, 1986)

Levee Unit (Year Completed)	Design Discharge[3] (cfs)	Location (1960 River Miles).	River Length (Miles)[4]	Approx. Capacity With 2 Feet Freeboard, Est. 1986 (cfs)[5]
R-520 (1960)	310,000	501.0-505.5	4.5	340,000
L-536 (1951)	306,000	515.5-522.2	6.7	250,000
R-548 (1951)	304,000	527.9-534.6	6.7	206,000
L-550 (1951)	305,000	522.2-543.5	21.3	204,000
R-562 (1949)	300,000	541.6-549.0	7.4	201,000
L-575 (1949)	295,000	543.5-575.7	30.2	220,000
R-573 (1949)	295,000	552.3-558.0	5.7	200,000
L-594 (1964)	295,000	573.7-580.3	6.6	242,000
L-601 (1966)	295,000	580.3-588.0	7.7	226,000
[1] L-611-614 (1986)	295,000	588.0-594.8	6.8	295,000
[2] L-611-614 (1986)	250,000	594.8-605.7	10.9	250,000
R-613 (1971)	250,000	595.2-596.6	1.4	240,000
R-616 (1986)	250,000	595.6-601.5	4.9	250,000
L-624 (1950)	250,000	605.7-607.9	2.2	256,000
L-627 (1950)	250,000	607.9-613.9	6.0	297,000
Council Bluffs (1950)	250,000	613.9-619.7	5.8	264,000
Omaha (1950)	250,000	611.6-624.9	13.3	264,000

1 Represents the portion of levee L-611-614 downstream of the Platte River.
2 Represents the portion of levee L-611-614 upstream of the Platte River.
3 Refers to the original design discharge. Missouri River stage-flow changes have altered levee capacity.
4 Refers to the length along the Missouri River and does not include any tieback levee length.
5 Approximate capacity estimated with 2 feet of freeboard in the report *Adequacy of Missouri River Levee System* (USACE, 1986).

Note: An estimate of levee capacity was not performed as part of this study. This study employed the top of levee elevation for all modeling. Levee capacity and the associated level of protection is also dependent upon a risk and uncertainty analysis that includes all components of levee capacity including a geotechnical evaluation following current Corps of Engineers guidance provided within EM 1110-2-1619, Risk Based Analysis for Flood Damage Reduction Studies (USACE, 1996). The risk analysis evaluates the computed stage-frequency and levee elevation with appropriate uncertainty estimates for hydrologic, hydraulic, and geotechnical parameters to determine the levee reliability. This analysis is typically performed during a floodplain delineation study or during a flood damage reduction study.

Private Levees.
Following construction of river training structures, federal levees, and chute closures, deposited sediment filled many areas riverward of the federal levees. Farming of these areas became extensive. To prevent crop damages caused by normal high flows on the Missouri River, farmers constructed secondary levees at or near the river bank. Many of the secondary private levees tie directly into the federal levees. Private levees have also been constructed along the river bank in areas where federal levees were not constructed. The left bank reach from river mile 515.5 to river mile 498.0 near Rulo, NE is protected solely by private levees. Total length of private levees along the Missouri River, interior levees, spoil banks, and tiebacks is unknown but is substantial.

UNET Levee Modeling Parameters.
All federal levees were included within the UNET model as separate cells. Description within the UNET model of the levee area consists of the specification of stage vs. storage curves. Many of the large levee cells were subdivided using interior topographic features such as roads or railroads. Stage-storage relationships were determined using the 1999 digital terrain model. The stage-storage curves were smoothed to reduce model instability. Stage-storage curves developed for each of the UNET model storage cells are displayed in Plates F-58 to F-84.

The levee cell is connected to the mainstem Missouri River within the UNET model. Connections were established within the UNET model at the upstream and downstream limits of each levee cell. During the POR analysis, the model will activate either or both levee connection if the computed water surface elevation exceeds the coded levee top elevation. When both the upstream and downstream connections are active, the levee cell conveys flow parallel to the main river. Levee connections are specified within the UNET model using the levee SF card. Plate F-85 summarizes levee design details and parameters specified within the UNET model. Incorporation of UNET modeling of levee failures is as follows:

UNET Model Levee Modeling Assumptions:

a. Private levees within the Omaha District were not included as levee cells.
b. Levee cells contain at least 2 river connections, generally located at the downstream and upstream end of the levee cell.
c. Levee top elevations were coded at the top of levee using the best available survey data.
d. Levees were coded within the UNET model to fail when the top of levee elevation is exceeded.
e. Flood fighting efforts were not considered in the analysis.
f. For the POR analysis, levee cells repair after the river stage drops below the stage specified within the UNET model. Thus, the model restores the levee to the original elevation for following years during the POR.

Connection with the SF card allows the simulation of flow within the levee cell during extreme events. Simulation with the SF card requires the specification of several factors as follows:

```
RE   19  534.90
SF        -25   903.7    892   .010   0.01    48.    0.0    0.0
```

The RE card specifies the reach number (19 for this example) and the river mile for the connection (534.90) to the Missouri River. The SF card specifies the storage cell number to connect with (-25), the water surface elevation at which the levee breach initiates (903.7), the elevation for the levee breach repair (892), the linear routing constant for flow from the river to the levee cell (.01), the linear routing constant for return flow from the levee to the river (.01), and the time in hours to fill the levee cell assuming a constant inflow (48). The specified linear routing coefficients impact the rate of flow transfer from the river to the levee cell. Model evaluation determined that setting the coefficient too high caused model instability. Linear routing coefficients were patterned after the L550 levee failure during the 1993 event. POR analysis employed routing coefficients of 0.01 and 0.02. Sensitivity analysis was performed to evaluate the impact of the levee failure routing coefficients.

Application to Regulatory Flood Profiles

The UNET model developed for this study employed the top of levee elevation for all levee connections. The model also assumes a levee breach occurs when the computed river elevation exceeds the levee top elevation. Levee modeling assumptions were coordinated during task force meetings with Corps of Engineers, FEMA, and state representatives. A description of the discussion and conclusions is presented within Appendix A. Previous Missouri River studies within the Omaha District conducted to develop regulatory products such as the stage-frequency elevation and floodway (USACE, 1978) used different assumptions including levee overtopping without any levee breach. Therefore, modeling for regulatory purposes to establish floodway locations may require additional evaluation of levee performance.

An estimate of the minimum level of protection provided by the individual federal levee units was not performed as part of this study. Levee level of protection and the associated levee capacity are dependent upon a risk and uncertainty analysis that includes estimating the uncertainty for many parameters. Risk and uncertainty analysis should follow the guidance provided within Appendix A and the current Corps of Engineers guidance provided within EM 1110-2-1619, *Risk Based Analysis for Flood Damage Reduction Studies* (USACE, 1996). The risk analysis evaluates the computed stage-frequency relationship and levee elevation at each location with appropriate uncertainty estimates for hydrologic, hydraulic, and geotechnical parameters to determine the levee reliability. This analysis is typically performed during a floodplain delineation study or during a flood damage reduction study. Refer to the *Risk and Uncertainty Analysis Data* section for further details.

UNET CALIBRATION.

UNET model calibration was performed in a series of steps. Initial model assembly and debugging was performed with HEC-RAS to set base roughness values, bank stations, reach lengths, and similar cross section parameters. UNET calibration was performed for historical events, measured water surface profiles, and high water mark data. Model calibration was performed for different flow periods to include a full range of flows. All UNET model calibration was performed with daily flow data. Previous studies have used hourly data to achieve better model reproduction of observed values. However, since the intended model use is for the POR analysis that uses daily flow records for all inflow, daily values were also used for model calibration to provide modeling consistency.

Calibration Data

Calibration data consisted of the gage station flow and stage records listed in Table F-64, measured water surface profiles, and high water mark data. Selected calibration events varied according to location. Calibration was performed with both flow and stage data. Gage station data consists of observed stage and flow hydrographs and actual USGS discharge measurements taken at the gaging station. Discharge measurements are taken at least once a week on the mainstem Missouri River. Discharge measurements illustrate seasonal variation in the stage-discharge relationship that occurs on the Missouri River.

UNET Calibration Procedure Overview.

Calibration of the UNET model was an iterative process performed in several stages. Calibration efforts focused on reproducing observed stage hydrographs at gaging stations along the Missouri River and verifying with discharge measurements. Calibration of an unsteady flow model is an iterative process. Significant changes to model geometry will also affect routed flow. The calibration process strives to maintain both flow and stage accuracy.

Initial calibration was performed by setting Manning roughness values at each cross section. The calibration was refined by adjusting the developed rating curves (KR records) in order to correct for deficiencies. The conveyance change and discharge conveyance relationship can also be used in conjunction with the rating curves to finalize the model calibration. Therefore, final calibration is a combination of the effects of all the parameters employed in both the geometry and boundary condition files. A brief overview of the main procedures used in model calibration is as follows:

Base Roughness. The base Mannings' roughness values were calibrated to recent measured steady water surface profiles. All measured profiles were for within channel flows in the normal operating flow range during the navigation season.

Ungaged Inflow. The model evaluates ungaged inflow using the Null Internal Boundary Condition. This parameter is an important feature to maintain model flow consistent with observed gage data.

Automated Calibration. Once the model is nearly calibrated, the automated calibration is performed by pairing observed stages at the stream gages on the Missouri River with routed flow. Initial values are determined by fitting a fifth order polynomial to the paired data to create a rating curve. Data is stored in a DSS file for use with UNET. Since for each flow, a water surface elevation is produced at each cross-section, this procedure develops a relationship between elevation and factor at each cross-section. Using a KR record in the UNET geometry file at each stream gage location, this relationship is then applied to the ordinates in the cross section tables. The KR DSS file record is modified during the calibration process to increase accuracy. Calibrated KR records were employed at all river gaging stations.

Final Calibration. Final calibration was performed using conveyance change and discharge-conveyance relationships for separate reaches within the model. The conveyance change relationship applies a constant factor to the cross section conveyance and storage determined from section geometry. The discharge-conveyance relationship applies a factor to cross section conveyance that may be varied according to flow rate.

Base Manning Roughness Values.

Initial horizontal roughness values were assigned based on material type using available aerial photographs. Various roughness values were assigned to represent the channel, sand bars, farmland, woody vegetation, and urban areas. Material types were defined using aerial photographs and then translated to the HEC-RAS model. Since the aerial photographs were not ortho-rectified with the digital terrain model, some difficulties were encountered when setting the horizontal roughness for each cross section. Adjustments were made to the horizontal roughness station within the cross section based on elevation data when required.

Within the reach from Gavins Point Dam to Ponca, the Missouri River is a braided stream with numerous islands. Significant channel degradation and bank failure has occurred following the collection of hydrographic data used within the model. The channel in this area is active with migrating sand bars and other indications of instability. Unreasonable roughness values were required in this location to compensate for the poor model geometry data. The roughness values allowed computational results to match observed water surface elevations from recent flow events.

Base roughness values were determined within the model using calibration data at the gaging stations and the measured profiles. Calibration of tributary routing reaches was not performed. Stage calibration was performed on a system wide basis for the entire hydrograph. Base channel roughness values varied throughout the model.

Note: The base roughness values **do not** represent final calibration values for the UNET model. In addition, roughness values for an unsteady flow model differ from a steady flow model such as HEC-RAS due to computational differences. Calibration with HEC-RAS or a similar model will require the use of different roughness values than those employed in the UNET model. In addition, roughness values at bridge sections were increased to provide additional head loss. UNET does not employ standard expansion and contraction losses such as steady flow model. Refer to the HEC-RAS manual users guide for an explanation of computation differences between unsteady and steady flow models at structures (HEC, 2002). Table F-66 summarizes the range of roughness values employed within the model.

Table F-66
Base Model Roughness Values

River Mile Range	Channel N	Floodplain N	Method[2]
810 – 804	.021[1]	.037 – 0.085	Horizontal Roughness
803 – 802	.024[1]	.037 – 0.085	Horizontal Roughness
801 – 789	.033 - .038[1]	.037 – 0.085	Horizontal Roughness
788 – 776	.025 - .027[1]	.037 – 0.085	Horizontal Roughness
775 – 768	.028 - .030[1]	.037 – 0.085	Horizontal Roughness
768 – 745	.026 - .023[1]	.037 – 0.085	Horizontal Roughness
745 – 710	.023[1]	.055	Channel Roughness
710 – 691	.022[1]	.055	Channel Roughness
690 – 669	.026	.055	Channel Roughness
668 – 618	.024	.055	Channel Roughness
618 – 615	.024	.042	Channel Roughness
614 – 590	.024	.038 - .057	Horizontal Roughness
590 – 584	.027	.038 - .057	Horizontal Roughness
584 – 567	.026	.038 - .057	Horizontal Roughness
566 – 498	.027	.038 - .057	Horizontal Roughness

1 Unreasonable Manning N values were required to match measured profile data at some locations. Hydrographic survey data, collected in 1994 and 1995, does not reflect the impact of the 1997 sustained high Gavins Point release that caused significant channel modification as previously described.
2 At some locations, the horizontal roughness variation was changed to standard channel roughness due to calibration errors.

Application of Null Internal Boundary Condition for Ungaged Inflow.
The Null Internal Boundary Condition (NIBC) is a tool for estimating ungaged lateral inflow in a river system. The NIBC feature is used by the Omaha District to reproduce flow at the USGS gage locations at Sioux City, Decatur, Omaha, Nebraska City, and Rulo. Use of the NIBC is an important component of calibrating the model to both flow and stage.

The technique optimizes ungaged inflow to reproduce either a stage hydrograph or a flow hydrograph at the NIBC station. When optimizing the stage hydrograph, the reproduction of flow is secondary, being dependent on the calibration of the model. Likewise, when optimizing the flow hydrograph, the reproduction of stage is secondary, being dependent on the calibration of the model. Optimizing stage is generally used for a flood forecast model, where stage accuracy is the primary goal. Optimizing flow is used whenever the observed flow record must be maintained, such as a period-of-record frequency analysis. In either case, the ungaged inflow compensates for all the errors in the measurement of stage and flow and for systematic changes in roughness and geometry that may not be included in the model. As a result, the ungaged inflow determined using the NIBC procedure includes both flow and an error correction term.

All ungaged inflow was determined by optimizing flow. Using the observed flow hydrographs, the river routing reach is divided into two routing reaches that are bounded by two streamflow gages. For example, Omaha to Nebraska City forms a routing reach bounded by gage stations. Flow is routed from the upstream station to the downstream station using the upstream flow. This flow does not include the ungaged flow. Next, to determine the flow at the downstream location with the ungaged included, the flow upstream based on a stage boundary condition is computed from the hydrodynamics and the geometry reach downstream. The ungaged inflow hydrograph is determined using DSSMATH procedures. The hydrograph is estimated by subtracting the routed hydrograph from the computed hydrograph. The computed difference is lagged backward in time and inserted into the model as a uniform lateral inflow. The lag time varies according to travel time between the gage stations. Ungaged inflow between the gaging stations is distributed according to drainage area. The ungaged drainage area is summarized within Plate F-52. A further description of the NIBC employed within the Omaha District is available in appendix F-E.

A comparison between UNET determined ungaged inflow using the Null Internal Boundary Condition and ungaged inflow determined for the Omaha District hydrologic analysis (the UFDM model) was not performed. The two models are not computationally similar and will not produce similar results. An evaluation of the impact of ungaged inflow on POR results was evaluated in the sensitivity analysis.

Application of Automatic Calibration Conveyance Adjustment
After setting base roughness values, the model was calibrated to reproduce rating curves at the principal gaging stations along the Missouri. The base roughness values were determined to match the highest observed event at each gage station. The automatic calibration conveyance adjustment record continues the base roughness replication at the highest stage and also allows modification of the stage-discharge relationship for other events. In essence, this allows the model to incorporate a change in roughness for different flows compared to the base calibration model that relies on fixed roughness values within each element of the horizontal section. The rating curve calibration technique is described in the report "Rating Curve Calibration" (Barkau 1994). A rating curve reflects the stage-conveyance structure of the cross-section. At elevation z the conveyance is computed from Manning's Equation,

$$K = \frac{1.49}{n} R^{2/3} A \qquad (1)$$

where:
K = conveyance.
n = Manning's roughness factor.
$R = \frac{A}{W_p}$, the hydraulic radius (ft).
$W_p =$ the wetted perimeter (ft).
A = cross-sectional area (sq ft).

In equation 1 the area and the wetted perimeter are cross-section properties, but the roughness is unknown. If the friction slope, S_f, is known, the conveyance can be computed from

$$S_f = \left(\frac{Q}{K}\right)^2 \qquad (2)$$

where:

Q = flow (cfs)

When the stream gradient is steep (greater than ten feet per mile), the water surface slope approximately equals the friction slope and conveyance can be computed from the rating curve. But, when the gradient is shallow, the friction slope is controlled by backwater and conveyance cannot be calculated from a single rating curve.

If a second rating curve is known at a downstream cross-section, the stage at the upstream cross-section can be computed using steady state backwater. A constant flow is assumed between the first and second rating curve and many cross-sections can be defined between the rating curves. Most likely the upstream stage will not match the stage at the upstream rating curve for the constant flow. Adjusting Manning's "n" to match the stage at the upstream rating curve calibrates the reach to reproduce the upstream rating curve. Note that the entire reach is being calibrated. The stages at the intermediate cross-sections may not be correct, but no information is available to further refine the calibration.

The Manning's "n" can be different from cross-section to cross-section. Generally, one assumes a constant "n" value for the wetted channel area along a reach, but "n" values for exposed areas such as islands in the channel and overbank areas can vary from cross-section to cross-section. The density and type of the vegetation is variable. Base roughness values address the observed variation at each cross section using available topographic and aerial data. Base channel calibration was performed using the measured profile data. Base cross section calibration was also performed using high water mark data.

When calibrating a model, the special variation of Manning's "n" from cross-section to cross-section poses a problem. How does one distribute changes in roughness throughout the reach? The calibration reach has stage information at the upstream and downstream ends and nothing in between. Therefore, changing roughness uniformly through the reach is a reasonable solution to this problem.

River stage is inversely related to conveyance: Increasing conveyance causes water levels to fall and decreasing conveyance causes water levels to rise. When calibrating river conveyance, multiplying a single conveyance factor times the conveyance properties at all the cross-section can adjust the reach to reproduce an upstream stage. Hence, optimizing a single reach calibration factor calibrates a reach for a single flow. While the base calibration remains the basis of the stage-flow relationship at each individual cross section, the calibration is refined on a reach basis using the automatic calibration adjustment. The automatic calibration technique was employed to modify the base roughness values for each reach. Base roughness values for the model were determined to match the maximum observed stage. Therefore, the automatic calibration record is employed to increase accuracy for a full range of flows.

Within the federal levee reach, the KR card selection must be consistent with the levee modeling method. For levee overtopping flows, total conveyance should reflect flow conveyed on the floodplain side of the levee. Within the Omaha District, all federal levees were modeled as cells. The predominant impact of levee cells is to provide storage. Limited conveyance through the upstream and downstream connections of the levee cell is possible. For extreme events, the linear storage routing coefficients limit the amount of flow conveyed behind the levee. UNET has an additional option, referred to as the Kansas City levee algorithm, for modeling floodplain conveyance. This method produces excellent results within the Kansas City District on the Missouri River for the 1993 flood event. Refer to Appendix E of this report for additional information regarding the Kansas City modeling methods. The 1993 flood provided sufficient data to calibrate the floodplain routing within the Kansas City District. However, within the Omaha District the 1993 flood peaks were much lower and calibration data for floodplain routing was not available. Model results for the POR analysis show that for extreme events flow is transferred between adjacent levee cells parallel to the main channel as previously described in the levee section of this appendix. The interaction between levee cells and computed river elevation is variable and dependent on model calibration and levee connection parameters. Therefore, sensitivity analysis was performed to evaluate the impact of levee parameters and the KR record on computed results.

Fine Tuning for Flow/Stage Effects

The UNET program has three tools for fine-tuning the calibration of the model. These tools are applied within the boundary condition file and consist of different methods to affect the discharge-stage-conveyance relationship at a cross section within the model.

Conveyance Change Factors. These factors, one for the channel and one for the overbank, adjust the conveyance at multiple cross-sections for all stages. The factors simulate a systematic change in roughness – one that is apparent for all stages over the entire length of the simulation.

Discharge-Conveyance Change Factors. This relationship adjusts conveyance with discharge over multiple cross-sections along the same river, a calibration reach. This relationship is the primary tool for adjusting systematic errors in stage at the same discharge.

Seasonal Conveyance Change Factors. This relationship changes an overall conveyance multiplier with time, simulating seasonal shifts in roughness. The seasonal factor is applied to all the cross-sections in a calibration reach at all stages.

Conveyance Change Factors

Increasing a conveyance change factor causes the computed stage to fall and decreasing the conveyance change factor causes the computed stage to rise. For each separate calibration reach, a table of discharge and conveyance change factors may be specified. A conveyance change factor for discharge Q_i is

$$F_i = \frac{K_{new}}{K_{old}}$$

where:
F_i = conveyance change factor for discharge i.
K_{new} = new conveyance value.
K_{old} = old conveyance value.

For each river discharge Q_i, the conveyance property is multiplied by $F_{i,}$ thereby adjusting the calibration of the model. An example of a conveyance change specified within the bc file is:

```
REACH=15
CONVEYANCE CHANGE FACTORS
591.5 568.63  1  21 0.95 0.95  -0.85  -0.85 0 0
```

The format of the conveyance change factors are explained within the UNET Manual. The channel and overbank factors are multiplied times the 21 channel and overbank conveyance entries in the cross section table for sections within the specified range. Within the final calibration model, conveyance change factors were employed on a limited basis.

Discharge – Conveyance Change Factors.

These factors are also applied to section conveyance. The factors are specified for a range of cross sections for various discharges. A table of flow and conveyance change factors are defined manually. The table values are always at an equal interval of flow, in this case 20,000 cfs. The flow range, 0 to 380,000 cfs, is the expected range of flow. At each time step, conveyance change factors are interpolated from the flow at each cross-section in the calibration reach. Therefore, each cross-section has a different factor, since the routed flow is different at each cross-section. Within the final calibration model, limited use of the discharge-conveyance factor was employed. Factors were employed in some reaches to enhance reproduction of high water mark data. An example of a discharge-conveyance specification is as follows:

```
REACH=15
DISCHARGE-CONVEYANCE RELATION
594.82 583.0 20000 20000 16
20000 1.00
40000 1.00
60000 0.92 … and continued at a 20000 cfs increment for 20 values.
```

Modify Seasonal Conveyance.
The seasonal conveyance change factors adjust the conveyance for all stages according to a time series of factors. Larger rivers such as the Mississippi and the Missouri have a cold season roughness regime and a warm season roughness regime. During the cold season, the more viscous water reduces the period and height of the dunes, reducing the roughness. The initiation of roughness changes can be predicted by water temperature. Studies conducted by the Omaha District have verified the roughness change (USGS, 1976). However, the time at which the roughness change occurs varies yearly. The fall season roughness transition usually occurs around October. The spring season transition occurs in late April or early May with a transition period from one to two weeks. Minor modifications in vegetation height and density may also be addressed by the seasonal factor. However, the factor is applied uniformly to the entire section. An example of a seasonal conveyance change specified is:

```
REACH=7
SEASONAL CONVEYANCE CORRECTION
714.99  669.23  11
 01JAN  1.05
 25APR  1.05
 15MAY  1.05
 25MAY  1.03
 05JUN  1.0
 20JUL 0.99
 15SEP 1.00
 01OCT  1.02
 15OCT  1.04
 01NOV  1.05
 31DEC  1.05
```

Seasonal calibration parameters were evaluated during the calibration process. Refer to section *Calibration Events and Results* for a discussion of seasonal factors employed for the POR analysis.

Model Implementation of Calibration Factors.
One or all of the section conveyance change factors may be specified within the model. Within the model, at cross-section i, the adjusted conveyance is

$$K_i = F_{cc} \cdot F_{QF}(Q_i) \cdot F_S(T) \cdot K_{xs\,i} \qquad (3)$$

where:
K_i = adjusted conveyance at cross-section i.
F_{CC} = conveyance change factor, a constant value.
$F_{QF}(Q_i)$ = discharge conveyance change factor, interpolated from the flow, Q_i, at cross-section i.
$F_S(T)$ = seasonal conveyance change factor at day T.

$K_{XS\,i}$ = conveyance from the cross-section property table at cross-section i.

CALIBRATION EVENTS AND RESULTS

Several different events were employed for calibration. Different events are required due to the conveyance impacts that have occurred on the Missouri River. Previous studies, discharge measurements, and observed data all indicate that the Missouri River stage-discharge has seasonal and annual fluctuations. The stage-discharge relationship at a given location generally has variability of 0.5 feet or more from one season to the next. Calibration methods focused on selecting a single best-fit relationship for the entire model reach. Therefore, some model calibration error is known to occur for each individual event. Final calibration represents the model determined to be best suited for the POR analysis. An example of the stage-discharge variation using measured data at the Sioux City gage is shown in Figure F-4. During the 1997 event, the stage varied from 1081.4 feet to 1078.7 feet for a flow of 71,500 cfs. Entering Figure F-4 with a stage of 1081 feet, the measured flow varied from about 58,000 cfs to 76,000 cfs between 1996 and 1997.

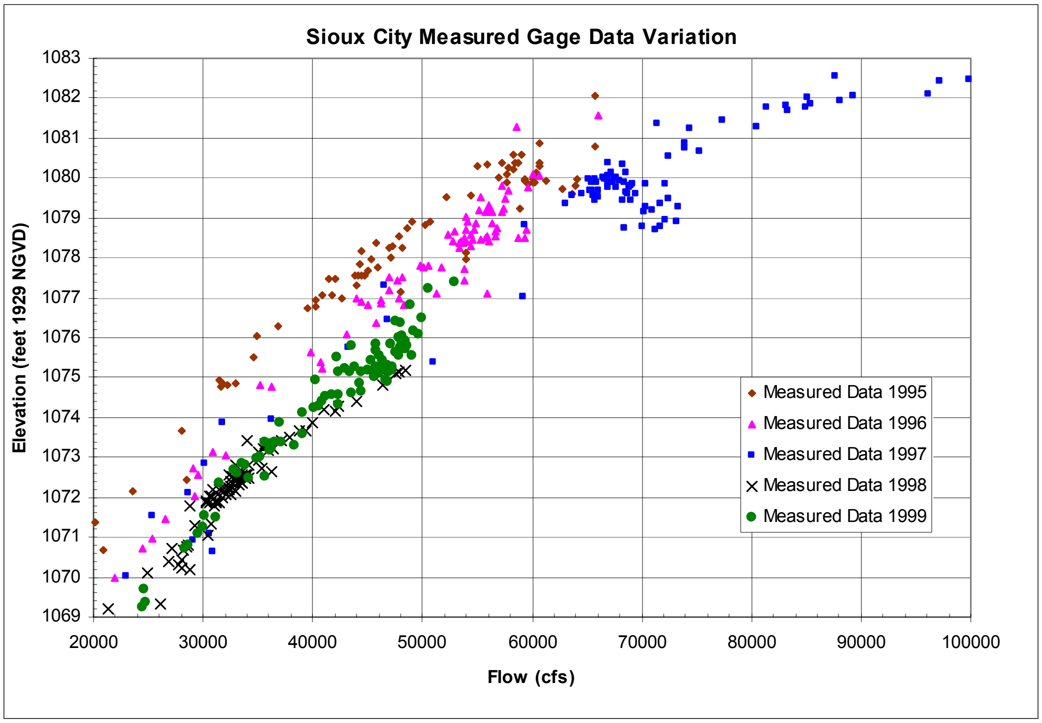


Figure F-4

For data illustrating the variation at the gage stations, refer to Plates F-86 thru F-90. For example, using 1997 measured data at the Nebraska City gage, the stage varied from 922.6 feet to 923.6 feet for a flow of 80,000 cfs. Most gage stations illustrate an annual variation in excess of 1 foot when comparing measured flow data.

Gage Station Calibrated KR Curves

The calibrated model employed the automatic calibration technique described in section *Application of Automatic Calibration Conveyance Adjustment*. The KR curves at all the gage stations represent the best fit for the calibrated data for a full range of flow events. The POR analysis requires modeling flows beyond the range of calibration events. In order to increase model accuracy for extreme events, an HEC-RAS model was constructed to represent unconfined conditions. The RAS model was employed to provide a lower limit for the stage-flow relationship at gaging station locations. Measured data was also consulted when available. The final model employed an automatic calibration record that reflects the best fit to the calibration events plus a method of extending model to simulate extreme events. Gage station UNET model curves, measured data, and HEC-RAS computed data are illustrated in Plates F-91 thru F-102. Sensitivity analysis to evaluate the impact of the automatic calibration was performed and is discussed in section *Sensitivity Analysis*.

Seasonal Variation Calibration

The UNET model was calibrated to reproduce summer stages with normal roughness values. Therefore, the spring and fall seasonal adjustments are to increase conveyance and generate a lower stage at the same flow that occurred during the summer. The gage station data shows that the seasonal roughness change magnitude varies with location. Observed data from the 1997 event, which had a fairly constant flow from May through October, demonstrates the seasonal change at the gaging stations.

For the POR analysis, the seasonal conveyance change was applied in a standard manner to account for possible variations in the date that the seasonal variation occurs. In addition, the seasonal conveyance change factors were reduced to a minimum in order to avoid underestimating stages for some events and reduce profile conflicts. In the historic record prior to dam construction, many annual peaks were caused by snowmelt and occur in the April time period. However, the system of reservoirs for the current condition significantly reduces spring snowmelt runoff below Gavins Point Dam. Therefore, the POR analysis capped seasonal adjustments at a reasonable value in order to accurately predict annual peak stages. The stage reduction caused by the seasonal factors is particularly noticeable at the Decatur, Blair, Omaha, and Plattsmouth gages. As a result, the April to May 1997 calibration at these gage stations shows more error than other locations. However, employing a larger seasonal adjustment to further reduce computed stage was determined to be non-conservative and not desirable for the POR analysis. A large seasonal adjustment factor will increase the variability of the computed stage-flow results. The time and degree of seasonal adjustment varies annually. Historical events illustrate that calibration to spring\fall and summer events is not possible with the same calibration parameters. The historical period of record includes a significant flow record that does not reflect the current flood control reservoir storage. Since most flood events in the post-reservoir construction era downstream of Omaha occur in the summer, the seasonal adjustment was limited to provide a summer weighted flow-stage relationship. For the purpose of determining valid annual maximum stage-flow relationships, the POR analysis focused on the reproduction of summer stages to develop an accurate annual maximum stage-flow relationship that is not dependent on the seasonal time that the event occurs.

The spring roughness change, expressed within the model as a conveyance factor, was limited to a maximum value that varied depending on location. The selected maximum value was used to reflect possible flood sources at each location. Within the Gavins Point Dam (RM 811.1) to Sioux City (RM 732.3) reach, the maximum adjustment factor applied to base summer conveyance was 1.05. This factor was transitioned downward to a value of 1.03 at Omaha (RM 615.9) and a value of 1.02 below the Platte River. The transition reach was selected based on Gavins Point releases for the regulated period and tributary inflow. Since the time and degree of the seasonal shift varies, using higher conveyance change factors was determined to be non-conservative for the POR analysis.

In order to evaluate the transition used for the seasonal adjustment, measured gage data was evaluated. The evaluation was performed in an attempt to determine a definite correction that could be applied within the model. Measured data at the Omaha gage was evaluated to determine an average seasonal adjustment. However, the measured data did not reveal a definite trend that could be used to set the maximum seasonal adjustment or refine the transition of the adjustment factor. Therefore, the empirically determined factors and the adopted transition reach from Sioux City to Plattsmouth were used in the POR analysis. Refer to Plate F-103 for an illustration of the varying seasonal shift at Omaha.

Measured Profiles

The Omaha District routinely collects Missouri River water surface profiles between Gavins Point Dam and Rulo, NE. The profiles are typically collected at a fairly constant inflow period to avoid changing tributary inflow to the extent possible. As a result, the profiles are usually collected during a normal flow period and are not available for high flow events. Calibration efforts used the measured profile data to verify the channel roughness value. Four different events were utilized for the calibration. Plots illustrating the calibration accuracy are illustrated in Plates F-104 thru F-109. The highest recent measured profile occurred in May 1997 with a flow rate that varied from 70,000 cfs at Yankton to 120,000 cfs at Rulo.

Selection of Calibration Events

As previously discussed in the section *Aggradation and Degradation Trends*, the Missouri River stage-discharge relationship has changed considerably with time. Calibration events are limited to include only events that are applicable to current conditions. The calibration event selected varied by gage station. A summary of the selected events are illustrated in Table F-67.

Table F-67
Selection of Missouri River Calibration Events

Missouri River Gage	River Mile	Observed Peak Elev.[1] (ft)	Peak Flow[1] (cfs)	Date	Appr. Flow Freq.[2] (Yrs)	Remark
Yankton, SD	805.8	1159.2	68,000	Oct 97	25	Degradation impact, only valid events are post 1997
Gayville, SD	796.0	1152.1	78,200	Apr 97	>10	Degradation impact, only valid events are post 1997
Maskell, SD	775.6	1128.1	76,000	Apr 97	>10	Degradation impact, only valid events are post 1997
Ponca, NE	751.0	1101.1	77,000	Apr 97	>10	Degradation impact, only valid events are post 1997
Sioux City, IA	732.3	1082.8 1080.0 1087.0	97,000 69,000 103,000	Apr 97 Jul 97 Jun 84	25 >5 >25	Degradation impact, only valid events are post 1997. 1984 event not used due to degradation.
Decatur, NE	691.0	1041.0 1042.0 1044.6	100,000 75,000 98,000	Apr 97 Jul 93 Jun 84	25 >5 <25	1997 is primary event, degradation in 1997 that may not be permanent. Note stage change since 1984
Blair, NE	648.3	1002.2 1004.2 1004.6	106,000 102,000 117,000	Apr 97 Jul 93 Jun 84	< 10 <10 10	1993 and 1997 are equal weighted events for calibration, 1984 is secondary
Omaha, NE	615.9	974.6 978.2 977.3	109,000 118,000 114,000	Apr 97 Jul 93 Jun 84	<10 <10 <10	1993 is primary event, 1997 and 1984 are secondary, some stage-flow changes have occurred
Plattsmouth, NE	591.5	957.2 964.2 963.1	116,000 193,000 184,000	Apr 97 Jul 93 Jun 84	5 >25 <25	1993 primary event, notable stage-flow change since 1984
Nebraska City, NE	562.6	926.5 932.1 930	115,000 188,000 180,000	Apr 97 Jul 93 Jun 84	<5 25 <25	1993 primary event, notable stage-flow change since 1984
Brownville, NE	535.3	896.8 904.2 900.5	117,000 230,000 210,000	Apr 97 Jul 93 Jun 84	<5 >50 50	1993 primary event, notable stage-flow change since 1984

Table F-67
Selection of Missouri River Calibration Events

Missouri River Gage	River Mile	Observed Peak Elev.[1] (ft)	Peak Flow[1] (cfs)	Date	Appr. Flow Freq.[2] (Yrs)	Remark
Rulo, NE	498.0	857.6 862.3 961.5	120,000 290,000 215,000	Apr 97 Jul 93 Jun 84	<5 >100 50	1993 primary event, limited stage-flow change since 1984

1 The tabulated peak flow and stage values are the average daily flow determined from gaging station records. Computed peak flow is tabulated at COE non-rated gages where USGS flow is not available.

2 The tabulated approximate frequency is that flow frequency that corresponds to the peak flow determined at the gage site. The stage value does not necessarily correspond to the results from the stage-frequency study at the gage location.

Flow and Stage Reproduction at Gages
Calibration was performed at all gage stations shown in Table F-64. The NIBC was employed to enhance model reproduction of observed gage station flow. For the 1997 event, flows were more constant through the summer months. For the 1993 event, significant inflow between the gage stations occurred. Good reproduction of observed flow was achieved for all calibration events. Model results determined large negative values for ungaged inflow for some reaches and events. In particular, the Omaha to Nebraska City reach shows a persistent negative inflow even during periods with constant tributary inflow from the Platte River and Weeping Water Creek. Negative ungaged inflow for calibration was allowed to achieve the proper flow distribution. For the POR analysis, negative ungaged inflow was limited to –5000 cfs to eliminate concerns regarding unforeseen impacts to the energy gradient. An illustration of the model computed results and observed data at the gage locations are illustrated in Plates F-110 thru F-135.

High Water Marks
High water mark data is available for the 1984 and 1993 events between RM 515 and RM 616. The 1984 event is of secondary importance since significant changes to the floodplain topography have occurred since the 1984 event. Therefore, the current condition model is expected to produce some variation from the 1984 event. High water mark data should be evaluated with caution. The collected data exhibits some discrepancies with several points conflicting. Setting high water mark points following an extreme event is subjective and also may be impacted by unsteady flow phenomenon, levee failures (both federal and private), localized heavy rainfall, and the distribution of ungaged inflow. High water mark calibration accuracy for the 1984 event is reduced due to the general upward stage trend. Plots illustrating the high water mark calibration are shown in Plates F-136 thru F-139.

Hourly Data Comparison
All model analysis was performed with daily values for all inflow hydrographs. Previous modeling efforts used hourly flow data when available. In order to be consistent with the POR analysis, daily data was used. As a result, calibration accuracy is reduced. The reduction of calibration accuracy does not impact the final stage-frequency results since the analysis method relies on the developed stage-flow relationship. The use of hourly data allows further refinement of the ungaged inflow estimate. An illustration of the difference between hourly and daily data during the 1993 flood peak at Nebraska City is provided in Plate F-140.

Calibration Results and Discussion
Calibration results varied with gage location. Missouri River stage trends, seasonal variation, and natural variation limit calibration accuracy. The stage trend impact is very noticeable when comparing the 1984 event to the 1993 event at Brownville, Nebraska City, and Plattsmouth gages. Data from 1997 indicates

that stages-flow relationship decreased at most locations. The data illustrate the impact of sustained high flows on the stage-flow relationship. Table F-68 summarizes calibration peak stage accuracy.

The 1952 flood is the record flow event through the Omaha District on the Missouri River. Because of the significant changes within the stage-flow relationship, this event is not suitable for use with calibration. The 1952 event was used to provide general information concerning the shape of the rating curve for extreme events using the measured flow data. Also, off channel storage areas were provided between Sioux City and Omaha to approximate the discharge reduction that was observed in the 1952 flood. Calibration of the 1993 flood required a deviation from the POR model in order to simulate failure of the L550 levee upstream of Brownville. During the 1993 flood, the L550 levee failed as the result of a geotechnical failure, not overtopping. All levee failure within the POR analysis was coded to fail by levee overtopping.

Table F-68
Missouri River Calibration Accuracy Summary

Missouri River Gage	River Mile	Observed Peak Elev.[1] (ft)	Computed Peak Elev.[1] (ft)	Difference (Computed -Observed) (ft)	Date of Peak	Peak Flow[1] (cfs)
Yankton, SD	805.8	1159.1	1159.2	0.1	1 Oct 97	67,700
Gayville, SD	796.0	1151.8	1152.0	0.2	1 May 97	78,200
Maskell, SD	775.6	1128.0	1127.9	-0.1	1 May 97	73,500
Ponca, NE	751.0	1101.1	1100.9	-0.2	29 Apr 97	77,000
Sioux City, IA	732.3	1082.8 1080.3 1087.0	1082.8 1080.3 1084.2	0.0 0.0 -2.8 (degradation)	10 Apr 97 2 Jul 97 25 Jun 84	97,400 67,200 103,000
Decatur, NE	691.0	1041.6 1042.0 1044.6	1042.3 1041.1 1042.9	0.7 (minimal degradation) -0.9 -1.7	12 Apr 97 16 Jul 93 26 Jun 84	99,000 75,000 98,000
Blair, NE	648.3	1002.2 1004.2 1004.6	1003.6 1004.3 1005.9	1.4 (seasonal adjust.) 0.1 1.3	16 Apr 97 17 Jul 93 27 Jun 84	106,000 100,000 117,000
Omaha, NE	615.9	974.6 978.2 977.3	976.3 977.9 978.1	1.7 (seasonal adjust.) -0.3 0.4	17 Apr 97 11 Jul 93 27 Jun 84	108,000 113,000 114,000
Plattsmouth, NE	591.5	957.2 964.2 963.1	957.4 964.4 964	0.2 0.2 0.9	17 Apr 97 25 Jul 93 14 Jun 84	117,000 196,000 187,000
Nebraska City, NE	562.6	926.5 932.1 930.0	926.6 932.0 931.5	0.1 -0.1 1.5	18 Apr 97 23 Jul 93 15 Jun 84	113,000 190,000 180,000
Brownville, NE	535.3	896.8 904.2 900.5	896.6 904.1 903.9	-0.2 -0.1 3.4	14 Apr 97 23 Jul 93 15 Jun 84	117,000 230,000 220,000
Rulo, NE	498	857.6 862.3 861.5	858.9 862.6 861.4	1.3 0.3 -0.1	15 Apr 97 24 Jul 93 16 Jun 84	121,000 290,000 215,000

1 The tabulated peak flow and stage values are determined from model and gaging station daily values.

2 The difference value may require a timing shift to compare peak values. Refer to the plotted hydrographs for detailed comparison.

Notes regarding calibration accuracy at specific locations are:

Sioux City to Gavins: The accuracy for the reach is good. Calibration is limited to a single event due to degradation impacts. Model results at Sioux City show nearly 3 feet of degradation from 1984 to 1997.
Decatur: Model results shows degradation in 1997 compared to 1993 and 1984. Final calibration is a combination of all 3 events.
Blair: Model results show over 1 foot of stage rise from 1984 to 1993 for a similar flow. The 1997 event shows significant seasonal adjustment.
Omaha: Model results show a seasonal impact for the 1997 event. The 1993 and 1984 events are consistent.
Plattsmouth: Model results show nearly 1 foot of change between 1993 and 1984 for a similar flow. Gage inundation may have impacted high water level accuracy for both the 1993 and 1984 event.
Nebraska City: Model results show about 1.5 feet of stage rise between 1993 and 1984 for a similar flow.
Brownville: Model results show over 3 feet of change between 1993 and 1984 for a similar flow. 1993 results are impacted by the L550 levee failure. Also, the Brownville gage was flooded and gage readings were performed manually.
Rulo: Model results are consistent for 1993 and 1984. This location has an extremely flat stage-flow rating curve due to the very wide floodplain. The accuracy of computed flow may be reduced as a result.

PERIOD OF RECORD SIMULATION

The calibrated UNET model was used to perform a period of record analysis. For the hydraulic model, the period of record refers to the time frame from 1900 to 2000. The POR is slightly different from the previously performed hydrologic analysis. The POR analysis period corresponds to the gaging station data length of record that was available for analysis and was extended to the year 2000 to allow for model calibration to the most recent data. Refer to the Omaha District Hydrologic technical summary for details regarding the hydrologic analysis that was performed to determine 100-years of flow data at the Missouri River gaging stations. While significant geometry and conveyance changes have occurred in the past 100 years, the POR analysis uses the historical flow record, not the stage record. Since the model is calibrated to the current condition, the period of record analysis computes stages that would occur if the historical record were repeated.

Ungaged Inflow Determination

Additional analysis was performed to determine ungaged inflow for the period of record. Ungaged inflow determination was performed for the period of record using the procedure outlined in the section *Application of Null Internal Boundary Condition for Ungaged Inflow*. Inflow for the period of record analysis used the tributary gaging station record for the available length. The computation of ungaged inflow results in negative flow for many periods. Negative flow occurs due to natural phenomenon such as floodplain storage and groundwater recharge. Negative flow also may be due to model error. For the POR analysis, negative flow was eliminated to prevent model timing issues from impacting results by changing the local slope of the energy gradient. As a result, the POR analysis volume is larger than the observed flow data indicates.

For the early portion of the record prior to the establishment of the tributary gage, the tributary drainage area was included in the ungaged drainage area. Most tributary gages were established in the period between 1928 and 1950. Therefore, prior to 1928 all inflow between the gaging stations was distributed within the UNET model based on drainage area. In addition, Missouri River mainstem flow data has reduced accuracy prior to 1928. Sensitivity analysis was performed to evaluate the impact of ungaged inflows.

Ungaged inflow determination for the POR analysis was performed by a contractor to the Omaha District. Refer to appendix F-F for details regarding the computation of ungaged inflow. It should be noted that the ungaged inflow determination was made with a series of models calibrated to produce reasonable flow and stages for the entire period of record. Computation of ungaged inflow also includes hydrograph timing. Channel changes and river shortening affect the timing of flow events. For these reasons, translating the ungaged inflow from the historic model to the current condition may have unforeseen impacts on the final results. The elimination of high negative ungaged inflow values mitigates potential impacts of these changes on POR results.

The ungaged inflow computation focused on the preservation of peaks. While preservation of volume is recognized as important, volume is of secondary importance compared to peak flow and stage. The unsteady flow model requires a minimum base flow for the Missouri River and tributary reaches to achieve model stability during the period of record. For these reasons, the period of record model is not intended to provide computed volumes that are suitable for further volumetric based computations. Volume computations using computed results will determine a difference between model routed flows and observed gage flows. Sensitivity analysis was performed to evaluate the change in computed stage-frequency results caused by volume changes.

Operational Policy

The period of record analysis uses observed historical flow data. Therefore, any future operational changes that occur are not incorporated in the analysis. Any changes that occur in the Missouri River basin reservoir system operational policy would primarily affect flow-frequency below Gavins Point. Operational changes could also impact flow volume that may have stage impacts. Future changes in depletions or other consumptive use that would impact flow volume are also not addressed. Downstream of Gavins Point Dam, there are no operable structures on the main stem Missouri River. The federal levee system does not require operation. Flood fighting efforts were not considered in this analysis.

UNET POR Simulation

The POR analysis is performed with the calibrated UNET model. The analysis uses daily flow data for all inflow hydrographs with a 3 hour computational time step. The purpose of the POR analysis is to generate 100 years of stage-flow data at all UNET model cross section locations by simulating the observed flows. Annual maximum flows and stages are collected using the Annual Maximum flag within the UNET boundary condition file. In order to correctly account for total flow at a cross section, the flow within the levee cell must be included in the total flow. The total flow is determined by using the Parallel Flow flag within the UNET boundary condition file. An explanation of the levee parallel flow method is included in appendix F-G. Boundary condition file flags specific to the POR analysis are as follows:

```
PARALLEL=ON
ANNUAL MAXIMUM=ON
annual.dss 5 5 5
```

The POR analysis stores output data in the dss file annual.dss. The three “5” parameters specified with the annual maximum command sets the curve fit algorithm to use a 5th order polynomial. Files created with this method are available for use with a separate spreadsheet method of determining stage-frequency. The POR analysis determines the annual maximum flow and stage that would occur for the current condition model using 100 years of observed historical flow data. The output from the POR analysis is a set of data files that can be used by further analysis to determine stage-frequency relationships at all cross sections.

For the portion of the model downstream of the Platte River, the upper end of the rating curve did not include sufficient points to define the 500-year event. Additional runs were employed using ratios of the 1952 flood, from 1.1 to 0.9, to provide additional data points at the upper end of the rating curve.

STAGE-FREQUENCY FROM UNET RESULTS

Using the output from the UNET POR analysis, stage-frequency relationships may be determined at all UNET model cross section locations. The POR analysis does not generate a traditional 100-year profile. Several additional steps are required using software analysis programs developed by the Hydrologic Engineering Center (HEC). A detailed description of the stage-frequency analysis is provided in appendix F-H. The steps involved are summarized as follows:

a. Run the UNET POR model from 1900-2000.
b. Run the UNET model with a ratio of the 1952 flood to define the upper end of the rating curve and combine with results from the POR model.
c. Extract the annual maximum flow and stage values at each cross section.
d. Fit a spline curve through the stage-flow relationship at each cross section.
e. Interpolate the flow-frequency between the gage stations to each cross section using period of record flow statistics from Gavins Point Dam to Sioux City and drainage area from Sioux City to Rulo, NE.
f. For the flow-frequency value at each cross section, determine the corresponding stage from the stage-flow relationship.
g. Develop the final profile after corrections for backwater areas and profile smoothing.

A spline curve was selected as the technique to fit a curve through the computed stage-flow points to form a rating curve at each cross section. The rating curve can be very non-linear, reflecting changes in channel cross section geometry. A polynomial curve fit uses all points for the curve to minimize the sum of squared residuals for all points. In this respect, the polynomial is weighting information for the low flow data points to fit the rating curve at the largest flow points. In general, this is not desirable since the upper end of the curve is more critical. Another issue is how the curve is fit between points at the upper end of the curve. The spline fit allows you to adjust this fit depending on 1) the bandwidth (how many points you average in the smoothing) and 2) the algorithm also allows you to fit the largest flood exactly. An analysis using a fifth order polynomial curve determined similar results with differences at the 100-year event at most locations of 0.1 feet or less.

Cross Section Flow Frequency

The previously described Omaha District hydrologic analysis determined the unregulated flow-frequency statistics at the Missouri River mainstem gaging stations. The hydrologic analysis also determined the unregulated vs. regulated relationship at all gaging station locations. Plates F-35 thru F-39 illustrate the regulatd-unregulated relationship at each gage station. Using software provided by HEC, a regulated flow-frequency relationship was determined at each cross section. The HEC program preserves the unregulated gage statistics and the regulated-unregulated relationship at the gage locations.

The flow-frequency at each cross section is determined by distributing the flow change between the gages by using two methods. Analysis used either the quantile method, that is based on the period of record flow statistics determined with the UNET model, or the drainage area at each cross section to determine flow-frequency at all cross section locations. Both methods preserve the regulated flow frequency determined by the hydrologic analysis at the Missouri River gage station locations. In the Yankton to Sioux City reach, the cross section flow-frequency values using the drainage area distribution method did not agree with the values determined using the period of record routings. Downstream of Sioux City, the two methods generated similar results.

The difference between the two methods upstream of Sioux City is due to the contribution from the James River. Between Yankton and Sioux City, the James and Big Sioux Rivers account for 85% of the drainage area. Of the 35,000 square mile drainage area increase, the James River drainage area is over 20,000 square miles and the Big Sioux River drainage area is about 8,500 square miles. Statistical analysis of the downstream gage for each stream was performed and historical flood hydrographs were compared. Although the James River drainage area is over twice the size of the Big Sioux, the James River 100-year peak flow is less than 30,000 cfs while the Big Sioux 100-year peak flow is nearly 80,000 cfs. In general, the Big Sioux River has a higher peak flow of shorter duration while the James River has lower peak flow and a prolonged receding limb on the hydrograph. The two streams are physically quite different. The James River basin flow length is quite long with a very small slope. In central South Dakota, the James River is noted for very small channel capacity. The James River also has considerable floodplain storage and attenuation.

After comparison of the two methods, the quantile method was selected to distribute cross-section flow frequency in the reach from Yankton to Sioux City. Downstream of Sioux City, the drainage area distribution method was employed. Although the two methods were similar downstream of Sioux City, the drainage area method was selected since the period of record flow distribution method introduced small undesirable flow variations that appeared to be correlated to the UNET POR simulation results. A condensed methodology summary follows. Refer to Appendix F-H for additional information.

Drainage Area Method Distribution.

1. Read in the regulated flow determined by the hydrologic analysis at each gage station location. Read in the drainage area at each cross section location. Compute the regulated flow at each cross section for the probability of interest using linear interpolation by drainage area and river mile.

2. Read in the previously determined spline fit relationship from the UNET POR simulation relating peak flow to peak stage. The POR simulation was performed using the observed flow record at Yankton for the entire POR from 1900 - 2000.

3. Compute the stage frequency curve at each cross section by combining the regulated frequency curve and the spline relationship at each cross-section.

Quantile Method Distribution.

1. Compute the difference between regulated flows at each gage for each exceedance probability of interest. Call this difference DQ.

2. Obtain estimates of the regulated frequency curve at each cross section from the 100-year UNET POR simulation using the regulated inflow from Gavins Point Dam combined with the observed tributary and ungaged inflow. The cross section frequency curve is obtained from UNET the output file based on the annual peaks. Compute the difference between regulated flows at each gage cross section location for each exceedance probability of interest. Call this difference DX.

3. Compute the difference between regulated flow at each cross-section for the probability of interest. The differences may be called dx2, .dxi.. dxN, where N is the number of cross-sections between two gages. Note that sum of the all the dx = DX. The value of dx2 is the difference in flow between the second and first cross-sections in the reach defined by a pair of gages.

4. Compute the adjusted flow at each cross section as Q(i)=Q(i-1)+(DQ/DX)dxi. For the cross section at the upstream gage Q(1)=gage estimate. Then at the next downstream cross-section Q(2)=Q(1)+(DQ/DX)dx2.

5. Read in the previously determined spline fit relationship from the UNET POR simulation that was performed using the observed Yankton flow relating peak flow to peak stage. Note the variation from step 2 which uses the regulated Gavins Point Dam flow.

6. Compute the stage frequency curve at each cross section by combining the regulated frequency curve and the spline relationship at each cross-section.

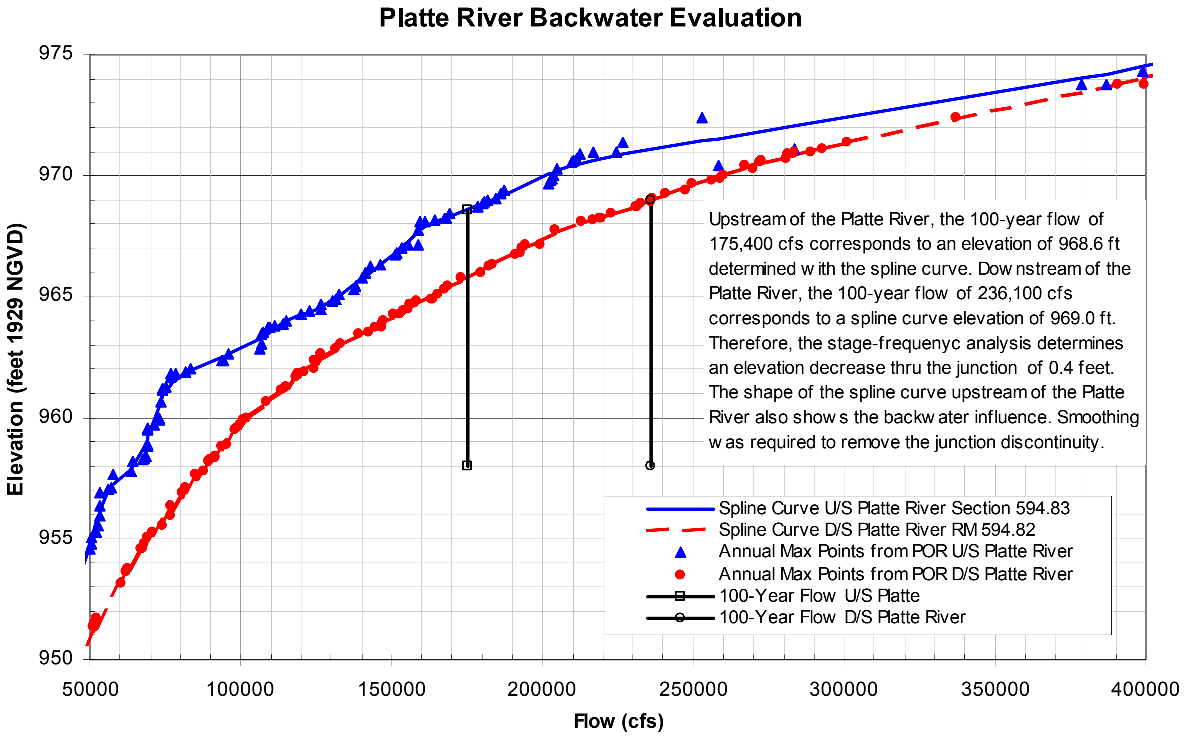
Flow Changes
Notable flow changes have occurred since the 1978 Flood Hazard Study. Downstream of the Platte River, the 500-year flow has increased substantially. Other locations of large flow changes include the reach from Gavins Point Dam to Sioux City. Flow-frequency at all sections and comparison to the 1978 Flood Hazard Study is shown in Plates F-141 thru F-146. The flow changes must be considered when evaluating stage-frequency results.

Association of Stages with flows
The UNET period-of-record simulation produced a DSS file containing the annual maximum discharge and annual maximum stage information for 1900 through 2000. Additional runs were performed with the UNET model using multiple inflow ratios of the 1952 flood to provide better definition to the 500-year event downstream of the Platte River. Results from the POR model and the 1952 flow ratio events were combined to form a single set of annual maximum data. The suite of HEC developed software programs were then used to process this annual maximum data to produce the 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 200-yr, and 500-year discharge and stage profiles. From the POR output file, the HEC software determines a best-fit spline curve of the paired, ranked data. While the spline curve is typically referred to as a rating curve, it is, in essence, a curve relating the discharge and stage frequencies. Using the developed discharge-frequency relationship, the HEC software then computes a stage-frequency relationship at each cross section. By combining the results at all cross sections, the profile for a single event, such as the 100-year, may be developed.

Open River Locations
For the majority of the study reach, the stage-frequency profiles were determined following the procedure previously outlined using HEC software. Omaha District does not include any locks or dams on the Missouri River within the study reach. The majority of the Missouri River is not impacted by tributary backwater affects.

Backwater Influenced locations
In reaches influenced by tributary backwater effects (backwater reaches), a plot of the paired data shows more scatter about the spline rating curve. The most severe backwater reach is upstream of the Platte River. A large amount of scatter was observed in the stage-flow data at Missouri River cross sections upstream of the Platte River. The scatter reflects the fact that the Missouri River stage in the reach upstream of a tributary that is backwater impacted is not simply a function of the Missouri River flow. The stage downstream of the junction is a function of the total flow between the Missouri River and the tributary. The stage upstream of the junction is a function of the downstream stage and the Missouri River flow. Since the stage in the backwater reach is a function of two variables, a family of rating curves is necessary to truly define the stage-discharge relationship.

Within the stage-frequency analysis procedure, rating curves generated by the rating_curve.exe program are only a function of the mainstem river discharge upstream of the tributary. Therefore, the stage obtained from the rating curve may not have the same frequency as the discharge used to get the stage from the rating curve. At backwater locations, the tributary flow that contributes to the total river flow also impacts the stage-flow relationship. If one does assume that the frequency of the stage obtained from the rating curve is equivalent to the frequency of the discharge, an unrealistic jump in the flood profile will occur across the tributary since the backwater affects are obscured. Figure F-5 illustrates the computed results upstream and downstream of the Platte River confluence.



Upstream of the Platte River, the 100-year flow of 175,400 cfs corresponds to an elevation of 968.6 ft determined with the spline curve. Downstream of the Platte River, the 100-year flow of 236,100 cfs corresponds to a spline curve elevation of 969.0 ft. Therefore, the stage-frequenyc analysis determines an elevation decrease thru the junction of 0.4 feet. The shape of the spline curve upstream of the Platte River also shows the backwater influence. Smoothing was required to remove the junction discontinuity.

Figure F-5

Results shown in Figure F-5 illustrate the problem with stage-flow relationships upstream of the tributary junction. Because this is a backwater location, the Missouri River annual maximum computed stage is not well correlated with the annual maximum Missouri River flow upstream of the junction. If the Platte River is contributing a significant portion of the flow, then the stage upstream of the junction is higher. If the Platte River flow is low, then the stage is more closely correlated with the Missouri River flow.

An alternative method that also may be used to develop a final profile uses the spreadsheet input files written by the POR analysis. The spreadsheet allows examination of the stage-frequency plot at each cross section. This method was examined at the tributary junctions but did not appear to perform better than the adopted procedure.

A smoothing procedure was required to eliminate the tributary backwater impact on final profiles. The procedure used an HEC-RAS model developed from UNET model cross sections to evaluate profile slope upstream of the confluence using the downstream starting stage. The final stage-frequency relationship at each cross section within the backwater area was a result of combining the POR analysis results with the backwater profile to develop a smooth profile. The backwater correction was performed in a spreadsheet. Plots of the stage-flow relationship upstream of the tributary junction were examined to determine the backwater influenced cross sections. For the Platte River junction, the backwater influenced reach extends upstream to RM 605 with a decreasing influence to about RM 610. The applied spreadsheet correction was generally 0.6 feet or less between RM 595 and 605. For all other tributaries, the backwater influenced area was less than 5 river miles.

SENSITIVITY ANALYSIS.

Sensitivity analysis was performed with the UNET model to evaluate the impact on computed profiles. Sensitivity analysis looked at several parameters including river conveyance increase, river conveyance reduction, levee confinement with no federal levee failure, a fast levee connection model that increased conveyance through the levee cell, simulating without any ungaged inflow, and factor flows for a portion of the period of record length. The parameters were designed to evaluate model sensitivity to parameters such as model calibration, model conveyance, period of record length, and flow volume. Sensitivity analysis was performed by river mile for the entire model.

Analysis compared results to the base calibrated model. Comparison between results was performed at each cross section and summarized for 50-mile incremental reaches. The results of the sensitivity analysis were used to verify model performance and develop stage error estimates for the risk analysis. Comparison analysis evaluated the stage-flow data computed at a specific cross section, the spline curve developed from the data, and the final estimated stage. Results are illustrated in Plates F-147 thru F-162.

River Conveyance Reduction

Model response to a conveyance change was assessed by applying a uniform conveyance reduction to all Missouri River cross sections. Within the UNET model, conveyance is inversely proportional to roughness. Therefore, the conveyance reduction is similar to a roughness value increase. The conveyance reduction evaluation was performed with a conveyance change factor within the UNET model boundary condition file. Results of the seasonal correction calibration were used to assist with selecting the appropriate conveyance change factor. Calibration indicated a maximum conveyance change of 1.1 to 1.12 was sufficient to bracket the seasonal stage variation. Model results show that the conveyance reduction causes a significant change from the base condition.

River Conveyance Increase

Similar to the river conveyance reduction, a conveyance increase was applied within the UNET model boundary condition file to all Missouri River cross sections. The same conveyance change factor of 10% was applied. Model results show that the conveyance increase causes a significant change from the base condition.

Confined Levee

The impact of levee overtopping and breaching was assessed by performing a POR analysis with all levee connections removed from the UNET model. Federal levee cells impact the stage-frequency relationship by removing flow from the main channel during a flood event. The impact of levee cells varies with the magnitude of the event and the timing of the levee overtopping compared to the peak. In order to model the confined condition, the levee connections were removed from the UNET model. This modification only impacts the portion of the model that has federal levees. Results provide an indication of the stage-frequency impact if flow is confined to the federal levee corridor. The greatest impact is for the 500-year event.

Fast Levee Connection

Within the UNET model, the levee connection parameters include the specification of a linear routing coefficient to describe the rate of flow transfer from the main river to the levee cell. The value selected for the base condition model was based on calibration to the 1993 event. The sensitivity analysis evaluated the impact of the routing coefficient by increasing the base condition coefficient of 0.02 to 0.12. The 0.12 value was selected based on model results and appears to be an upper threshold for model stability. Therefore, the fast levee connection alternative represents a condition with the maximum flow within the levee cell after the cell is breached. This alternative only impacts the federal levee reach and flood events that cause levee breaching. Since the flow through the levee cell is increased, the expected result is that the corresponding main river flow and stage are reduced.

Results from this alternative should be interpreted with caution. The fast levee connection alternative represents the maximum floodplain conveyance if all federal levees have been breached and flow is "bluff to bluff". This alternative has a dramatic impact on extreme events including the 500-year. The levee routing coefficients used in the base condition model were based on the calibration for the 1993 event. The fast levee routing coefficients are significantly greater and do not have a calibration basis. The coefficients represent the maximum rate of flow transfer possible while maintaining model stability. The purpose of the fast levee connection is to demonstrate a lower bound and should not be construed as reasonable. Flow through the floodplain would be reduced by infrastructure (roads and railroads) as well as flow roughness. The fast levee connection model ignores these constraints since the floodplain is modeled as interconnected storage cells with the UNET routing procedure.

No Ungaged Inflow

The sensitivity analysis for this change from the base condition evaluates the impact of ungaged inflow and flow volume on computed results. All ungaged inflow was removed from the model boundary condition file. Since the ungaged inflows were determined from model simulations, the model results for this alternative are used to assess if the simulated ungaged inflow has a major impact on model results. Based on the sensitivity analysis, it does not appear that the ungaged inflow data set skews results.

Period of Record Length – Flow Factoring

Performing a POR analysis from 1950 to 2000 instead of 1900 to 2000 assessed the impact of the record length on computed results. Most tributary gages were installed by 1950 and Missouri River gaging station data has a higher level of accuracy. After performing the analysis, results showed that the 1950-2000 period does not contain sufficient high flow values to define the upper end of the stage-flow relationship at each cross section. Therefore, a second run was performed for the 1950-2000 period with all inflow values factored by a value of 2.1 in order to generate sufficient high flow values to define the upper end of the stage-flow relationship and provide additional values for the stage-frequency analysis and curve fit procedures. Factoring was applied to tributary inflows only and not the ungaged inflow data. Sufficient high flow values were produced for the entire model reach using this approach. In addition to increasing peak flows, flow factoring also increases flow volume and may skew results that are volume dependent. Therefore, the sensitivity analysis assesses both the period of record length and flow factoring impact on results. The dss files generated by the 2 sets of analysis were combined using the store_rating module within the HEC program software as described in appendix F-H. Minor changes were observed compared to the base condition.

RISK AND UNCERTAINTY ANALYSIS DATA.

Analysis was performed to determine an estimate of stage uncertainty. The estimated stage uncertainty is used to develop reliability estimates. Development of the stage uncertainty estimate follows the Corps of Engineers guidance provided within EM 1110-2-1619, *Risk Based Analysis for Flood Damage Reduction Studies* (USACE, 1996). Stage uncertainty can be estimated using calibration error at gage stations. However, the feasibility of using model calibration error is limited within the Omaha District. Many reaches of the model have experienced significant change in the stage-discharge relationship during the period of record. Due to the ongoing rating curve shift, the peak stage model calibration is based on a single event with a corresponding low model calibration error. Model calibration is based on the 1993 event from Omaha and downstream. Above Decatur, model calibration is based on the 1997 event. In addition, the seasonal correction was limited to prevent low estimates of stage-frequency that are dependent upon the season at which the flood event occurs. Therefore, the April 1997 calibration model results are high since the peak occurred before the seasonal shift. Based on an assessment of all contributing factors, model calibration error within the Omaha District does not provide a reasonable method of estimating the stage uncertainty range.

Results from the sensitivity analysis were used to develop an estimate of stage-error for the Omaha District portion of the Missouri River study reach. Sensitivity analysis can be used to define the reasonable upper and lower bounds for a given discharge. For use with the risk model, sensitivity analysis was limited to computed results for the 100-year event. If the stage difference between the upper and lower limits is taken to be the reasonable bounds, then the standard deviation may be estimated as (USACE, 1996):

$$S = E_{mean} / 4$$

Where E_{mean} is the mean stage difference between the upper and lower limits. The mean stage difference was computed from the sensitivity analysis. The risk guidance (USACE, 1996) also provides values for the minimum standard deviation of error (USACE, 1996). The minimum values reflect survey error and n value reliability. Cross section data was extracted from data based on combined aerial topographic surveys and Missouri River hydrographic surveys data. The river survey data is assumed to be the critical component with respect to data accuracy. For cross sections based on field survey with fair n value reliability the minimum recommended standard deviation is 0.7 feet. The different alternatives evaluated with the sensitivity analysis were compared to the base condition throughout the study reach on a 10-mile incremental basis for the 100-year event. The comparison was made between the base condition and all alternatives. The analysis did not determine a significant change by each reach. In order to determine the stage deviation, the maximum and minimum difference between the base condition and all alternatives was determined throughout the study reach. Figure F-6 presents the computed results.

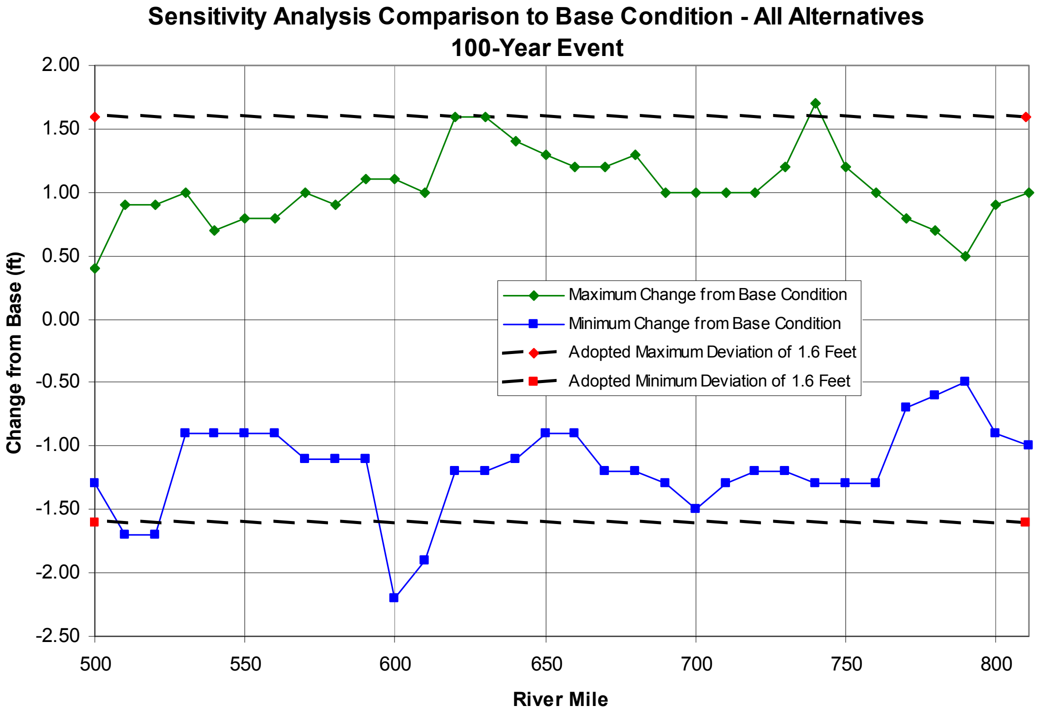


Figure F-6.

Using the sensitivity analysis results and professional judgment, the reasonable upper and lower bounds of stage were estimated as 1.6 feet as shown on figure F-6. Using the adopted deviation of 1.6 feet, the standard stage error may be computed as:

$$S = (1.6 + 1.6)/4 \text{ or } S = 0.8 \text{ feet.}$$

The standard stage error of 0.8 feet exceeds the minimum recommend value of 0.7 feet. The selected standard stage error is applied to the risk analysis (HEC, 1996). Plots that illustrate the change from the base condition for each alternative for the 100-year event are shown in Plates F-163 and F-164.

FINAL PROFILE DEVELOPMENT

The final step in determination of the stage-frequency relationship is to import the data from the HEC suite of programs into the profile plotting spreadsheet. The final output file from the HEC program contains tabulated flow-frequency and stage-frequency for each cross section. Refer to appendix F-H for an example of the final output file. Spreadsheet modifications performed to develop the final profiles consist of profile smoothing and adjustment within backwater areas.

Profile Smoothing.

Initial results exhibited some areas where the profile had dips or inconsistencies. These variations were most pronounced for the 500-year event and the 100-year event to a lesser extent. Given that the methodology employed a single geometry file for the entire analysis, some inconsistencies are not unexpected. For large events, top width and flow velocity variation contributes to excessive stage variation between adjacent sections. A simple profile smoothing algorithm was applied to the final results within a spreadsheet prior to plotting. Refer to Appendix F-I for a description of the profile smoothing.

Interface at Rulo, NE.

The boundary between the Kansas City and Omaha Districts occurs at Rulo, NE. The Rulo area geometry includes a system of privately constructed levees that provides a limited level of protection. The floodplain is extremely wide at Rulo with a flat sloping stage-flow rating curve for extreme events. Stage at Rulo can also be impacted by flows from the Big Nemaha River that enters the Missouri River approximately 3.2 miles downstream of the gage.

Both Districts developed UNET models for the period of record analysis that included an overlap section with the adjacent District. The downstream boundary of the Omaha model was at St. Joseph, Missouri, while the upstream boundary of the Kansas City model was at Nebraska City, Nebraska. Considerable differences occurred between the methodology employed in model construction within the two Districts. For example, the Kansas City District employed a different UNET levee routing algorithm. In addition, the Kansas City District employed a different approach to generate stage-frequency from the POR results. Kansas City District also used UNET model results to modify the flow-frequency relationships derived from the hydrologic analysis. Because of the analysis variations between the two Corps Districts, differences in the flow-frequency and stage-frequency results occurred at Rulo, NE. Refer to Appendix E for a complete description of the Kansas City District analysis methods.

In order to develop consistent profiles at the Rulo, NE, interface, the results from the two Districts were merged as practical. Flow-frequency differences for the 2-year through the 100-year were minor and may be attributed to numerical round off and slight computational differences. For the 200-year and 500-year profiles, Kansas City District adjusted the flow values based on the UNET analysis. The flow adjustment was not performed in the Omaha District, therefore the flow values are different. Stage-frequency differences were minor and generally less than 0.5 feet. Comparison illustrated that Kansas City District results were slightly higher than Omaha District results for all profiles. This is true even for the 200-year and 500-year events for which Kansas City District has a lower flow. In order to develop a smooth profile, Omaha District adopted Kansas City District stage-frequency results at Rulo,NE. Slight adjustments at the next two cross sections upstream of Rulo, NE, were necessary to merge the profile. The final tabulated stage-frequency results reflect the merged profile condition.

Final Profiles.
Profile smoothing was applied to adjust the final profiles and remove all inconsistencies. The output results were also modified in the vicinity of the major tributaries as previously discussed in the section *Backwater Influenced Locations*. The combined results from the stage-frequency software, the smoothing algorithm, and the backwater analysis were used to determine the final profiles. Additional profile modification was required at the Omaha District boundary with the Kansas City District located at Rulo, NE. A few profiles required some minor adjustments in elevations, but these adjustments were generally less than 0.5 ft. The final smoothed profiles were then interpolated from cross section locations to locations at even river miles to provide the standard tabulated format. Water surface profiles developed for various flood events are shown in Plates F-165 thru F-173. Tabulated values for the same events are illustrated in Plate F-174 thru F-186.

Study Applicability to the National Flood Insurance Program
Development of revised Flood Insurance Rate Maps (FIRM) was not a task of this study. The Federal Insurance and Mitigation Administration (FIMA) within FEMA are responsible for administering the National Flood Insurance Program (NFIP). FEMA defines technical requirements and policy for Flood Hazard Maps and related NFIP products in *Guidelines and Specifications for Flood Hazard Mapping Partners*, (FEMA, 2002). Comparison to the existing Flood Hazard Study (USACE, 1978) determined significant change in the flow-frequency and stage-frequency results determined by this study. A comparison between study profiles and the 100-year profile from the Flood Hazard Study (USACE, 1978) is shown in Plates F-187 thru F-195. Prior to revising the existing Flood Hazard Study (USACE, 1978) with the new results computed with this study, an additional study that develops FEMA regulatory parameters is required. Regulatory parameters that may be revised include the 10-, 50-, 100-, and 500-year flood profile, the 100- and 500-year flood boundary, and the 100-year floodway boundary.

Products of this study that may be used to assist in development of revised NFIP parameters include the computed flow-frequency and stage-frequency values along the Missouri River from Gavins Point Dam to Rulo, NE. However, substantial effort is required to translate these products into the necessary parameters required by FEMA to administer the NFIP along the Missouri River. While the FEMA study methodology has not been determined, items that would require additional effort may include the development of a traditional hydraulic regulatory model such as HEC-RAS, performance of floodway computations, and flood outline mapping according to FEMA guidelines to develop Flood Insurance Rate Maps (FIRM). Ice impacts should be evaluated according to FEMA guidelines and adjustments may be required where ice is determined to be a problem. The flow-frequency and stage-frequency relationships determined at each location by this study would serve as a base for development of a HEC-RAS model. The HEC-RAS model can be calibrated to the stage-frequency results obtained from this study. Minor variation of computed elevations should be expected. Determination of regulatory elevations within levee reaches must also consider the possibility that two NFIP regulatory elevations may be required to provide different elevations riverward and landward of the levee. The profile riverward of the levee would reflect the computed river water surface elevation. The NFIP regulatory elevation landward of the levee would reflect the maximum water surface computed within the levee unit that reflects several possible conditions including an upstream breach that fills levee storage. The regulatory elevation will also consider tributary inflow along tie-back levees in applicable locations.

HYDRAULIC SUMMARY

Hydrologic and hydraulic analysis was conducted by the Omaha District as part of the Upper Mississippi, Lower Missouri and Illinois Rivers Flow Frequency Study. Prior to this study, the discharge frequency relationships established for the Missouri River are those that were developed in 1962 and published in the Missouri River Agricultural Levee Restudy Program Hydrology Report. This hydrology information was used for the water surface profiles and flood inundation areas that were developed for the Missouri River Flood Plain Study during the mid to late 1970's. Almost 40 years of additional streamflow data were available since the Missouri River Hydrology was last updated. Also, significant channel changes have occurred since the previous hydraulic studies were completed.

The hydraulic model extends from Gavins Point Dam, at RM 811.1, downstream to Rulo, NE, at RM 498.0. Rulo, NE, corresponds with the Omaha District boundary with Kansas City District. A UNET period of record analysis was employed to develop stage-flow relationships at all cross sections.

The UNET model developed for this study employed the top of levee elevation for all levee connections. The model also assumes a levee breach occurs when the computed river elevation exceeds the levee top elevation. Levee modeling assumptions were coordinated during task force meetings with Corps of Engineers, FEMA, and state representatives. A description of the discussion and conclusions is presented within appendix A. Previous Missouri River studies within the Omaha District conducted to develop regulatory products such as the stage-frequency elevation and 100-year floodway (USACE, 1978) used different assumptions including levee overtopping without any levee breach. Therefore, modeling for regulatory purposes to establish floodway locations may require additional evaluation of levee performance.

An estimate of the minimum level of protection provided by each individual federal levee unit was not performed as part of this study. Levee level of protection and the associated levee capacity are dependent upon a risk and uncertainty analysis that includes estimating the uncertainty for many parameters. A complete risk and uncertainty analysis should follow the guidance provided within Appendix A and the current Corps of Engineers guidance provided within EM 1110-2-1619, Risk Based Analysis for Flood Damage Reduction Studies (USACE, 1996). The risk analysis evaluates the computed stage-frequency relationship and levee elevation at each location with appropriate uncertainty estimates for hydrologic, hydraulic, and geotechnical parameters to determine the levee reliability. This analysis is typically performed during a floodplain delineation study or during a flood damage reduction study.

Products of this study that may be used to assist in development of revised NFIP parameters include the computed flow-frequency and stage-frequency values along the Missouri River from Gavins Point Dam to Rulo, NE. However, substantial effort is required to translate these products into the necessary parameters required by FEMA to administer the NFIP along the Missouri River.

Software was employed to determine stage-frequency relationship at all cross sections using hydrologic data, regulated-unregulated relationships, and UNET results. Profile smoothing and adjustment to the profile through backwater areas was also required. A sensitivity analysis was performed to evaluate the impact of model parameters on computed results. Final profiles for the study reach were developed that include a comparison to the previous study results. Significant results include the following:

- Final profiles for the 10-, 50-, 100- and 500-year events were determined from Gavins Point Dam (RM 811.1) to Rulo, NE (RM 498).

- Significant changes to the flow-frequency relationship have occurred since the previous flood hazard study (USACE, 1978). The most notable changes are the 500-year event downstream of the Platte River and all events upstream of Sioux City.
- Significant changes to stage-frequency have occurred since the previous flood hazard study (USACE, 1978). The 100-year profile has increased significantly downstream of the Platte River. The federal levees in this area do not provide 100-year protection.
- Profiles in the vicinity of the Omaha and Council Bluffs urban levees have not changed significantly from previous studies. Increases in the stage-discharge relationship within this reach have been offset by decreases in the flow-frequency relationship.
- Calibration accuracy was limited by the dynamic stage-flow relationship on the Missouri River. Degradation within the upper end of the model and aggradation in the lower end has significantly impacted the stage-flow relationship.
- The UNET period of record (POR) analysis employed a single calibrated model to best-fit current conditions. Missouri River stage-discharge relationship has seasonal and annual fluctuations. Model calibration error is known to occur for each individual event. Final calibration represents the model determined to be best suited for the POR analysis.
- The POR analysis employed a model calibrated to summer stages. The impact of seasonal stage-flow was minimized in order to reduce model variability and prevent computation of lower stages for spring or fall events in the POR analysis.
- Stage-frequency results are based on the calibrated model for current conditions. Model calibration does not reflect any future stage trends.
- Ice impacts on peak stages were not included in the analysis and are not reflected in the stage-frequency results.
- All model calibration and the POR analysis was performed with daily flow data. While calibration accuracy may be reduced, the computed results, which rely on the developed stage-flow relationships, are still valid.
- The POR analysis used the Null Internal Boundary Condition to determine ungaged inflow. The impact of ungaged inflows on final model results was evaluated and determined to be minimal. The POR analysis was focused on the peak stage and flow relationship. Using model results for performing volumetric computations or evaluations that are volume sensitive is not recommended.
- A sensitivity analysis was performed to evaluate the impact of model parameters such as model calibration method, ungaged inflow, levee overtopping and conveyance, the period of record length, and flow factoring. Results indicated that the model performed adequately.
- A risk and uncertainty analysis to estimate of the minimum level of protection provided by each individual federal levee unit was not performed as part of this study. This analysis is typically performed during a floodplain delineation study or during a flood damage reduction study.
- Prior to revising the current National Flood Insurance Program regulatory parameters with presented results, an additional study to develop regulatory parameters essential for the NFIP is required.

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Upper Mississippi River System
Flow Frequency Study

Appendix F-A
Tables of Study Results and Data

Table A-1. Peak Annual Unregulated Flows at Omaha District Gages

Year	Yankton	Sioux City	Decatur	Omaha	Nebraska City
1898	173600	175000	175300	168400	206400
1899	252600	254000	252700	241700	273000
1900	132100	131400	127900	122000	177600
1901	143000	150600	149400	144200	182100
1902	131800	132700	131900	124800	166800
1903	151000	152700	151000	152900	223300
1904	189900	180400	178700	184700	184000
1905	251500	239000	227200	175300	244500
1906	181300	184300	188400	200800	195700
1907	184300	184300	184800	194900	231300
1908	173000	188000	195400	232000	260200
1909	166900	174500	181500	217200	236000
1910	202100	204600	202200	231900	207000
1911	144600	141500	143500	158400	175300
1912	194000	194500	196300	204100	225900
1913	209600	200700	199200	208000	205600
1914	155400	158900	155100	140900	239000
1915	189700	181100	176900	178200	210200
1916	188000	186900	186200	176600	212300
1917	199700	201400	196700	206800	223600
1918	180600	183300	184200	188500	211400
1919	151600	141800	138500	151900	150500
1920	206800	201100	204100	233500	270300
1921	188700	180200	185100	215500	296600
1922	166600	163500	165400	180500	216200
1923	166400	157200	161500	190000	230700
1924	127600	134800	135000	151400	213200
1925	180100	173900	179900	205800	218000
1926	118900	114700	114600	122300	156700
1927	211300	209200	207400	233900	250300
1928	154700	153900	157200	170400	192200
1929	194000	191100	196600	219000	252100
1930	87700	88800	88000	87300	127000
1931	81200	83000	83500	85900	130800
1932	151400	151400	153000	157900	182800
1933	134200	132700	132500	129900	144900
1934	74100	79200	79700	91000	134100
1935	162500	160800	148500	133400	164300
1936	102900	102100	100900	101000	122200
1937	130700	130000	131300	133100	144900
1938	174400	171900	170300	164800	216600
1939	171500	170000	165500	146400	159800
1940	85700	91100	89300	93700	153100
1941	167700	151400	148700	138200	146500
1942	151300	153200	149700	154400	223500
1943	291400	221600	214800	218400	237200
1944	196700	208100	202400	188700	296400
1945	120100	133200	130900	128500	172100
1946	126300	126700	126700	122400	160600
1947	187600	195000	189700	186800	247700
1948	169700	173400	174700	173500	224700
1949	183200	192000	192000	201600	207600

Year	Yankton	Sioux City	Decatur	Omaha	Nebraska City
1950	260300	247700	244700	226500	220600
1951	130200	161000	158300	163500	225200
1952	497300	479400	464300	469200	487800
1953	272700	262500	263200	271600	283800
1954	95900	105100	108800	138600	185300
1955	105400	106900	107800	115500	137100
1956	161800	159700	160800	161500	180700
1957	150500	160800	163100	169500	273900
1958	152400	148800	150300	153000	179000
1959	138100	135900	136500	140100	200300
1960	219200	256300	259700	273800	328900
1961	111900	112000	113100	114800	140500
1962	176800	185400	186100	188900	224100
1963	175100	173900	174400	176200	274300
1964	237700	231900	233900	234500	272300
1965	173400	178600	178600	181300	273400
1966	132600	134600	135000	135900	147200
1967	238700	242300	245700	255700	323000
1968	160600	158100	159300	161600	244500
1969	157400	196400	201900	225700	236500
1970	169900	169200	170200	172300	205900
1971	166400	166500	168100	172200	216800
1972	245200	244500	245600	247300	253700
1973	115200	114300	115500	118200	169800
1974	190000	188000	189500	191400	211600
1975	216200	213900	216100	219500	231600
1976	144700	145400	146700	149200	183400
1977	91000	91300	92200	95100	118200
1978	271400	281100	283200	287400	316100
1979	179000	180400	182700	188000	225200
1980	114100	114800	115900	119000	177100
1981	170300	172000	174000	182800	210800
1982	175300	175100	178400	193000	242000
1983	125500	151500	157100	188200	280500
1984	130700	220100	221900	235300	315400
1985	92700	98700	99500	105400	134200
1986	169800	187200	193500	227000	250100
1987	207500	219600	219300	232300	276800
1988	89600	89200	90500	92600	119700
1989	104300	104400	106800	109600	150600
1990	101600	103900	106600	123300	253600
1991	164800	164000	165300	205800	248700
1992	89100	95900	99800	111700	132100
1993	117100	170500	176200	216000	327000
1994	144200	152900	154800	156800	171800
1995	193900	198500	200300	209700	274600
1996	177700	185800	188900	230900	307000
1997	245300	290300	289800	293800	299600

Table A-2. Peak Jan-April Unregulated Flows at Omaha District Gages

Year	Yankton	Sioux City	Decatur	Omaha	Nebraska City
1898	134900	129900	125500	123500	114200
1899	252600	254000	252700	241700	273000
1900	118300	123600	110500	106500	120800
1901	97700	95500	90300	80700	107800
1902	104900	107200	100500	97300	106500
1903	109000	112200	109600	110500	135700
1904	189900	180400	178700	184700	168600
1905	75300	73200	72000	68900	87300
1906	128000	126900	116500	124700	122000
1907	147500	145100	137400	135100	109800
1908	80600	84400	83500	97000	94600
1909	112200	105600	105900	151200	147800
1910	202100	204600	202200	231900	207000
1911	90400	86900	91000	111600	106000
1912	194000	194500	196300	204100	225900
1913	209600	200700	199200	208000	205600
1914	116700	113600	97400	65700	111500
1915	182200	168300	169200	167300	204900
1916	159200	147900	144800	139500	141100
1917	199700	201400	196700	206800	211100
1918	165400	165100	163400	180000	162300
1919	151600	141800	138500	151900	142400
1920	192800	179800	178400	207600	192500
1921	68400	72000	73400	77600	107200
1922	120700	120200	118400	133600	150300
1923	99900	101600	105500	122000	122100
1924	124200	126600	130700	151100	180500
1925	151500	135300	137200	153600	160900
1926	97300	86500	85700	101800	113400
1927	97800	97300	91200	99000	171000
1928	141300	127700	122400	137800	144900
1929	194000	181400	175700	169700	183000
1930	76600	85300	85100	87300	92100
1931	44100	39600	38500	39100	53600
1932	83200	84100	79700	69000	85800
1933	90100	90000	89000	78500	91300
1934	72500	71700	71000	89300	82000
1935	46000	45900	45200	44900	50100
1936	90900	93300	89600	87800	114300
1937	58600	63300	62900	73000	86500
1938	142500	145200	140300	118900	119200
1939	171500	170000	165500	146400	159800
1940	39800	40500	40000	41400	48600
1941	55700	58300	58500	60200	70100
1942	71200	83500	83100	86100	86900
1943	291400	221600	214800	218400	214000
1944	196700	196400	190800	163600	186500
1945	103700	118200	118200	113800	121900
1946	62000	67100	65100	65100	81400
1947	183100	182500	176000	165300	178100
1948	105500	114800	113700	111100	129500
1949	183200	192000	192000	201600	207600

Year	Yankton	Sioux City	Decatur	Omaha	Nebraska City
1950	260300	247700	244700	226500	220600
1951	130200	161000	158300	163500	169600
1952	497300	479400	464300	469200	487800
1953	71300	79200	79900	80000	89900
1954	78900	77400	78000	82500	96400
1955	64200	62200	62800	65000	81400
1956	67100	62700	63400	64200	70300
1957	37400	38200	38300	38200	48900
1958	88200	89100	89300	88900	107400
1959	138100	135900	136500	135300	148300
1960	219200	256300	259700	273800	328900
1961	30100	34400	36900	49900	59500
1962	76900	133500	137000	157400	224100
1963	60700	59700	60800	66200	82000
1964	50000	45400	44100	37500	55100
1965	118700	118800	119900	123500	130100
1966	132600	134600	135000	135900	147200
1967	66100	68700	69300	69500	76800
1968	59800	60200	60400	59800	65600
1969	157400	196400	201900	225700	236500
1970	62200	65400	66300	68500	80000
1971	115700	119000	120000	125500	140900
1972	245200	244500	245600	247300	253700
1973	53800	73200	74600	81100	103800
1974	50900	50700	51300	53700	67600
1975	87900	85000	87600	100800	118800
1976	74300	76000	76800	78300	87000
1977	48300	48300	48700	49500	66500
1978	271400	281100	283200	287400	316100
1979	171000	163200	162300	168200	184900
1980	45800	48100	48800	50700	65600
1981	38400	38500	38500	39900	45000
1982	124400	124200	124200	126000	131100
1983	56400	73500	78700	110400	127900
1984	55200	88700	91800	108700	149000
1985	52700	65000	66400	77700	109700
1986	169400	187200	193500	227000	250100
1987	207500	219600	219300	232300	276800
1988	39700	39700	38800	42400	53500
1989	68000	69400	69900	72400	80500
1990	38300	37600	38300	40800	46400
1991	27900	27900	28100	36700	41500
1992	29100	32600	33200	40800	50800
1993	65900	89500	97300	114900	156900
1994	144200	152900	154800	156800	167400
1995	82600	112700	113100	123200	139700
1996	99600	105300	106900	111200	120500
1997	245300	290300	289800	293800	299600

Table A-3. Peak May-Dec Unregulated Flows at Omaha District Gages

Year	Yankton	Sioux City	Decatur	Omaha	Nebraska City
1898	173600	175000	175300	168400	206400
1899	164100	164100	164800	162300	210200
1900	132100	131400	127900	122000	177600
1901	143000	150600	149400	144200	182100
1902	131800	132700	131900	124800	166800
1903	151000	152700	151000	152900	223300
1904	149600	152200	152700	149100	184000
1905	251500	239000	227200	175300	244500
1906	181300	184300	188400	200800	195700
1907	184300	184300	184800	194900	231300
1908	173000	188000	195400	232000	260200
1909	166900	174500	181500	217200	236000
1910	119300	111700	113300	123400	134400
1911	144600	141500	143500	158400	175300
1912	184300	185800	182700	170900	185800
1913	152500	155400	152600	141300	178500
1914	155400	158900	155100	140900	239000
1915	189700	181100	176900	178200	210200
1916	188000	186900	186200	176600	212300
1917	164400	164600	165200	170600	223600
1918	180600	183300	184200	188500	211400
1919	100300	101700	104400	122700	150500
1920	206800	201100	204100	233500	270300
1921	188700	180200	185100	215500	296600
1922	166600	163500	165400	180500	216200
1923	166400	157200	161500	190000	230700
1924	127600	134800	135000	151400	213200
1925	180100	173900	179900	205800	218000
1926	118900	114700	114600	122300	156700
1927	211300	209200	207400	233900	250300
1928	154700	153900	157200	170400	192200
1929	188700	191100	196600	219000	252100
1930	87700	88800	88000	84700	127000
1931	81200	83000	83500	85900	130800
1932	151400	151400	153000	157900	182800
1933	134200	132700	132500	129900	144900
1934	74100	79200	79700	91000	134100
1935	162500	160800	148500	133400	164300
1936	102900	102100	100900	101000	122200
1937	130700	130000	131300	133100	144900
1938	174400	171900	170300	164800	216600
1939	102500	106500	102900	103800	131000
1940	85700	91100	89300	93700	153100
1941	167700	151400	148700	138200	146500
1942	151300	153200	149700	154400	223500
1943	184700	176200	179100	188400	237200
1944	182200	208100	202400	188700	296400
1945	120100	133200	130900	128500	172100
1946	126300	126700	126700	122400	160600
1947	187600	195000	189700	186800	247700
1948	169700	173400	174700	173500	224700
1949	113500	115100	115200	119300	151600

Year	Yankton	Sioux City	Decatur	Omaha	Nebraska City
1950	136800	132000	132400	134800	181700
1951	126300	132600	132300	147300	225200
1952	125000	133300	133800	140500	202000
1953	272700	262500	263200	271600	283800
1954	95900	105100	108800	138600	185300
1955	105400	106900	107800	115500	137100
1956	161800	159700	160800	161500	180700
1957	150500	160800	163100	169500	273900
1958	152400	148800	150300	153000	179000
1959	137100	135300	136500	140100	200300
1960	96500	99400	100100	104600	179000
1961	111900	112000	113100	114800	140500
1962	176800	185400	186100	188900	222300
1963	175100	173900	174400	176200	274300
1964	237700	231900	233900	234500	272300
1965	173400	178600	178600	181300	273400
1966	81300	79900	80400	81800	131600
1967	238700	242300	245700	255700	323000
1968	160600	158100	159300	161600	244500
1969	157000	157400	158500	162700	178200
1970	169900	169200	170200	172300	205900
1971	166400	166500	168100	172200	216800
1972	183400	184700	185700	186200	201800
1973	115200	114300	115500	118200	169800
1974	190000	188000	189500	191400	211600
1975	216200	213900	216100	219500	231600
1976	144700	145400	146700	149200	183400
1977	91000	91300	92200	95100	118200
1978	175000	176200	177700	177800	213500
1979	179000	180400	182700	188000	225200
1980	114100	114800	115900	119000	177100
1981	170300	172000	174000	182800	210800
1982	175300	175100	178400	193000	242000
1983	125500	151500	157100	188200	280500
1984	130700	220100	221900	235300	315400
1985	92700	98700	99500	105400	134200
1986	169800	178300	180800	190200	242800
1987	84500	87900	89200	94000	139300
1988	89600	89200	90500	92600	119700
1989	104300	104400	106800	109600	150600
1990	101600	103900	106600	123300	253600
1991	164800	164000	165300	205800	248700
1992	89100	95900	99800	111700	132100
1993	117100	170500	176200	216000	327000
1994	100500	111100	115600	132100	171800
1995	193900	198500	200300	209700	274600
1996	177700	185800	188900	230900	307000
1997	212100	216100	219300	230100	265400

Table A-4. Peak Annual Unregulated Mean Flow Volumes at Yankton

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	167600	167100	163500	158900	143700	113300	78000
1899	243800	242100	227000	175200	139400	121000	96100
1900	127500	120600	116400	113200	106900	87900	62900
1901	138000	130700	128800	124700	116200	94000	65200
1902	127200	126200	124300	119200	110700	94100	75200
1903	145800	140900	132900	130000	125200	103600	78400
1904	183300	162700	138600	125400	115700	96400	78300
1905	242800	218300	168000	137200	119400	87100	60600
1906	175000	171100	151000	135500	122900	96800	73400
1907	177900	161300	147900	140900	134300	112900	91800
1908	167000	166000	158400	150700	139500	109200	75000
1909	161100	155600	145300	140400	135200	102300	69800
1910	195100	172300	123400	93700	88100	71800	61400
1911	139600	135000	131900	128300	120300	89000	64600
1912	187300	182600	165100	133400	127000	98400	86100
1913	202300	195800	150800	136800	135700	109900	88200
1914	150000	146100	142600	132600	125400	105900	79400
1915	183100	162500	150600	129200	115700	102500	84700
1916	181500	173900	165700	159800	153800	116800	101000
1917	192800	186400	162300	151400	139700	116600	96300
1918	174300	172900	170300	163100	138800	101700	83300
1919	146300	116900	95600	89000	86500	70400	59600
1920	199600	178000	161200	145300	133600	111400	85600
1921	182100	175400	168600	151500	130100	95000	63700
1922	160800	156400	144400	139800	128200	98000	77100
1923	160600	142700	137500	127600	118800	104000	78500
1924	123200	117200	111500	96600	95200	83300	68000
1925	173800	161900	146900	131700	114200	93800	72400
1926	114800	106700	98500	94000	91700	80600	59300
1927	204000	173300	150500	147400	133500	104900	78200
1928	149300	145800	141700	130900	117200	97100	70400
1929	187300	179800	168700	143400	121300	84100	62500
1930	84700	81900	78900	72500	68300	57100	48700
1931	78400	76300	74300	71500	66400	47400	35200
1932	146100	141000	131000	116800	107800	78500	57200
1933	129500	127300	126400	120500	106200	77700	54400
1934	71500	66700	62600	60200	58900	49000	37800
1935	156900	128200	114200	102800	96200	66600	46200
1936	99300	92700	80000	73700	70700	57500	45400
1937	126200	124500	108600	96300	83700	65800	46500
1938	168300	160300	154300	143300	122500	80900	57400
1939	165500	164200	142800	101500	67700	61000	50800
1940	82700	79400	76100	73200	68500	53300	40000
1941	161900	153700	129800	104100	86500	61000	44800
1942	146000	140300	132700	123700	116800	95800	67300
1943	281300	261200	220000	164500	140300	98800	83600
1944	189900	187400	174800	156300	141300	94600	72300
1945	115900	113400	104500	91300	85600	68100	53500
1946	121900	117100	105700	97600	85800	63700	47200
1947	181100	179100	167900	144500	116800	91400	72400
1948	163800	160600	157000	148100	136400	95900	72000
1949	176800	174100	161500	124600	95300	72200	60100

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1950	251300	241000	216200	156400	126600	87000	74600
1951	125700	124700	118100	102000	94200	80300	66700
1952	480000	455100	378300	283800	194700	123800	87100
1953	263200	253900	234700	210600	166800	107100	76900
1954	92600	88700	85100	84600	76600	66500	48800
1955	101700	100000	95700	91400	84800	67700	51800
1956	156200	154100	148200	137800	122500	81600	59000
1957	145300	143500	138800	134700	122700	90900	60400
1958	147100	144800	140400	129900	119300	88500	66000
1959	133300	131500	127800	125000	110500	72700	57400
1960	211600	207100	187400	154800	104000	68400	55700
1961	108000	106200	103800	101100	89300	56000	38200
1962	170700	168000	161600	155700	148000	106800	73800
1963	169000	165900	157800	150200	142900	105900	74400
1964	229400	223300	205000	178800	159500	105400	66500
1965	167400	165200	163000	159500	150900	114600	79700
1966	128000	127100	115800	92100	74800	63400	54200
1967	230400	227300	213500	203600	191400	124200	83200
1968	155000	151900	147000	142100	127600	84900	60300
1969	151900	146500	138600	134600	109400	89700	78000
1970	164000	163800	160100	150700	147100	110400	74500
1971	160600	159700	158300	157300	149500	105600	83700
1972	236700	230300	210500	172100	138900	94700	81700
1973	111200	109600	106200	100700	97900	76600	55700
1974	183400	181800	176300	162200	141800	93100	62700
1975	208700	205600	197400	191800	171000	131000	90900
1976	139700	138600	133400	128000	121700	97100	68800
1977	87800	87300	85800	81000	69700	52100	41400
1978	262000	257600	243000	215300	163900	116500	101700
1979	172800	165500	144400	116700	108400	91000	74700
1980	110100	109400	107500	107000	99500	73800	51700
1981	164400	163300	158000	148500	125900	83300	53900
1982	169200	167000	163700	152400	138000	108800	81400
1983	121100	119200	115200	109400	102800	80800	59600
1984	126200	125000	120700	117800	115700	90800	65000
1985	89500	88500	84000	77100	70500	57500	47200
1986	163900	162000	156700	149600	127800	93600	78500
1987	200300	187500	150900	110100	87500	63900	53800
1988	86500	85400	84300	80000	72600	55500	40100
1989	100700	99700	96400	92100	82700	67800	53100
1990	98100	95100	94300	91500	89200	65700	47600
1991	159100	154600	150200	139900	137200	96600	61800
1992	86000	83900	80000	76900	69000	56900	40800
1993	113000	111800	110600	107100	102800	95000	69600
1994	139200	133300	119600	103400	82100	62900	55100
1995	187200	183300	174600	157900	139300	114600	82000
1996	171500	170800	168000	162800	145800	103900	82600
1997	236800	232300	221500	192800	173800	124000	107900

Table A-5. Peak Annual Unregulated Mean Flow Volumes at Sioux City

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	171100	171100	167600	162800	147700	117400	81500
1899	248300	245600	231700	179300	142700	126400	99600
1900	128400	122500	118200	114600	109200	90800	66700
1901	147200	142400	139400	133300	124000	99800	70000
1902	129700	128700	126000	120600	112200	96300	77700
1903	149300	145600	135600	134500	129000	108000	82800
1904	176300	163600	140700	129700	121700	100300	81600
1905	233600	214400	170300	140300	124100	90800	64100
1906	180200	177700	158000	145000	131700	103800	80000
1907	180200	167500	154900	147100	142400	120500	99600
1908	183800	182500	174500	164200	150900	115800	80700
1909	170600	166000	157300	150300	147900	110900	78100
1910	200000	182000	132200	103400	89400	74200	65300
1911	138300	134600	132400	128900	121400	90000	65500
1912	190100	187400	169400	137900	129300	101200	89400
1913	196200	190900	153500	139600	139400	113900	92700
1914	155300	152500	149400	138800	134000	110500	82900
1915	177000	164600	156500	134800	120800	108600	91200
1916	182700	179200	170700	165100	159200	122100	107200
1917	196900	186200	165100	154500	142900	119500	98900
1918	179200	177500	174700	166900	141700	104700	86500
1919	138600	116800	97600	93100	90100	72900	62100
1920	196600	186600	168500	151700	139300	118100	91900
1921	176100	173500	168200	152000	131500	97900	67100
1922	159800	154800	144800	140500	129000	99300	78400
1923	153700	146800	143100	136400	125500	109500	82900
1924	131800	121600	117200	113700	105400	89000	72800
1925	170000	162300	148600	133700	116800	95200	73300
1926	112100	107300	100200	95400	93400	81800	60300
1927	204500	179500	151000	148300	135200	108500	81900
1928	150400	148300	144400	133800	119700	99900	72700
1929	186800	184800	172800	149100	128300	88900	70200
1930	86800	83400	80100	73700	70300	59500	52800
1931	81100	79300	75700	73200	67400	47800	35400
1932	148000	142700	132900	118600	109000	79200	58300
1933	129700	127500	126500	120700	106600	78000	55100
1934	77400	72200	65700	61600	60200	49700	38200
1935	157200	128500	114900	103500	96700	67000	46500
1936	99800	93400	80500	74100	71900	58000	46800
1937	127100	125500	109600	97400	84700	66700	47900
1938	168000	162300	157000	147400	124800	82200	58900
1939	166200	157200	135000	101200	68800	62000	51900
1940	89100	83100	77600	74200	69200	54000	40900
1941	148000	142800	120800	100900	85700	61200	45400
1942	149800	143100	129300	126500	120000	98400	69800
1943	216600	202800	185300	155800	139800	101100	85100
1944	203400	186200	170900	160600	146100	103000	79000
1945	130200	123700	111300	97900	93300	72800	58200
1946	123900	121000	108100	98600	86400	64400	49000
1947	190600	187100	169900	142900	118300	93200	75500
1948	169500	168100	164300	152900	139300	99100	76500
1949	187700	184400	170800	134300	104000	76900	64200

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1950	242100	234000	204100	149300	127400	90300	77900
1951	157400	153000	140500	116000	104800	88700	75600
1952	468600	454000	393900	305300	214300	135500	94700
1953	256600	246800	229700	207200	166900	109200	80200
1954	102700	100200	97600	91400	85000	70300	51600
1955	104500	100200	95200	90900	84400	66700	51200
1956	156100	155100	149200	138700	123500	82200	59500
1957	157200	155500	149300	141800	128100	93400	61900
1958	145500	144400	140600	130100	119700	89000	66500
1959	132800	130800	127600	125200	110700	73600	58300
1960	250500	246500	232400	200200	133200	81100	63200
1961	109500	108000	105600	102900	91600	58000	40400
1962	181200	178100	171100	166100	158400	116200	84500
1963	170000	167200	157900	150600	143600	106600	75100
1964	226700	222400	206000	179200	159700	106000	67600
1965	174600	171700	167300	163100	154300	118400	83500
1966	131600	129900	118700	96300	78700	65200	56500
1967	236900	235400	220000	208600	195500	127200	85200
1968	154500	152600	147900	142000	127600	84900	60400
1969	192000	189200	180900	174400	135900	100700	85400
1970	165400	164300	161200	152200	148300	111800	76400
1971	162800	161600	159500	158700	151700	108100	86800
1972	239000	233300	214200	175100	142400	99700	86100
1973	111700	110300	107200	102600	100000	78900	59800
1974	183800	182300	177200	162800	143700	94500	63600
1975	209100	206500	199200	193800	173000	132600	92200
1976	142100	140600	135800	130000	123900	99200	71000
1977	89200	89000	88000	83300	71900	53900	43400
1978	274800	270300	255500	225800	175800	122700	107900
1979	176300	169400	150500	125400	117500	98300	81600
1980	112200	111700	110400	109400	102200	76700	54500
1981	168100	166600	161200	150800	128200	84900	55000
1982	171200	169600	166900	156400	141200	112300	84600
1983	148100	146500	142600	133800	120400	89700	69900
1984	215200	208900	196300	173400	152300	108200	81500
1985	96500	92900	87500	79800	72600	59500	51600
1986	183000	176500	171100	158400	134800	104900	89300
1987	214700	201700	166200	123900	99400	70300	58800
1988	87200	87000	85900	81900	75000	57400	42000
1989	102100	101500	98400	93500	84000	68800	54600
1990	101600	100500	99000	96400	92800	68800	49100
1991	160300	157200	153400	143200	140600	98800	63200
1992	93700	92300	88400	84300	74800	60700	44200
1993	166700	164300	158500	152200	139200	119400	89000
1994	149500	144800	132400	116100	93600	71900	64000
1995	194000	191500	183000	166500	147200	128700	94400
1996	181600	180400	177500	173900	157700	113300	89700
1997	283800	277000	262800	226400	180800	141100	122500

Table A-6. Peak Annual Unregulated Mean Flow Volumes at Decatur

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	170000	169400	165900	160400	145800	117000	82100
1899	245100	241800	227000	178500	142700	127000	100400
1900	124100	120300	117200	113400	107800	89900	66400
1901	144900	141200	138400	132900	123800	99500	69500
1902	127900	127200	124500	119700	111800	96400	77700
1903	146500	142700	133000	132300	127200	107800	83200
1904	173300	160700	141000	130100	122600	101600	81800
1905	220400	202700	164900	136600	121200	87200	61600
1906	182700	177400	159600	146700	133600	104300	81400
1907	179200	169600	157600	151100	146400	124800	102500
1908	189500	188200	181200	171200	157300	120500	84400
1909	176000	172200	163300	158200	155200	116300	82700
1910	196100	180900	139000	109500	91400	76500	68300
1911	139200	137200	134900	131600	123700	92500	67800
1912	190400	187400	170000	136600	128700	100500	89200
1913	193200	188400	152600	137700	137300	110800	90700
1914	150400	149400	146400	136000	132100	108200	80400
1915	171600	164900	157200	137200	122600	109400	91100
1916	180600	176400	169700	164100	157800	121100	106700
1917	190800	184000	167100	155000	144000	120800	100300
1918	178700	177800	175200	167600	143200	106100	87500
1919	134300	118400	102600	95600	92600	75700	64500
1920	198000	187700	171800	155600	143000	121700	95200
1921	179500	178000	171100	154800	134300	99800	68000
1922	160400	157600	147600	142800	131400	100700	80300
1923	156600	152000	148200	140200	129100	112000	85200
1924	130900	124800	120500	116800	107800	91200	74900
1925	174500	166800	152000	137000	120200	98000	75800
1926	111200	108200	101200	96200	94300	83300	61700
1927	201200	183100	157700	155100	141900	114900	86300
1928	152500	150800	147100	136900	123200	103100	75600
1929	190700	186500	174100	149900	129000	89200	70800
1930	85400	81400	79200	73500	70400	59600	53100
1931	81000	79300	76100	73400	67500	47800	35400
1932	148400	144400	134200	119300	109100	79400	58500
1933	128500	126900	125900	119900	106000	77700	55000
1934	77300	73000	66800	62000	60200	49800	38300
1935	144000	127000	114700	103300	96500	67100	46700
1936	97900	92800	80100	73900	71800	58000	47000
1937	127400	124000	110400	97700	84800	67100	48300
1938	165200	160800	156600	147100	124800	82300	59200
1939	160500	153700	133400	100700	69200	62100	52000
1940	86600	82500	77300	74200	69400	54300	41200
1941	144200	139400	120600	101100	86000	61300	45600
1942	145200	139800	130600	127300	121000	99300	70400
1943	208300	198600	180600	155400	140800	101800	85500
1944	196300	183600	169900	161100	147700	103800	79500
1945	127000	123100	111200	98200	93700	73800	59100
1946	122900	119800	107300	98200	86200	64400	49000
1947	184000	181700	169500	144000	119800	94100	76100
1948	169400	167600	164200	153000	139400	99200	76700
1949	186200	181800	167800	136100	105600	77600	64700

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1950	237300	226200	198200	149500	127100	90800	78300
1951	153500	150800	140800	117900	106200	89800	77100
1952	450300	439800	389000	304500	214700	135800	95100
1953	255300	245600	230600	208100	167700	109900	80700
1954	105500	104400	101200	93500	86600	71000	52200
1955	104600	101200	95900	91500	84800	67000	51500
1956	156000	154800	149000	138800	123600	82300	59700
1957	158200	156200	150300	142500	128900	93800	62100
1958	145800	144600	140800	130200	119700	89000	66700
1959	132400	131100	128100	125500	111100	74100	58600
1960	251900	248000	234800	203200	135000	82300	63900
1961	109700	108200	105900	103300	91900	58300	40700
1962	180500	178500	171400	166600	159100	117200	85700
1963	169200	166700	158000	150800	143900	107000	75500
1964	226900	222500	206000	179300	159800	106200	67800
1965	173200	171400	167400	163200	154400	118800	84300
1966	130900	129600	118400	96500	78900	65400	56700
1967	238300	235700	221100	209200	196100	128000	85700
1968	154500	152700	147900	142000	127800	85100	60500
1969	195800	192500	184300	177800	138400	102000	86400
1970	165100	164500	161100	152200	148300	111900	76600
1971	163000	162000	160000	159200	152100	108600	87400
1972	238200	232700	214100	175500	142700	100100	86500
1973	112000	110600	107400	103000	100500	79300	60400
1974	183800	182300	177200	163000	144000	94900	64000
1975	209600	206900	199500	194000	173400	133400	93000
1976	142300	140800	136000	130200	124100	99400	71200
1977	89400	89200	88100	83400	72200	54200	43600
1978	274700	270500	255700	226400	176300	123100	108500
1979	177200	170500	150900	127200	118600	99400	82600
1980	112400	112100	110600	109600	102500	77100	54900
1981	168800	167600	162000	151600	129000	85500	55500
1982	173000	171700	168500	158200	142600	113500	85600
1983	152400	151200	146800	137800	123800	91700	72300
1984	215200	210600	199900	178100	155900	110800	83700
1985	96500	93900	88200	80500	73400	60700	52600
1986	187700	180800	174300	159900	136400	106900	90900
1987	212700	201000	168200	125900	101400	71700	60000
1988	87800	87600	86500	82800	76000	58100	42600
1989	103600	102000	99200	94100	85000	69500	55100
1990	103400	100800	99300	96600	93100	69300	49500
1991	160300	157000	153600	144000	141200	99400	63700
1992	96800	95300	91600	86600	76800	62100	45400
1993	170900	167000	162000	156200	142000	121400	90900
1994	150100	145100	133000	117000	94900	73100	65300
1995	194300	191800	183800	167700	148300	129600	95300
1996	183200	182400	179300	176300	160500	114900	91000
1997	281100	276000	262500	227300	182100	142900	124100

Table A-7. Peak Annual Unregulated Mean Flow Volumes at Omaha

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	162100	160300	155600	146200	135900	114100	84800
1899	232600	229700	212600	172000	141800	129300	104900
1900	117400	114800	111600	106700	100400	84900	64300
1901	138800	137400	134100	130300	123500	97300	66400
1902	120100	119100	115800	113600	108800	96700	77100
1903	147200	138100	128100	119200	116600	105800	84900
1904	177800	168500	151100	132100	127200	107800	81800
1905	168700	157700	136900	115600	104100	68500	48600
1906	193300	185200	171200	154600	143100	107100	88600
1907	187600	185200	183500	176300	169600	146900	116900
1908	223300	222400	218900	209100	190400	145100	103100
1909	209000	206400	203000	201500	194100	144400	109000
1910	223200	212600	177500	142300	120000	89400	84200
1911	152500	150600	148200	144700	135200	105100	79900
1912	196400	195100	182400	147700	124700	97800	87400
1913	200200	189000	159400	127700	125700	98600	78900
1914	135600	132700	130600	123000	121800	95000	66900
1915	171500	169600	166400	150600	131700	112800	91500
1916	170000	168100	163000	157500	149100	114900	102900
1917	199000	197200	187800	157900	149000	127600	106800
1918	181400	179500	177100	170700	151000	112400	92600
1919	146200	140200	128300	117500	105000	90300	77000
1920	224700	208800	191700	175700	161600	140300	112500
1921	207400	200600	189600	170600	149000	109600	72000
1922	173700	170800	162600	156300	143100	107400	89500
1923	182900	179800	174300	162300	147900	125100	96800
1924	145700	144800	140900	134700	122600	102200	86000
1925	198100	190100	173800	154700	139000	112400	88700
1926	117700	115500	106400	100000	98700	90600	69700
1927	225100	211700	194000	190700	176700	148500	108700
1928	164000	163600	161300	153300	141000	119700	90900
1929	210800	202100	181500	155000	131900	90300	73200
1930	84000	80300	75600	72500	70800	60000	54100
1931	82700	80400	77600	74100	67700	47900	35600
1932	152000	151500	140000	122600	108700	79700	59600
1933	125000	124300	122300	115200	102200	75600	54200
1934	87600	82600	72200	64500	60500	50300	38300
1935	128400	118600	114000	101600	95100	67600	47000
1936	97200	90800	77800	72300	70500	57600	47700
1937	128100	124500	114300	98800	84800	69400	50000
1938	158600	156700	152700	144200	123700	82500	60500
1939	140900	139800	126100	97400	70400	62700	52300
1940	90200	80900	76700	74300	71100	55700	42200
1941	133000	130700	120500	102600	87100	61700	46300
1942	148600	145800	138300	132900	125600	103600	73300
1943	210200	204100	179300	160600	146100	104600	87100
1944	181600	174900	168400	163300	155900	107400	81700
1945	123700	119900	110800	98800	96100	79100	63800
1946	117800	114600	104000	95900	84500	63600	48700
1947	179800	178400	170000	149500	126900	98400	78900
1948	167000	165200	162300	152500	139800	99400	77400
1949	194000	186800	175200	144700	113200	80600	67100

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1950	218000	210600	189500	149500	124300	92600	79700
1951	157400	156000	150400	127300	112900	95500	84800
1952	451600	430700	382100	301600	215300	136700	96700
1953	261400	250800	234800	212100	171700	113200	83100
1954	133400	129800	121400	105700	94800	74600	54700
1955	111200	105900	99300	94500	86800	67900	52900
1956	155400	154400	149200	139100	123700	82400	60000
1957	163100	161400	156100	147100	133400	95400	63000
1958	147300	145900	141800	130700	119800	89100	67200
1959	134800	133600	130600	127300	112600	76600	60100
1960	263500	259100	249500	220900	144700	88500	67300
1961	110500	110200	107500	104700	93300	59200	42700
1962	181800	180100	173400	169200	163400	122200	91600
1963	169600	167300	159000	151800	144700	108900	77400
1964	225700	221600	206100	179800	160400	107200	68800
1965	174500	171900	168100	163700	155000	120300	88200
1966	130800	129300	118900	97300	79900	65800	57400
1967	246100	242300	227300	213500	199500	131900	88000
1968	155500	153000	148300	142300	128400	85400	60800
1969	217200	212500	203400	196300	151200	108400	91500
1970	165800	164900	161000	152200	148400	112200	77200
1971	165700	164500	162100	161200	154100	110500	90500
1972	238000	232900	214800	176800	143900	101800	88200
1973	113800	111900	108600	105100	102500	81100	63600
1974	184200	182500	177600	163500	145100	96800	65900
1975	211300	208700	200800	194900	175200	137400	97100
1976	143600	141900	137400	131100	124900	100300	72200
1977	91500	90600	89300	84400	73000	55100	44700
1978	276600	272800	258600	229300	179000	124900	111400
1979	180900	174300	154900	137400	124700	104800	88400
1980	114500	113900	112100	110400	103600	79000	56700
1981	175900	173600	167800	155700	133100	88200	57800
1982	185800	182400	178100	167400	150200	119700	90400
1983	181100	177200	169800	160400	141600	102400	84900
1984	226500	224600	219100	204100	176500	124100	95000
1985	101400	98200	91700	83800	77200	66800	57400
1986	218500	204800	189800	167900	145300	116800	99300
1987	223600	211700	178000	136300	111700	78700	66400
1988	89100	88800	87800	84200	77600	60100	45300
1989	105500	103800	100800	95900	86400	71100	57000
1990	118700	114200	110200	108500	101700	76200	53800
1991	198100	192300	175500	155600	151600	106200	69500
1992	107500	104700	99900	92700	83600	67900	51500
1993	207900	199400	192300	187400	169000	139700	106600
1994	150900	146500	134600	119400	101400	80000	71300
1995	201800	199400	191400	175300	155200	137800	102300
1996	222200	217500	202800	193600	174900	126000	98500
1997	282800	277900	265200	231700	189800	149300	129800

Table A-8. Peak Annual Unregulated Mean Flow Volumes at Nebraska City

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	198100	196900	190800	176000	162600	128600	96900
1899	262000	255400	229700	196600	181700	152500	123800
1900	170400	160900	153900	150400	142900	126400	98300
1901	174800	171400	169800	160300	149000	120200	94500
1902	160100	154700	152700	149900	140300	124700	102900
1903	214300	208100	186600	157400	145000	135300	111900
1904	176600	176600	171800	160400	150200	124100	101900
1905	234600	223300	196900	172500	154900	117600	90200
1906	187800	176800	162400	156900	143900	118100	99000
1907	222000	220800	214700	200000	186300	162700	122400
1908	249700	245800	240300	235100	213800	160300	117000
1909	226500	222500	209300	207400	200200	158900	121500
1910	198700	191500	157600	134500	117800	108700	100200
1911	168200	166700	164700	159800	147600	123700	98300
1912	216800	215500	198500	166500	153500	125100	119500
1913	197300	192700	165700	163200	159200	132400	110700
1914	229400	222000	206900	182000	169900	130300	100600
1915	201700	201000	195700	176400	160200	143100	117700
1916	203700	202700	196600	190700	174900	138900	120000
1917	214600	212400	211400	209500	199400	167100	134400
1918	202900	201800	199000	192000	168500	135700	112100
1919	144400	143500	139300	137200	131600	113100	97100
1920	259400	250400	234800	216900	195500	169200	135800
1921	284600	279600	265600	233200	198200	149300	111500
1922	207500	206300	194200	188300	173100	139700	117000
1923	221400	215900	207000	195700	182600	154600	120400
1924	204600	201600	194800	188900	175200	143000	122300
1925	209200	204100	190600	175700	163000	138900	114600
1926	150400	146700	141100	136900	136100	123000	99800
1927	240200	227800	223800	221500	204000	170400	133200
1928	184500	182200	177000	169700	163300	144900	118900
1929	241900	234800	215200	192400	167100	117500	95000
1930	121900	116200	114300	108800	102100	87900	74700
1931	125500	118600	109800	98100	91100	66700	51800
1932	175400	174300	162700	142900	133100	105500	79500
1933	139100	138500	136100	128000	121900	97400	71200
1934	128700	125900	107400	87500	78100	67400	52900
1935	157700	153600	149900	143100	127400	95300	66300
1936	117300	108100	100800	97600	91400	75600	64100
1937	139100	138500	133000	123700	107300	90200	65900
1938	207900	205000	195600	174900	148100	101900	75800
1939	153400	149700	137400	106700	90200	79400	66600
1940	146900	143200	129100	109400	99300	75600	57500
1941	140600	139500	130700	116000	102900	77900	59600
1942	214500	206600	189200	178800	159700	128200	90900
1943	227600	223400	212600	188900	179700	126700	102600
1944	284500	280200	244000	200900	188900	134300	103300
1945	165200	160100	146900	132300	125900	105600	83300
1946	154100	153300	139300	128200	109900	80100	61500
1947	237700	232800	220900	208900	178000	131400	101500
1948	215600	208300	195300	180300	159600	117200	93100
1949	199200	196700	184300	159000	134900	103700	91500

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1950	211700	202600	190900	156300	135200	112600	98300
1951	216100	195000	172000	155300	144200	122700	107500
1952	468100	433100	387900	312000	231000	161800	117600
1953	272400	266400	251400	228400	188800	128200	97500
1954	177800	174400	158900	133600	118900	90200	68500
1955	131600	125200	120100	117400	110600	84600	65600
1956	173400	170700	163100	155600	140000	95600	72300
1957	262900	250000	222700	199500	177200	122200	81700
1958	171800	169400	165300	151800	137700	114600	88100
1959	192200	188200	176700	161500	138500	102100	79400
1960	315600	314500	307900	275800	182900	120000	92600
1961	134800	133900	132600	130600	116500	79800	59300
1962	215100	210700	203100	191500	188300	151600	115800
1963	263200	250800	215300	194800	174000	127800	93400
1964	261300	254300	237800	210300	190000	130400	87500
1965	262400	246400	225400	205700	184600	148400	109600
1966	141300	139200	130100	110100	91400	83200	72800
1967	310000	292700	277800	266200	247100	163600	107800
1968	234600	229100	214100	188400	158100	104100	75200
1969	227000	222300	218600	213700	167900	126300	110500
1970	197600	195600	189700	185600	177200	135100	95900
1971	208100	206500	202400	198200	187000	139600	114600
1972	243500	238900	221900	185600	158100	121500	104100
1973	163000	157900	150100	148100	137900	111700	89100
1974	203100	202200	198900	185300	162500	115700	82300
1975	222300	219900	211000	207800	196200	156500	112900
1976	176000	173700	165800	153500	145800	120500	87700
1977	113400	112900	110600	103900	93100	75200	61700
1978	303400	301200	283000	252900	204400	148300	134600
1979	216100	204400	179100	151100	139800	122100	108300
1980	170000	168000	161900	149500	135100	106400	78800
1981	202300	198600	189600	174800	152500	107800	73100
1982	232200	228900	216500	207600	179100	151600	111600
1983	269200	264100	249500	225200	204000	142800	116600
1984	302700	298200	290600	273300	241100	173600	132700
1985	128800	126700	118800	108100	98600	89200	76300
1986	240000	230500	214200	206300	184900	145200	122300
1987	265600	252000	218000	183200	148300	106900	90200
1988	114900	114400	110800	103000	98600	79600	61600
1989	144500	143800	141200	128900	112500	87500	71100
1990	243400	228200	186900	153600	127600	96900	70000
1991	238700	228100	209900	191700	177100	130300	87300
1992	126800	124600	117100	107800	100900	85300	66500
1993	313800	306200	271200	250800	227300	178100	137000
1994	164900	161300	147700	130700	120100	99900	89500
1995	263500	260600	249600	224500	198400	174300	129200
1996	294600	282500	254500	228200	202500	156500	118600
1997	287500	284400	271900	245700	219600	165800	146200

Table A-9. Peak Jan-Apr Unregulated Mean Flow Volumes at Yankton

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	130200	105800	81400	71900	58900	63800	69000
1899	243800	242100	227000	175200	127900	93600	84700
1900	114200	98900	71400	56700	52700	62700	57800
1901	94300	69400	50300	39800	32800	51300	53700
1902	101300	90300	76400	66400	62400	66200	61700
1903	105200	96000	71100	53700	47700	55300	61300
1904	183300	162700	138600	110200	87800	80000	69800
1905	72700	58900	47300	39300	33900	36900	50700
1906	123600	100500	79900	76300	57100	57200	56700
1907	142400	115100	97100	87900	85400	81100	81400
1908	77800	69200	61000	50000	45100	58000	66000
1909	108300	68000	58000	48100	46700	48000	60500
1910	195100	172300	123400	93700	76200	63800	57300
1911	87300	77500	63700	47100	37800	44200	53600
1912	187300	182600	165100	124000	103200	79000	73500
1913	202300	195800	150800	107700	81300	74600	73800
1914	112600	96500	72500	60100	55400	71800	69100
1915	175900	148200	142000	103200	77200	72400	69900
1916	153700	137500	128200	122500	110500	92000	93500
1917	192800	186400	162300	129100	107500	97300	86700
1918	159700	150100	135200	108900	85500	70300	75400
1919	146300	116900	95600	86300	64300	61600	58000
1920	186100	168700	136600	103900	81200	79400	75300
1921	66000	63200	49000	37700	30900	47800	56500
1922	116500	106800	98000	85300	68800	70200	66800
1923	96400	91900	78000	59500	52200	58700	60700
1924	119900	117200	111500	93200	71100	66300	59900
1925	146200	115100	91500	70200	58400	69400	66800
1926	93900	61400	46700	37000	39200	51700	51800
1927	94400	83900	73800	73400	72800	70800	70600
1928	136400	109400	102200	80800	57500	66200	68200
1929	187300	116800	83300	67100	54800	59400	54600
1930	73900	68500	55200	46100	43500	46700	43900
1931	42600	35300	30700	24300	20900	25000	30800
1932	80300	75500	62600	46700	35800	45800	48800
1933	87000	80100	63800	57400	40400	45400	48000
1934	70000	46200	34900	27200	27700	36400	33900
1935	44400	40900	35000	30300	27100	28900	38400
1936	87700	77000	63500	47800	39700	44700	40300
1937	56600	50400	41900	34300	28300	33100	38900
1938	137500	123900	93400	63700	41200	37000	48500
1939	165500	164200	142800	101500	67400	51500	43700
1940	38400	36000	32000	32200	30500	34800	34200
1941	53800	48900	41300	33700	27100	34700	36900
1942	68700	62700	53500	56300	62200	64200	59600
1943	281300	261200	220000	164500	114400	76400	75800
1944	189900	187400	174800	136100	87500	60200	64800
1945	100100	97900	93900	86500	64900	42400	47900
1946	59800	52300	41200	37900	34100	37300	42600
1947	176700	161100	128200	112100	86400	70000	65800
1948	101800	88500	77500	70700	61200	60600	64000

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1949	176800	174100	161500	124600	95300	66900	55500
1950	251300	241000	216200	156400	126600	76800	65400
1951	125700	124700	118100	102000	75500	61400	55300
1952	480000	455100	378300	283800	194700	112800	82400
1953	68800	68500	61900	54700	47400	47900	65700
1954	76200	71300	58800	46400	36600	40000	42900
1955	62000	60100	53600	48400	42800	41200	43800
1956	64800	61400	53800	51200	48500	47900	52500
1957	36100	34600	32800	32000	30800	44100	52900
1958	85100	83300	75700	68000	60500	67300	63900
1959	133300	130100	119900	100100	69900	47500	51000
1960	211600	207100	187400	154800	104000	61100	51400
1961	29100	28300	27200	24400	21800	24300	34300
1962	74200	72400	66300	62600	53900	57200	65000
1963	58600	57700	55500	51000	49400	61600	71800
1964	48300	44700	38500	37300	35600	40400	58900
1965	114600	112100	107200	90000	71400	62500	70300
1966	128000	127100	115800	92100	74800	56800	49700
1967	63800	61500	58300	56000	50600	54300	74500
1968	57700	57300	54900	49200	41200	39500	53700
1969	151900	146500	138600	134600	108700	80700	68600
1970	60000	58700	56600	56600	50500	60300	67300
1971	111700	108600	100900	88500	80100	70900	78100
1972	236700	230300	210500	172100	116000	80200	75300
1973	51900	51700	49700	46700	41200	49700	52200
1974	49100	47500	44700	41800	37700	40800	58700
1975	84800	85400	85300	85300	78100	73400	77800
1976	71700	71000	68700	62000	48600	56500	63400
1977	46600	45500	43600	39200	34100	37800	38500
1978	262000	257600	243000	215300	163900	108400	90200
1979	165100	162500	144200	116700	108400	80900	67900
1980	44200	43100	41600	36400	33400	40300	45900
1981	37100	33600	29800	27200	24900	32500	46900
1982	120100	111900	94200	73900	69000	64900	71100
1983	54400	52600	49900	46000	44500	40500	51600
1984	53300	51000	50000	45100	39700	49700	58600
1985	50900	49900	47400	47200	43000	44200	42700
1986	163500	160200	154800	135700	97700	77200	73600
1987	200300	187500	150900	110100	87500	61200	49900
1988	38300	36200	31900	29000	27700	35300	37700
1989	65600	64100	63600	55600	50600	48700	46300
1990	37000	36000	34200	31300	26500	33800	41400
1991	26900	26700	25300	23100	24300	42900	54800
1992	28100	27700	26100	23700	21600	29700	34700
1993	63600	59200	53900	52800	50700	52000	55200
1994	139200	133300	119600	103400	79900	61700	52600
1995	79700	75300	69100	59800	51500	67300	72000
1996	96100	91900	87500	80800	67500	68200	77900
1997	236800	232300	221500	182600	134400	103300	101300

Table A-10. Peak May-Dec Unregulated Mean Flow Volumes at Yankton

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	167600	167100	163500	158900	143700	113300	78000
1899	158400	156200	154600	151100	139400	121000	96100
1900	127500	120600	116400	113200	106900	87900	62900
1901	138000	130700	128800	124700	116200	94000	65200
1902	127200	126200	124300	119200	110700	94100	75200
1903	145800	140900	132900	130000	125200	103600	78400
1904	144400	143400	136700	125400	115700	96400	78300
1905	242800	218300	168000	137200	119400	87100	60600
1906	175000	171100	151000	135500	122900	96800	73400
1907	177900	161300	147900	140900	134300	112900	91800
1908	167000	166000	158400	150700	139500	109200	75000
1909	161100	155600	145300	140400	135200	102300	69800
1910	115200	100500	95300	93400	88100	71800	61400
1911	139600	135000	131900	128300	120300	89000	64600
1912	177900	173200	151900	133400	127000	98400	86100
1913	147200	144000	138600	136800	135700	109900	88200
1914	150000	146100	142600	132600	125400	105900	79400
1915	183100	162500	150600	129200	115700	102500	84700
1916	181500	173900	165700	159800	153800	116800	101000
1917	158700	156300	154200	151400	139700	116600	96300
1918	174300	172900	170300	163100	138800	101700	83300
1919	96800	93500	91600	89000	86500	70400	59600
1920	199600	178000	161200	145300	133600	111400	85600
1921	182100	175400	168600	151500	130100	95000	63700
1922	160800	156400	144400	139800	128200	98000	77100
1923	160600	142700	137500	127600	118800	104000	78500
1924	123200	106200	101100	96600	95200	83300	68000
1925	173800	161900	146900	131700	114200	93800	72400
1926	114800	106700	98500	94000	91700	80600	59300
1927	204000	173300	150500	147400	133500	104900	78200
1928	149300	145800	141700	130900	117200	97100	70400
1929	182100	179800	168700	143400	121300	84100	62500
1930	84700	81900	78900	72500	68300	57100	48700
1931	78400	76300	74300	71500	66400	47400	35200
1932	146100	141000	131000	116800	107800	78500	57200
1933	129500	127300	126400	120500	106200	77700	54400
1934	71500	66700	62600	60200	58900	49000	37800
1935	156900	128200	114200	102800	96200	66600	46200
1936	99300	92700	80000	73700	70700	57500	45400
1937	126200	124500	108600	96300	83700	65800	46500
1938	168300	160300	154300	143300	122500	80900	57400
1939	98900	92300	78500	71800	67700	61000	50800
1940	82700	79400	76100	73200	68500	53300	40000
1941	161900	153700	129800	104100	86500	61000	44800
1942	146000	140300	132700	123700	116800	95800	67300
1943	178300	175800	172600	158500	140300	98800	83600
1944	175900	167200	160600	156300	141300	94600	72300
1945	115900	113400	104500	91300	85600	68100	53500
1946	121900	117100	105700	97600	85800	63700	47200
1947	181100	179100	167900	144500	116800	91400	72400
1948	163800	160600	157000	148100	136400	95900	72000

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1949	109600	106000	99300	91500	84400	72200	60100
1950	132000	125900	117700	111700	105700	87000	74600
1951	121900	114600	102700	95200	94200	80300	66700
1952	120700	118000	113700	105500	106900	123800	87100
1953	263200	253900	234700	210600	166800	107100	76900
1954	92600	88700	85100	84600	76600	66500	48800
1955	101700	100000	95700	91400	84800	67700	51800
1956	156200	154100	148200	137800	122500	81600	59000
1957	145300	143500	138800	134700	122700	90900	60400
1958	147100	144800	140400	129900	119300	88500	66000
1959	132300	131500	127800	125000	110500	72700	57400
1960	93100	91800	90700	88300	76600	68400	55700
1961	108000	106200	103800	101100	89300	56000	38200
1962	170700	168000	161600	155700	148000	106800	73800
1963	169000	165900	157800	150200	142900	105900	74400
1964	229400	223300	205000	178800	159500	105400	66500
1965	167400	165200	163000	159500	150900	114600	79700
1966	78500	76200	75100	73400	70000	63400	54200
1967	230400	227300	213500	203600	191400	124200	83200
1968	155000	151900	147000	142100	127600	84900	60300
1969	151500	146000	135300	123900	109400	89700	78000
1970	164000	163800	160100	150700	147100	110400	74500
1971	160600	159700	158300	157300	149500	105600	83700
1972	177000	175400	170800	160500	138900	94700	81700
1973	111200	109600	106200	100700	97900	76600	55700
1974	183400	181800	176300	162200	141800	93100	62700
1975	208700	205600	197400	191800	171000	131000	90900
1976	139700	138600	133400	128000	121700	97100	68800
1977	87800	87300	85800	81000	69700	52100	41400
1978	168900	164200	148200	139200	134900	116500	101700
1979	172800	165500	144400	115800	101200	91000	74700
1980	110100	109400	107500	107000	99500	73800	51700
1981	164400	163300	158000	148500	125900	83300	53900
1982	169200	167000	163700	152400	138000	108800	81400
1983	121100	119200	115200	109400	102800	80800	59600
1984	126200	125000	120700	117800	115700	90800	65000
1985	89500	88500	84000	77100	70500	57500	47200
1986	163900	162000	156700	149600	127800	93600	78500
1987	81600	80800	78600	75500	68700	63900	53800
1988	86500	85400	84300	80000	72600	55500	40100
1989	100700	99700	96400	92100	82700	67800	53100
1990	98100	95100	94300	91500	89200	65700	47600
1991	159100	154600	150200	139900	137200	96600	61800
1992	86000	83900	80000	76900	69000	56900	40800
1993	113000	111800	110600	107100	102800	95000	69600
1994	97000	95000	90000	83500	82100	62900	55100
1995	187200	183300	174600	157900	139300	114600	82000
1996	171500	170800	168000	162800	145800	103900	82600
1997	204700	203300	198800	192800	173800	124000	107900

Table A-11. Peak Jan-Apr Unregulated Mean Flow Volumes at Sioux City

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	127000	106000	85800	77200	64200	67800	72500
1899	248300	245600	231700	179300	133600	97500	87900
1900	120800	103000	80100	65100	54600	66100	62100
1901	93400	76200	56600	45300	38200	56400	59300
1902	104800	92100	77800	69400	65500	68400	63900
1903	109700	99300	73600	59300	52600	60700	66100
1904	176300	163600	139200	113000	90600	82400	72900
1905	71600	61900	50500	43200	37100	40300	54000
1906	124000	102500	83100	79800	62900	63300	63000
1907	141800	120800	105700	96500	92900	90000	88600
1908	82500	71600	65300	54600	51900	63600	71700
1909	103200	77200	68800	57400	55100	56300	69100
1910	200000	182000	132200	103400	85700	67600	61000
1911	84900	77700	65200	49400	39500	44800	54500
1912	190100	187400	169400	128700	107900	82100	76900
1913	196200	190900	153500	110600	85700	79600	78100
1914	111000	93600	74000	62700	58700	74700	72400
1915	164500	153500	148200	110100	85600	79400	76400
1916	144600	139800	131900	126800	116600	99400	99000
1917	196900	186200	165100	132700	112200	99700	89400
1918	161400	153400	137500	111900	88600	74700	78400
1919	138600	116800	97600	88300	66900	64100	60400
1920	175800	166500	138200	107500	87100	87500	81300
1921	70400	66000	53300	42400	35700	51500	60000
1922	117500	106900	99700	86400	70800	71500	67800
1923	99300	94300	81500	64100	56800	63000	65300
1924	123800	121600	116300	97800	74800	69800	64300
1925	132300	115100	91200	70300	58700	69900	67300
1926	84600	60300	48200	38500	39300	52600	52600
1927	95100	85600	77600	76600	79600	75800	74300
1928	124800	109300	104700	82800	59400	67600	70100
1929	177300	133600	96200	85200	71400	70100	63000
1930	83400	78200	69800	60900	52300	51100	47500
1931	38700	32900	29000	24100	21200	24500	31000
1932	82200	77500	64600	50200	38600	46400	50100
1933	88000	81800	65800	58800	41300	45000	48200
1934	70100	46300	35000	27300	27300	36600	34100
1935	44900	41400	35600	30900	27700	29000	38700
1936	91200	77700	67900	51000	45600	45800	41600
1937	61900	55800	47100	38900	31800	35000	40200
1938	141900	128400	98200	67400	43500	38600	50100
1939	166200	157200	135000	101200	68600	52300	44700
1940	39600	36200	32100	32200	30800	35900	35000
1941	57000	51400	42100	35000	28800	35200	38000
1942	81600	73700	58000	56100	63700	67400	61400
1943	216600	202800	185300	155800	112100	78000	76500
1944	192000	186200	170900	134500	91400	66000	70400
1945	115500	113900	105600	94700	72500	47400	52600
1946	65600	56100	48300	46400	41300	40300	44800
1947	178400	159600	132000	118000	92700	74400	68800
1948	112200	102900	91100	81700	71700	66300	68600

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1949	187700	184400	170800	134300	104000	72300	59400
1950	242100	234000	204100	149300	127400	80400	68500
1951	157400	153000	140500	116000	89400	70200	62700
1952	468600	454000	393900	305300	214300	123600	90600
1953	77400	76300	68700	63100	53500	52800	68300
1954	75700	71500	59600	47300	37700	42500	46000
1955	60800	59000	52500	47600	41600	40700	43800
1956	61300	59200	55000	51800	48900	47800	52800
1957	37300	36000	33400	31700	31400	44300	54200
1958	87100	84600	78000	69800	61900	67300	64500
1959	132800	129800	120000	100500	70600	48900	51800
1960	250500	246500	232400	200200	133200	73300	58200
1961	33600	32700	30300	27800	26400	26600	36500
1962	130500	126500	115800	107900	83800	71000	74800
1963	58400	57400	54800	51200	49900	61700	72200
1964	44400	41600	38400	38100	36700	41200	59500
1965	116100	114000	108800	92300	74200	67400	73800
1966	131600	129900	118700	96300	78700	59700	52400
1967	67200	65000	61300	58400	52000	55200	76500
1968	58800	58300	55800	49800	41800	39500	53800
1969	192000	189200	180900	174400	135900	92300	75900
1970	63900	63000	61100	60600	54500	63100	69900
1971	116300	113700	106300	93300	83400	73700	81400
1972	239000	233300	214200	175100	121200	85700	79500
1973	71600	70400	66000	59600	52800	53600	56500
1974	49600	48000	44800	41900	37700	41300	59700
1975	83100	83200	82900	84200	78200	73800	78300
1976	74300	73600	71800	65000	51200	58400	65600
1977	47200	46500	44700	40700	35900	39600	40200
1978	274800	270300	255500	225800	175800	115800	95300
1979	159500	157700	146800	125400	117500	89300	73700
1980	47000	46200	44900	39900	36600	43400	48800
1981	37600	34700	30600	27000	24800	31700	47500
1982	121400	115100	98100	77700	72300	68400	74100
1983	71800	70300	67200	63200	59800	51000	62200
1984	86700	84100	79700	78500	68400	67100	75500
1985	63500	62600	59000	57600	51900	51200	47200
1986	183000	176500	171100	150500	112200	94400	84000
1987	214700	201700	166200	123900	99400	68000	54700
1988	38800	37300	33600	30500	29600	36400	39500
1989	67800	66700	66100	58300	53400	50200	47800
1990	36800	35900	33400	30500	26500	34400	42700
1991	27300	27000	25500	22900	24400	42800	56000
1992	31900	30300	28600	26100	24900	30700	37200
1993	87500	85000	80800	77100	67900	66900	71800
1994	149500	144800	132400	116100	93600	71100	61600
1995	110200	107600	102700	87600	75900	86400	84000
1996	102900	100100	97000	88300	74100	74700	84500
1997	283800	277000	262800	226400	172200	126400	115300

Table A-12. Peak May-Dec Unregulated Mean Flow Volumes at Sioux City

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	171100	171100	167600	162800	147700	117400	81500
1899	160400	158400	156600	154200	142700	126400	99600
1900	128400	122500	118200	114600	109200	90800	66700
1901	147200	142400	139400	133300	124000	99800	70000
1902	129700	128700	126000	120600	112200	96300	77700
1903	149300	145600	135600	134500	129000	108000	82800
1904	148800	147700	140700	129700	121700	100300	81600
1905	233600	214400	170300	140300	124100	90800	64100
1906	180200	177700	158000	145000	131700	103800	80000
1907	180200	167500	154900	147100	142400	120500	99600
1908	183800	182500	174500	164200	150900	115800	80700
1909	170600	166000	157300	150300	147900	110900	78100
1910	109200	101300	96400	94100	89400	74200	65300
1911	138300	134600	132400	128900	121400	90000	65500
1912	181600	176100	156600	137900	129300	101200	89400
1913	151900	148800	144000	139600	139400	113900	92700
1914	155300	152500	149400	138800	134000	110500	82900
1915	177000	164600	156500	134800	120800	108600	91200
1916	182700	179200	170700	165100	159200	122100	107200
1917	160900	158800	157300	154500	142900	119500	98900
1918	179200	177500	174700	166900	141700	104700	86500
1919	99400	97000	95900	93100	90100	72900	62100
1920	196600	186600	168500	151700	139300	118100	91900
1921	176100	173500	168200	152000	131500	97900	67100
1922	159800	154800	144800	140500	129000	99300	78400
1923	153700	146800	143100	136400	125500	109500	82900
1924	131800	120000	117200	113700	105400	89000	72800
1925	170000	162300	148600	133700	116800	95200	73300
1926	112100	107300	100200	95400	93400	81800	60300
1927	204500	179500	151000	148300	135200	108500	81900
1928	150400	148300	144400	133800	119700	99900	72700
1929	186800	184800	172800	149100	128300	88900	70200
1930	86800	83400	80100	73700	70300	59500	52800
1931	81100	79300	75700	73200	67400	47800	35400
1932	148000	142700	132900	118600	109000	79200	58300
1933	129700	127500	126500	120700	106600	78000	55100
1934	77400	72200	65700	61600	60200	49700	38200
1935	157200	128500	114900	103500	96700	67000	46500
1936	99800	93400	80500	74100	71900	58000	46800
1937	127100	125500	109600	97400	84700	66700	47900
1938	168000	162300	157000	147400	124800	82200	58900
1939	104100	96500	79300	71800	68800	62000	51900
1940	89100	83100	77600	74200	69200	54000	40900
1941	148000	142800	120800	100900	85700	61200	45400
1942	149800	143100	129300	126500	120000	98400	69800
1943	172200	170500	166300	154300	139800	101100	85100
1944	203400	186100	170200	160600	146100	103000	79000
1945	130200	123700	111300	97900	93300	72800	58200
1946	123900	121000	108100	98600	86400	64400	49000
1947	190600	187100	169900	142900	118300	93200	75500
1948	169500	168100	164300	152900	139300	99100	76500
1949	112500	110100	103700	94500	87700	76900	64200

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1950	129000	124600	117000	112800	108000	90300	77900
1951	129600	124900	115600	108100	104800	88700	75600
1952	130300	126000	119800	112100	130000	135500	94700
1953	256600	246800	229700	207200	166900	109200	80200
1954	102700	100200	97600	91400	85000	70300	51600
1955	104500	100200	95200	90900	84400	66700	51200
1956	156100	155100	149200	138700	123500	82200	59500
1957	157200	155500	149300	141800	128100	93400	61900
1958	145500	144400	140600	130100	119700	89000	66500
1959	132300	130800	127600	125200	110700	73600	58300
1960	97200	95000	93000	89900	78700	81100	63200
1961	109500	108000	105600	102900	91600	58000	40400
1962	181200	178100	171100	166100	158400	116200	84500
1963	170000	167200	157900	150600	143600	106600	75100
1964	226700	222400	206000	179200	159700	106000	67600
1965	174600	171700	167300	163100	154300	118400	83500
1966	78100	77600	76600	75300	72300	65200	56500
1967	236900	235400	220000	208600	195500	127200	85200
1968	154500	152600	147900	142000	127600	84900	60400
1969	153900	149500	139200	126800	112800	100700	85400
1970	165400	164300	161200	152200	148300	111800	76400
1971	162800	161600	159500	158700	151700	108100	86800
1972	180500	178300	173700	163700	142400	99700	86100
1973	111700	110300	107200	102600	100000	78900	59800
1974	183800	182300	177200	162800	143700	94500	63600
1975	209100	206500	199200	193800	173000	132600	92200
1976	142100	140600	135800	130000	123900	99200	71000
1977	89200	89000	88000	83300	71900	53900	43400
1978	172200	168100	154000	142900	139100	122700	107900
1979	176300	169400	150500	123000	106000	98300	81600
1980	112200	111700	110400	109400	102200	76700	54500
1981	168100	166600	161200	150800	128200	84900	55000
1982	171200	169600	166900	156400	141200	112300	84600
1983	148100	146500	142600	133800	120400	89700	69900
1984	215200	208900	196300	173400	152300	108200	81500
1985	96500	92900	87500	79800	72600	59500	51600
1986	174300	173000	166500	158400	134800	104900	89300
1987	85900	85000	82800	79600	72800	70300	58800
1988	87200	87000	85900	81900	75000	57400	42000
1989	102100	101500	98400	93500	84000	68800	54600
1990	101600	100500	99000	96400	92800	68800	49100
1991	160300	157200	153400	143200	140600	98800	63200
1992	93700	92300	88400	84300	74800	60700	44200
1993	166700	164300	158500	152200	139200	119400	89000
1994	108600	105000	99000	94100	91400	71900	64000
1995	194000	191500	183000	166500	147200	128700	94400
1996	181600	180400	177500	173900	157700	113300	89700
1997	211200	209900	206200	200100	180800	141100	122500

Table A-13. Peak Jan-Apr Unregulated Mean Flow Volumes at Decatur

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	121700	105400	86200	77900	64800	67500	72200
1899	245100	241800	227000	178500	133800	97700	88300
1900	107200	99700	78900	64900	54200	65200	61600
1901	87600	73200	55500	44900	37900	55600	59100
1902	97500	91200	78100	69000	65400	67700	63800
1903	106300	97200	74400	59800	53000	61500	66400
1904	173300	160700	141000	114900	92800	83100	73200
1905	69800	60900	50200	42500	36300	39000	52600
1906	113000	103100	84500	82700	67100	66500	64900
1907	133300	119600	105100	96700	93200	91500	90900
1908	81000	74500	67100	56800	53900	65700	75100
1909	102700	81200	73700	62800	60100	60200	73700
1910	196100	180900	139000	109500	90900	71000	64300
1911	88300	80200	68700	52600	42100	46700	56300
1912	190400	187400	170000	130600	109700	82800	77300
1913	193200	188400	152600	110100	86200	79000	76800
1914	94500	85100	69200	59000	55600	71300	70000
1915	164100	153300	147200	110100	84700	77900	76000
1916	140400	138500	131400	126200	116600	99000	98500
1917	190800	184000	167100	136500	115100	100600	90400
1918	158500	154500	139800	114000	89900	75300	80100
1919	134300	118400	102600	92600	70600	66900	62700
1920	173000	166100	141200	112200	91200	92200	84800
1921	71200	66300	53600	41600	34900	51300	60700
1922	114800	109700	102700	90100	73600	73500	69500
1923	102300	96500	84700	68000	59400	65300	67800
1924	126800	124800	119300	101400	77800	71700	66700
1925	133100	118800	95300	74500	61900	72100	69800
1926	83100	62600	49900	40300	39700	53500	54000
1927	88500	86900	79700	77800	82900	79800	78300
1928	118700	112600	106800	87300	62500	70400	72300
1929	170400	133000	98200	87000	73000	70800	63500
1930	82500	78000	70200	61900	53000	51500	47800
1931	37300	33000	28800	24100	21300	24500	31100
1932	77300	74000	63000	49900	38900	46800	50300
1933	86300	79000	65000	59100	41700	44900	48100
1934	68900	47900	35700	27500	27000	36400	34200
1935	43800	41100	35600	30900	27700	29100	38800
1936	86900	76400	68400	51800	46500	46000	41700
1937	61000	57300	47800	39300	32100	35200	40400
1938	136100	122700	97400	67600	43700	38900	50300
1939	160500	153700	133400	100700	68400	52200	44800
1940	38800	36400	32300	32200	30800	36000	35100
1941	56700	51400	42500	35400	29000	35100	38200
1942	80600	73700	58800	55800	63500	67700	62000
1943	208300	198600	180600	154600	112100	78000	76800
1944	185100	179400	167600	134000	91200	66200	70900
1945	114600	112200	104900	94600	73500	48200	53400
1946	63100	55000	47900	46200	41400	40400	44900
1947	170700	155500	132700	118500	93300	74800	69400
1948	110300	102300	90300	81900	71900	66400	68900
1949	186200	181800	167800	136100	105600	72900	60000

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1950	237300	226200	198200	149500	127100	80600	68900
1951	153500	150800	140800	117900	91900	71900	63900
1952	450300	439800	389000	304500	214700	123900	91200
1953	77500	76100	68700	63300	53900	53300	68900
1954	75700	71800	60000	47800	38100	42700	46500
1955	60900	59100	53000	48300	42000	41000	44100
1956	61500	59300	55200	51900	49100	47800	52900
1957	37100	35600	33500	31900	31300	44200	54400
1958	86600	84300	78100	69900	62000	67200	64600
1959	132400	129400	119900	100200	70600	49300	52100
1960	251900	248000	234800	203200	135000	74300	58800
1961	35800	34900	32200	29300	27800	27000	37000
1962	132900	128900	119500	110800	86100	72400	75900
1963	59000	58200	55200	51300	50300	62100	72500
1964	42800	40900	38300	38300	36900	41400	59700
1965	116300	113800	109400	92700	74600	68700	74600
1966	130900	129600	118400	96500	78900	59900	52700
1967	67200	64700	61300	58400	52200	55600	77000
1968	58600	58000	55600	49800	41800	39500	53800
1969	195800	192500	184300	177800	138400	93600	76800
1970	64300	63400	61300	60800	54700	63200	70200
1971	116400	114300	107000	94000	84000	74200	82000
1972	238200	232700	214100	175500	121500	86100	79900
1973	72400	71200	67100	60700	54200	54300	57100
1974	49800	48200	45200	42300	38200	41800	60200
1975	85000	85000	84900	85700	79600	74900	79000
1976	74500	73900	72000	65300	51600	58600	65800
1977	47200	46700	45000	40800	36300	39800	40400
1978	274700	270500	255700	226400	176300	116400	95800
1979	157400	155800	146700	127200	118600	90900	74700
1980	47300	46500	45100	40200	37200	43800	49200
1981	37300	34700	30800	27200	25100	32000	47900
1982	120500	114300	98300	78300	73000	69300	75100
1983	76300	74400	71200	66700	62600	53800	64700
1984	89000	87000	83300	81400	71000	69500	77700
1985	64400	63500	59900	58500	52800	52500	48300
1986	187700	180800	174300	152800	114100	96500	85600
1987	212700	201000	168200	125900	101400	69300	55900
1988	37600	36300	33400	31000	30300	37000	40100
1989	67800	66800	66300	58500	53500	50600	48400
1990	37100	36300	33300	30400	26500	34700	43100
1991	27300	27000	25700	23100	24800	42900	56300
1992	32200	30800	28700	25900	25000	31500	38100
1993	94400	90800	87600	82400	71100	68800	73500
1994	150100	145100	133000	117000	94900	72400	62900
1995	109700	107700	102900	88100	76000	87000	84800
1996	103700	100900	97500	89200	74800	75300	85600
1997	281100	276000	262500	227300	174200	128200	117000

Table A-14. Peak May-Dec Unregulated Mean Flow Volumes at Decatur

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	170000	169400	165900	160400	145800	117000	82100
1899	159800	158000	155900	153800	142700	127000	100400
1900	124100	120300	117200	113400	107800	89900	66400
1901	144900	141200	138400	132900	123800	99500	69500
1902	127900	127200	124500	119700	111800	96400	77700
1903	146500	142700	133000	132300	127200	107800	83200
1904	148100	146900	140400	130100	122600	101600	81800
1905	220400	202700	164900	136600	121200	87200	61600
1906	182700	177400	159600	146700	133600	104300	81400
1907	179200	169600	157600	151100	146400	124800	102500
1908	189500	188200	181200	171200	157300	120500	84400
1909	176000	172200	163300	158200	155200	116300	82700
1910	109900	103000	98600	96100	91400	76500	68300
1911	139200	137200	134900	131600	123700	92500	67800
1912	177200	173100	154900	136600	128700	100500	89200
1913	148000	146200	141400	137700	137300	110800	90700
1914	150400	149400	146400	136000	132100	108200	80400
1915	171600	164900	157200	137200	122600	109400	91100
1916	180600	176400	169700	164100	157800	121100	106700
1917	160200	159400	157900	155000	144000	120800	100300
1918	178700	177800	175200	167600	143200	106100	87500
1919	101300	99000	98100	95600	92600	75700	64500
1920	198000	187700	171800	155600	143000	121700	95200
1921	179500	178000	171100	154800	134300	99800	68000
1922	160400	157600	147600	142800	131400	100700	80300
1923	156600	152000	148200	140200	129100	112000	85200
1924	130900	123700	120500	116800	107800	91200	74900
1925	174500	166800	152000	137000	120200	98000	75800
1926	111200	108200	101200	96200	94300	83300	61700
1927	201200	183100	157700	155100	141900	114900	86300
1928	152500	150800	147100	136900	123200	103100	75600
1929	190700	186500	174100	149900	129000	89200	70800
1930	85400	81400	79200	73500	70400	59600	53100
1931	81000	79300	76100	73400	67500	47800	35400
1932	148400	144400	134200	119300	109100	79400	58500
1933	128500	126900	125900	119900	106000	77700	55000
1934	77300	73000	66800	62000	60200	49800	38300
1935	144000	127000	114700	103300	96500	67100	46700
1936	97900	92800	80100	73900	71800	58000	47000
1937	127400	124000	110400	97700	84800	67100	48300
1938	165200	160800	156600	147100	124800	82300	59200
1939	99800	95600	79100	71500	69200	62100	52000
1940	86600	82500	77300	74200	69400	54300	41200
1941	144200	139400	120600	101100	86000	61300	45600
1942	145200	139800	130600	127300	121000	99300	70400
1943	173700	171600	167700	155400	140800	101800	85500
1944	196300	183600	169900	161100	147700	103800	79500
1945	127000	123100	111200	98200	93700	73800	59100
1946	122900	119800	107300	98200	86200	64400	49000
1947	184000	181700	169500	144000	119800	94100	76100
1948	169400	167600	164200	153000	139400	99200	76700
1949	111700	110200	104000	94800	87900	77600	64700

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1950	128400	124000	116900	112800	108400	90800	78300
1951	128300	124800	116800	109500	106200	89800	77100
1952	129800	126400	119900	112600	135800	135800	95100
1953	255300	245600	230600	208100	167700	109900	80700
1954	105500	104400	101200	93500	86600	71000	52200
1955	104600	101200	95900	91500	84800	67000	51500
1956	156000	154800	149000	138800	123600	82300	59700
1957	158200	156200	150300	142500	128900	93800	62100
1958	145800	144600	140800	130200	119700	89000	66700
1959	132400	131100	128100	125500	111100	74100	58600
1960	97100	95500	93600	90300	79200	82300	63900
1961	109700	108200	105900	103300	91900	58300	40700
1962	180500	178500	171400	166600	159100	117200	85700
1963	169200	166700	158000	150800	143900	107000	75500
1964	226900	222500	206000	179300	159800	106200	67800
1965	173200	171400	167400	163200	154400	118800	84300
1966	78000	77500	76600	75300	72500	65400	56700
1967	238300	235700	221100	209200	196100	128000	85700
1968	154500	152700	147900	142000	127800	85100	60500
1969	153700	149700	139900	127700	113800	102000	86400
1970	165100	164500	161100	152200	148300	111900	76600
1971	163000	162000	160000	159200	152100	108600	87400
1972	180100	178100	173600	163900	142700	100100	86500
1973	112000	110600	107400	103000	100500	79300	60400
1974	183800	182300	177200	163000	144000	94900	64000
1975	209600	206900	199500	194000	173400	133400	93000
1976	142300	140800	136000	130200	124100	99400	71200
1977	89400	89200	88100	83400	72200	54200	43600
1978	172400	168200	153900	143300	139700	123100	108500
1979	177200	170500	150900	123900	106500	99400	82600
1980	112400	112100	110600	109600	102500	77100	54900
1981	168800	167600	162000	151600	129000	85500	55500
1982	173000	171700	168500	158200	142600	113500	85600
1983	152400	151200	146800	137800	123800	91700	72300
1984	215200	210600	199900	178100	155900	110800	83700
1985	96500	93900	88200	80500	73400	60700	52600
1986	175400	174100	167900	159900	136400	106900	90900
1987	86500	85800	83800	80600	73800	71700	60000
1988	87800	87600	86500	82800	76000	58100	42600
1989	103600	102000	99200	94100	85000	69500	55100
1990	103400	100800	99300	96600	93100	69300	49500
1991	160300	157000	153600	144000	141200	99400	63700
1992	96800	95300	91600	86600	76800	62100	45400
1993	170900	167000	162000	156200	142000	121400	90900
1994	112100	107800	101900	96100	93200	73100	65300
1995	194300	191800	183800	167700	148300	129600	95300
1996	183200	182400	179300	176300	160500	114900	91000
1997	212700	211700	207900	201600	182100	142900	124100

Table A-15. Peak Jan-Apr Unregulated Mean Flow Volumes at Omaha

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	118900	106200	91300	82400	66700	65100	70200
1899	232600	229700	212600	172000	133600	98100	89800
1900	102500	96600	78100	64400	54600	59900	58400
1901	77700	70200	52800	43800	36000	50700	57600
1902	93600	89800	78900	69700	64200	63400	62600
1903	106400	94700	77300	62900	54500	65500	67300
1904	177800	168500	151100	126600	103400	85700	74400
1905	66300	59900	49100	39300	32200	32500	44700
1906	120000	113000	102800	101200	89600	83000	73900
1907	130000	118300	107800	102700	96800	99100	101800
1908	93400	88500	78400	68400	64200	76000	92600
1909	145500	134000	120100	101700	95300	80500	97500
1910	223200	212600	177500	142300	120000	89400	81500
1911	107400	95500	86600	70400	56000	56500	65200
1912	196400	195100	182400	147700	119600	85700	78900
1913	200200	189000	159400	120900	92100	75000	69600
1914	63200	55300	47100	39000	39300	52100	56600
1915	161000	154100	146700	115000	86800	68500	72800
1916	134300	132400	128100	122800	116000	95800	94600
1917	199000	197200	187800	157900	129800	104000	94600
1918	173200	168800	151800	127800	96600	79400	88900
1919	146200	140200	128300	117500	90500	81300	74200
1920	199800	187300	164000	137800	114800	116000	103000
1921	74700	68300	54600	37300	30400	49500	63800
1922	128600	126200	120800	109800	88800	83400	77700
1923	117400	112300	102600	88800	76400	77000	81000
1924	145400	142000	136300	119800	93200	81500	78700
1925	147800	138800	117700	96100	78700	83100	82900
1926	98000	77700	60500	50000	43700	57600	60900
1927	95300	94500	92600	89100	97800	99600	99000
1928	132600	129800	124400	110700	82300	85100	83000
1929	163300	136900	107500	96300	80600	73900	65600
1930	84000	80000	74500	66500	56700	53200	48800
1931	37600	34100	28900	24000	21300	24200	31000
1932	66400	60200	55100	48000	41200	48300	51200
1933	75600	72800	63300	59900	43500	43700	47400
1934	85900	53100	38100	28400	25500	35300	34200
1935	43200	40900	35800	31400	27800	28900	38700
1936	84500	77400	72400	56600	50600	46700	42100
1937	70300	64800	51400	41200	33300	36100	41400
1938	114400	110700	94800	68000	44500	39700	51100
1939	140900	139800	126100	97400	67000	51400	45200
1940	39800	36900	32800	32500	30700	36600	35700
1941	57900	53100	44800	37100	30000	34600	39000
1942	82900	78200	64000	52800	62400	69200	64500
1943	210200	204100	179300	151500	111300	77500	78200
1944	157500	156800	152200	130600	89400	67000	73300
1945	109500	107600	100900	93400	78100	52600	57600
1946	62700	56000	47000	45500	41400	40400	45000
1947	159100	150200	140100	121400	95700	76500	72100
1948	106900	100900	87100	82400	75000	65900	69700
1949	194000	186800	175200	144700	113200	75600	62600

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1950	218000	210600	189500	149500	124300	80800	70000
1951	157400	156000	150400	127300	105100	80000	69900
1952	451600	430700	382100	301600	215300	124900	93500
1953	77000	75400	69100	64500	56000	55600	71300
1954	79400	75100	62200	50200	39800	43800	48700
1955	62600	60900	55200	51500	44200	42400	45400
1956	61800	60000	56000	52500	49700	47500	53300
1957	36800	36200	34300	32900	31000	43800	55000
1958	85600	83500	78400	70200	62600	66700	65000
1959	130200	127300	118500	99000	70200	51100	53100
1960	263500	259100	249500	220900	144700	79400	62200
1961	48000	46600	42500	37500	35200	29100	39200
1962	151500	148900	145200	129100	98800	79500	81100
1963	63700	62300	59600	53600	52300	63900	74100
1964	36100	36800	37900	39200	37900	41900	60300
1965	118900	116500	111900	94800	77400	75100	78700
1966	130800	129300	118900	97300	79900	60800	53600
1967	66900	64900	61600	58600	52800	56700	79000
1968	57600	57400	55200	49300	41700	39200	53600
1969	217200	212500	203400	196300	151200	100200	81400
1970	65900	64900	62600	61500	55900	63400	70900
1971	120800	119400	111800	98000	86700	76200	84800
1972	238000	232900	214800	176800	123300	87800	81700
1973	78100	77200	72600	66700	61700	57300	60200
1974	51700	50100	47300	44400	40400	44300	62000
1975	97000	96800	94300	93000	86800	79900	82300
1976	75400	74600	73100	66700	53000	59200	66400
1977	47600	47400	45800	41500	38100	40600	41200
1978	276600	272800	258600	229300	179000	119000	97900
1979	161900	159800	151700	137400	124700	99200	80000
1980	48800	48000	46300	41900	39500	45800	51300
1981	38400	35400	32000	28600	26300	32700	49800
1982	121300	116100	100900	81700	76500	73700	79800
1983	106300	102800	94200	85200	77500	68400	77700
1984	104600	103400	101500	96600	85000	81500	89400
1985	74800	72300	67700	63100	59800	58900	53700
1986	218500	204800	189800	165600	124300	107300	93600
1987	223600	211700	178000	136300	111700	76100	61800
1988	40800	39900	37100	34600	34000	39700	42800
1989	69700	69000	68500	60700	55400	52000	49700
1990	39300	38400	35300	32500	28900	37300	47000
1991	35300	34500	34200	32100	33200	49600	62600
1992	39300	38300	35900	32000	30400	36700	43200
1993	110600	108100	106000	98400	85500	81800	87400
1994	150900	146500	134600	119400	99500	76100	68600
1995	118600	116500	111100	96900	83800	95700	91700
1996	107000	106200	102800	93200	78900	79500	91800
1997	282800	277900	265200	231700	178400	133300	123000

Table A-16. Peak May-Dec Unregulated Mean Flow Volumes at Omaha

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	162100	160300	155600	146200	135900	114100	84800
1899	156200	154300	150800	150300	141800	129300	104900
1900	117400	114800	111600	106700	100400	84900	64300
1901	138800	137400	134100	130300	123500	97300	66400
1902	120100	119100	115800	113600	108800	96700	77100
1903	147200	138100	128100	119200	116600	105800	84900
1904	143500	143500	139300	132100	127200	107800	81800
1905	168700	157700	136900	115600	104100	68500	48600
1906	193300	185200	171200	154600	143100	107100	88600
1907	187600	185200	183500	176300	169600	146900	116900
1908	223300	222400	218900	209100	190400	145100	103100
1909	209000	206400	203000	201500	194100	144400	109000
1910	118800	116400	111100	105900	101400	88800	84200
1911	152500	150600	148200	144700	135200	105100	79900
1912	164500	161300	145400	128600	124700	97800	87400
1913	136000	134400	130800	127700	125700	98600	78900
1914	135600	132700	130600	123000	121800	95000	66900
1915	171500	169600	166400	150600	131700	112800	91500
1916	170000	168100	163000	157500	149100	114900	102900
1917	164200	161800	159700	157000	149000	127600	106800
1918	181400	179500	177100	170700	151000	112400	92600
1919	118100	117200	112500	110500	105000	90300	77000
1920	224700	208800	191700	175700	161600	140300	112500
1921	207400	200600	189600	170600	149000	109600	72000
1922	173700	170800	162600	156300	143100	107400	89500
1923	182900	179800	174300	162300	147900	125100	96800
1924	145700	144800	140900	134700	122600	102200	86000
1925	198100	190100	173800	154700	139000	112400	88700
1926	117700	115500	106400	100000	98700	90600	69700
1927	225100	211700	194000	190700	176700	148500	108700
1928	164000	163600	161300	153300	141000	119700	90900
1929	210800	202100	181500	155000	131900	90300	73200
1930	81500	80300	75600	72500	70800	60000	54100
1931	82700	80400	77600	74100	67700	47900	35600
1932	152000	151500	140000	122600	108700	79700	59600
1933	125000	124300	122300	115200	102200	75600	54200
1934	87600	82600	72200	64500	60500	50300	38300
1935	128400	118600	114000	101600	95100	67600	47000
1936	97200	90800	77800	72300	70500	57600	47700
1937	128100	124500	114300	98800	84800	69400	50000
1938	158600	156700	152700	144200	123700	82500	60500
1939	99900	94400	78600	72600	70400	62700	52300
1940	90200	80900	76700	74300	71100	55700	42200
1941	133000	130700	120500	102600	87100	61700	46300
1942	148600	145800	138300	132900	125600	103600	73300
1943	181300	178500	174100	160600	146100	104600	87100
1944	181600	174900	168400	163300	155900	107400	81700
1945	123700	119900	110800	98800	96100	79100	63800
1946	117800	114600	104000	95900	84500	63600	48700
1947	179800	178400	170000	149500	126900	98400	78900
1948	167000	165200	162300	152500	139800	99400	77400
1949	114800	110700	105300	96200	88500	80600	67100

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1950	129700	122800	115900	116900	109600	92600	79700
1951	141800	130100	123700	117000	112900	95500	84800
1952	135200	128400	120000	115300	163700	136700	96700
1953	261400	250800	234800	212100	171700	113200	83100
1954	133400	129800	121400	105700	94800	74600	54700
1955	111200	105900	99300	94500	86800	67900	52900
1956	155400	154400	149200	139100	123700	82400	60000
1957	163100	161400	156100	147100	133400	95400	63000
1958	147300	145900	141800	130700	119800	89100	67200
1959	134800	133600	130600	127300	112600	76600	60100
1960	100700	98600	96100	92400	82000	88500	67300
1961	110500	110200	107500	104700	93300	59200	42700
1962	181800	180100	173400	169200	163400	122200	91600
1963	169600	167300	159000	151800	144700	108900	77400
1964	225700	221600	206100	179800	160400	107200	68800
1965	174500	171900	168100	163700	155000	120300	88200
1966	78700	77200	76300	75100	73200	65800	57400
1967	246100	242300	227300	213500	199500	131900	88000
1968	155500	153000	148300	142300	128400	85400	60800
1969	156600	153100	143100	131900	118800	108400	91500
1970	165800	164900	161000	152200	148400	112200	77200
1971	165700	164500	162100	161200	154100	110500	90500
1972	179200	177700	173600	164500	143900	101800	88200
1973	113800	111900	108600	105100	102500	81100	63600
1974	184200	182500	177600	163500	145100	96800	65900
1975	211300	208700	200800	194900	175200	137400	97100
1976	143600	141900	137400	131100	124900	100300	72200
1977	91500	90600	89300	84400	73000	55100	44700
1978	171100	167200	154200	145200	142300	124900	111400
1979	180900	174300	154900	128300	109000	104800	88400
1980	114500	113900	112100	110400	103600	79000	56700
1981	175900	173600	167800	155700	133100	88200	57800
1982	185800	182400	178100	167400	150200	119700	90400
1983	181100	177200	169800	160400	141600	102400	84900
1984	226500	224600	219100	204100	176500	124100	95000
1985	101400	98200	91700	83800	77200	66800	57400
1986	183100	181200	175900	167900	145300	116800	99300
1987	90500	90200	88800	85700	79300	78700	66400
1988	89100	88800	87800	84200	77600	60100	45300
1989	105500	103800	100800	95900	86400	71100	57000
1990	118700	114200	110200	108500	101700	76200	53800
1991	198100	192300	175500	155600	151600	106200	69500
1992	107500	104700	99900	92700	83600	67900	51500
1993	207900	199400	192300	187400	169000	139700	106600
1994	127100	123000	117000	108600	101400	80000	71300
1995	201800	199400	191400	175300	155200	137800	102300
1996	222200	217500	202800	193600	174900	126000	98500
1997	221500	220000	216500	210500	189800	149300	129800

Table A-17. Peak Jan-Apr Unregulated Mean Flow Volumes at Nebraska City

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	109600	104400	92400	87300	76600	81600	90400
1899	262000	255400	229700	183700	144100	112600	114700
1900	115900	112100	100500	93300	94900	102200	89000
1901	103500	95600	86200	81500	74400	86400	85100
1902	102200	98200	93800	90400	87000	90600	84800
1903	130200	108700	104400	96600	87900	97000	93500
1904	161800	156000	145500	124800	106300	99800	92500
1905	83800	79500	77800	72600	70200	78000	83500
1906	117100	112800	101400	98600	87500	87300	79300
1907	105400	100300	93400	90000	85700	91100	102000
1908	90800	89200	84200	80300	73500	87600	103100
1909	141800	131800	117600	100500	95100	90300	105300
1910	198700	191500	157600	134500	116000	100000	95600
1911	101700	95800	87700	79000	68900	79800	82400
1912	216800	215500	198500	166500	153500	121700	109300
1913	197300	192700	165700	132900	118000	110000	99500
1914	107000	94000	82900	75700	76400	92000	89900
1915	196600	189400	176300	135800	108500	98700	98600
1916	135400	133100	127500	122200	115000	104100	109100
1917	202600	196400	185200	158400	134700	126500	121400
1918	155800	151300	136900	120000	101500	99200	106400
1919	136700	131400	122600	116100	102900	101300	92000
1920	184700	174900	157100	132800	117800	133200	123900
1921	102900	97900	87900	79300	80400	95500	101800
1922	144200	141000	130300	120000	108100	110100	103000
1923	117200	114000	105800	95900	90300	98900	101900
1924	173200	169300	162800	142600	124000	116300	111800
1925	154400	148000	127300	110300	100300	110100	107000
1926	108800	95300	84200	78800	81100	93600	90900
1927	164100	152800	137300	125600	126900	127200	122300
1928	139100	135400	133300	123100	105500	114000	108400
1929	175600	149100	119800	107800	94100	95100	85600
1930	88400	85600	80200	70700	74200	75000	68700
1931	51400	48900	44300	37800	34700	38600	46200
1932	82300	81300	71000	61000	59100	68000	69900
1933	87600	83900	73400	70300	53100	62000	63500
1934	78700	63200	46900	36600	38000	47500	46700
1935	48100	43200	40500	40200	36100	44900	55400
1936	109700	97500	87700	71500	66900	61800	56400
1937	83000	76900	61400	50200	44800	48100	55000
1938	114400	110700	97000	71900	51600	51800	64200
1939	153400	149700	137400	106700	76300	63700	57000
1940	46600	43500	41000	46700	44600	51400	48700
1941	67300	64200	55400	47100	43100	47500	50700
1942	83400	79900	70000	60300	74300	82500	80500
1943	205400	198300	179300	153700	117500	86800	92200
1944	179000	172600	165400	143400	111300	90000	92800
1945	117000	115900	109300	102300	88200	71100	76100
1946	78100	72000	59300	56400	51800	50600	57500
1947	170900	164100	156000	135000	106700	93500	92700
1948	124300	113900	103900	96800	89400	77900	83200
1949	199200	196700	184300	159000	134900	98700	85500

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1950	211700	202600	190900	156300	135200	99300	87100
1951	162800	160400	155600	136800	120600	103700	89600
1952	468100	433100	387900	312000	231000	146800	114000
1953	86300	86100	79400	75400	67700	71400	85600
1954	92500	86400	74400	62600	54200	56500	61900
1955	78100	73900	66500	57600	51700	51600	56800
1956	67500	65400	62400	59500	56300	59600	64000
1957	46900	46300	43900	42100	39400	55900	71500
1958	103100	101700	98800	86800	78200	84300	81400
1959	142300	139600	131800	112100	83200	70400	70500
1960	315600	314500	307900	275800	182900	106000	84800
1961	57100	55900	51900	48500	45300	44100	53600
1962	215100	202900	191000	165000	126700	104700	102100
1963	78700	77700	75900	71400	66800	76800	89400
1964	52900	54100	55600	55800	55400	56300	77300
1965	124900	124300	119800	102900	90800	95900	98400
1966	141300	139200	130100	110100	91400	75400	67400
1967	73700	70900	68300	65800	59500	68200	96700
1968	63000	62700	61000	55100	48600	50300	67500
1969	227000	222300	218600	213700	167900	118100	98500
1970	76800	76100	75700	81700	76200	80600	88200
1971	135200	132200	125500	111300	102400	98700	107200
1972	243500	238900	221900	185600	132400	104100	95700
1973	99600	97900	91500	85800	83000	86300	84400
1974	64900	64000	61500	59700	58000	62800	78700
1975	114000	113200	106900	105800	99400	90800	96000
1976	83500	82500	81800	75700	62800	73100	80600
1977	63800	63400	60600	54800	48800	55700	55400
1978	303400	301200	283000	252900	204400	143500	118500
1979	177400	174700	166800	151100	139800	116900	97600
1980	63000	61900	60600	57600	54400	68600	71600
1981	43200	41600	38400	34900	33000	42200	60100
1982	125800	121700	108000	88800	82800	90200	98200
1983	122700	120400	110700	101200	95900	92300	107000
1984	143000	140300	137100	133400	129700	123000	125700
1985	105300	98000	91800	85000	74400	76700	69800
1986	240000	230500	210200	182000	139000	125800	114000
1987	265600	252000	218000	183200	148300	104300	84000
1988	51300	50500	48400	46000	43400	54700	57400
1989	77300	75100	73600	66900	61800	60900	61600
1990	44500	43800	41200	39300	35800	46100	59200
1991	39800	39300	40500	41200	44000	64400	77200
1992	48800	48200	46300	42000	39500	48700	54800
1993	150600	140600	122400	113000	101000	100200	112400
1994	160700	156500	145200	129300	111700	89400	83800
1995	134100	131700	125900	113700	105400	119300	115000
1996	115600	114800	110900	99600	86800	96800	109000
1997	287500	284400	271900	239500	188000	145200	137800

Table A-18. Peak May-Dec Unregulated Mean Flow Volumes at Nebraska City

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1898	198100	196900	190800	176000	162600	128600	96900
1899	201700	201500	198700	196600	181700	152500	123800
1900	170400	160900	153900	150400	142900	126400	98300
1901	174800	171400	169800	160300	149000	120200	94500
1902	160100	154700	152700	149900	140300	124700	102900
1903	214300	208100	186600	157400	145000	135300	111900
1904	176600	176600	171800	160400	150200	124100	101900
1905	234600	223300	196900	172500	154900	117600	90200
1906	187800	176800	162400	156900	143900	118100	99000
1907	222000	220800	214700	200000	186300	162700	122400
1908	249700	245800	240300	235100	213800	160300	117000
1909	226500	222500	209300	207400	200200	158900	121500
1910	129000	125200	121400	118700	117800	108700	100200
1911	168200	166700	164700	159800	147600	123700	98300
1912	178300	175900	164000	151200	150600	125100	119500
1913	171300	168900	164800	163200	159200	132400	110700
1914	229400	222000	206900	182000	169900	130300	100600
1915	201700	201000	195700	176400	160200	143100	117700
1916	203700	202700	196600	190700	174900	138900	120000
1917	214600	212400	211400	209500	199400	167100	134400
1918	202900	201800	199000	192000	168500	135700	112100
1919	144400	143500	139300	137200	131600	113100	97100
1920	259400	250400	234800	216900	195500	169200	135800
1921	284600	279600	265600	233200	198200	149300	111500
1922	207500	206300	194200	188300	173100	139700	117000
1923	221400	215900	207000	195700	182600	154600	120400
1924	204600	201600	194800	188900	175200	143000	122300
1925	209200	204100	190600	175700	163000	138900	114600
1926	150400	146700	141100	136900	136100	123000	99800
1927	240200	227800	223800	221500	204000	170400	133200
1928	184500	182200	177000	169700	163300	144900	118900
1929	241900	234800	215200	192400	167100	117500	95000
1930	121900	116200	114300	108800	102100	87900	74700
1931	125500	118600	109800	98100	91100	66700	51800
1932	175400	174300	162700	142900	133100	105500	79500
1933	139100	138500	136100	128000	121900	97400	71200
1934	128700	125900	107400	87500	78100	67400	52900
1935	157700	153600	149900	143100	127400	95300	66300
1936	117300	108100	100800	97600	91400	75600	64100
1937	139100	138500	133000	123700	107300	90200	65900
1938	207900	205000	195600	174900	148100	101900	75800
1939	125700	118600	103900	96500	90200	79400	66600
1940	146900	143200	129100	109400	99300	75600	57500
1941	140600	139500	130700	116000	102900	77900	59600
1942	214500	206600	189200	178800	159700	128200	90900
1943	227600	223400	212600	188900	179700	126700	102600
1944	284500	280200	244000	200900	188900	134300	103300
1945	165200	160100	146900	132300	125900	105600	83300
1946	154100	153300	139300	128200	109900	80100	61500
1947	237700	232800	220900	208900	178000	131400	101500
1948	215600	208300	195300	180300	159600	117200	93100
1949	145500	143300	138500	134400	125000	103700	91500

Year	1-day	3-day	7-day	15-day	31-day	91-day	181-day
1950	174400	163700	151000	144900	131700	112600	98300
1951	216100	195000	172000	155300	144200	122700	107500
1952	193900	175200	156600	149000	190500	161800	117600
1953	272400	266400	251400	228400	188800	128200	97500
1954	177800	174400	158900	133600	118900	90200	68500
1955	131600	125200	120100	117400	110600	84600	65600
1956	173400	170700	163100	155600	140000	95600	72300
1957	262900	250000	222700	199500	177200	122200	81700
1958	171800	169400	165300	151800	137700	114600	88100
1959	192200	188200	176700	161500	138500	102100	79400
1960	171800	166600	145700	134400	117200	120000	92600
1961	134800	133900	132600	130600	116500	79800	59300
1962	213300	210700	203100	191500	188300	151600	115800
1963	263200	250800	215300	194800	174000	127800	93400
1964	261300	254300	237800	210300	190000	130400	87500
1965	262400	246400	225400	205700	184600	148400	109600
1966	126300	115800	104200	95800	90900	83200	72800
1967	310000	292700	277800	266200	247100	163600	107800
1968	234600	229100	214100	188400	158100	104100	75200
1969	171000	168400	158600	150500	142400	126300	110500
1970	197600	195600	189700	185600	177200	135100	95900
1971	208100	206500	202400	198200	187000	139600	114600
1972	193700	191500	188700	178800	158100	121500	104100
1973	163000	157900	150100	148100	137900	111700	89100
1974	203100	202200	198900	185300	162500	115700	82300
1975	222300	219900	211000	207800	196200	156500	112900
1976	176000	173700	165800	153500	145800	120500	87700
1977	113400	112900	110600	103900	93100	75200	61700
1978	204900	201300	188600	170900	169800	148300	134600
1979	216100	204400	179100	148400	138300	122100	108300
1980	170000	168000	161900	149500	135100	106400	78800
1981	202300	198600	189600	174800	152500	107800	73100
1982	232200	228900	216500	207600	179100	151600	111600
1983	269200	264100	249500	225200	204000	142800	116600
1984	302700	298200	290600	273300	241100	173600	132700
1985	128800	126700	118800	108100	98600	89200	76300
1986	233000	229400	214200	206300	184900	145200	122300
1987	133700	127100	113900	109700	106500	106900	90200
1988	114900	114400	110800	103000	98600	79600	61600
1989	144500	143800	141200	128900	112500	87500	71100
1990	243400	228200	186900	153600	127600	96900	70000
1991	238700	228100	209900	191700	177100	130300	87300
1992	126800	124600	117100	107800	100900	85300	66500
1993	313800	306200	271200	250800	227300	178100	137000
1994	164900	161300	147700	130700	120100	99900	89500
1995	263500	260600	249600	224500	198400	174300	129200
1996	294600	282500	254500	228200	202500	156500	118600
1997	254700	253800	251000	245700	219600	165800	146200

Table A-19. Peak Annual Regulated Flows at Omaha District Gages

Year	Yankton	Sioux City	Omaha	Nebraska City
1898	62700	62000	63000	79600
1899	62200	64100	76600	142000
1900	50000	49900	66600	69900
1901	61600	59200	56100	75800
1902	48900	49300	50700	68700
1903	55700	53700	62000	125200
1904	57300	57200	84900	74500
1905	58400	56400	38000	84800
1906	52200	51700	75600	82600
1907	53500	52700	70200	94000
1908	64200	64800	89700	107500
1909	68900	71200	132800	126100
1910	53800	49400	115400	98200
1911	50600	48100	69100	94400
1912	63200	62500	84200	181200
1913	63200	62300	122900	106000
1914	63700	64700	57100	101800
1915	63700	64100	70900	92700
1916	64200	65600	71900	86800
1917	64000	63500	86900	94900
1918	62100	57000	73400	85500
1919	43900	40400	79200	83400
1920	45300	40100	115500	133300
1921	48100	46200	72100	126100
1922	37500	38100	62700	80100
1923	64200	64400	96000	106300
1924	63200	61500	77700	125800
1925	58700	55200	77600	79200
1926	38100	37300	72600	78000
1927	67900	67600	126700	129500
1928	68900	70200	96900	108200
1929	53700	48900	58400	87000
1930	44000	51300	52900	81600
1931	44800	41900	43700	48500
1932	37900	36400	42900	68000
1933	43400	38900	38000	46600
1934	39800	37300	37300	43000
1935	40400	39500	40900	82700
1936	49300	47400	47600	69200
1937	15500	21000	34500	45700
1938	45100	42800	55000	65600
1939	53000	48200	60100	82400
1940	41800	40100	57100	64600
1941	21500	20200	22500	35600
1942	39800	49900	49800	74900
1943	50800	47400	47100	75100
1944	42200	65000	62700	130100
1945	39100	53000	70100	93300
1946	43000	38900	38900	60100
1947	43500	53300	59600	118400
1948	42300	52600	49500	88400
1949	42700	53200	82800	98100

Year	Yankton	Sioux City	Omaha	Nebraska City
1950	54700	62300	67000	99300
1951	61800	77400	96200	149000
1952	73300	86200	82300	111600
1953	51100	48400	69300	93100
1954	40700	50300	77100	101800
1955	45400	42000	44500	56100
1956	39500	39100	41000	42000
1957	34200	40900	45900	110000
1958	38700	35500	35800	76700
1959	36600	35900	57900	80100
1960	68500	92300	124600	181600
1961	40700	41400	43500	55200
1962	39200	78600	125500	179000
1963	40000	38700	62300	84100
1964	37800	37900	55100	107500
1965	51400	50400	71400	99100
1966	41400	41400	55600	82900
1967	56700	55500	66100	176000
1968	42700	41100	50100	67500
1969	60800	78900	103300	107600
1970	58300	55100	56000	59200
1971	57000	73700	83700	130300
1972	54300	58400	72100	84400
1973	43600	42200	47300	86000
1974	40800	40200	48300	75600
1975	63700	63400	68900	74100
1976	52100	54200	54800	63400
1977	35700	36900	44100	56600
1978	62700	68600	89500	160600
1979	46000	57200	83400	114000
1980	36800	41200	49200	67100
1981	39500	37000	48100	59200
1982	58800	64200	74900	103400
1983	49800	58400	97500	141800
1984	50000	119000	130700	206500
1985	35700	47300	67500	79100
1986	66300	71000	92400	129300
1987	41500	40400	54900	114400
1988	37300	37300	43300	50200
1989	33400	33300	42200	81700
1990	32600	34400	75100	116500
1991	34200	36000	79800	95300
1992	32600	42800	53300	61800
1993	32600	91400	125200	209700
1994	35700	46800	56000	83300
1995	67300	97700	113700	142400
1996	59400	99000	142400	141700
1997	72500	108400	113800	119400

Table A-20. Historic Depletions Above Fort Peck Dam (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	-7.6	-3.3	-0.8	38.2	117.6	326.4	383.2	354.8	129.8	-30.9	-30.6	-16.1	1261
1899	-6.1	-1.7	0.7	21.4	241.7	474.2	486.1	240.9	178.1	-32.2	-35.3	-19.0	1549
1900	-8.8	-4.0	-1.7	22.5	268.2	539.2	413.9	232.1	73.6	-13.1	-20.7	-9.9	1491
1901	-2.8	0.1	1.5	36.6	290.3	317.5	563.6	438.0	9.5	-6.9	-33.4	-17.5	1596
1902	-9.7	-4.1	-1.6	41.8	188.9	395.1	362.8	367.4	169.3	-10.2	-36.6	-19.8	1444
1903	-8.8	-3.7	-0.9	15.2	255.9	537.4	340.3	340.3	149.1	-9.9	-37.3	-20.0	1558
1904	-7.7	-2.8	-0.1	53.6	477.4	459.1	409.5	315.2	215.9	-17.5	-43.1	-22.9	1837
1905	-12.2	-6.7	-3.6	21.2	222.1	304.0	513.8	419.2	236.6	-32.1	-42.0	-22.5	1598
1906	-11.0	-5.0	-1.7	47.2	123.2	398.6	642.2	248.0	194.0	-3.3	-38.5	-21.9	1572
1907	-11.4	-5.4	-2.7	-1.1	306.9	143.1	494.3	301.7	167.1	-1.4	-34.5	-18.9	1338
1908	-9.5	-4.1	-1.5	57.6	37.8	235.1	663.2	321.9	126.5	-34.7	-31.4	-17.2	1344
1909	-7.4	-2.1	0.3	1.5	255.8	289.1	423.4	454.4	128.4	-3.9	-37.4	-19.9	1482
1910	-6.7	-1.0	2.0	72.4	561.7	547.2	625.3	325.8	45.8	-29.1	-39.5	-20.4	2084
1911	-12.6	-6.9	-4.5	-3.3	292.7	456.3	577.6	293.4	55.5	-41.1	-31.7	-16.4	1559
1912	-6.3	-1.6	0.4	55.4	296.7	709.2	517.4	262.9	40.6	-30.5	-33.9	-17.8	1792
1913	-6.8	-2.1	-0.1	47.1	433.4	451.1	489.0	467.4	218.0	-53.2	-46.1	-23.7	1974
1914	-11.0	-5.0	-1.5	47.4	376.5	292.8	821.7	488.4	147.1	-61.9	-44.6	-23.0	2027
1915	-14.0	-7.1	-3.8	65.2	485.6	113.8	355.6	529.4	66.1	3.1	-36.9	-18.9	1538
1916	-10.5	-5.0	-1.8	29.0	157.5	313.2	582.4	424.8	142.6	-45.7	-36.3	-19.0	1531
1917	-5.1	0.4	3.2	4.4	246.3	589.7	892.3	511.3	138.5	-39.3	-49.9	-26.7	2265
1918	-13.4	-5.5	-1.9	-0.6	410.3	915.5	423.2	351.1	87.9	-17.2	-43.6	-23.0	2083
1919	-7.4	-1.9	0.9	64.2	559.9	700.9	732.6	492.3	156.3	-45.8	-36.4	-16.7	2599
1920	-7.6	-2.4	0.2	1.4	365.9	672.2	777.2	478.2	191.0	-61.1	-51.6	-26.9	2337
1921	-11.1	-3.8	-0.2	33.7	487.4	728.7	764.3	524.4	142.2	-20.1	-56.0	-29.8	2560
1922	-15.6	-7.4	-3.5	9.2	463.1	700.1	373.6	555.3	324.8	-10.2	-60.5	-32.4	2297
1923	-16.6	-9.0	-4.3	20.4	458.7	378.0	656.9	382.4	340.4	-56.8	-52.2	-27.7	2070
1924	-9.5	-2.6	1.2	60.3	742.4	607.0	759.9	514.8	180.8	-37.0	-58.5	-30.4	2728
1925	-16.4	-8.2	-4.2	32.5	730.3	524.6	881.0	430.3	7.0	-78.5	-43.9	-21.4	2433
1926	-10.9	-4.4	-1.8	69.8	645.9	515.8	802.5	500.2	-80.0	-8.1	-43.4	-22.3	2363
1927	-13.8	-6.6	-3.8	-2.9	1.4	751.8	741.6	291.2	262.4	-5.4	-48.9	-28.1	1939
1928	-8.8	-1.5	1.8	40.2	1146.5	327.6	561.9	321.2	308.1	-36.1	-57.3	-29.4	2574
1929	-21.9	-15.3	-10.5	3.9	146.8	601.8	1000.5	736.6	90.2	-43.7	-39.8	-25.8	2423
1930	-17.6	-12.0	-7.8	12.5	219.6	876.3	818.3	510.4	165.4	-62.5	-38.1	-24.4	2440
1931	-16.0	-10.5	-6.5	19.3	215.8	771.1	774.2	711.0	122.0	-24.0	-34.8	-21.3	2500
1932	-14.3	-9.3	-5.6	11.7	288.7	522.5	863.0	579.7	335.2	-73.7	-45.0	-28.6	2424
1933	-19.5	-13.5	-9.0	-2.8	54.5	918.9	1079.1	300.8	220.9	-53.1	-37.3	-23.6	2415
1934	-15.3	-10.0	-6.1	23.7	447.9	378.6	931.7	729.6	132.4	-53.5	-35.0	-21.8	2502
1935	-14.2	-9.2	-5.5	0.4	100.7	707.3	885.1	651.4	312.8	-59.3	-38.3	-22.9	2508
1936	-13.7	-8.3	-4.4	7.9	363.2	647.4	1008.6	550.1	204.2	-39.1	-34.9	-21.5	2659
1937	-14.8	-9.7	-5.9	18.1	480.2	374.2	866.9	741.0	176.5	-41.8	-44.9	-28.0	2512
1938	-21.2	-15.2	-10.7	1.8	31.4	436.2	721.1	669.3	389.3	-74.9	-40.7	-24.5	2062
1939	-14.2	-8.7	-4.9	21.6	193.1	343.9	1072.0	681.8	233.3	-68.3	-41.3	-25.8	2383
1940	-16.3	-10.6	-6.4	-0.8	379.3	709.6	772.8	742.3	51.1	-46.5	-33.6	-20.0	2521
1941	-16.0	-11.0	-7.4	2.2	147.5	463.3	920.4	442.6	-26.5	-28.2	-29.2	-18.6	1839
1942	-11.7	-7.7	-4.7	13.9	16.9	373.6	903.5	642.4	197.3	-46.1	-36.1	-21.9	2020
1943	-15.3	-10.4	-6.8	1.5	86.3	237.7	850.0	545.0	263.9	-53.6	-36.7	-22.8	1839
1944	-17.9	-13.0	-9.5	10.9	75.2	37.3	719.4	426.6	200.0	-17.0	-26.8	-16.4	1369
1945	-9.3	-5.9	-3.3	0.2	71.4	156.0	916.1	530.1	115.2	-24.9	-29.3	-18.4	1698
1946	-12.3	-8.3	-5.3	34.6	69.9	462.2	702.2	510.4	65.4	-46.3	-27.3	-17.9	1727
1947	-10.7	-6.8	-3.9	8.3	312.1	235.5	946.4	531.0	95.0	-31.0	-32.9	-20.9	2022
1948	-16.0	-11.5	-8.1	6.4	27.4	243.7	696.8	574.1	269.3	-29.1	-32.0	-19.4	1702
1949	-9.7	-5.5	-2.4	42.8	143.0	646.2	815.6	604.9	189.2	-54.5	-35.4	-22.8	2312
1950	-17.9	-12.8	-9.0	-3.6	229.2	347.4	714.9	517.5	154.1	-29.6	-32.2	-20.5	1837
1951	-13.4	-9.1	-5.9	1.5	208.5	507.1	858.7	375.5	171.0	-54.8	-35.2	-23.8	1980
1952	-14.5	-9.7	-6.1	49.4	109.5	652.0	844.7	567.5	333.5	-42.4	-41.4	-25.4	2417
1953	-17.1	-11.4	184.3	22.7	91.0	1011.3	1142.9	637.4	366.1	30.3	34.5	-39.6	3453
1954	-87.5	-21.4	-12.3	24.6	447.4	693.3	1120.8	434.3	227.4	15.6	-27.5	-110.2	2705
1955	-93.4	-98.4	-54.3	79.4	320.9	1026.9	788.1	733.3	148.3	-116.9	-69.4	-78.4	2586

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	-71.2	-122.3	75.8	129.0	625.4	1108.5	840.8	367.9	219.2	-89.8	17.7	-83.6	3017
1957	-170.3	-111.6	-77.5	4.8	632.7	561.8	879.8	436.5	146.9	-77.9	-13.0	-80.3	2132
1958	-143.3	-84.6	28.0	-17.9	793.9	509.3	432.3	586.8	123.5	-86.8	-50.1	-25.8	2065
1959	-47.2	-24.4	138.0	168.6	70.5	819.2	929.8	434.7	80.3	2.1	-99.6	-237.6	2234
1960	25.7	70.2	114.4	-2.9	212.1	930.5	900.2	289.8	130.5	-167.5	-98.0	-33.5	2371
1961	-90.9	9.4	26.2	-54.9	225.2	1252.0	685.6	438.5	-33.3	33.1	-21.3	-110.5	2359
1962	-106.6	-21.1	-73.4	249.6	403.1	938.4	712.6	358.7	188.1	-34.6	6.8	-9.0	2612
1963	-78.7	34.0	-7.4	12.5	195.8	311.7	878.6	536.1	198.7	-70.8	-23.5	-105.3	1882
1964	-44.5	-5.5	-16.5	-18.9	285.4	670.5	965.1	194.3	199.5	-26.4	-55.0	-106.3	2042
1965	-64.1	-57.3	-97.3	89.8	294.9	1090.9	850.9	310.3	-180.1	-347.2	-158.7	-114.1	1618
1966	-89.8	-28.2	-8.1	-18.4	366.3	559.3	822.4	349.1	167.7	1.4	58.0	-124.1	2056
1967	-172.9	-164.1	-144.7	-29.5	605.0	1131.2	834.3	550.5	191.1	-32.1	42.9	-159.5	2652
1968	-123.7	-88.7	-243.1	-79.2	174.3	963.8	890.5	257.9	158.0	-56.0	-25.8	-110.2	1718
1969	-113.1	-75.2	-65.7	219.4	591.0	459.3	843.2	586.5	173.7	19.5	-32.2	-118.8	2488
1970	-140.8	-69.1	-83.3	-152.3	370.6	1237.1	709.6	444.7	44.7	-76.7	-46.0	-121.3	2117
1971	-122.4	-28.9	-163.0	-79.0	320.2	1283.1	866.9	439.7	117.2	-36.7	-24.8	-142.5	2430
1972	-116.2	-83.3	138.6	-121.4	218.8	1246.8	520.3	240.5	22.6	-80.6	-28.9	-136.9	1820
1973	-100.9	-54.0	46.8	119.4	609.5	735.7	835.6	395.0	178.1	15.6	13.4	-81.7	2712
1974	-100.5	-85.7	-80.9	55.7	165.1	1386.6	699.1	125.0	143.8	-6.0	24.9	-78.4	2249
1975	-162.9	-125.2	-111.3	22.1	403.7	1223.3	585.4	326.2	208.4	-56.0	-111.1	-71.1	2132
1976	-84.1	-100.9	-159.7	-72.4	748.9	685.3	812.3	347.8	167.6	8.2	-17.7	-92.5	2243
1977	-142.8	-57.2	-31.6	108.1	138.6	947.5	766.4	322.9	106.8	57.0	-33.5	-117.0	2065
1978	-136.8	-136.6	64.0	32.9	253.6	1149.0	837.9	526.1	121.3	-9.3	-102.1	-158.5	2442
1979	-216.1	-106.6	92.2	56.1	662.3	1072.7	805.5	498.4	292.0	-65.4	8.2	-81.5	3018
1980	-176.3	-45.3	17.0	175.5	638.8	725.2	866.5	340.9	268.1	-40.5	-44.7	-78.1	2647
1981	-116.2	-120.2	-62.7	38.8	631.7	510.2	840.9	676.1	281.9	36.0	14.9	-81.8	2650
1982	-185.5	-68.8	-73.7	42.1	361.7	994.8	959.7	582.5	164.0	-11.8	-8.0	-75.2	2682
1983	-70.7	-92.3	-50.6	-21.0	373.9	1057.8	801.9	604.3	183.8	37.9	-76.8	-167.6	2581
1984	-84.2	-91.3	-73.5	37.5	614.3	863.1	934.1	517.2	-101.8	-87.9	-2.0	-139.1	2386
1985	-101.2	-114.0	24.4	221.1	505.7	1087.9	930.6	284.2	59.8	56.0	-149.6	-98.6	2706
1986	-86.2	27.2	19.6	85.3	394.6	1197.8	709.2	471.4	23.3	-7.1	-71.7	-131.1	2632
1987	-172.4	-35.0	23.7	114.3	180.1	971.0	621.0	379.1	293.7	-48.5	-59.1	-98.3	2170
1988	-117.9	-34.6	-14.7	117.5	389.1	1003.1	789.7	434.8	56.4	-43.6	-13.5	-15.4	2551
1989	-70.2	-123.3	65.2	96.6	319.6	1029.2	812.9	289.0	317.5	-39.9	98.6	-80.4	2715
1990	-87.0	-105.7	-60.4	147.9	228.3	1109.6	809.6	331.3	357.4	-58.0	34.7	-145.4	2562
1991	-168.0	-54.9	-39.7	13.3	443.8	818.1	953.7	429.5	54.8	-80.9	11.6	-70.7	2311
1992	-112.5	-64.8	-11.0	74.3	434.6	626.9	724.8	528.9	201.7	5.3	35.2	-74.3	2369
1993	-119.9	-82.0	108.5	107.3	543.8	549.6	325.4	294.9	207.4	-88.1	-68.7	-116.4	1662
1994	-135.0	-127.0	24.7	167.8	419.8	766.6	710.6	538.1	256.2	-64.4	1.8	-43.4	2516
1995	-66.0	-9.4	-3.8	12.1	175.7	1082.4	612.2	505.8	124.5	-41.8	45.8	-69.0	2368
1996	-180.8	-51.8	-181.8	32.1	397.9	1033.8	709.4	526.4	77.4	-43.0	5.6	-109.4	2216

Note: Positive numbers indicate streamflow depletions from the system, negative numbers indicate returns of water withdrawals back into the system.

Table A-21. Historic Depletions Between Fort Peck and Garrison Dams (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	-4.4	-1.8	-0.4	47.1	43.0	134.3	272.5	198.7	73.6	-20.3	-17.0	-9.1	716
1899	-4.0	-1.4	0.0	31.8	153.4	205.6	200.5	162.4	88.6	-17.7	-18.3	-9.6	791
1900	-2.9	-0.6	0.8	26.4	352.4	358.9	230.1	119.7	26.1	-14.0	-13.3	-5.9	1078
1901	-1.3	0.4	1.1	72.8	402.3	185.0	337.5	228.8	38.2	-11.1	-23.9	-12.2	1218
1902	-6.5	-3.0	-1.4	75.5	313.0	253.6	304.7	207.8	94.4	-16.9	-25.5	-13.3	1182
1903	-7.7	-4.3	-2.6	13.7	210.7	318.7	226.7	195.2	48.9	-8.0	-21.0	-11.0	959
1904	-3.5	-0.7	0.8	107.8	301.5	244.7	333.5	232.6	121.9	-17.8	-28.0	-14.8	1278
1905	-8.4	-4.5	-2.5	77.5	72.2	231.9	326.5	341.1	110.1	-30.5	-26.3	-13.8	1073
1906	-4.7	-1.0	1.3	102.8	217.8	382.8	467.6	175.7	162.4	-20.2	-31.6	-17.4	1436
1907	-8.2	-3.8	-1.8	30.9	178.0	369.8	421.3	305.3	145.8	-7.9	-33.7	-18.4	1377
1908	-7.9	-3.0	-0.5	136.7	170.7	414.7	493.1	266.7	141.7	-43.8	-32.4	-17.3	1519
1909	-8.4	-3.9	-1.7	6.9	237.3	388.6	430.1	360.4	90.5	-23.4	-32.5	-17.0	1427
1910	-6.1	-1.4	1.0	146.3	406.2	517.0	458.6	236.9	76.4	-9.4	-23.4	-11.2	1791
1911	-5.0	-1.7	-0.2	81.9	363.1	621.6	400.3	207.3	58.4	-49.7	-29.5	-14.9	1631
1912	-7.5	-4.0	-2.3	75.0	299.1	589.8	330.9	227.4	0.3	-42.9	-24.9	-12.3	1429
1913	-2.3	0.7	2.2	129.6	507.6	566.6	475.3	345.1	87.7	-57.8	-33.7	-22.2	1999
1914	-10.3	-6.2	-10.4	89.8	634.4	420.2	651.5	373.3	170.3	-29.5	-51.6	-46.4	2185
1915	-37.8	-26.2	-26.0	264.2	337.1	168.6	333.4	410.8	16.8	-7.7	-45.1	-30.4	1358
1916	-27.9	-17.2	0.7	128.8	430.2	440.8	471.3	259.4	71.5	-53.2	-47.9	-37.6	1619
1917	-31.1	-16.3	-17.4	3.0	250.8	631.8	797.3	351.1	152.3	-58.3	-60.2	-37.9	1965
1918	-26.5	-17.4	-3.3	32.0	577.2	976.1	572.3	283.6	84.0	-11.4	-60.8	-44.6	2361
1919	-28.1	-18.0	-18.7	152.7	810.9	799.7	576.1	408.7	166.7	-81.0	-52.2	-31.6	2685
1920	-27.4	-21.0	-17.8	-12.7	559.9	798.9	794.0	476.2	179.9	-65.5	-98.9	-99.0	2467
1921	-35.3	-21.7	-60.4	106.8	609.1	816.7	721.8	517.1	143.7	-26.6	-60.1	-36.6	2674
1922	-15.4	-7.7	-2.4	7.9	555.0	940.0	280.5	582.1	230.4	-68.0	-62.3	-39.8	2400
1923	-18.2	-9.1	-8.6	106.4	690.3	604.1	666.5	379.9	-22.8	-50.8	-46.8	-32.3	2259
1924	-14.9	-4.4	-2.5	89.6	458.2	255.2	698.9	515.1	246.4	-35.9	-55.7	-39.2	2111
1925	-16.0	-4.4	1.0	311.8	1004.6	493.8	649.9	526.1	167.7	-95.6	-63.7	-37.6	2938
1926	-24.7	-12.5	-7.4	205.7	799.0	763.3	657.0	438.1	52.2	-19.4	-36.5	-29.8	2785
1927	-38.0	-9.5	-2.5	98.1	299.5	822.8	695.4	384.3	161.1	-26.6	-54.1	-38.9	2292
1928	-13.0	-9.5	1.7	166.5	1388.9	423.3	605.2	440.4	254.8	-96.8	-66.6	-35.8	3059
1929	-19.3	-9.9	2.6	59.6	571.8	828.4	866.9	610.1	91.3	-64.4	-63.2	-34.0	2840
1930	-19.2	-4.7	-0.6	288.7	739.9	815.6	793.9	478.1	176.7	-74.9	-99.6	-62.8	3031
1931	-18.7	-8.5	5.8	139.3	868.4	1097.4	726.7	498.0	157.4	-43.5	-52.2	-37.8	3332
1932	-19.1	-8.8	-7.1	101.1	844.3	598.7	866.5	474.7	119.9	-81.0	-61.8	-37.2	2790
1933	-15.8	-8.4	0.6	68.4	552.1	1290.0	940.0	227.5	246.7	-44.3	-54.3	-29.4	3173
1934	-9.8	0.2	2.8	284.8	1476.4	695.8	767.4	502.3	93.8	-32.0	-56.9	-29.2	3696
1935	-19.8	-8.1	-5.8	30.8	443.9	1017.3	907.7	547.2	288.7	-93.9	-70.7	-39.1	2998
1936	-16.4	-6.0	1.7	196.8	1307.0	886.6	921.1	497.8	183.1	-66.1	-63.2	-30.9	3811
1937	-18.1	-9.4	-1.8	152.5	1180.0	620.2	808.6	630.6	203.3	-85.5	-68.3	-36.2	3376
1938	-22.3	-12.4	-4.2	168.3	556.8	871.8	752.3	545.4	346.8	-66.4	-67.9	-36.9	3031
1939	-15.9	-9.1	11.0	310.0	913.0	444.3	1017.3	481.1	238.1	-106.9	-157.4	-70.9	3055
1940	-23.9	-6.3	18.6	101.0	1180.6	916.8	841.2	593.0	245.8	-79.3	-126.9	-110.3	3550
1941	-22.6	-11.0	2.7	132.9	1133.1	908.1	855.5	575.5	46.7	-52.3	-68.7	-41.1	3459
1942	-27.8	-17.1	3.6	213.0	366.2	772.2	994.2	561.4	163.0	-81.3	-70.0	-51.6	2826
1943	-34.8	-13.9	26.9	367.4	640.8	551.8	947.3	573.3	268.5	-77.5	-80.3	-51.6	3118
1944	-46.6	-31.3	-24.1	167.2	847.6	610.7	755.4	474.8	135.7	-41.4	-79.1	-42.8	2726
1945	-38.4	-26.5	-10.1	11.3	477.0	591.3	1044.8	531.0	132.9	-26.8	-63.1	-43.7	2580
1946	-30.5	-18.5	-1.6	365.4	470.6	717.5	906.5	520.5	105.8	-89.6	-70.4	-49.5	2826
1947	-33.8	-19.7	63.2	100.4	973.4	428.3	954.5	579.8	166.9	-39.7	-78.8	-52.4	3042
1948	-35.1	-27.4	-15.7	256.5	1033.6	725.9	643.4	581.3	266.4	-75.1	-92.0	-70.6	3191
1949	-58.8	-38.9	-28.6	335.3	974.4	960.6	819.3	624.4	164.9	-115.3	-85.1	-68.1	3484
1950	-61.2	-46.2	-21.1	79.9	585.4	842.0	839.7	499.7	96.1	6.6	-67.5	-57.2	2696
1951	-44.2	-18.8	6.0	74.9	991.0	653.3	1009.6	462.5	108.9	-104.9	-85.7	-64.3	2988
1952	-56.6	-28.6	87.0	420.9	1048.8	1336.4	788.6	562.9	294.6	-112.8	-126.6	-80.9	4134
1953	-58.6	-62.0	-42.3	-12.5	396.0	1354.3	1205.1	596.7	273.3	-107.6	-115.6	-95.8	3331
1954	-36.4	15.1	18.8	145.6	1071.7	911.0	1197.7	464.7	165.3	-120.5	-126.4	-106.8	3600
1955	-86.7	-42.3	-55.3	89.7	656.5	1090.2	1037.0	715.4	168.2	-75.8	-113.5	-82.5	3301

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	-95.4	-100.0	7.0	113.1	1197.9	1739.2	881.5	427.3	194.4	-151.6	-170.5	-122.5	3920
1957	-84.2	-51.6	-11.0	55.2	947.2	1120.5	1072.8	600.2	198.6	-129.3	-145.7	-116.6	3456
1958	-134.7	-109.9	-62.7	204.7	1956.1	747.5	543.9	565.5	163.2	-197.9	-166.4	-125.2	3384
1959	-93.9	-2.6	86.2	127.1	726.4	1556.8	1105.2	607.3	119.5	-98.3	-96.6	-74.9	3962
1960	-56.7	-47.5	52.1	151.4	1019.5	1075.8	976.5	417.7	231.0	-29.1	-33.9	-23.7	3733
1961	-13.4	2.1	17.4	82.4	952.0	1644.3	864.6	693.9	-15.7	-43.2	-81.9	-85.7	4017
1962	-65.1	10.6	-78.8	402.9	567.3	1388.4	764.7	484.7	188.6	-112.5	-116.1	-108.4	3326
1963	-68.5	-2.8	-18.6	101.5	1197.5	1090.2	954.6	663.5	384.9	-101.9	-148.2	-148.1	3904
1964	-118.2	-39.7	-44.9	55.8	1073.7	959.2	1260.9	413.5	242.2	-97.1	-114.8	-90.2	3500
1965	-68.9	-77.6	-76.5	173.0	655.8	1317.8	940.2	470.8	8.6	-54.0	14.6	-83.3	3221
1966	-72.8	11.0	141.4	130.2	1324.5	1097.6	995.4	463.7	345.8	-32.0	-55.7	-83.3	4266
1967	-37.4	-39.8	20.4	-14.7	880.8	1522.8	733.6	618.0	224.2	-67.1	-140.4	-228.2	3472
1968	-224.1	-98.0	-75.0	-36.9	610.6	1186.8	1113.7	538.6	212.8	-84.5	-125.3	-150.7	2868
1969	-119.8	-104.4	-53.5	322.4	1451.5	824.6	844.6	643.4	251.8	-154.5	-123.7	-161.7	3621
1970	-169.8	-113.9	-11.2	75.2	1037.6	1519.4	877.6	681.8	127.8	-97.7	-111.3	-183.2	3632
1971	-134.9	-67.4	-136.8	-37.1	724.7	1839.6	1002.0	672.1	139.8	-131.0	-174.8	-156.4	3540
1972	-138.5	-23.5	24.8	-120.7	856.8	1673.5	669.9	522.3	167.5	-115.9	-199.9	-150.4	3166
1973	-127.1	-103.3	-26.1	93.6	1155.2	1136.4	954.9	516.2	112.2	-102.7	-178.9	-73.3	3357
1974	-76.4	-117.4	-126.6	100.3	648.3	1794.4	896.1	281.9	132.2	-137.3	-129.0	-169.1	3097
1975	-155.2	-115.8	-50.2	-4.7	430.4	1076.0	1425.7	378.0	209.4	-99.9	-166.1	-149.2	2779
1976	-136.9	-107.6	-92.2	38.8	1275.4	1100.5	1224.7	562.7	270.3	-68.1	-196.6	-163.2	3708
1977	-166.6	-62.6	-6.0	438.0	961.7	1254.3	781.2	416.4	173.8	4.2	-21.3	-50.9	3722
1978	-74.7	-96.4	50.9	117.2	646.1	1584.3	844.5	460.8	36.5	-91.7	-172.0	-176.8	3128
1979	-118.8	-93.3	102.8	61.7	1044.2	1336.7	809.2	583.4	329.2	-49.1	-67.7	-113.6	3825
1980	-109.9	-83.3	-44.9	322.9	1342.0	1390.7	930.5	343.1	188.5	-142.3	-86.3	-101.8	3949
1981	-99.1	-73.0	-12.0	303.8	871.7	1199.3	789.1	637.0	293.0	-124.0	-157.9	-153.4	3474
1982	-136.4	-87.6	-84.4	-18.6	627.5	1242.1	1135.7	591.1	95.9	-3.1	-190.8	-197.4	2974
1983	-129.3	-86.8	-68.1	44.5	755.0	1548.3	798.2	761.4	86.2	-81.7	-178.3	-163.3	3286
1984	-84.9	-81.3	0.0	123.6	1298.7	1154.1	1073.9	622.5	54.0	-133.0	-170.2	-162.9	3695
1985	-115.8	-110.2	-13.2	323.5	1246.0	1096.3	934.3	395.2	97.2	-46.2	-106.0	-104.3	3597
1986	-75.1	25.3	-34.3	90.9	777.8	1835.3	664.9	545.6	-7.4	-80.0	-140.3	-149.9	3453
1987	-103.1	-41.5	1.9	424.5	1176.1	1269.5	606.9	388.1	264.3	-41.7	-135.6	-125.7	3684
1988	-97.2	-51.7	-4.0	252.1	1068.1	1414.2	802.1	523.2	63.3	-24.2	-50.2	-55.3	3840
1989	-47.5	-41.1	53.1	186.4	919.3	1382.6	1179.9	507.2	267.0	13.1	-73.3	-147.4	4199
1990	-116.7	-89.0	-39.3	182.9	888.5	1387.8	888.5	594.2	374.3	-50.0	-83.4	-146.6	3791
1991	-133.9	-44.6	-13.5	169.5	1243.0	1223.7	765.3	690.2	110.4	-152.8	-129.6	-149.5	3578
1992	-130.9	-42.7	11.2	156.1	1143.9	1064.6	716.6	451.6	254.6	-38.6	-109.6	-123.4	3353
1993	-97.2	-49.7	61.0	164.1	1450.1	955.7	293.1	455.1	204.1	-153.5	-177.1	-115.5	2990
1994	-104.3	-67.7	26.0	222.3	1318.2	854.2	658.8	572.7	214.7	-19.0	-36.3	-51.4	3588
1995	-46.0	23.3	39.5	25.6	725.7	1549.3	935.8	606.3	147.3	-118.9	-81.7	-107.3	3699
1996	-87.2	-44.9	-86.4	-37.5	505.1	1714.5	1118.4	686.8	119.3	-81.4	-105.0	-128.6	3573

Table A-22. Historic Depletions Between Garrison and Oahe Dams (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	-1.4	-0.6	-0.2	0.0	33.6	69.2	71.1	69.2	28.3	-8.9	-6.1	-3.1	251
1899	-1.7	-0.9	-0.4	-0.2	17.2	54.8	68.9	43.0	36.4	-1.9	-5.7	-3.2	207
1900	-0.9	-0.1	0.3	13.3	105.5	81.2	69.8	38.8	-0.2	1.6	-3.8	-1.7	304
1901	-0.8	-0.3	-0.1	13.8	106.3	22.6	67.5	61.0	11.8	1.2	-4.1	-1.9	277
1902	-0.8	-0.2	0.1	7.2	93.2	36.9	85.4	40.8	38.1	1.7	-7.0	-3.9	292
1903	-2.2	-1.2	-0.7	7.7	60.3	66.4	78.0	28.3	8.4	7.4	-5.3	-3.1	244
1904	-1.3	-0.5	-0.1	16.1	56.3	44.7	81.0	53.3	34.6	5.8	-7.1	-4.0	279
1905	-2.2	-1.1	-0.6	0.9	18.4	46.8	70.4	78.5	47.5	-1.1	-7.4	-4.1	246
1906	-2.0	-1.0	-0.3	11.4	-0.9	51.4	91.2	44.9	49.8	4.6	-7.1	-4.2	238
1907	-2.1	-1.0	-0.5	-0.1	13.7	67.9	49.3	65.2	22.3	2.1	-5.7	-3.2	208
1908	-1.3	-0.5	0.0	5.9	22.6	50.7	76.1	61.9	44.8	-5.2	-6.7	-3.6	245
1909	-1.9	-0.9	-0.4	-0.1	21.7	67.9	51.6	43.7	38.9	1.9	-6.1	-3.4	213
1910	-1.2	-0.4	0.1	13.0	53.9	57.0	76.6	50.4	30.6	6.4	-4.7	-2.5	279
1911	-0.9	-0.2	0.2	6.1	76.6	93.8	79.0	36.1	26.1	-5.1	-6.3	-3.3	302
1912	-1.8	-1.0	-0.6	6.4	51.8	75.3	55.5	44.7	18.0	2.8	-5.7	-3.1	242
1913	-1.4	-0.6	-0.2	9.7	25.8	83.4	62.7	61.4	33.7	-2.7	-4.4	-2.2	265
1914	-1.0	-0.4	0.0	0.2	49.2	19.2	77.3	48.8	40.5	5.1	-6.5	-3.7	229
1915	-2.3	-1.2	-0.7	15.5	16.6	23.2	33.5	59.1	21.9	-0.3	-4.5	-2.4	158
1916	-0.9	-0.3	0.1	1.5	22.0	42.4	88.7	44.3	32.4	0.1	-5.8	-3.3	221
1917	-1.2	-0.3	0.1	0.3	48.1	65.4	90.5	60.9	25.6	0.1	-6.7	-3.7	279
1918	-1.8	-0.8	-0.3	-0.1	51.2	80.2	70.0	45.5	30.7	3.8	-6.7	-3.8	268
1919	-1.8	-0.9	-0.4	0.8	20.4	61.5	85.2	71.1	38.2	-5.0	-4.6	-2.3	262
1920	-1.1	-0.4	0.0	0.1	30.9	32.5	69.4	59.0	27.3	4.5	-5.9	-3.3	213
1921	-1.4	-0.4	0.1	0.3	51.2	88.9	77.1	46.9	11.9	2.2	-5.9	-3.2	268
1922	-1.8	-0.9	-0.5	2.3	36.3	30.4	60.2	69.1	33.1	2.7	-4.4	-2.2	224
1923	-1.2	-0.5	-0.1	2.0	47.1	31.7	54.8	44.9	14.4	1.4	-4.5	-2.4	188
1924	-1.4	-0.7	-0.3	-0.2	20.8	20.1	55.6	53.8	25.6	-3.0	-4.6	-2.4	163
1925	-1.0	-0.3	0.1	12.9	60.6	1.1	62.3	53.1	33.6	-3.9	-5.4	-2.8	210
1926	-1.4	-0.6	-0.2	9.6	56.6	54.2	61.2	43.6	9.6	-3.8	-4.6	-2.3	222
1927	-1.5	-0.9	-0.6	-0.4	8.2	44.8	39.3	43.9	23.9	3.5	-4.6	-2.6	153
1928	-1.1	-0.5	-0.1	0.9	69.5	23.8	41.6	25.3	22.3	-1.2	-4.1	-2.2	174
1929	-0.8	-0.3	-0.1	0.0	9.7	37.9	49.3	34.8	11.4	-1.8	-3.1	-1.7	135
1930	-0.7	-0.2	0.1	0.2	28.5	28.3	43.5	41.2	22.6	-2.8	-3.9	-2.0	155
1931	-0.8	-0.3	0.0	1.6	31.9	54.2	47.6	33.7	21.0	-1.5	-2.8	-1.4	183
1932	-0.6	-0.2	0.0	0.1	18.4	43.3	52.6	35.4	22.8	-4.5	-3.8	-2.0	162
1933	-0.9	-0.4	-0.1	0.0	3.7	56.4	53.7	29.0	20.9	-0.2	-2.9	-1.6	158
1934	-0.5	-0.1	0.2	1.5	60.8	26.8	45.4	31.8	8.5	-0.3	-2.4	-1.1	170
1935	-0.6	-0.2	-0.1	0.4	0.9	32.6	60.4	37.0	22.9	-1.1	-3.9	-2.2	146
1936	-0.7	-0.1	0.2	0.4	49.3	48.6	55.3	40.5	16.8	-2.6	-3.0	-1.4	204
1937	-0.9	-0.5	-0.2	2.6	24.6	24.7	36.3	42.9	13.3	-0.9	-3.4	-1.8	137
1938	-0.9	-0.4	-0.1	0.8	5.8	37.6	43.2	36.9	18.0	-0.1	-3.6	-2.0	135
1939	-0.8	-0.3	0.0	3.7	43.4	23.5	46.0	26.2	17.6	-1.9	-3.2	-1.6	153
1940	-0.8	-0.4	-0.1	0.0	39.1	30.6	38.9	29.0	14.9	-0.4	-2.3	-1.1	147
1941	-0.6	-0.3	-0.1	0.0	34.9	16.7	43.5	23.1	5.0	-1.8	-2.4	-1.2	117
1942	-0.7	-0.3	-0.2	-0.1	2.0	18.6	46.5	30.4	9.0	-1.3	-2.5	-1.3	100
1943	-0.5	0.0	0.2	4.0	24.1	14.1	38.3	38.2	20.6	-1.9	-3.4	-1.8	132
1944	-1.0	-0.5	-0.2	0.3	20.9	12.4	33.8	28.9	19.6	-1.0	-2.9	-1.6	109
1945	-0.8	-0.4	-0.1	2.0	12.7	8.4	47.1	32.1	5.7	0.4	-2.4	-1.3	103
1946	-0.7	-0.2	0.0	0.5	0.6	19.4	50.0	35.2	6.0	-3.9	-2.3	-1.2	103
1947	-0.2	0.1	0.3	0.4	34.8	8.8	58.9	47.7	16.2	-2.0	-3.7	-1.9	159
1948	-1.0	-0.4	-0.1	0.3	35.9	20.8	46.8	35.3	26.0	-1.8	-3.9	-2.1	156
1949	-0.8	-0.3	0.1	1.3	36.8	46.0	60.2	44.4	17.1	-5.0	-4.1	-2.1	194
1950	-1.1	-0.5	-0.2	-0.1	29.3	53.3	47.2	35.6	9.8	-0.2	-3.6	-1.9	168
1951	-1.1	-0.6	-0.3	1.5	34.4	17.0	46.2	26.8	8.6	4.8	4.4	4.7	146
1952	6.7	16.6	29.6	27.6	42.9	48.1	26.4	-9.1	-0.9	-5.8	-7.3	-0.5	174
1953	1.4	3.6	30.0	4.8	47.8	89.8	1.1	22.3	-8.7	-1.8	1.6	4.9	197
1954	4.9	12.7	13.1	21.5	36.9	37.8	13.7	-5.6	-10.8	-2.8	0.5	6.0	128
1955	7.0	7.7	35.0	92.5	43.7	32.2	4.4	21.4	-1.1	3.0	-3.5	11.7	254

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	5.5	7.4	25.2	10.2	29.5	30.9	-9.7	-16.1	-1.7	-1.5	5.5	8.0	93
1957	5.5	11.8	16.4	20.3	71.4	44.5	20.3	-5.9	5.9	1.0	2.9	3.8	198
1958	-2.8	8.8	22.2	32.2	68.6	26.6	28.2	-4.4	-5.9	-4.3	-3.8	3.1	168
1959	4.0	4.3	30.8	13.2	20.5	44.2	43.4	6.6	2.2	3.4	2.0	6.9	182
1960	7.5	8.2	51.0	15.1	21.3	39.8	29.4	15.2	20.6	0.6	1.0	5.6	215
1961	6.4	8.1	8.9	5.4	40.7	64.7	26.0	48.4	5.6	2.8	0.9	4.2	222
1962	6.3	32.2	27.8	10.3	148.2	97.7	57.0	14.2	-6.0	4.6	3.7	6.1	402
1963	6.8	35.0	21.9	11.4	54.5	54.1	17.8	-5.1	12.5	-6.2	1.3	4.9	209
1964	8.9	10.0	14.1	24.1	43.9	105.7	46.1	-21.3	3.0	8.2	0.9	8.2	252
1965	11.9	18.8	22.2	41.5	33.6	26.5	48.3	3.8	-9.9	-0.3	6.2	9.3	212
1966	10.9	4.3	17.9	3.4	60.9	-0.6	25.9	17.4	-3.8	5.0	8.7	6.2	156
1967	13.5	20.2	39.9	16.1	58.1	32.0	36.9	-9.2	-1.0	4.2	6.8	7.2	225
1968	11.5	15.5	31.6	17.5	25.0	41.7	17.4	5.8	9.6	0.9	5.9	7.2	190
1969	10.1	10.3	43.7	37.8	53.5	18.4	43.0	3.8	0.9	-2.2	7.8	7.7	235
1970	14.5	18.7	20.2	44.4	50.9	70.6	14.0	8.2	-5.5	6.5	8.0	11.6	262
1971	12.9	42.8	47.4	54.9	31.9	58.1	9.5	-8.1	-1.5	31.1	14.4	13.2	307
1972	13.7	46.0	33.4	0.6	14.6	32.0	11.9	18.0	4.7	9.2	12.3	11.2	207
1973	16.7	4.2	9.5	11.3	46.7	65.7	17.5	2.7	24.1	14.0	13.3	12.9	238
1974	27.5	21.9	17.8	3.0	23.1	50.9	15.3	-7.1	20.2	6.8	7.4	9.6	196
1975	12.7	13.5	49.6	47.8	68.7	54.2	52.8	-1.6	8.2	3.5	5.1	11.0	325
1976	16.7	18.1	24.1	20.6	61.7	93.8	60.5	37.6	25.1	4.9	5.9	8.6	377
1977	11.5	13.0	26.1	60.7	82.0	65.2	63.1	27.1	29.9	17.5	4.0	8.8	409
1978	11.7	12.2	145.9	29.5	73.2	53.1	53.8	17.9	22.9	6.1	5.1	9.8	441
1979	10.2	11.9	44.8	27.6	32.5	39.9	27.8	31.3	14.3	-1.3	2.0	7.3	248
1980	10.1	21.5	15.2	17.8	42.8	73.8	21.4	2.3	36.7	1.3	3.8	10.8	258
1981	10.5	10.3	12.9	10.8	17.7	45.6	35.4	19.2	8.3	5.6	4.3	7.4	188
1982	7.0	17.2	22.3	15.4	125.5	103.3	73.4	38.0	6.3	28.2	11.6	10.2	458
1983	18.6	21.2	4.0	2.5	39.5	65.3	35.8	43.7	5.9	8.5	7.2	8.5	261
1984	13.3	21.7	43.7	17.9	107.6	45.3	63.9	34.4	3.3	11.7	8.1	8.7	380
1985	10.6	10.4	38.2	19.9	42.7	6.7	8.0	-1.1	8.3	8.8	6.9	9.1	168
1986	10.8	23.9	59.0	51.5	73.3	58.4	9.3	19.7	5.3	23.5	9.0	7.6	351
1987	11.5	17.8	41.5	33.6	33.8	72.9	24.9	20.8	27.1	5.8	0.9	6.5	297
1988	7.8	12.8	23.6	22.7	33.5	27.0	56.8	17.6	18.4	10.1	5.5	8.4	244
1989	9.3	9.1	30.3	20.5	87.2	50.9	39.6	124.7	27.1	2.2	5.5	9.9	416
1990	11.1	16.1	24.1	17.5	57.6	57.4	27.8	31.8	30.7	3.2	2.0	5.6	285
1991	7.1	10.0	12.8	15.7	114.0	61.2	66.2	45.1	27.9	0.9	6.8	8.0	376
1992	8.2	10.6	12.6	15.2	55.5	48.9	29.5	16.1	31.9	4.8	3.9	5.2	242
1993	7.2	8.0	54.5	36.7	76.1	91.9	55.4	48.8	13.1	2.7	-6.4	8.1	396
1994	12.8	32.9	46.9	14.9	83.4	51.6	23.8	24.9	37.7	20.5	6.9	9.2	365
1995	11.4	14.5	26.0	20.0	50.5	58.3	65.3	42.8	16.3	12.8	15.1	1.9	335
1996	14.1	31.4	46.7	12.2	26.6	82.9	62.9	57.0	0.8	9.9	-2.9	7.5	349

Table A-23. Historic Depletions Between Oahe and Big Bend Dams (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1899	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1901	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1902	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1903	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1904	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1905	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1906	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1907	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1908	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1909	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1910	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1911	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1912	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1913	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1914	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1915	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1916	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1917	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1918	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1919	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1920	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1921	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1922	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1923	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1924	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1925	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1926	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1927	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1928	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1929	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1930	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1931	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0
1932	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0
1933	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0
1934	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0
1935	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0
1936	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.0	0.0	0.0	0.0	1
1937	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.0	0.0	0.0	1
1938	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	1
1939	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.2	0.0	0.0	0.0	0.0	1
1940	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.0	1
1941	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0
1942	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0
1943	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0
1944	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1945	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1946	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1947	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1948	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1949	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1950	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0
1951	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0
1952	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.2	0.1	0.0	0.0	0.0	1
1953	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.2	0.1	0.0	0.0	0.0	1
1954	0.0	0.0	0.0	0.0	0.2	0.1	0.5	0.3	0.1	0.0	0.0	0.0	1
1955	0.0	0.0	0.0	0.0	0.2	0.2	0.5	0.4	0.1	0.0	0.0	0.0	1

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	0.0	0.0	0.0	0.0	0.1	0.6	0.3	0.2	0.1	0.0	0.0	0.0	1
1957	0.0	0.0	0.0	0.0	0.0	0.2	0.6	0.3	0.1	0.0	0.0	0.0	1
1958	0.0	0.0	0.0	0.0	0.2	0.2	0.5	0.6	0.2	0.0	0.0	0.0	2
1959	0.0	0.0	0.0	0.0	0.0	0.5	0.6	0.6	0.0	0.0	0.0	0.0	2
1960	0.0	0.0	0.0	0.0	0.1	0.2	0.9	0.4	0.2	0.0	0.0	0.0	2
1961	0.0	0.0	0.0	0.0	0.1	0.7	0.8	0.8	0.1	0.0	0.0	0.0	2
1962	0.0	0.0	0.0	0.1	0.0	0.4	0.7	1.0	0.4	0.0	0.0	0.0	2
1963	0.0	0.0	0.0	0.0	0.3	0.7	0.9	1.1	0.2	0.0	-0.1	0.0	3
1964	0.0	0.0	0.0	0.0	0.5	0.6	1.4	0.9	0.4	0.0	-0.1	0.0	4
1965	0.0	0.0	0.0	0.0	0.2	0.7	1.8	1.5	-0.1	0.0	-0.1	0.0	4
1966	0.0	0.0	0.0	0.0	1.1	2.4	2.5	1.3	0.3	-0.1	-0.1	0.0	7
1967	0.0	0.0	0.0	0.0	0.4	0.5	3.7	3.0	0.4	-0.1	-0.1	-0.1	8
1968	0.0	0.0	0.0	0.0	0.6	0.9	3.0	2.1	0.9	-0.1	-0.1	-0.1	7
1969	0.0	0.0	0.0	0.2	1.1	1.1	2.8	4.2	0.8	-0.2	-0.2	-0.1	10
1970	0.0	0.0	0.0	0.0	1.2	2.9	4.2	2.3	0.3	-0.2	-0.1	-0.1	11
1971	0.0	0.0	0.0	0.0	0.6	1.6	3.3	2.8	0.5	-0.2	-0.1	-0.1	8
1972	0.0	0.0	0.0	0.0	0.1	1.4	1.3	2.0	0.9	-0.1	-0.1	-0.1	5
1973	0.0	0.0	0.1	0.1	1.0	4.4	5.3	4.3	-0.1	-0.3	-0.2	-0.1	15
1974	0.0	0.0	0.0	0.0	0.4	5.2	5.8	3.7	1.8	-0.2	-0.2	-0.1	17
1975	0.0	0.0	0.0	0.0	1.6	2.1	9.2	5.3	0.5	-0.3	-0.2	-0.1	18
1976	0.1	0.1	0.2	0.4	4.7	11.0	12.7	9.7	3.4	-0.3	-0.4	-0.1	41
1977	0.0	0.0	0.1	0.4	5.0	9.4	13.7	7.6	0.5	-0.8	-0.4	-0.2	35
1978	-0.1	0.0	0.0	0.0	2.2	8.9	9.1	7.9	4.4	-0.2	-0.5	-0.3	31
1979	-0.1	-0.1	0.0	0.0	2.6	4.2	6.1	4.8	5.8	-0.5	-0.5	-0.2	22
1980	0.0	0.0	0.1	0.5	4.5	7.5	13.3	5.0	4.3	-0.8	-0.5	-0.2	34
1981	-0.1	0.0	0.0	0.4	0.9	6.4	8.3	8.0	4.5	-0.6	-0.5	-0.2	27
1982	-0.1	-0.1	0.0	0.1	0.1	3.2	8.2	8.6	2.1	-0.6	-0.4	-0.2	21
1983	0.0	0.1	0.1	0.1	1.1	2.0	15.2	12.5	1.8	-0.8	-0.5	-0.2	31
1984	-0.1	0.0	0.0	0.0	1.5	4.3	9.7	10.8	1.9	-0.6	-0.4	-0.2	27
1985	-0.1	0.0	0.1	0.3	4.2	7.2	12.2	7.4	-0.1	-0.5	-0.4	-0.2	30
1986	0.0	0.0	0.1	0.1	1.6	8.2	12.4	10.4	0.0	-0.5	-0.4	-0.2	32
1987	0.0	0.1	0.1	0.5	1.4	12.1	15.2	7.0	3.5	-0.4	-0.5	-0.3	39
1988	-0.1	0.0	0.0	0.3	2.2	8.5	14.5	10.4	1.6	-0.3	-0.3	-0.1	37
1989	0.0	0.1	0.1	0.1	3.2	12.2	13.9	9.7	0.0	-0.3	-0.3	-0.1	39
1990	0.0	0.0	0.1	0.1	2.0	7.4	9.8	10.5	3.9	-0.5	-0.5	-0.3	33
1991	-0.1	0.0	0.0	0.0	0.6	4.2	13.3	11.8	2.1	-0.8	-0.5	-0.2	30
1992	-0.1	0.0	0.0	0.2	5.6	4.1	3.8	7.3	2.9	-0.4	-0.4	-0.2	23
1993	-0.1	0.0	0.0	0.0	1.7	3.7	4.6	10.2	0.9	-0.3	-0.3	-0.1	20
1994	0.0	0.0	0.0	0.1	2.5	6.0	6.9	6.2	2.2	-0.5	-0.3	-0.2	23
1995	-0.1	0.0	0.0	0.0	0.2	3.1	11.3	5.5	3.1	-0.6	-0.3	-0.2	22
1996	0.0	0.0	0.1	0.3	0.1	9.7	9.7	9.2	-0.4	-0.5	-0.3	-0.1	28

Table A-24. Historic Depletions Between Big Bend and Fort Randall Dams (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	-0.1	-0.1	0.0	0.0	0.7	3.8	3.6	6.2	2.8	-0.4	-0.5	-0.2	16
1899	-0.1	-0.1	0.0	0.0	0.7	1.3	4.7	4.2	3.7	-0.4	-0.4	-0.2	13
1900	-0.1	0.0	0.0	0.4	5.1	5.0	4.3	4.1	1.5	-0.7	-0.4	-0.2	19
1901	-0.1	-0.1	0.0	0.5	5.3	0.1	7.0	5.4	-0.8	-0.3	-0.3	-0.2	17
1902	-0.1	0.0	0.0	0.3	5.7	3.2	7.0	2.7	2.3	-0.3	-0.5	-0.2	20
1903	-0.1	-0.1	0.0	0.7	1.8	4.7	3.2	5.8	0.1	-0.2	-0.3	-0.2	15
1904	-0.1	0.0	0.0	0.5	2.7	1.2	4.8	5.3	3.8	-0.4	-0.5	-0.3	17
1905	-0.1	-0.1	0.0	0.3	0.6	0.4	5.4	7.2	2.3	-0.4	-0.4	-0.2	15
1906	-0.1	0.0	0.0	0.7	3.1	1.7	7.2	2.5	1.0	-0.2	-0.3	-0.2	15
1907	-0.1	0.0	0.0	0.0	1.5	2.3	1.4	7.7	1.6	0.1	-0.4	-0.2	14
1908	-0.1	-0.1	0.0	0.4	0.0	0.7	6.5	4.7	3.6	-0.3	-0.5	-0.3	15
1909	-0.1	0.0	0.0	0.1	0.5	3.9	6.4	4.1	2.4	-0.3	-0.4	-0.2	16
1910	-0.1	0.0	0.0	0.7	2.8	4.2	5.6	3.6	1.9	0.1	-0.3	-0.2	18
1911	-0.1	0.0	0.0	0.6	4.9	3.9	5.4	3.1	1.5	-0.6	-0.4	-0.2	18
1912	-0.1	0.0	0.0	0.4	4.9	5.4	3.4	1.8	2.0	0.2	-0.4	-0.2	17
1913	-0.1	0.0	0.0	0.3	1.2	4.9	4.7	5.4	2.9	0.0	-0.3	-0.2	19
1914	-0.1	0.0	0.0	0.5	1.8	1.2	6.5	4.2	1.1	-0.4	-0.3	-0.2	14
1915	-0.1	-0.1	0.0	0.6	1.1	0.7	0.1	5.3	2.2	0.0	-0.3	-0.2	9
1916	0.0	0.0	0.0	0.2	0.7	3.0	10.0	4.6	2.2	-0.1	-0.5	-0.3	20
1917	-0.1	-0.1	0.0	0.0	0.8	4.5	7.3	5.4	1.0	-0.2	-0.4	-0.2	18
1918	-0.1	-0.1	0.0	0.1	1.4	2.6	2.9	5.2	2.6	-0.1	-0.4	-0.2	14
1919	-0.1	0.0	0.0	0.1	4.1	1.8	7.2	5.9	2.6	-0.5	-0.5	-0.3	20
1920	-0.2	-0.1	-0.1	0.1	0.5	0.8	5.5	4.7	2.9	0.3	-0.5	-0.3	14
1921	-0.1	0.0	0.0	0.6	2.2	7.9	6.5	3.2	2.2	0.1	-0.3	-0.2	22
1922	-0.1	0.0	0.0	0.8	3.6	4.5	2.3	6.3	4.4	0.0	-0.4	-0.2	21
1923	-0.1	-0.1	0.0	0.3	4.7	0.9	7.1	1.9	3.1	0.1	-0.5	-0.3	17
1924	-0.1	-0.1	0.0	0.7	3.0	1.9	6.3	5.4	1.7	0.1	-0.5	-0.3	18
1925	-0.1	0.0	0.0	0.9	4.8	3.7	6.2	6.2	4.1	-0.2	-0.4	-0.2	25
1926	-0.1	-0.1	0.0	1.1	4.1	3.3	7.1	4.7	0.5	0.0	-0.3	-0.1	20
1927	-0.1	0.0	0.0	0.0	0.6	5.2	5.1	4.6	2.7	0.2	-0.3	-0.2	18
1928	0.0	0.0	0.0	0.4	6.8	0.7	6.4	5.1	2.8	-0.3	-0.5	-0.3	21
1929	-0.1	0.0	0.0	0.0	2.5	3.6	7.8	5.9	2.0	-0.7	-0.5	-0.2	20
1930	-0.1	0.0	0.0	0.0	2.0	4.1	9.4	6.3	3.2	-0.9	-0.6	-0.3	23
1931	-0.1	0.0	0.0	0.8	3.0	6.9	8.2	5.4	3.2	-0.4	-0.6	-0.3	26
1932	-0.2	-0.1	0.0	0.0	2.5	3.3	7.5	6.4	3.8	-0.7	-0.6	-0.3	22
1933	-0.1	-0.1	0.0	0.2	1.1	8.1	7.0	4.9	4.3	0.0	-0.5	-0.2	25
1934	-0.1	0.0	0.0	0.4	7.5	6.0	7.6	5.6	1.3	-0.3	-0.4	-0.2	27
1935	-0.1	0.0	0.0	0.0	0.0	4.0	8.1	6.9	4.6	-0.2	-0.7	-0.4	22
1936	-0.1	0.0	0.0	0.0	4.0	6.1	9.9	6.7	2.2	-0.3	-0.4	-0.2	28
1937	-0.1	0.0	0.0	0.2	3.4	4.3	7.8	6.5	3.6	-0.2	-0.4	-0.2	25
1938	-0.1	0.0	0.0	0.0	1.4	5.0	7.0	7.5	3.6	0.0	-0.7	-0.4	23
1939	-0.2	-0.1	0.0	0.4	3.4	2.9	9.9	6.4	1.6	-0.6	-0.5	-0.3	23
1940	-0.1	-0.1	0.0	0.0	5.0	3.5	7.5	5.1	3.7	-0.3	-0.6	-0.3	23
1941	-0.2	-0.1	-0.1	0.0	3.4	2.4	6.3	4.8	0.5	-0.6	-0.3	-0.2	16
1942	-0.1	0.0	0.0	0.0	0.0	1.8	5.6	5.7	1.7	-0.2	-0.4	-0.2	14
1943	-0.1	0.0	0.0	0.3	0.9	1.7	6.9	5.2	2.8	-0.5	-0.5	-0.2	16
1944	-0.1	-0.1	0.0	0.1	1.7	1.5	3.2	3.8	2.6	0.0	-0.3	-0.2	12
1945	-0.1	0.0	0.0	0.2	1.8	1.0	3.9	4.0	1.9	0.0	-0.3	-0.2	12
1946	-0.1	0.0	0.0	0.4	0.4	2.2	6.2	4.5	0.0	-0.4	-0.2	-0.1	13
1947	0.0	0.0	0.0	0.1	2.6	1.1	6.8	6.9	2.2	0.1	-0.3	-0.1	19
1948	-0.1	0.0	0.0	0.2	2.0	1.6	6.4	5.5	3.0	-0.2	-0.4	-0.2	18
1949	-0.1	0.0	0.0	0.0	1.4	5.2	6.9	5.8	2.6	-0.7	-0.5	-0.2	20
1950	-0.1	0.0	0.0	0.0	2.0	7.0	5.0	4.4	0.8	0.2	-0.4	-0.2	19
1951	-0.1	-0.1	0.0	0.4	1.1	2.0	6.3	4.8	1.1	-0.4	-0.3	-0.2	15
1952	0.0	0.1	0.1	1.3	1.7	5.6	10.3	5.8	4.5	0.1	-0.4	-0.2	29
1953	-0.1	0.0	0.0	0.1	2.7	4.0	9.8	9.1	6.6	-0.6	-0.8	-0.4	31
1954	-0.2	-0.1	0.0	0.3	6.2	3.4	12.9	9.2	4.9	-0.9	-0.7	-0.4	35
1955	-0.2	-0.1	0.0	1.0	3.5	6.6	14.7	7.6	3.8	0.0	-0.7	-0.4	36

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	-0.2	-0.1	0.0	0.0	4.7	10.9	7.6	6.4	5.7	-0.2	-0.8	-0.4	34
1957	-0.2	-0.1	-0.1	0.0	1.0	3.6	12.8	6.3	5.2	-0.7	-0.6	-0.4	27
1958	-0.1	0.0	0.0	0.1	8.8	4.6	5.6	11.1	6.4	-0.1	-0.9	-0.5	35
1959	-0.2	-0.1	-0.1	0.0	1.8	8.8	10.0	10.9	0.8	-0.5	-0.6	-0.3	30
1960	-0.2	-0.1	0.0	0.0	2.0	5.4	9.6	8.5	3.7	-0.1	-0.7	-0.4	28
1961	-0.2	0.0	0.0	0.5	1.0	7.1	11.7	8.5	2.6	-0.3	-0.6	-0.3	30
1962	-0.2	-0.1	0.0	0.7	0.2	2.8	6.1	9.4	4.9	-0.3	-0.6	-0.3	23
1963	-0.1	0.0	0.0	0.1	3.5	4.5	9.2	10.6	1.7	0.1	-0.6	-0.3	28
1964	-0.1	0.0	0.0	0.0	4.6	5.8	10.5	9.1	5.4	-0.1	-0.8	-0.4	34
1965	-0.3	-0.1	-0.1	0.0	2.0	4.3	8.0	9.3	-0.9	0.1	-0.4	-0.2	22
1966	-0.1	0.0	0.1	0.1	9.9	6.9	9.9	4.9	1.7	-0.5	-0.5	-0.3	32
1967	-0.1	0.0	0.0	1.0	3.0	2.5	13.3	10.8	5.3	-0.5	-0.8	-0.4	34
1968	-0.2	-0.1	0.0	0.0	2.9	3.7	12.3	6.3	4.1	0.0	-0.6	-0.3	28
1969	-0.1	0.0	0.1	0.9	8.0	4.9	9.2	11.2	6.6	-1.3	-0.8	-0.4	38
1970	-0.2	-0.1	0.0	0.0	4.5	8.2	12.5	10.2	4.7	-0.5	-0.5	-0.2	39
1971	-0.1	0.0	0.0	0.0	3.0	8.2	9.3	10.4	3.2	-0.6	-0.4	-0.2	33
1972	-0.1	0.0	0.0	0.0	1.0	6.9	5.8	8.0	5.2	-0.5	-0.6	-0.3	25
1973	-0.1	0.0	0.0	0.1	2.8	9.9	11.5	9.6	-0.5	-0.3	-0.5	-0.2	32
1974	0.0	0.1	0.1	0.1	3.2	10.6	13.3	11.5	6.9	-0.1	-0.9	-0.5	44
1975	-0.2	0.0	0.1	0.1	7.4	7.2	20.4	13.1	5.2	-0.5	-0.9	-0.4	51
1976	-0.1	0.1	0.1	0.3	9.5	17.1	18.8	15.3	8.2	-0.2	-0.7	-0.3	68
1977	-0.1	0.0	0.1	1.2	8.3	19.0	20.0	13.4	5.6	-1.0	-1.0	-0.5	65
1978	-0.1	0.1	0.1	0.2	5.8	16.8	21.7	23.3	14.5	-0.2	-1.4	-0.7	80
1979	-0.3	-0.1	0.0	0.3	9.2	15.9	15.9	14.9	14.7	-1.4	-1.3	-0.6	67
1980	-0.2	0.0	0.1	1.9	14.8	16.5	26.7	11.3	11.1	-0.8	-0.9	-0.4	80
1981	-0.1	0.1	0.1	2.6	8.0	16.3	19.2	21.3	14.8	-1.8	-1.4	-0.7	78
1982	-0.4	-0.2	-0.1	0.4	0.0	13.9	19.7	18.0	3.1	-1.4	-0.8	-0.4	52
1983	0.0	0.1	0.2	0.2	3.6	9.4	24.6	27.3	8.7	-1.3	-1.3	-0.6	71
1984	-0.3	-0.1	0.1	0.1	7.0	12.0	21.0	18.7	9.6	-1.4	-1.2	-0.6	65
1985	-0.2	-0.1	0.0	0.3	16.5	14.3	21.6	11.4	0.7	-0.1	-0.8	-0.4	63
1986	-0.1	0.0	0.1	0.1	7.9	13.4	24.9	19.4	0.2	-0.4	-0.9	-0.4	64
1987	-0.1	0.0	0.1	1.3	8.7	17.0	20.6	15.7	8.4	-0.4	-1.2	-0.6	69
1988	-0.2	0.0	0.1	1.0	0.9	21.3	26.9	23.5	5.4	0.3	-0.8	-0.3	78
1989	0.0	0.2	0.2	1.0	15.6	20.8	23.2	22.7	6.4	0.5	-1.3	-0.6	89
1990	-0.3	-0.1	0.0	0.3	2.0	14.7	19.7	21.8	16.4	-0.5	-1.5	-0.8	72
1991	-0.3	-0.1	0.0	0.1	1.2	11.4	30.7	22.8	8.1	-1.8	-1.2	-0.6	70
1992	-0.3	-0.1	0.1	1.5	20.0	10.4	9.3	16.5	7.9	0.4	-1.1	-0.5	64
1993	-0.3	-0.2	-0.1	0.0	6.7	5.4	10.6	22.3	3.6	0.1	-0.9	-0.4	47
1994	-0.1	0.0	0.1	0.2	17.1	7.6	16.5	16.5	8.1	-0.9	-1.1	-0.5	63
1995	-0.2	-0.1	0.0	0.0	0.1	12.4	25.4	17.2	7.0	-1.7	-1.0	-0.5	59
1996	-0.2	0.0	0.1	0.6	0.1	16.7	20.4	21.9	1.0	-1.0	-0.9	-0.4	58

Table A-25. Historic Depletions Between Fort Randall and Gavins Point Dams (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	-0.1	-0.1	0.0	0.3	0.4	5.0	3.6	5.9	4.3	-0.7	-0.5	-0.3	18
1899	-0.1	0.0	0.0	0.2	2.5	3.3	6.8	4.1	5.1	0.4	-0.7	-0.4	21
1900	-0.2	-0.1	0.0	0.2	3.0	6.1	1.9	8.0	2.6	-0.1	-0.6	-0.3	20
1901	-0.2	-0.1	0.0	0.3	2.7	0.0	12.0	6.1	-1.0	0.2	-0.4	-0.2	19
1902	-0.2	-0.1	0.0	0.2	4.6	-0.1	3.9	2.8	-0.3	0.7	-0.3	-0.2	11
1903	-0.1	0.0	0.0	0.3	0.0	3.8	4.1	3.7	3.4	0.2	-0.5	-0.3	15
1904	-0.1	-0.1	0.0	0.1	1.0	2.7	4.8	3.2	4.4	-0.4	-0.5	-0.3	15
1905	-0.1	-0.1	0.0	0.2	0.3	1.7	3.3	4.5	1.2	0.3	-0.3	-0.2	11
1906	-0.1	0.0	0.0	0.2	1.3	3.1	6.1	4.2	2.5	-0.6	-0.4	-0.2	16
1907	-0.1	-0.1	0.0	0.1	1.2	0.3	2.1	8.1	1.8	0.8	-0.5	-0.3	13
1908	-0.1	-0.1	0.0	0.3	0.7	0.1	6.4	4.7	5.7	-0.1	-0.6	-0.3	17
1909	-0.2	-0.1	0.0	0.2	0.0	0.3	6.5	8.2	4.5	-0.2	-0.6	-0.3	18
1910	-0.2	-0.1	0.0	0.3	2.1	5.6	5.0	4.8	3.3	0.3	-0.6	-0.3	20
1911	-0.1	-0.1	0.0	0.2	4.2	6.9	4.8	4.6	2.6	-0.8	-0.5	-0.3	22
1912	-0.1	-0.1	0.0	0.2	0.6	6.1	4.2	4.5	3.0	0.3	-0.5	-0.3	18
1913	-0.1	-0.1	0.0	0.2	0.4	2.1	7.4	5.0	4.2	0.1	-0.4	-0.2	19
1914	-0.1	0.0	0.0	0.3	1.5	5.1	7.8	7.1	-0.3	0.4	-0.5	-0.3	21
1915	-0.2	-0.1	0.0	0.2	0.3	1.1	1.3	7.3	4.9	0.7	-0.6	-0.3	15
1916	-0.1	0.0	0.0	0.3	4.3	4.6	8.4	6.1	1.5	0.3	-0.4	-0.2	25
1917	-0.1	0.0	0.0	0.1	0.1	2.8	8.1	5.5	3.4	0.4	-0.6	-0.3	19
1918	-0.2	-0.1	0.0	0.2	0.6	1.5	7.3	4.0	3.6	0.1	-0.5	-0.3	16
1919	-0.1	-0.1	0.0	0.2	0.9	0.2	6.9	6.7	2.9	-0.1	-0.5	-0.3	17
1920	-0.1	0.0	0.0	0.0	0.7	2.3	6.3	5.5	4.5	0.6	-0.6	-0.4	19
1921	-0.2	-0.1	0.0	0.3	0.2	7.0	3.7	5.1	4.7	0.5	-0.6	-0.4	20
1922	-0.2	-0.1	0.0	0.3	3.9	4.3	3.3	6.4	4.7	0.2	-0.5	-0.2	22
1923	-0.1	-0.1	0.0	0.3	0.3	2.1	8.9	1.9	2.5	0.4	-0.4	-0.3	16
1924	-0.1	0.0	0.0	0.2	2.0	1.3	6.1	6.2	2.8	0.5	-0.5	-0.3	18
1925	-0.1	-0.1	0.0	0.4	4.2	1.2	5.0	7.7	2.8	0.0	-0.6	-0.3	20
1926	-0.2	-0.1	0.0	0.4	4.1	3.4	8.0	4.8	1.2	0.3	-0.5	-0.3	21
1927	-0.2	-0.1	-0.1	0.0	0.5	0.9	6.8	3.4	4.3	0.7	-0.5	-0.3	15
1928	-0.1	-0.1	0.0	0.2	1.6	2.8	7.1	5.9	2.0	-0.2	-0.3	-0.2	19
1929	-0.1	0.0	0.0	0.1	0.8	1.1	3.2	5.3	0.0	-0.4	-0.2	-0.1	10
1930	0.0	0.0	0.0	0.0	0.3	2.0	5.8	3.5	2.5	-0.5	-0.3	-0.2	13
1931	-0.1	0.0	0.0	0.3	1.5	2.3	5.1	4.4	2.5	-0.2	-0.4	-0.2	15
1932	-0.1	0.0	0.0	0.1	1.1	2.1	4.8	4.5	3.1	-0.6	-0.4	-0.2	14
1933	-0.1	0.0	0.0	0.1	0.3	5.1	5.7	3.3	3.4	0.1	-0.4	-0.2	17
1934	-0.1	0.0	0.0	0.3	3.4	3.1	5.8	5.6	1.2	0.0	-0.4	-0.2	19
1935	-0.1	0.0	0.0	0.0	0.1	1.8	7.2	6.3	3.7	0.0	-0.5	-0.3	18
1936	-0.1	0.0	0.0	0.1	1.9	3.3	8.5	6.2	3.2	0.0	-0.3	-0.2	23
1937	-0.1	0.0	0.0	0.1	1.6	1.5	6.7	6.7	3.2	-0.4	-0.3	-0.1	19
1938	0.0	0.0	0.0	0.0	0.3	3.9	4.4	8.3	2.6	0.4	-0.5	-0.3	19
1939	-0.1	0.0	0.0	0.2	1.5	3.2	7.3	6.5	4.3	-0.7	-0.5	-0.2	21
1940	-0.1	0.0	0.0	0.0	3.2	3.7	7.5	6.5	2.6	-0.2	-0.3	-0.1	23
1941	-0.1	0.0	0.0	0.0	2.3	1.5	5.6	6.5	1.8	-0.6	-0.3	-0.2	17
1942	-0.1	0.0	0.0	0.0	0.1	1.5	5.7	6.9	1.9	-0.4	-0.3	-0.2	15
1943	-0.1	0.0	0.0	0.2	1.0	1.6	6.6	6.8	3.1	-0.5	-0.4	-0.2	18
1944	-0.1	-0.1	0.0	0.1	1.0	1.0	3.4	5.6	3.7	0.1	-0.3	-0.2	14
1945	0.0	0.0	0.0	0.2	1.4	1.2	7.9	6.8	3.2	0.4	-0.4	-0.2	21
1946	0.0	0.0	0.1	0.8	0.5	5.1	11.2	11.4	1.0	-0.8	-0.4	-0.2	29
1947	0.0	0.1	0.1	0.3	2.0	1.9	15.5	18.8	7.2	0.5	-0.5	-0.2	46
1948	0.0	0.1	0.1	0.7	3.6	3.7	15.7	19.3	10.3	0.2	-1.0	-0.5	52
1949	-0.2	0.0	0.1	0.2	0.9	8.2	23.4	24.2	8.0	-1.2	-0.6	-0.2	63
1950	-0.1	0.0	0.1	0.1	1.9	9.9	12.3	17.6	5.0	1.8	-0.9	-0.4	47
1951	-0.3	-0.1	0.0	0.3	1.9	2.8	11.4	12.6	7.0	-0.8	-0.6	-0.3	34
1952	0.2	0.3	0.3	0.4	1.3	15.9	31.8	21.6	17.7	1.5	-0.9	-0.4	90
1953	-0.1	0.1	0.2	0.2	4.8	7.9	16.7	29.3	22.5	-1.8	-1.6	-0.8	77
1954	-0.3	-0.1	0.1	0.5	5.6	5.9	34.8	20.9	10.6	-0.9	-1.2	-0.6	75
1955	-0.1	0.1	0.2	1.3	3.9	6.6	40.8	32.5	9.8	1.9	-0.9	-0.3	96

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	0.1	0.3	0.4	0.8	7.6	26.8	35.5	24.5	21.2	-1.6	-1.6	-0.7	113
1957	-0.3	-0.1	0.1	0.1	1.0	9.4	38.3	33.2	13.7	-1.7	-1.4	-0.6	92
1958	-0.1	0.2	0.3	0.4	7.0	9.8	16.8	57.2	28.3	3.1	-2.3	-1.1	120
1959	-0.4	0.0	0.2	0.8	1.9	28.5	53.5	38.0	12.4	-2.1	-1.6	-0.7	130
1960	-0.2	0.1	0.2	0.3	1.8	11.1	56.6	37.6	16.2	2.0	-1.8	-0.9	123
1961	-0.3	0.0	0.2	1.3	0.8	21.3	44.4	45.4	9.7	1.5	-1.6	-0.8	122
1962	-0.3	0.0	0.2	1.7	1.2	6.3	33.1	53.8	22.7	-1.4	-1.5	-0.9	115
1963	-0.3	0.1	0.3	0.9	4.6	17.7	43.6	48.3	12.6	3.0	-1.8	-0.8	128
1964	-0.2	0.2	0.3	0.4	10.9	14.3	51.0	50.8	17.4	3.5	-2.1	-1.0	146
1965	-0.5	-0.1	0.2	0.8	2.2	8.4	51.5	68.4	-2.9	-1.7	-1.4	-0.5	124
1966	0.2	0.5	0.7	1.3	24.5	25.0	84.5	40.8	13.5	-1.8	-1.5	-0.5	187
1967	0.1	0.4	0.6	2.7	2.1	9.8	78.6	81.1	36.3	-3.2	-2.6	-1.1	205
1968	-0.2	0.3	0.6	1.0	4.2	26.0	84.9	72.6	44.3	-0.5	-2.9	-1.3	229
1969	0.0	0.5	0.8	2.3	18.7	24.3	73.2	117.2	45.8	-3.9	-2.1	-0.6	276
1970	0.5	1.0	1.2	1.3	11.7	62.9	117.0	116.3	42.9	-5.7	-3.6	-1.4	344
1971	-0.2	0.4	0.8	1.0	4.2	62.4	105.5	128.2	41.0	-5.5	-3.6	-1.4	333
1972	-0.3	0.4	0.8	0.9	4.1	40.0	76.1	142.4	64.1	-4.8	-4.2	-1.8	318
1973	0.1	0.8	1.3	1.5	7.0	107.7	129.9	186.7	-8.0	-6.1	-3.0	-0.8	417
1974	0.9	1.6	2.0	3.6	15.4	107.8	211.3	137.6	73.5	-0.3	-3.1	-0.8	550
1975	0.7	1.5	1.9	3.2	35.2	56.8	214.9	159.6	81.5	7.1	-3.6	-1.1	558
1976	1.3	2.2	2.7	3.5	28.9	178.4	216.8	239.6	50.6	3.1	-3.1	-0.3	724
1977	0.5	1.4	1.9	2.0	11.8	109.6	241.3	159.0	75.9	-5.3	-5.6	-2.2	590
1978	0.7	1.9	2.5	2.7	15.1	152.9	185.0	242.4	148.7	9.2	-8.8	-3.9	748
1979	-1.3	0.2	1.2	3.5	8.9	71.3	194.3	256.4	127.7	-11.4	-7.7	-3.1	640
1980	0.4	1.8	2.7	9.1	20.8	130.2	365.3	174.1	139.6	-6.9	-4.5	-1.1	831
1981	0.2	1.4	1.9	11.0	11.9	147.8	172.8	211.6	129.9	-10.9	-7.0	-2.7	668
1982	-0.6	0.5	1.3	3.7	3.6	79.9	223.2	237.2	53.9	-10.0	-5.2	-1.8	586
1983	0.6	1.8	2.4	2.6	6.2	24.9	189.6	383.9	113.1	-4.8	-8.3	-3.2	709
1984	-0.7	0.9	2.0	2.3	10.8	93.2	192.4	306.9	113.6	-3.0	-7.6	-2.9	708
1985	-0.8	0.6	1.6	3.8	59.1	108.5	282.7	182.8	16.9	-4.9	-4.1	-1.2	645
1986	0.5	1.6	2.1	2.2	13.5	107.9	293.9	252.3	15.8	-9.0	-4.5	-1.2	675
1987	0.7	1.8	2.4	8.3	20.7	127.4	271.0	193.0	102.6	0.9	-5.2	-1.8	722
1988	1.0	2.2	2.8	5.6	13.5	177.2	307.9	243.0	71.4	11.0	-5.5	-1.7	828
1989	0.7	2.1	2.8	9.0	51.3	145.3	294.4	249.6	103.4	6.7	-5.8	-1.8	858
1990	0.6	2.0	2.7	4.7	7.4	153.0	264.4	267.7	165.2	2.9	-8.1	-3.1	859
1991	-0.1	1.4	2.4	2.8	9.7	98.3	302.4	297.8	152.6	-9.5	-6.4	-2.0	849
1992	-0.9	0.4	1.3	6.0	51.9	76.7	164.6	160.1	120.4	5.5	-5.5	-2.1	578
1993	0.1	1.1	1.7	2.1	38.3	75.6	188.5	248.7	67.4	-6.8	-4.9	-1.5	610
1994	1.1	2.1	2.8	4.7	72.1	99.5	213.2	237.5	152.2	-7.4	-6.6	-2.3	769
1995	0.6	1.8	2.6	3.0	4.9	124.4	319.1	349.3	55.3	-12.1	-5.8	-1.5	842
1996	0.2	1.6	2.4	5.2	6.8	150.1	295.1	322.6	1.6	-6.7	-4.4	-0.9	774

Table A-26. Historic Depletions Between Gavins Point Dam and Sioux City (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1899	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1900	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1901	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1902	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1903	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1904	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1905	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1906	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1907	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1908	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1909	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1910	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1911	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1912	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1913	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1914	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1915	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1916	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1917	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1918	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1919	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1920	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1921	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1922	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1923	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1924	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1925	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1926	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1927	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1928	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1929	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1930	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1931	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
1932	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0
1933	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0
1934	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0
1935	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0
1936	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0
1937	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0
1938	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0
1939	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0	0.0	0
1940	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0
1941	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.0	0.0	0.0	0.0	0
1942	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0
1943	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0
1944	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0
1945	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0	1
1946	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.3	0.0	0.0	0.0	0.0	1
1947	0.0	0.0	0.0	0.0	0.1	0.1	0.7	0.6	0.0	0.0	0.0	0.0	2
1948	0.0	0.0	0.0	0.0	0.1	0.1	0.6	0.6	0.1	0.0	0.0	0.0	2
1949	0.0	0.0	0.0	0.0	0.1	0.4	0.9	0.6	0.0	0.0	0.0	0.0	2
1950	0.0	0.0	0.0	0.0	0.1	1.0	1.0	1.2	0.0	0.0	0.0	0.0	3
1951	0.0	0.0	0.0	0.0	0.1	0.2	1.4	0.8	0.3	0.0	0.0	0.0	3
1952	0.1	0.1	0.1	0.1	0.5	1.2	2.4	1.5	0.9	0.0	0.0	0.0	7
1953	0.0	0.1	0.1	0.1	0.2	0.7	2.6	2.0	0.8	0.0	0.0	0.0	7
1954	0.0	0.1	0.1	0.1	0.3	1.1	3.5	2.3	0.5	-0.1	0.0	0.0	8
1955	0.1	0.1	0.1	0.2	0.6	1.6	4.7	4.8	1.4	0.0	0.0	0.1	14

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	0.1	0.2	0.2	0.2	1.0	5.4	4.7	3.2	1.9	0.0	0.0	0.1	17
1957	0.1	0.1	0.2	0.2	0.3	2.1	9.4	5.6	0.6	-0.2	0.0	0.1	19
1958	0.2	0.3	0.3	0.3	2.2	5.1	6.4	11.0	2.6	0.3	0.0	0.1	29
1959	0.2	0.3	0.3	0.4	0.6	6.5	14.3	7.6	0.8	-0.1	0.0	0.2	31
1960	0.2	0.2	0.3	0.3	1.0	3.3	15.8	6.4	0.9	0.0	0.0	0.1	28
1961	0.2	0.3	0.3	0.3	0.5	4.8	11.9	12.8	1.0	-0.3	0.0	0.1	32
1962	0.1	0.1	0.1	0.1	0.3	2.1	5.9	9.5	0.6	0.0	0.0	0.1	19
1963	0.2	0.3	0.3	0.3	1.1	6.4	9.3	11.5	1.6	0.0	0.0	0.1	31
1964	0.2	0.3	0.3	0.3	2.4	8.2	14.4	7.8	1.7	0.4	0.1	0.2	36
1965	0.2	0.2	0.2	0.2	0.6	2.2	13.3	10.1	-0.4	-0.2	0.0	0.1	26
1966	0.3	0.3	0.3	0.3	2.5	7.8	14.8	8.0	1.2	-0.2	0.1	0.2	36
1967	0.3	0.4	0.4	0.5	2.6	2.8	18.9	12.8	3.4	-0.1	-0.1	0.1	42
1968	0.2	0.2	0.3	0.3	1.7	4.1	14.8	12.2	0.6	-0.2	0.0	0.1	34
1969	0.2	0.3	0.3	0.4	1.1	4.0	12.1	13.8	4.7	-0.4	-0.1	0.1	37
1970	0.6	0.7	0.8	0.8	2.5	13.3	27.1	29.1	2.5	-0.4	0.0	0.3	77
1971	0.3	0.4	0.5	0.5	2.8	9.7	19.6	23.8	3.2	-0.4	0.0	0.3	61
1972	0.2	0.3	0.3	0.3	0.6	10.4	10.3	15.6	3.5	-0.3	0.0	0.2	41
1973	0.8	0.9	0.9	0.9	4.5	23.0	28.8	31.7	-0.6	-0.5	0.1	0.5	91
1974	0.8	0.9	1.0	1.0	1.8	19.5	46.1	21.7	13.4	0.1	0.2	0.5	107
1975	1.3	1.4	1.5	1.5	7.9	12.5	79.9	33.0	11.0	0.9	0.4	0.9	152
1976	2.7	2.9	3.0	3.4	18.0	61.7	95.0	84.7	21.5	0.5	1.2	2.0	296
1977	2.2	2.5	2.6	2.8	19.5	75.3	115.5	55.4	3.5	-1.0	0.5	1.5	280
1978	1.9	2.3	2.4	2.4	7.4	58.6	79.8	83.5	29.9	1.3	0.1	1.2	271
1979	1.1	1.5	1.7	1.7	7.1	42.5	71.0	51.7	25.9	-1.3	-0.1	0.8	204
1980	2.0	2.2	2.4	3.4	15.7	46.7	109.1	45.4	34.1	-0.6	0.3	1.3	262
1981	2.2	2.5	2.6	4.2	23.1	59.3	91.6	68.5	34.2	-0.5	0.4	1.4	290
1982	1.4	1.8	1.9	2.1	3.0	61.1	86.5	63.0	10.7	-1.1	0.3	1.2	232
1983	2.4	2.7	2.9	2.9	11.5	16.7	119.2	135.5	12.4	-1.8	0.2	1.5	306
1984	2.2	2.6	2.9	2.9	10.2	45.4	120.3	107.8	22.1	-1.8	0.2	1.5	316
1985	1.1	1.6	1.8	2.0	14.7	46.9	101.2	51.9	0.0	-0.1	0.5	1.2	223
1986	2.1	2.3	2.4	2.4	12.5	56.1	107.9	77.3	-1.3	-0.6	0.5	1.4	263
1987	2.4	2.7	2.9	4.1	14.9	72.4	105.5	83.1	16.1	0.9	0.7	1.7	308
1988	3.1	3.5	3.6	3.9	17.4	113.4	144.1	81.0	5.7	4.0	1.9	2.7	384
1989	2.8	3.1	3.3	3.4	19.9	55.0	136.3	95.1	19.0	4.1	1.4	2.3	346
1990	2.5	2.9	3.0	3.0	6.4	39.8	103.8	111.7	46.0	-0.7	0.4	1.6	320
1991	1.9	2.3	2.5	2.6	5.1	28.9	114.7	110.4	10.1	-1.0	0.2	1.3	279
1992	0.6	1.0	1.3	1.4	23.7	39.0	36.1	51.5	6.0	-0.2	0.2	0.9	161
1993	0.9	1.1	1.2	1.3	6.4	11.0	35.3	73.5	10.4	-0.3	-0.1	0.6	141
1994	1.8	2.1	2.2	2.2	21.5	26.8	83.2	75.7	11.5	-0.9	0.3	1.2	228
1995	1.8	2.1	2.3	2.3	2.8	54.7	100.4	68.9	10.5	-1.0	0.4	1.3	246
1996	1.8	2.1	2.2	3.0	2.2	57.7	87.5	84.7	1.9	-0.8	0.4	1.3	244

Table A-27. Historic Depletions Between Omaha and Nebraska City (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	-28.5	-18.8	-13.2	58.2	91.2	641.6	735.6	834.7	262.7	-42.5	-76.9	-46.5	2398
1899	-27.7	-18.0	-12.5	68.5	327.5	727.6	722.8	754.2	337.6	-63.0	-82.2	-49.3	2685
1900	-29.3	-19.8	-14.2	-10.1	571.6	717.9	755.1	752.2	251.3	-50.0	-74.7	-44.2	2806
1901	-26.9	-18.2	-13.4	13.8	439.9	494.4	1072.9	752.0	181.2	-39.2	-66.5	-41.2	2749
1902	-25.8	-16.4	-11.9	75.5	410.0	557.9	773.6	711.8	91.2	-47.2	-63.7	-39.1	2416
1903	-24.0	-15.5	-11.1	60.7	421.4	518.6	786.1	758.7	257.7	-13.0	-78.9	-47.4	2613
1904	-28.7	-18.4	-12.9	72.4	290.0	631.0	728.0	805.2	268.8	-43.3	-75.7	-46.2	2570
1905	-27.4	-17.7	-12.1	4.5	227.6	663.6	715.3	852.2	351.3	-75.5	-80.0	-46.6	2555
1906	-26.3	-16.7	-10.8	62.3	412.7	678.9	882.5	813.6	275.2	-103.7	-79.6	-45.9	2842
1907	-27.6	-18.0	-5.7	40.1	247.6	606.9	712.6	775.8	306.1	45.3	-81.9	-49.9	2551
1908	-29.0	-17.7	-11.7	88.2	187.5	560.2	773.6	702.1	495.3	-78.7	-81.0	-47.6	2541
1909	-25.5	-15.8	-9.8	32.3	386.2	492.3	1023.7	980.9	300.5	-32.2	-88.9	-52.1	2991
1910	-29.1	-16.9	12.3	157.5	664.6	911.6	1050.1	741.0	229.4	-14.0	-91.8	-56.1	3559
1911	-31.7	-19.3	4.6	40.0	731.8	1228.8	824.8	704.3	311.2	-105.6	-95.3	-53.6	3540
1912	-33.4	-2.0	18.3	213.2	767.5	965.2	695.3	493.5	-207.0	-304.7	-110.3	-34.1	2461
1913	-17.9	11.0	42.2	382.6	767.1	1000.9	615.5	1068.2	124.3	-67.9	-50.8	-31.5	3844
1914	-8.5	3.0	48.7	225.8	901.3	1142.2	848.9	764.6	215.6	-149.9	-70.4	-35.7	3886
1915	-17.5	-4.6	16.1	133.3	430.2	606.9	729.1	495.6	237.0	2.2	-39.9	-13.5	2575
1916	4.4	20.4	128.2	186.2	568.3	1059.5	1036.0	703.1	326.3	-58.9	-65.6	-26.7	3881
1917	-7.5	2.4	24.0	305.0	436.0	1028.4	1342.5	688.3	176.1	-24.1	-58.8	-23.6	3889
1918	-1.8	7.4	61.3	98.3	773.6	1394.9	796.6	684.9	86.0	-47.5	-57.7	-21.3	3775
1919	-9.7	6.6	34.8	178.2	886.5	723.4	771.8	879.3	232.2	-122.9	-64.9	-26.3	3489
1920	-6.1	16.7	60.7	158.9	962.3	944.5	1000.7	736.9	345.3	-43.4	-61.5	-36.5	4079
1921	-3.3	13.1	91.7	57.5	850.4	989.0	1142.3	911.7	372.4	-70.7	-87.5	-41.5	4225
1922	-14.9	-3.7	51.0	128.5	488.1	1116.0	1039.2	954.1	381.7	-90.6	-78.2	-41.0	3930
1923	-11.2	1.0	18.3	118.9	653.3	1025.9	927.5	710.7	159.6	-39.3	-31.9	-24.2	3509
1924	-1.7	20.4	29.8	202.1	257.6	1137.0	978.1	843.4	-96.0	-0.4	-47.9	-22.5	3300
1925	0.5	17.1	88.7	254.6	844.0	818.2	1086.0	684.5	348.3	-34.0	-52.3	-21.0	4035
1926	-9.6	19.0	75.6	439.6	872.2	997.2	860.9	978.5	109.7	-44.4	-76.5	-44.3	4178
1927	-32.9	1.0	34.7	203.6	1299.1	512.7	965.7	660.4	238.3	17.2	-36.3	-31.9	3832
1928	15.5	18.8	107.6	214.3	889.3	323.8	696.7	943.3	318.9	-120.7	-61.2	-32.3	3314
1929	-11.4	7.6	33.0	319.9	877.8	1167.4	1252.9	784.8	-83.8	-27.7	-57.3	-14.7	4248
1930	-11.2	17.3	52.7	320.3	565.9	1194.7	956.5	659.0	376.3	-24.6	-80.4	-35.8	3991
1931	-7.2	15.1	31.7	236.2	662.4	1125.5	1110.0	676.9	535.7	-41.8	-89.3	-38.3	4217
1932	-9.1	12.7	47.8	329.6	1139.8	963.4	1017.6	919.9	322.2	-79.0	-72.9	-42.8	4549
1933	-7.9	1.0	51.2	141.8	569.8	1605.8	967.6	466.1	268.0	54.7	-56.9	-30.5	4031
1934	4.6	21.9	44.6	205.4	859.0	899.3	1156.4	984.0	282.6	-8.2	-56.2	-18.1	4375
1935	0.1	16.0	26.2	49.2	219.6	1124.7	1227.9	945.1	286.5	24.2	-64.2	-35.6	3820
1936	-4.4	12.2	53.6	243.3	865.1	1000.9	1065.8	871.0	275.3	-43.8	-56.0	-25.5	4257
1937	-22.4	5.2	62.2	309.3	649.1	851.0	1134.2	978.1	231.2	-31.9	-56.1	-16.0	4094
1938	-0.6	-2.1	50.0	192.0	548.2	1040.4	866.2	840.3	190.7	76.7	-60.1	-20.8	3721
1939	4.7	8.0	69.9	197.2	701.6	731.9	1037.8	831.4	460.6	-30.4	-62.3	-33.8	3917
1940	-15.4	3.4	26.0	160.0	890.4	1022.0	1071.0	923.3	227.0	-30.0	-58.4	-30.6	4189
1941	-16.9	23.5	46.5	223.0	983.9	700.0	793.2	833.9	173.3	81.5	60.8	21.4	3924
1942	62.7	65.2	96.0	270.9	890.4	894.9	894.2	719.0	147.0	15.4	12.9	8.0	4077
1943	25.4	80.0	141.4	155.4	246.2	1014.2	874.3	885.6	325.0	-54.2	-77.7	-2.6	3613
1944	17.0	75.4	113.7	157.7	754.9	779.1	649.1	786.1	305.2	58.9	-18.6	-42.3	3636
1945	31.0	55.5	99.4	94.5	752.5	839.3	964.8	503.6	224.4	166.3	31.4	-11.0	3752
1946	93.5	92.7	143.6	268.0	346.3	888.0	932.9	360.4	209.6	117.2	45.5	52.7	3551
1947	54.9	58.9	112.7	269.5	608.3	960.0	1186.6	985.4	265.0	-5.5	8.6	64.1	4568
1948	56.8	80.4	167.6	294.5	610.7	687.8	896.5	695.4	432.1	-9.5	16.6	19.1	3948
1949	20.1	80.0	150.9	313.0	767.6	986.3	1102.5	752.9	324.8	2.9	-43.6	-12.9	4444
1950	41.7	81.2	90.0	226.4	436.5	1184.9	654.1	763.8	246.7	143.0	-7.4	26.6	3887
1951	18.8	61.1	41.7	57.4	725.9	749.3	712.7	668.0	244.1	-4.8	15.2	4.6	3294
1952	34.1	-5.1	21.0	293.4	655.3	1387.2	758.5	476.9	256.1	35.3	-4.7	71.5	3979
1953	110.1	86.9	99.2	87.8	551.9	832.0	503.1	585.6	417.2	2.3	17.5	71.2	3365
1954	72.7	65.0	108.4	243.9	467.5	725.7	776.6	510.0	338.2	32.2	-27.1	12.9	3326
1955	56.8	72.1	105.7	267.3	450.2	644.1	1048.5	781.4	139.3	32.0	-24.1	29.4	3603

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	89.4	85.7	128.2	198.7	820.8	916.5	386.6	690.3	523.1	-20.2	26.4	75.8	3921
1957	59.4	93.6	53.4	209.1	581.0	1314.9	1199.3	699.0	314.6	29.2	49.3	56.4	4659
1958	94.0	129.2	184.1	212.8	1017.7	822.9	617.4	1040.2	302.4	88.0	-2.0	74.6	4581
1959	77.5	87.4	113.6	257.8	477.3	1085.2	1077.0	904.5	78.7	3.8	9.7	63.2	4236
1960	75.1	101.1	194.8	312.9	702.8	913.1	946.8	871.2	408.8	36.5	-26.8	21.4	4558
1961	58.7	88.9	103.5	191.8	547.1	1138.3	727.0	1019.9	17.9	147.7	64.2	75.0	4180
1962	95.1	150.9	170.1	520.6	695.1	1008.3	882.7	1133.1	276.2	46.0	0.9	26.3	5005
1963	64.2	132.8	153.8	248.5	709.8	976.4	980.4	578.1	237.4	49.9	33.3	27.2	4192
1964	72.6	88.7	109.9	239.0	865.7	812.2	1125.3	725.8	278.0	53.4	15.7	39.3	4426
1965	65.1	74.6	94.7	196.3	743.9	1117.1	886.3	851.2	-38.9	170.6	60.6	69.9	4291
1966	77.4	125.6	186.4	182.8	846.8	615.5	901.5	678.7	368.5	69.1	-11.1	58.6	4100
1967	85.0	84.7	124.1	167.9	262.1	911.1	1087.8	906.0	382.9	69.0	-16.2	34.2	4099
1968	87.7	114.6	98.1	258.9	600.8	1313.0	916.5	555.4	436.5	42.4	-42.0	9.5	4391
1969	99.3	111.6	113.9	326.5	676.9	725.1	940.8	929.8	415.0	-18.7	29.4	63.9	4414
1970	91.7	131.9	118.0	235.5	1262.7	1182.9	1200.6	1005.8	158.7	40.3	32.3	3.2	5464
1971	94.9	122.9	186.7	293.8	871.4	1185.2	1062.6	1088.9	158.2	54.3	21.2	2.3	5142
1972	32.4	77.3	83.5	255.5	683.3	990.9	672.1	856.1	269.1	-5.7	55.1	59.5	4029
1973	82.9	103.2	139.2	313.2	1272.1	1064.3	755.8	1145.4	-171.9	-28.1	2.7	15.7	4695
1974	80.8	57.5	-99.9	167.7	1065.5	928.4	935.4	719.0	438.7	104.4	79.5	56.3	4533
1975	102.2	101.1	195.5	266.1	439.7	1057.7	1201.6	1025.9	414.5	160.9	50.0	77.6	5093
1976	116.1	160.3	168.6	276.3	732.9	1089.0	1090.7	1048.7	315.9	84.6	29.8	77.0	5190
1977	70.0	129.8	164.4	308.7	633.1	1109.7	915.8	763.0	472.8	72.2	5.5	51.9	4697
1978	86.1	124.3	205.6	244.8	572.4	1507.1	1324.0	972.3	758.9	98.2	7.3	55.7	5957
1979	76.5	111.6	207.1	340.7	647.8	1044.7	1049.7	1145.4	871.5	43.0	25.4	67.5	5631
1980	89.2	158.8	169.4	291.6	920.0	1407.6	1438.8	977.9	669.9	44.1	23.6	75.5	6266
1981	98.8	109.2	150.7	233.1	398.3	1086.7	946.7	1067.8	818.7	19.3	-8.3	42.9	4964
1982	56.8	105.2	129.6	166.5	539.5	907.2	1308.1	1125.6	401.1	82.6	41.2	53.9	4917
1983	101.8	111.3	200.3	300.9	937.2	1048.4	1652.3	1296.3	489.8	195.3	54.5	-37.9	6350
1984	50.9	-11.6	-104.5	106.6	1437.7	929.8	1393.9	1282.8	489.5	8.0	-35.0	-20.4	5528
1985	63.5	70.4	51.7	290.0	847.6	860.9	928.0	1265.9	95.6	77.1	25.9	92.4	4669
1986	127.9	164.6	125.8	285.8	761.0	1377.5	1332.1	1139.2	165.0	-54.2	-14.7	55.9	5466
1987	64.9	3.5	286.8	289.3	496.1	1065.9	1236.8	740.8	678.4	21.2	-11.8	22.2	4894
1988	81.6	139.9	168.6	339.6	637.8	1199.3	1094.3	1159.8	326.2	158.7	22.6	63.8	5392
1989	106.4	118.6	201.6	232.3	622.8	598.5	1274.9	983.7	306.8	124.4	30.6	60.6	4661
1990	124.4	120.1	171.8	203.1	532.1	1207.5	608.6	1200.4	838.9	36.7	29.2	51.0	5124
1991	95.7	134.5	144.9	225.9	795.8	1128.0	1100.2	1314.9	631.0	63.3	55.6	84.1	5774
1992	93.7	120.7	176.8	280.5	790.6	708.5	771.7	759.6	909.1	11.5	7.5	48.6	4679
1993	81.8	101.5	199.2	285.0	1034.5	1063.0	977.4	1276.7	499.1	35.2	12.1	62.2	5628
1994	106.0	114.5	190.0	256.0	817.2	842.2	954.7	1377.1	710.4	-4.4	19.0	98.5	5481
1995	112.9	134.5	156.7	167.2	788.1	1618.4	1776.7	1633.2	373.4	29.3	25.2	66.7	6882
1996	78.0	139.3	125.2	280.6	666.3	1413.5	1127.6	1181.4	125.0	149.3	8.8	35.7	5331

Table A-28. Current Level Depletions Above Fort Peck Dam (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	-101.1	-64.5	23.8	78.4	291.6	750.5	566.0	612.0	288.1	-88.2	-66.1	-87.9	2203
1899	-99.4	-62.8	25.5	80.1	343.9	1105.9	688.2	446.8	359.9	-95.9	-71.9	-91.7	2628
1900	-102.8	-65.9	22.3	77.2	332.9	1189.8	623.1	391.1	158.3	-59.6	-44.8	-75.5	2446
1901	-93.0	-59.2	26.8	80.4	333.7	795.9	777.3	700.6	62.2	-37.1	-64.7	-87.7	2435
1902	-102.0	-64.2	23.8	91.1	316.9	910.6	487.7	582.3	330.1	-48.1	-71.9	-92.1	2364
1903	-102.7	-65.4	23.2	78.2	371.6	1116.4	443.3	528.0	287.1	-47.5	-71.4	-91.7	2469
1904	-102.7	-65.8	22.5	88.8	538.9	962.4	468.9	413.3	313.2	-46.9	-49.9	-78.2	2465
1905	-94.9	-60.8	25.8	79.9	347.7	731.0	643.8	613.4	398.2	-75.9	-74.3	-93.1	2441
1906	-104.0	-66.3	22.6	77.8	304.7	858.0	778.2	363.5	324.1	-45.0	-68.8	-91.4	2353
1907	-103.5	-65.9	21.9	76.8	489.8	550.2	582.7	439.7	297.9	-38.4	-64.7	-88.2	2098
1908	-102.4	-65.6	22.3	90.4	290.5	549.1	741.3	447.6	194.3	-97.9	-55.1	-82.0	1932
1909	-98.1	-62.3	24.9	79.0	345.3	600.1	448.9	607.4	209.8	-34.6	-61.6	-85.9	1973
1910	-98.8	-62.3	25.8	93.1	498.1	960.3	690.4	468.9	99.2	-68.1	-60.6	-85.0	2461
1911	-101.7	-65.5	21.8	75.8	330.1	755.6	659.8	403.3	108.7	-93.7	-52.0	-80.1	1962
1912	-96.1	-61.0	25.7	79.5	319.4	1148.7	569.9	350.5	100.5	-82.0	-55.4	-82.3	2217
1913	-97.2	-62.2	24.5	78.3	371.4	826.9	530.1	571.4	330.9	-112.6	-67.3	-88.1	2306
1914	-101.1	-64.9	23.4	78.0	331.5	584.0	847.6	605.4	230.3	-111.8	-63.7	-86.4	2272
1915	-102.7	-65.8	22.2	76.5	436.2	489.8	349.5	601.8	101.8	-25.0	-54.4	-81.5	1748
1916	-98.6	-63.0	24.6	78.5	306.1	577.0	557.0	496.1	205.6	-102.9	-54.3	-80.9	1845
1917	-95.1	-59.9	27.4	81.5	307.9	887.7	817.5	584.9	189.9	-77.7	-67.2	-89.0	2508
1918	-102.0	-64.5	23.5	77.8	496.5	1273.8	363.4	415.3	142.8	-50.8	-62.2	-86.0	2428
1919	-98.4	-63.1	24.2	101.3	482.3	1081.2	680.2	511.3	207.7	-79.3	-49.3	-77.3	2721
1920	-94.9	-60.5	26.0	79.8	360.5	1029.3	706.6	516.2	260.8	-115.5	-67.7	-88.7	2552
1921	-100.7	-64.2	23.7	78.1	380.9	1023.6	658.9	565.8	230.6	-41.9	-71.0	-91.6	2592
1922	-103.7	-66.1	22.2	76.8	383.9	987.6	353.8	563.3	383.0	-42.2	-74.5	-93.5	2391
1923	-105.2	-68.1	20.7	75.9	356.4	644.2	527.7	403.6	410.0	-98.1	-64.3	-87.3	2015
1924	-97.4	-61.6	26.4	94.2	705.1	943.0	631.3	536.7	239.2	-81.7	-71.1	-90.3	2774
1925	-104.8	-67.9	20.2	74.8	529.9	765.1	739.8	450.1	32.6	-105.9	-53.3	-80.1	2201
1926	-98.0	-62.7	24.0	90.7	410.4	775.5	652.1	513.1	-45.3	-27.4	-53.0	-81.1	2098
1927	-98.5	-62.4	24.5	78.0	265.5	944.2	555.7	281.5	310.9	-48.9	-62.3	-87.5	2101
1928	-99.1	-63.1	24.3	79.0	917.4	613.8	420.4	329.3	352.6	-71.3	-66.8	-88.1	2348
1929	-56.2	-89.1	-2.4	52.1	462.2	963.9	875.3	414.0	-34.2	-72.1	-85.8	-69.3	2358
1930	-69.0	-73.8	80.2	288.2	481.3	911.5	604.1	309.4	44.3	-99.9	-69.4	-94.1	2313
1931	-78.4	-40.3	72.5	117.3	390.1	846.9	569.0	479.0	27.7	-77.3	-80.4	-30.7	2195
1932	-25.1	-3.2	81.6	137.6	565.9	862.6	701.4	316.6	175.8	-147.8	-64.2	-63.8	2537
1933	-71.7	-64.1	30.2	44.6	395.3	1172.8	810.6	112.5	100.0	-148.8	-53.7	-62.3	2265
1934	-51.8	-59.7	56.1	92.2	482.2	390.4	687.3	439.8	-1.2	-85.9	-59.5	-52.6	1837
1935	-46.6	-5.8	49.0	77.6	279.4	931.0	736.4	402.6	202.7	-91.4	-47.5	2.9	2490
1936	21.9	-49.0	64.9	141.8	741.0	811.5	738.2	379.6	127.4	-61.1	-19.6	-8.4	2888
1937	-58.0	-37.9	76.0	90.2	613.5	468.6	651.8	470.7	84.2	-70.4	-60.2	-17.1	2211
1938	-19.4	-36.6	31.0	41.1	354.4	827.0	589.5	379.6	196.2	-119.4	-42.9	-66.0	2134
1939	-87.1	-80.0	118.9	199.9	523.4	418.5	805.0	417.9	124.6	-113.1	-99.6	-75.8	2153
1940	-72.4	-41.8	79.6	130.8	667.4	870.8	523.8	506.9	-17.3	-88.5	-99.2	-54.7	2405
1941	-65.9	-63.9	55.9	71.9	311.9	683.2	711.9	266.5	38.3	1.6	-32.2	-55.8	1923
1942	-124.3	197.0	-86.6	187.5	309.8	746.5	764.9	410.1	100.8	-92.4	-43.5	-69.1	2301
1943	-159.3	-119.2	-77.3	152.2	406.2	807.4	809.9	339.2	106.3	-121.8	-50.6	-75.7	2017
1944	-90.7	-61.2	12.7	41.2	216.3	614.8	895.0	330.6	136.7	-74.3	-58.9	-103.8	1858
1945	-59.4	-48.9	69.7	62.3	318.5	568.7	1018.2	497.1	54.4	-72.4	-54.9	-91.4	2262
1946	-79.8	-67.7	42.3	206.7	452.0	724.8	707.2	405.5	68.4	-162.5	-54.8	-75.4	2167
1947	-113.1	-106.2	-97.4	25.0	822.1	679.7	1061.4	399.4	25.4	-81.6	-44.4	-84.2	2486
1948	-103.7	-81.2	-24.9	133.0	457.3	493.1	742.5	459.2	200.5	-66.8	-44.3	-80.8	2084
1949	-100.6	-70.6	29.3	210.3	583.6	860.6	773.3	502.3	172.6	-86.4	-65.1	-98.8	2710
1950	-120.4	-47.5	34.1	73.4	410.8	865.5	755.4	373.4	36.3	-50.4	-59.8	-61.7	2209
1951	-125.1	-72.1	-2.3	89.0	696.3	738.5	793.4	270.2	97.8	-85.8	-58.1	-100.7	2241
1952	-119.4	-100.9	-139.8	149.2	748.4	915.4	864.6	436.4	218.4	-138.7	-78.2	-80.0	2675
1953	-52.2	-55.0	6.7	35.7	104.4	1073.2	1102.7	475.0	217.1	-75.0	-34.2	-107.7	2691
1954	-103.8	-39.6	97.3	124.5	540.8	728.0	1011.2	262.8	121.5	-71.9	-28.5	-95.0	2547
1955	-101.0	-95.3	46.1	111.6	338.4	975.9	643.8	675.0	115.0	-122.6	-64.6	-59.8	2463

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	-66.8	-95.8	1.7	87.3	585.3	1076.2	793.6	305.6	217.7	-104.7	-0.8	-91.8	2708
1957	-135.6	-65.2	-43.8	-48.4	482.5	836.7	1005.0	429.2	159.1	-107.5	-55.9	-89.8	2366
1958	-112.8	-68.5	43.2	123.7	910.9	456.2	501.8	614.3	172.8	-77.8	-76.6	-69.6	2418
1959	-97.7	-90.2	98.2	74.9	189.3	1147.4	1029.8	359.1	-19.2	-47.6	52.5	37.3	2734
1960	-202.8	-143.4	171.9	190.5	401.8	1035.9	964.8	329.1	219.1	-143.3	-90.7	-66.0	2667
1961	-73.3	-29.8	57.3	37.2	242.5	1319.5	778.2	557.5	32.3	14.8	10.7	-70.7	2876
1962	-77.1	-24.4	9.5	176.2	206.9	1071.9	691.8	351.6	159.3	-87.0	-13.5	-80.3	2385
1963	-152.6	19.6	-15.5	-43.7	364.8	827.7	979.8	514.3	209.8	-99.3	-42.0	-113.9	2449
1964	-112.2	9.3	-103.8	-110.2	311.0	1178.3	1065.2	147.7	131.1	-93.7	-68.1	-108.4	2246
1965	-61.6	-68.2	-116.9	165.2	494.4	1256.3	915.0	262.2	-158.5	-96.8	-64.5	-153.7	2373
1966	-174.3	-141.2	142.4	148.4	461.9	646.1	913.9	452.7	224.4	-110.6	-136.6	-85.8	2341
1967	-86.9	-112.5	-157.3	-178.2	419.6	1316.4	1007.8	620.8	288.9	-151.9	-81.6	-191.7	2693
1968	-139.3	-81.3	4.7	-15.5	187.5	1010.1	1048.4	241.2	88.7	-38.1	-38.1	-144.0	2124
1969	-138.4	-86.6	-14.2	271.7	740.5	457.4	1016.8	611.2	149.7	-81.9	-50.9	-119.3	2756
1970	-132.4	-89.0	-127.5	-104.0	479.2	1476.7	803.6	515.9	-4.0	-124.9	-69.7	-138.0	2486
1971	-116.4	-14.7	-172.7	24.3	584.9	1218.1	1001.9	444.2	91.8	-53.8	-47.3	-160.7	2800
1972	-129.9	-75.8	127.6	6.5	361.3	1329.9	608.3	290.6	106.4	-50.1	-20.5	-142.1	2412
1973	-130.9	-100.7	114.7	141.4	647.9	817.1	901.8	421.2	159.4	-50.9	0.4	-82.1	2839
1974	-90.0	-66.9	-26.1	94.8	197.0	1582.8	846.2	194.3	171.7	-32.8	-54.3	-64.7	2752
1975	-112.0	-106.0	-109.3	-17.6	320.7	1386.8	684.9	410.2	233.0	-146.6	-91.9	-98.7	2353
1976	-177.1	-171.6	-174.3	52.6	1054.0	701.8	851.8	374.3	174.2	-56.8	-63.7	-148.3	2417
1977	-199.2	-139.9	60.8	209.5	197.4	934.3	727.7	339.5	81.9	-19.9	-52.0	-76.7	2064
1978	-86.8	-50.6	135.7	53.9	263.5	1121.8	789.1	482.0	60.8	-42.4	-79.5	-117.7	2530
1979	-155.3	-94.1	150.1	89.2	671.1	961.3	751.7	442.2	237.7	-119.3	-47.9	-70.5	2816
1980	-118.0	-48.5	-67.4	71.5	536.1	1057.1	901.9	222.9	93.5	-80.4	-48.9	-71.5	2448
1981	-94.7	-114.1	-174.7	-91.7	537.4	1087.2	872.8	610.9	189.0	-88.0	-46.1	-83.6	2604
1982	-138.5	-63.7	-97.1	2.6	377.2	1172.9	926.9	559.9	78.7	-76.6	-64.7	-133.4	2544
1983	-22.2	-117.3	46.1	59.9	402.5	1102.7	766.9	584.9	106.5	-45.9	-34.2	-197.4	2652
1984	-126.2	-117.8	-135.3	-56.5	633.9	1183.6	947.9	627.7	135.5	-107.2	-57.4	-191.8	2737
1985	-191.8	-291.4	126.2	324.6	568.1	1014.6	846.3	207.5	-2.4	13.0	-140.6	-108.0	2366
1986	-102.3	18.1	3.6	71.2	414.5	1322.1	749.2	472.6	-3.3	-82.6	-68.4	-138.7	2656
1987	-169.6	-111.9	87.1	213.2	219.3	1003.4	638.4	404.7	309.9	-53.8	-62.4	-102.3	2376
1988	-122.6	-38.8	-20.2	113.4	383.1	998.2	773.6	417.2	50.5	-48.1	-17.9	-19.5	2469
1989	-73.9	-127.4	61.9	92.1	319.0	1021.4	798.3	276.4	307.7	-42.8	95.5	-84.2	2644
1990	-91.0	-110.3	-63.9	143.9	224.7	1105.6	799.0	319.6	349.8	-62.0	30.1	-149.7	2496
1991	-171.7	-58.5	-43.5	9.2	441.3	812.7	944.9	421.0	50.3	-83.8	8.1	-74.5	2255
1992	-116.1	-69.2	-14.5	70.8	431.5	624.0	721.2	525.4	199.1	-1.8	30.8	-78.1	2323
1993	-121.8	-83.9	106.1	104.7	542.0	546.8	323.5	293.4	204.9	-89.8	-71.3	-118.9	1636
1994	-139.4	-130.6	20.3	164.6	415.2	758.8	703.3	533.6	251.4	-68.2	-2.3	-47.4	2459
1995	-69.4	-12.2	-6.7	9.0	172.8	1079.2	609.8	502.7	122.3	-44.6	44.4	28.8	2436
1996	-84.1	44.8	-186.1	28.9	394.2	1030.0	705.6	522.7	74.5	-47.1	1.9	-113.2	2372

Table A-29. Current Level Depletions Between Fort Peck and Garrison Dams (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	-142.9	-100.6	-36.8	208.9	326.7	1024.8	1042.2	634.6	213.1	-119.3	-143.6	-154.2	2753
1899	-142.5	-100.2	-36.4	127.8	774.4	1250.9	691.7	444.6	243.6	-105.6	-144.1	-153.9	2850
1900	-139.0	-98.2	-34.9	96.3	1511.2	1739.7	739.2	259.4	12.0	-92.0	-125.4	-140.7	3728
1901	-133.9	-96.1	-35.2	253.8	1578.2	1075.9	1029.4	570.4	43.3	-79.8	-155.2	-159.2	3891
1902	-149.2	-106.0	-42.5	248.3	1188.8	1255.1	867.6	468.2	200.9	-93.5	-154.3	-159.6	3524
1903	-149.9	-107.6	-44.0	39.2	812.7	1404.1	596.8	402.2	62.5	-64.7	-136.4	-149.8	2665
1904	-137.7	-97.6	-35.1	318.4	1039.6	1145.6	846.5	468.2	243.2	-90.1	-152.5	-158.9	3390
1905	-149.1	-106.8	-43.2	219.8	340.7	1082.1	788.5	710.0	201.3	-116.1	-142.6	-153.1	2631
1906	-139.3	-97.7	-33.8	277.0	731.0	1425.1	1085.1	276.0	306.9	-91.1	-153.7	-161.3	3424
1907	-147.2	-104.4	-41.2	75.2	598.6	1352.3	927.8	549.0	253.8	-60.1	-154.1	-160.9	3089
1908	-145.3	-102.0	-38.0	337.7	559.5	1413.6	1041.7	434.8	229.6	-136.7	-148.6	-157.2	3289
1909	-145.3	-103.4	-40.2	10.9	702.0	1318.1	863.0	603.4	113.3	-90.3	-145.2	-154.4	2932
1910	-140.3	-98.3	-34.9	332.3	1071.1	1551.7	882.7	329.5	76.5	-63.0	-126.4	-142.8	3638
1911	-137.7	-98.8	-37.4	175.4	935.7	1716.4	730.0	253.3	35.9	-137.7	-135.7	-148.5	3151
1912	-141.2	-102.2	-40.4	155.3	769.8	1610.0	572.7	277.3	-71.9	-120.8	-124.3	-142.0	2643
1913	-132.3	-94.5	-33.3	255.8	1158.9	1522.2	807.6	464.9	78.7	-145.4	-146.5	-153.8	3582
1914	-135.5	-96.7	-44.4	159.9	1291.2	1107.7	1111.6	550.8	247.3	-82.5	-158.8	-173.7	3777
1915	-166.2	-118.9	-62.0	479.9	663.0	641.6	535.4	591.2	-5.0	-33.6	-135.6	-148.2	2242
1916	-149.7	-105.0	-31.0	213.3	836.3	1079.0	749.5	337.0	91.1	-104.6	-140.1	-156.2	2620
1917	-153.1	-104.5	-49.7	3.2	462.6	1329.4	1241.4	487.8	223.7	-110.4	-157.5	-160.2	3013
1918	-149.7	-105.9	-35.4	38.5	996.4	1833.8	848.5	363.6	104.6	-49.7	-157.6	-166.5	3520
1919	-151.4	-107.2	-51.8	247.3	1350.9	1574.2	845.5	516.2	210.7	-138.3	-143.9	-149.8	4002
1920	-149.8	-110.3	-51.4	-21.0	920.5	1482.6	1118.3	588.1	219.7	-114.0	-194.4	-220.1	3468
1921	-158.9	-111.1	-93.7	171.2	961.2	1469.9	985.0	627.9	164.4	-61.3	-154.5	-157.4	3643
1922	-139.2	-97.5	-36.2	-0.6	900.1	1671.3	358.0	693.1	286.7	-107.8	-155.4	-159.4	3213
1923	-140.6	-98.3	-41.7	147.6	1083.4	1150.9	854.1	417.3	-63.5	-93.8	-131.8	-147.1	2936
1924	-135.6	-92.3	-35.0	118.2	721.8	692.4	878.7	577.7	277.2	-76.4	-140.9	-154.4	2632
1925	-136.5	-91.9	-30.8	412.4	1471.9	988.8	787.9	560.7	170.2	-143.7	-151.2	-154.1	3684
1926	-146.6	-101.8	-41.1	293.0	1156.6	1314.3	781.7	445.2	29.8	-50.4	-118.1	-143.1	3420
1927	-157.7	-97.1	-35.0	116.6	488.7	1341.6	810.1	371.8	155.6	-54.9	-134.9	-152.0	2653
1928	-132.3	-96.6	-30.1	208.8	1862.4	860.5	672.7	417.5	253.8	-137.1	-149.9	-150.1	3579
1929	-174.6	-154.2	258.3	73.2	818.1	1248.1	884.1	612.7	98.3	-107.3	-150.5	-156.5	3250
1930	-183.3	-114.0	-13.0	333.9	974.2	1268.7	930.7	560.7	143.7	-144.0	-196.9	-184.2	3376
1931	-163.9	-127.2	-47.1	174.5	1238.2	1575.8	650.1	481.2	121.7	-64.5	-120.0	-156.8	3562
1932	-130.3	-93.6	-55.1	15.7	1228.9	1084.9	940.6	437.2	125.9	-175.0	-131.0	-158.1	3090
1933	-139.8	-129.9	-36.0	21.1	716.8	2061.2	863.3	217.0	222.8	-105.8	-139.8	-110.9	3440
1934	-92.5	-68.9	-57.3	330.9	1711.3	694.2	716.0	461.3	61.7	-28.0	-66.7	-59.0	3603
1935	-59.5	-52.5	20.5	-57.9	437.3	1802.4	949.7	488.4	247.9	-146.0	-141.2	-138.0	3351
1936	-131.7	-113.3	-35.8	212.8	1572.2	1399.1	892.7	460.9	122.7	-108.3	-136.9	-142.2	3992
1937	-167.7	-138.8	-57.6	72.7	1355.2	1111.2	958.7	551.4	138.8	-122.8	-143.4	-115.9	3442
1938	-115.8	-95.1	-89.5	91.1	668.4	1344.6	854.3	482.8	325.1	-103.5	-154.8	-143.5	3064
1939	-135.4	-132.8	-17.1	324.4	1093.6	682.0	963.2	404.7	199.9	-145.6	-176.1	-96.7	2964
1940	-73.5	-49.6	-10.5	95.9	1270.2	1010.7	808.4	562.6	254.3	-26.2	-165.7	-100.0	3577
1941	-91.2	-87.0	-78.7	165.2	1439.8	1205.9	859.0	544.9	25.6	-54.8	-178.2	-145.1	3605
1942	-185.6	-151.3	-76.2	263.8	692.3	1091.9	966.8	502.0	121.7	-114.3	-156.6	-205.7	2749
1943	-171.0	-106.7	-9.5	260.8	636.3	1099.8	1233.1	552.1	249.9	-140.8	-156.9	-185.3	3262
1944	-193.9	-148.3	-119.1	61.7	1214.4	1251.2	857.5	472.2	114.5	-88.9	-156.5	-192.3	3072
1945	-144.8	-105.7	-62.6	-75.6	630.6	1059.8	1408.2	589.2	150.3	-72.7	-173.2	-184.2	3019
1946	-167.3	-114.1	-44.5	415.7	663.0	1218.4	1025.3	524.4	70.4	-67.9	-192.2	-188.2	3143
1947	-198.0	-150.0	-19.6	-58.6	1261.0	924.4	1295.1	598.9	153.1	-74.0	-169.4	-193.7	3369
1948	-175.8	-96.1	-33.8	284.3	1259.8	1286.6	610.3	582.0	273.1	-127.7	-174.1	-193.3	3495
1949	-185.9	-137.0	-65.1	359.7	1258.7	1451.6	882.1	625.5	148.5	-137.5	-165.1	-201.2	3834
1950	-191.1	-148.3	-116.7	123.9	636.4	1195.4	1149.1	502.2	81.1	-14.0	-159.8	-178.7	2880
1951	-182.7	-136.9	-105.8	18.2	1177.4	1058.6	1270.5	447.1	104.5	-140.5	-172.5	-187.5	3150
1952	-180.6	-145.2	-64.7	428.6	1160.9	1319.5	834.8	610.7	275.0	-141.8	-205.6	-167.9	3724
1953	-145.8	-96.7	-75.5	81.3	473.0	1328.9	1217.2	632.9	302.0	-69.8	-116.8	-105.0	3426
1954	-75.9	-101.4	-100.7	145.1	1226.4	991.5	1287.7	420.2	144.4	-175.5	-148.2	-151.4	3462
1955	-126.4	-138.6	-43.0	223.0	775.0	1230.8	989.5	688.5	155.0	-102.7	-110.5	-103.4	3437

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	-95.5	-70.2	-92.4	58.7	1250.6	1864.0	763.6	394.3	200.2	-134.6	-170.3	-137.1	3831
1957	-153.8	-115.6	-146.6	-236.3	855.7	1475.2	1340.8	588.6	172.2	-129.4	-185.5	-208.0	3257
1958	-154.5	-124.5	-111.9	224.8	2140.7	865.8	515.7	517.9	178.7	-168.7	-162.1	-88.6	3633
1959	-74.4	-120.3	20.7	146.6	753.2	1702.8	1137.1	571.1	75.9	-113.0	-156.9	-155.3	3788
1960	-139.2	-122.4	62.7	127.5	1028.0	1130.5	947.2	387.3	199.4	-24.0	-57.8	-54.5	3485
1961	-40.0	-7.8	-7.0	25.8	1000.0	1696.0	844.4	668.7	17.9	29.5	-10.2	-201.0	4016
1962	-196.5	21.7	-52.2	403.8	535.0	1554.6	679.0	470.1	181.1	-111.1	-180.8	-148.4	3156
1963	-174.9	-73.3	-112.3	-65.6	1062.6	1673.4	980.1	607.2	358.1	-139.9	-181.1	-164.3	3770
1964	-138.5	-155.1	-138.1	23.0	1117.9	1115.8	1348.1	369.8	216.4	-119.1	-164.0	-156.1	3320
1965	-122.3	-98.4	-152.2	40.4	445.3	1605.0	1340.7	325.1	-12.5	-40.2	-173.8	-125.8	3031
1966	-159.0	-149.7	-26.0	52.8	1267.6	1053.1	972.0	416.5	271.1	-35.4	-29.7	-93.5	3540
1967	-70.7	-36.2	-60.8	-237.2	586.9	1643.0	1128.0	573.8	188.6	-130.2	-160.2	-197.2	3228
1968	-193.5	-94.1	-34.7	43.7	671.5	1432.9	1044.8	390.8	229.7	-140.9	-149.5	-195.6	3005
1969	-205.4	-128.0	1.7	318.6	1374.2	810.2	952.5	719.9	274.0	-161.3	-162.6	-177.2	3616
1970	-176.1	-93.1	-64.1	-19.5	986.3	1630.2	1026.5	695.4	43.2	-160.8	-152.5	-192.9	3523
1971	-149.0	-63.5	-143.6	-62.3	779.4	1985.6	920.4	742.2	68.0	-112.9	-180.9	-256.9	3527
1972	-200.8	-63.8	16.9	52.5	909.9	1888.3	608.0	500.4	158.8	-120.7	-165.2	-183.4	3401
1973	-174.2	-167.0	-88.9	76.0	1332.5	1303.5	922.4	579.6	48.5	-112.1	-162.0	-194.4	3364
1974	-198.3	-137.4	-74.7	184.7	636.2	1936.5	1163.4	311.0	131.9	-135.0	-154.1	-155.6	3509
1975	-157.3	-134.5	-102.8	-171.2	368.7	1106.6	1601.6	542.4	251.4	-143.4	-168.7	-180.5	2812
1976	-151.5	-97.8	-54.1	141.5	1383.1	1159.8	1136.1	458.1	223.8	-126.3	-191.0	-148.7	3733
1977	-152.0	-128.3	-86.7	404.0	935.8	1277.5	806.5	502.8	136.2	-21.9	-64.9	-83.6	3525
1978	-79.6	-82.9	62.8	4.1	402.3	1553.5	1116.1	588.9	-11.3	-90.8	-174.0	-179.7	3109
1979	-183.1	-156.5	91.0	159.1	1083.8	1380.1	841.8	560.5	305.5	-134.0	-154.5	-161.6	3632
1980	-145.4	-93.4	-67.2	325.2	1229.2	1441.0	1085.7	335.6	205.5	-143.7	-138.6	-125.7	3908
1981	-125.4	-102.7	-46.5	219.8	784.9	1394.2	821.2	628.3	280.7	-137.3	-141.9	-134.8	3441
1982	-148.6	-95.1	-48.8	22.9	554.3	1169.9	1239.2	636.7	60.8	8.8	-197.2	-212.0	2991
1983	-172.7	-131.4	-135.6	-88.4	641.6	1636.7	1147.1	812.6	131.1	-76.6	-163.9	-217.3	3383
1984	-160.8	-131.9	-25.4	97.3	1351.8	1244.8	1066.8	661.7	60.4	-132.4	-162.8	-177.7	3692
1985	-172.5	-174.7	0.7	406.2	1301.5	1109.1	956.9	403.6	96.9	-22.8	-90.9	-113.7	3700
1986	-91.8	4.4	-39.8	-13.5	626.9	1957.0	711.4	540.2	3.7	-83.2	-143.2	-185.4	3287
1987	-170.4	-95.7	25.0	553.2	1224.0	1300.1	601.6	350.1	216.2	-52.6	-140.5	-130.6	3681
1988	-103.6	-58.1	-9.4	245.0	1052.9	1414.1	804.1	518.9	55.7	-30.1	-56.8	-61.9	3771
1989	-53.3	-47.2	46.4	181.4	909.3	1375.3	1176.1	502.9	259.2	7.4	-78.6	-153.9	4125
1990	-122.1	-94.9	-43.3	178.6	880.3	1382.3	886.3	592.4	369.9	-56.0	-89.8	-151.7	3732
1991	-139.3	-49.4	-19.7	164.2	1246.7	1219.6	761.5	685.6	103.3	-159.0	-134.5	-153.0	3526
1992	-136.3	-47.6	6.8	151.1	1139.1	958.7	712.9	447.6	250.2	-43.2	-115.6	-129.2	3195
1993	-100.6	-54.0	57.2	159.1	1445.9	951.4	289.4	452.8	200.4	-156.7	-181.4	-119.5	2944
1994	-109.2	-73.7	18.9	216.9	1311.0	847.8	653.2	568.5	207.8	-25.3	-42.9	-58.2	3515
1995	-52.0	18.1	32.6	20.7	721.7	1547.9	939.6	572.3	123.8	-122.5	-116.1	-115.4	3571
1996	-92.1	-51.2	-91.2	-42.6	499.6	1707.6	1112.9	681.5	112.2	-87.0	-110.4	-134.3	3505

Table A-30. Current Level Depletions Between Garrison and Oahe Dams (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	9.7	12.0	24.8	15.7	51.9	79.5	37.1	30.5	13.8	0.1	4.8	7.6	288
1899	9.5	11.8	24.6	15.5	28.4	62.1	34.5	-0.1	22.8	7.9	5.3	7.6	230
1900	10.3	12.6	25.4	35.2	159.1	97.2	38.2	-3.8	-19.4	11.4	6.7	8.8	382
1901	10.3	12.4	25.0	38.2	176.9	27.3	44.8	30.9	-4.2	9.7	4.0	7.2	383
1902	9.0	11.5	24.3	24.9	132.8	39.0	53.8	-2.7	24.9	11.9	3.7	6.8	340
1903	8.9	11.4	24.3	26.5	87.6	75.3	45.7	-17.0	-9.2	18.1	5.5	7.6	285
1904	9.8	12.1	24.8	38.4	82.9	49.7	49.4	12.0	21.0	16.6	3.7	6.6	327
1905	8.9	11.5	24.4	17.1	30.1	52.4	36.6	41.7	36.2	9.2	3.6	6.7	278
1906	9.2	11.7	24.7	32.3	2.2	58.3	62.4	2.5	38.7	15.5	4.0	6.6	268
1907	9.1	11.7	24.6	15.7	23.4	78.7	11.1	26.3	7.0	12.4	5.2	7.6	233
1908	9.9	12.2	25.0	24.2	36.3	57.3	43.8	22.5	33.1	4.3	4.2	7.1	280
1909	9.3	11.7	24.6	15.6	35.1	78.7	14.0	0.9	26.0	12.2	4.8	7.3	240
1910	10.0	12.3	25.1	34.9	83.6	67.5	47.5	10.8	18.1	17.5	6.0	8.2	342
1911	10.2	12.4	25.1	24.1	110.8	109.0	47.7	-7.3	11.6	4.2	4.4	7.3	359
1912	9.3	11.6	24.3	25.2	79.2	87.8	18.8	2.1	1.8	12.9	5.0	7.5	286
1913	9.7	12.0	24.8	30.7	43.0	101.4	30.2	24.6	22.1	6.8	6.4	8.5	320
1914	10.1	12.2	25.0	15.9	75.3	18.4	45.2	6.8	28.0	15.8	4.3	7.0	264
1915	8.9	11.4	24.3	38.6	28.1	23.8	-8.5	19.0	6.2	9.4	6.4	8.3	176
1916	10.2	12.4	25.1	17.8	35.5	47.5	60.0	2.1	18.9	10.1	5.1	7.4	252
1917	9.9	12.3	25.1	16.1	73.8	75.9	62.4	21.9	11.1	10.2	4.0	6.9	330
1918	9.3	11.8	24.7	15.6	78.5	94.4	37.2	3.5	16.9	14.3	4.0	6.8	317
1919	9.3	11.8	24.6	17.1	35.3	75.2	59.9	36.7	27.8	4.2	6.2	8.4	316
1920	10.0	12.2	25.0	15.9	50.3	36.6	39.2	21.9	14.1	15.3	4.7	7.2	253
1921	9.8	12.3	25.1	16.0	83.1	111.6	52.8	9.8	-3.6	12.6	4.4	7.2	341
1922	9.5	11.9	24.7	20.6	73.2	46.0	46.7	54.9	32.7	12.2	2.6	6.2	341
1923	8.5	11.2	24.3	18.6	83.0	39.9	28.3	10.7	0.3	11.5	5.5	7.8	249
1924	9.5	11.8	24.6	15.5	40.3	25.0	33.0	26.2	17.1	5.9	5.4	7.8	222
1925	10.1	12.4	25.2	38.8	112.1	-3.5	46.5	28.1	30.3	4.5	4.0	7.1	315
1926	9.4	11.8	24.7	33.4	108.3	81.8	49.6	17.9	-3.8	4.3	4.7	7.5	350
1927	9.1	11.5	24.2	15.2	20.1	71.5	17.3	21.0	19.3	15.6	4.7	7.2	237
1928	9.7	12.2	25.0	17.6	145.9	37.3	24.2	-7.9	18.1	7.7	4.7	7.5	302
1929	9.6	12.0	24.9	16.2	33.0	71.2	66.3	32.2	0.2	3.4	4.9	7.5	281
1930	9.7	12.1	24.9	15.8	48.0	49.5	70.8	27.9	20.9	1.9	4.0	7.0	293
1931	9.6	12.1	25.0	21.4	65.6	89.6	61.9	17.3	23.2	7.3	5.6	8.0	346
1932	9.8	12.1	24.9	15.8	39.0	69.4	63.5	24.1	24.3	0.2	3.9	7.0	294
1933	9.6	12.1	25.0	16.1	15.1	117.2	75.1	30.5	28.1	8.0	5.1	7.6	349
1934	10.1	12.5	25.3	24.0	140.4	56.9	61.8	37.9	4.4	6.8	5.7	8.3	394
1935	9.7	11.9	24.7	16.0	10.2	58.8	81.8	43.2	32.6	7.8	3.8	6.8	307
1936	10.0	12.6	25.6	18.1	122.7	101.7	98.3	41.5	24.5	3.5	4.5	7.6	471
1937	9.3	11.6	24.5	21.0	58.2	53.7	36.5	64.4	18.8	6.5	3.2	6.6	314
1938	9.0	11.6	24.6	19.5	19.8	68.0	64.9	52.8	14.7	8.9	3.4	6.5	304
1939	9.3	11.9	24.9	22.3	93.7	35.3	70.4	29.4	28.1	4.6	4.4	7.3	342
1940	9.6	12.0	24.9	15.8	98.1	69.8	43.9	34.6	24.5	6.4	5.5	8.1	353
1941	9.7	11.9	24.7	15.6	77.1	33.2	56.7	32.0	-13.5	3.7	5.6	8.0	265
1942	9.5	11.9	24.6	15.5	9.3	30.4	49.5	39.1	3.8	7.6	5.3	7.6	214
1943	10.0	12.4	25.3	24.5	47.3	26.1	63.0	44.7	34.8	4.6	3.1	6.5	302
1944	8.8	11.4	24.4	16.6	48.7	26.3	45.4	14.7	22.8	7.6	4.5	7.1	238
1945	9.3	11.8	24.6	19.5	30.4	14.7	53.9	38.5	-4.5	9.9	5.5	7.7	221
1946	9.5	12.0	24.8	17.4	6.6	33.9	54.3	33.6	-8.9	1.0	6.3	8.3	199
1947	10.4	12.7	25.5	16.3	69.5	10.7	79.7	60.3	12.5	3.3	3.7	6.9	311
1948	9.1	11.7	24.7	16.0	66.6	31.9	47.9	25.6	39.0	4.6	3.5	6.7	287
1949	9.4	11.9	24.8	19.5	62.0	83.7	54.2	44.0	16.0	-0.4	3.8	7.0	336
1950	9.1	11.5	24.5	15.4	38.3	83.3	43.4	15.5	1.4	9.0	4.9	7.4	264
1951	9.3	11.7	24.5	19.1	62.1	24.0	49.4	-9.3	-6.9	3.4	6.7	8.5	203
1952	7.9	19.3	39.5	44.9	32.4	47.8	68.5	21.3	31.2	1.3	-2.9	5.1	316
1953	0.1	2.8	29.5	4.5	53.7	99.9	57.2	54.4	15.8	-4.1	-1.1	3.3	316
1954	4.0	12.2	12.7	23.1	49.1	49.4	70.5	32.2	0.3	-5.0	-1.9	4.6	251
1955	6.2	7.3	34.8	92.6	61.9	47.2	54.2	77.4	12.9	3.0	-6.3	10.2	401

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	4.5	6.7	24.8	11.4	37.4	75.7	16.9	11.7	20.3	-1.0	2.8	6.3	218
1957	4.6	11.1	15.9	19.9	73.7	51.3	64.6	27.6	10.0	-1.5	1.3	2.9	281
1958	-3.3	8.6	22.0	32.6	94.6	37.0	52.4	40.4	18.1	-5.4	-6.5	1.6	292
1959	3.1	3.7	30.4	14.8	20.6	67.6	97.0	46.7	8.5	2.5	0.6	6.0	302
1960	7.0	7.9	50.9	15.8	29.5	61.7	81.7	49.5	41.1	0.5	-0.7	4.6	350
1961	5.8	7.7	8.6	5.7	48.2	100.6	62.7	91.5	4.7	3.4	-0.5	3.4	342
1962	5.7	31.9	27.6	10.9	147.8	106.4	85.8	51.4	-3.7	4.1	2.3	5.3	476
1963	6.3	34.7	21.7	11.2	61.8	75.1	54.4	26.4	20.9	-6.3	-0.6	3.8	309
1964	8.2	9.5	13.7	23.9	55.5	112.2	86.1	4.3	16.3	8.4	-0.9	7.1	344
1965	11.3	18.4	21.9	41.0	34.6	37.4	83.3	36.9	-11.7	0.3	4.9	8.5	287
1966	10.3	3.9	17.6	3.1	70.1	15.7	54.1	29.4	10.5	4.8	7.2	5.2	232
1967	13.0	19.9	39.6	15.9	63.1	37.3	81.7	24.4	7.2	2.8	5.1	6.2	316
1968	10.9	15.2	31.3	17.2	31.1	47.6	56.9	32.5	25.0	0.3	4.1	6.1	278
1969	9.4	9.8	43.3	39.4	59.9	26.2	67.2	43.0	19.5	-4.3	5.8	6.5	326
1970	13.7	18.1	19.7	44.0	53.3	90.2	45.2	38.9	-1.6	6.0	7.0	11.0	345
1971	12.5	42.5	47.3	54.7	35.5	69.4	45.3	26.3	5.3	28.6	12.7	12.2	392
1972	13.1	45.6	33.2	0.4	15.2	48.1	42.2	49.4	21.0	6.7	10.4	10.1	296
1973	15.9	3.5	9.0	10.9	49.3	80.9	45.6	24.9	26.0	13.1	12.5	12.4	304
1974	27.0	21.5	17.5	2.6	21.4	69.5	38.6	4.7	26.9	6.5	6.7	9.1	252
1975	12.1	13.0	49.0	47.3	66.5	53.8	64.9	8.1	10.1	2.9	4.4	10.4	342
1976	15.9	17.3	23.3	19.8	51.6	88.5	51.8	31.9	19.0	5.4	6.8	8.9	340
1977	11.1	12.4	25.4	58.7	56.8	37.2	38.8	10.8	21.3	19.2	5.6	9.4	307
1978	12.2	12.5	146.1	29.5	70.3	51.2	54.8	18.3	22.3	6.3	4.9	9.5	438
1979	9.9	11.6	44.4	27.1	28.8	44.5	34.3	39.6	17.9	-1.5	1.3	6.8	265
1980	9.5	21.0	14.6	17.7	40.1	74.3	24.0	4.4	38.5	0.8	3.3	10.3	258
1981	10.2	9.9	12.6	10.7	14.3	44.8	38.4	22.5	9.9	5.4	3.8	7.0	190
1982	6.5	16.7	21.8	15.0	121.7	101.5	74.7	38.1	5.9	28.0	11.3	9.8	451
1983	18.1	20.7	3.5	2.0	36.9	62.4	33.0	41.2	5.8	8.3	6.8	8.0	247
1984	12.8	21.2	43.3	17.4	105.2	45.5	64.0	33.8	3.6	11.4	7.6	8.2	374
1985	10.2	10.1	37.8	19.9	42.5	10.0	12.6	2.8	9.6	8.2	6.1	8.5	178
1986	10.5	23.5	58.7	51.2	75.2	65.1	17.2	29.8	4.1	22.7	8.2	7.0	373
1987	10.9	17.3	41.0	34.2	35.5	82.2	33.3	26.0	30.4	5.3	-0.1	5.7	322
1988	7.1	12.2	23.0	22.8	35.7	34.2	65.9	23.3	20.8	9.5	4.5	7.6	267
1989	8.4	8.2	29.5	19.7	89.4	54.9	45.3	98.2	29.7	2.4	5.2	9.3	400
1990	10.8	15.8	23.8	17.2	58.5	60.7	32.2	36.1	32.5	2.6	1.2	5.0	296
1991	6.4	9.4	12.3	15.1	114.1	61.9	68.1	46.4	28.2	0.3	6.2	7.5	376
1992	7.7	10.1	12.2	14.7	55.6	48.7	29.4	16.2	31.8	4.5	3.4	4.8	239
1993	7.0	7.8	54.3	36.5	79.3	92.7	57.1	58.1	17.2	2.7	-7.2	7.5	413
1994	12.0	32.2	46.2	14.3	83.1	51.5	24.1	25.4	37.7	19.9	6.4	8.7	361
1995	11.0	14.1	25.6	19.6	50.1	58.8	67.4	44.8	16.8	12.2	14.6	1.4	337
1996	13.6	30.9	46.2	11.7	26.1	82.5	62.5	56.5	0.3	9.5	-3.4	7.0	343

Table A-31. Current Level Depletions Between Oahe and Big Bend Dams (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	-0.1	0.0	0.0	0.1	3.4	5.8	8.1	7.3	2.4	-0.3	-0.4	-0.2	26
1899	-0.1	-0.1	0.0	0.0	1.9	5.1	8.5	5.8	2.6	-0.1	-0.4	-0.2	23
1900	0.0	0.0	0.1	0.9	13.5	10.8	9.9	4.8	-0.6	-0.2	-0.5	-0.2	38
1901	-0.1	-0.1	0.0	1.4	12.1	2.7	11.1	7.0	0.3	-0.3	-0.5	-0.2	33
1902	-0.1	-0.1	0.0	0.7	11.5	2.7	10.8	5.0	3.3	0.1	-0.5	-0.3	33
1903	-0.2	-0.1	0.0	0.8	9.6	5.6	7.7	5.2	1.5	0.3	-0.5	-0.2	30
1904	-0.1	-0.1	0.0	1.4	3.4	8.4	9.1	7.2	2.6	0.3	-0.5	-0.3	31
1905	-0.2	-0.1	0.0	0.3	1.0	4.3	8.4	8.4	5.3	-0.2	-0.6	-0.3	26
1906	-0.1	-0.1	0.0	1.2	0.1	9.0	10.3	4.3	3.5	0.0	-0.5	-0.3	27
1907	-0.1	0.0	0.0	0.0	1.2	8.6	8.0	9.2	2.0	-0.3	-0.5	-0.2	28
1908	-0.1	0.0	0.0	1.3	2.8	5.8	6.7	6.9	5.2	-0.2	-0.5	-0.3	27
1909	-0.1	-0.1	0.0	0.1	4.4	9.1	3.9	7.3	3.2	0.2	-0.5	-0.3	27
1910	-0.1	0.0	0.0	2.1	4.2	10.0	11.7	8.7	2.9	0.3	-0.4	-0.2	39
1911	-0.1	0.0	0.0	2.2	10.2	14.0	11.3	5.7	1.2	0.0	-0.4	-0.2	44
1912	-0.1	0.0	0.0	1.0	10.2	12.0	9.8	5.1	2.0	0.1	-0.6	-0.3	39
1913	-0.1	0.0	0.0	1.9	4.8	13.0	12.8	10.3	3.7	-0.1	-0.5	-0.2	46
1914	-0.1	0.0	0.0	0.9	6.3	8.7	11.9	7.4	3.1	-0.2	-0.4	-0.2	37
1915	-0.1	-0.1	-0.1	1.2	-0.1	3.0	4.7	8.6	2.0	0.3	-0.4	-0.2	19
1916	0.0	0.0	0.1	0.5	2.9	7.4	13.1	7.7	4.5	-0.1	-0.6	-0.3	35
1917	-0.2	-0.1	0.0	0.2	2.6	10.6	13.9	7.5	3.5	-0.1	-0.6	-0.3	37
1918	-0.2	-0.1	0.0	0.1	6.4	12.5	9.5	6.7	2.1	0.2	-0.6	-0.3	36
1919	-0.1	-0.1	0.0	0.2	7.8	4.8	11.2	10.0	4.3	-0.5	-0.4	-0.2	37
1920	-0.1	0.0	0.0	0.0	1.6	5.6	13.1	8.5	3.2	0.1	-0.6	-0.3	31
1921	-0.1	0.0	0.0	1.1	5.1	12.9	8.6	8.8	3.4	0.1	-0.4	-0.2	39
1922	-0.1	0.0	0.0	0.3	4.6	4.9	3.7	11.8	5.7	0.1	-0.7	-0.3	30
1923	-0.2	-0.1	-0.1	0.4	6.0	4.3	7.0	5.8	1.8	-0.1	-0.4	-0.2	24
1924	-0.1	0.0	0.0	0.5	7.2	6.2	10.0	9.0	3.6	0.1	-0.6	-0.3	36
1925	-0.1	-0.1	0.0	2.1	9.7	3.7	12.0	10.4	4.3	-0.3	-0.4	-0.2	41
1926	-0.1	0.0	0.0	1.6	7.6	8.9	8.2	9.1	4.0	-0.1	-0.6	-0.3	38
1927	-0.2	-0.1	-0.1	0.0	1.4	6.6	8.7	6.8	4.4	0.4	-0.5	-0.3	27
1928	-0.1	0.0	0.0	1.0	11.0	3.8	8.4	10.1	2.7	-0.1	-0.6	-0.3	36
1929	-0.1	0.0	0.0	0.0	1.7	6.7	13.0	10.1	1.2	-0.6	-0.3	-0.1	31
1930	0.0	0.0	0.0	0.0	1.9	8.6	14.7	6.4	3.1	-0.6	-0.3	-0.2	34
1931	0.0	0.0	0.0	0.2	1.6	10.2	13.9	9.4	2.0	-0.3	-0.3	-0.2	37
1932	-0.1	0.0	0.0	0.0	1.0	7.7	14.4	7.8	2.9	-0.7	-0.5	-0.3	32
1933	-0.1	0.0	0.0	0.0	1.3	11.0	12.5	4.6	3.3	-0.1	-0.3	-0.2	32
1934	0.0	0.0	0.0	0.2	7.6	9.0	12.2	9.3	0.1	-0.4	-0.3	-0.1	38
1935	0.0	0.0	0.0	0.0	1.0	7.8	16.2	10.4	4.0	-0.3	-0.4	-0.2	39
1936	0.0	0.0	0.1	0.2	3.0	12.6	17.6	7.9	3.1	-0.4	-0.4	-0.2	43
1937	-0.1	0.0	0.0	0.2	1.6	6.1	11.6	11.9	4.3	-0.2	-0.4	-0.2	35
1938	-0.1	0.0	0.0	0.0	1.0	7.4	10.9	12.6	1.0	-0.2	-0.5	-0.3	32
1939	-0.1	0.0	0.0	0.2	2.1	4.5	13.1	10.3	2.4	-0.5	-0.3	-0.2	32
1940	0.0	0.0	0.1	0.1	5.4	7.3	12.7	8.3	3.5	-0.4	-0.4	-0.2	36
1941	-0.1	0.0	0.0	0.0	1.5	4.1	12.4	8.9	0.3	-0.7	-0.4	-0.2	26
1942	-0.1	0.0	0.0	0.0	0.1	7.9	9.5	7.5	-0.1	-0.4	-0.3	-0.2	24
1943	-0.1	0.0	0.0	0.4	1.4	3.2	12.0	10.5	3.7	-0.6	-0.5	-0.3	30
1944	-0.2	-0.1	0.0	0.0	1.4	5.5	8.2	5.1	3.2	-0.2	-0.4	-0.2	22
1945	-0.1	0.0	0.0	0.1	1.2	2.5	11.7	5.3	0.5	-0.2	-0.3	-0.2	21
1946	-0.1	0.0	0.0	0.2	0.3	3.9	10.9	4.7	0.0	-0.5	-0.2	-0.1	19
1947	0.0	0.1	0.1	0.1	3.1	2.3	14.3	12.7	2.9	-0.4	-0.4	-0.2	34
1948	-0.1	0.0	0.0	0.0	1.5	2.4	10.0	7.4	3.5	-0.5	-0.4	-0.2	23
1949	-0.1	0.0	0.0	0.1	1.2	9.8	11.8	8.2	1.2	-0.8	-0.4	-0.2	31
1950	-0.1	0.0	0.0	0.2	1.0	12.3	8.4	8.0	0.3	-0.5	-0.4	-0.2	29
1951	-0.1	-0.1	0.0	0.0	1.1	2.7	9.2	4.3	2.5	-0.5	-0.3	-0.2	19
1952	0.0	0.0	0.1	0.4	2.0	6.2	12.8	8.4	3.9	-0.2	-0.4	-0.2	33
1953	-0.1	0.0	0.0	0.0	1.6	3.8	11.9	5.3	4.7	-0.5	-0.5	-0.3	26
1954	-0.1	0.0	0.0	0.1	2.1	2.8	15.4	8.7	2.8	-0.8	-0.5	-0.3	30
1955	-0.1	0.0	0.0	0.1	2.2	4.0	14.4	9.6	2.3	-0.4	-0.5	-0.3	31

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	-0.1	-0.1	0.0	0.0	1.4	13.0	8.5	4.4	3.0	-0.5	-0.5	-0.2	29
1957	-0.1	0.0	0.0	0.0	0.4	4.1	14.7	8.0	2.7	-0.7	-0.5	-0.2	28
1958	-0.1	0.0	0.0	0.0	2.6	4.5	10.4	12.2	4.6	-0.5	-0.6	-0.3	33
1959	-0.2	-0.1	0.0	0.2	0.5	9.8	12.8	10.4	-0.4	-0.6	-0.4	-0.2	32
1960	-0.1	0.0	0.0	0.2	1.1	3.3	16.3	6.5	2.8	-0.4	-0.5	-0.3	29
1961	-0.1	0.0	0.0	0.1	0.7	9.9	11.0	11.6	0.3	-0.3	-0.3	-0.1	33
1962	-0.1	0.0	0.0	0.2	0.3	2.4	8.0	11.5	3.4	-0.5	-0.5	-0.2	24
1963	-0.1	0.0	0.0	0.0	1.3	5.7	9.2	11.0	0.3	-0.6	-0.4	-0.2	26
1964	-0.1	0.0	0.0	0.0	1.8	6.0	11.3	9.3	3.6	-0.3	-0.6	-0.3	31
1965	-0.2	-0.1	0.0	0.0	0.7	4.6	11.9	9.8	-0.9	-0.4	-0.4	-0.2	25
1966	-0.1	0.0	0.0	0.0	4.0	11.4	11.1	6.4	1.0	-0.5	-0.5	-0.2	33
1967	-0.1	-0.1	0.0	0.0	0.8	1.4	14.6	11.4	0.6	-0.5	-0.4	-0.2	27
1968	-0.1	-0.1	0.0	0.0	1.1	2.5	9.1	6.9	2.7	-0.2	-0.4	-0.2	21
1969	-0.1	0.0	0.0	0.2	2.2	2.8	7.8	11.8	1.4	-0.6	-0.4	-0.2	25
1970	-0.1	0.0	0.0	0.0	2.3	7.0	11.3	5.1	0.4	-0.5	-0.3	-0.2	25
1971	0.0	0.0	0.0	0.0	2.0	5.5	13.2	10.6	1.7	-0.8	-0.5	-0.2	31
1972	-0.1	-0.1	0.0	0.0	0.4	6.6	6.0	9.8	4.2	-0.7	-0.5	-0.3	25
1973	-0.1	0.0	0.0	0.0	1.8	10.1	12.8	10.5	-0.5	-0.8	-0.4	-0.2	33
1974	-0.1	0.0	0.0	0.0	0.3	10.5	11.8	7.9	3.4	-0.4	-0.4	-0.2	33
1975	-0.1	0.0	0.0	0.0	1.5	2.8	14.9	8.1	-0.1	-0.5	-0.3	-0.2	26
1976	0.0	0.0	0.1	0.2	4.1	11.7	13.5	9.8	3.2	-0.4	-0.4	-0.2	42
1977	-0.1	-0.1	0.0	0.1	2.9	6.6	10.4	5.8	0.1	-0.6	-0.3	-0.2	25
1978	-0.1	0.0	0.0	0.0	1.7	8.6	9.1	7.9	4.3	-0.3	-0.5	-0.3	30
1979	-0.2	-0.1	0.0	0.0	2.1	4.1	6.0	4.5	5.7	-0.5	-0.4	-0.2	21
1980	-0.1	0.0	0.0	0.4	3.8	7.6	13.8	5.0	4.3	-0.9	-0.5	-0.3	33
1981	-0.1	-0.1	0.0	0.3	0.8	6.6	8.6	8.4	4.6	-0.7	-0.5	-0.3	27
1982	-0.1	-0.1	0.0	0.0	0.1	3.3	8.6	9.1	2.2	-0.7	-0.4	-0.2	22
1983	-0.1	0.0	0.0	0.1	1.0	1.8	15.4	12.5	1.7	-0.8	-0.5	-0.3	31
1984	-0.2	-0.1	0.0	0.0	1.4	4.0	9.3	10.4	1.8	-0.6	-0.4	-0.2	25
1985	-0.1	0.0	0.0	0.2	3.7	6.6	11.2	6.8	-0.2	-0.5	-0.4	-0.2	27
1986	-0.1	0.0	0.0	0.0	1.4	7.1	11.0	9.1	0.0	-0.5	-0.4	-0.2	27
1987	-0.1	0.0	0.0	0.4	1.1	10.2	12.9	6.0	2.9	-0.4	-0.5	-0.3	32
1988	-0.1	0.0	0.0	0.2	1.9	7.3	12.7	9.1	1.4	-0.3	-0.3	-0.1	32
1989	0.0	0.0	0.0	0.1	2.9	11.0	12.6	8.7	0.0	-0.4	-0.3	-0.1	34
1990	-0.1	0.0	0.0	0.0	1.8	6.9	9.1	9.7	3.6	-0.5	-0.5	-0.3	30
1991	-0.1	-0.1	0.0	0.0	0.5	4.0	12.8	11.3	2.0	-0.8	-0.5	-0.2	29
1992	-0.1	-0.1	0.0	0.2	5.5	4.1	3.7	7.3	2.8	-0.4	-0.4	-0.2	22
1993	-0.1	-0.1	0.0	0.0	1.7	3.6	4.6	10.2	0.9	-0.4	-0.4	-0.2	20
1994	-0.1	0.0	0.0	0.0	2.4	5.9	6.8	6.1	2.2	-0.6	-0.4	-0.2	22
1995	-0.1	0.0	0.0	0.0	0.1	3.1	11.3	5.4	3.1	-0.6	-0.4	-0.2	22
1996	-0.1	0.0	0.0	0.3	0.0	9.6	9.7	9.2	-0.5	-0.6	-0.4	-0.2	27

Table A-32. Current Level Depletions Between Big Bend and Fort Randall Dams (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	-0.4	-0.2	0.0	0.0	3.1	16.4	17.1	29.1	13.5	-1.2	-1.6	-0.8	75
1899	-0.4	-0.2	-0.1	0.0	3.5	5.8	21.5	19.9	17.0	-1.0	-1.5	-0.8	64
1900	-0.3	-0.1	0.1	1.9	23.9	22.2	20.6	19.5	7.5	-2.3	-1.4	-0.7	91
1901	-0.4	-0.2	-0.1	2.5	24.6	0.8	32.6	25.4	-2.8	-0.9	-1.1	-0.5	80
1902	-0.2	0.0	0.0	1.4	26.5	14.3	32.7	13.1	11.3	-0.8	-1.6	-0.8	96
1903	-0.5	-0.3	-0.2	3.4	8.6	20.4	15.1	27.2	1.0	-0.2	-1.2	-0.6	73
1904	-0.3	-0.1	0.0	2.3	12.8	5.1	22.3	25.1	17.6	-0.9	-1.7	-0.9	81
1905	-0.5	-0.3	-0.1	1.3	3.0	1.9	24.8	33.6	11.2	-1.3	-1.5	-0.8	71
1906	-0.4	-0.2	0.0	3.1	14.6	7.5	33.5	12.2	5.2	-0.2	-1.1	-0.6	74
1907	-0.3	-0.2	-0.1	0.0	7.1	10.0	6.7	35.7	7.9	1.0	-1.5	-0.8	66
1908	-0.4	-0.2	0.0	1.8	-0.1	3.0	30.0	21.9	16.8	-0.6	-1.5	-0.9	70
1909	-0.4	-0.1	0.0	0.5	2.3	17.0	29.6	19.5	11.7	-0.8	-1.4	-0.8	77
1910	-0.3	-0.1	0.0	3.6	13.9	19.3	27.3	17.9	9.8	1.2	-1.0	-0.5	91
1911	-0.2	-0.1	0.0	2.7	22.9	17.3	25.5	15.2	7.4	-2.2	-1.3	-0.7	87
1912	-0.3	-0.2	-0.1	1.7	22.9	23.6	16.1	9.3	9.6	1.4	-1.4	-0.8	82
1913	-0.3	-0.2	-0.1	1.6	6.0	22.4	23.1	26.6	14.6	0.5	-1.2	-0.6	93
1914	-0.3	-0.1	0.0	2.2	8.7	5.3	29.9	20.0	5.5	-1.1	-1.1	-0.6	68
1915	-0.4	-0.2	-0.1	3.0	5.5	2.9	0.5	24.6	10.0	0.4	-1.1	-0.6	45
1916	-0.1	0.0	0.1	0.6	3.3	12.9	46.1	22.1	10.6	0.2	-1.7	-0.9	93
1917	-0.5	-0.2	-0.1	0.0	4.0	19.6	33.8	25.7	5.4	-0.1	-1.5	-0.8	85
1918	-0.5	-0.2	-0.1	0.4	6.6	11.3	13.6	24.4	12.4	0.2	-1.4	-0.8	66
1919	-0.3	-0.1	0.1	0.6	18.8	8.1	33.4	27.7	12.3	-1.4	-1.8	-0.9	97
1920	-0.6	-0.3	-0.2	0.3	2.6	3.4	25.2	22.2	13.6	1.8	-1.5	-0.9	66
1921	-0.3	0.0	0.1	3.0	11.2	36.5	31.9	16.5	11.5	1.2	-1.2	-0.6	110
1922	-0.2	0.0	0.0	4.0	17.8	20.8	11.4	30.8	21.8	0.7	-1.5	-0.7	105
1923	-0.4	-0.2	-0.1	1.3	21.7	4.2	32.9	9.4	14.6	1.1	-1.6	-0.9	82
1924	-0.4	-0.2	-0.1	3.1	14.0	8.2	29.4	25.4	8.6	1.0	-1.6	-0.9	87
1925	-0.3	-0.1	0.1	4.4	23.4	17.0	30.1	30.6	20.2	-0.3	-1.5	-0.7	123
1926	-0.4	-0.2	-0.1	5.5	20.1	15.2	34.6	23.3	3.2	0.4	-1.0	-0.4	100
1927	-0.2	-0.1	0.0	0.0	2.9	23.9	24.7	22.9	13.5	1.6	-1.1	-0.6	88
1928	-0.2	0.0	0.1	1.9	31.7	3.4	30.0	24.0	13.4	-0.8	-1.8	-0.9	101
1929	-0.3	-0.1	0.0	0.0	7.4	12.3	25.3	21.8	6.1	-1.9	-1.2	-0.6	69
1930	-0.3	-0.1	0.0	0.0	7.1	12.8	32.2	19.1	9.9	-2.1	-1.4	-0.7	76
1931	-0.3	-0.1	0.0	2.3	8.9	19.9	28.5	19.3	10.0	-0.9	-1.4	-0.7	85
1932	-0.4	-0.2	-0.1	0.2	7.8	11.2	27.4	20.4	11.2	-1.6	-1.4	-0.8	74
1933	-0.3	-0.1	0.0	0.5	3.6	27.9	23.9	16.0	14.2	0.6	-1.1	-0.6	85
1934	-0.2	0.0	0.1	1.3	25.5	18.9	27.2	19.6	4.6	-0.5	-1.0	-0.4	95
1935	-0.3	-0.1	0.0	0.0	0.1	12.9	30.0	23.5	13.9	-0.2	-1.5	-0.8	78
1936	-0.3	-0.1	0.1	0.1	13.2	20.6	36.4	24.1	7.8	-0.4	-1.1	-0.5	100
1937	-0.3	-0.1	0.0	0.5	10.4	13.8	29.2	22.8	12.0	-0.3	-1.1	-0.5	86
1938	-0.2	-0.1	0.0	0.1	3.7	17.1	24.6	26.2	11.2	0.3	-1.7	-0.9	80
1939	-0.4	-0.2	-0.1	1.1	10.2	10.4	32.0	23.3	7.0	-1.2	-1.4	-0.7	80
1940	-0.4	-0.1	0.0	0.0	17.6	12.6	29.1	17.3	12.8	-0.3	-1.5	-0.8	86
1941	-0.5	-0.3	-0.1	-0.1	12.7	9.4	26.9	19.2	2.8	-1.9	-1.1	-0.5	67
1942	-0.3	-0.1	-0.1	0.0	0.0	7.5	25.4	23.2	6.3	-0.3	-1.2	-0.7	60
1943	-0.2	0.0	0.1	1.0	4.4	9.1	33.4	24.5	12.4	-1.6	-1.6	-0.9	81
1944	-0.5	-0.2	-0.1	0.4	8.3	8.9	19.8	18.7	12.7	-0.1	-1.4	-0.8	66
1945	-0.4	-0.2	-0.1	0.7	7.2	4.8	22.3	19.0	8.5	0.1	-1.2	-0.7	60
1946	-0.4	-0.2	-0.1	1.4	1.3	10.7	28.2	19.2	0.1	-1.6	-0.9	-0.4	57
1947	-0.1	0.0	0.1	0.3	9.8	5.1	29.7	30.5	9.0	0.1	-1.2	-0.6	83
1948	-0.3	-0.1	0.0	0.5	7.3	6.2	25.1	21.7	11.0	-0.4	-1.4	-0.8	69
1949	-0.4	-0.2	0.0	0.0	4.6	18.9	23.9	20.0	7.4	-2.1	-1.3	-0.7	70
1950	-0.3	-0.2	-0.1	0.0	5.3	22.9	16.6	14.3	3.1	0.5	-1.0	-0.6	60
1951	-0.3	-0.2	-0.1	0.9	2.6	6.4	18.7	14.4	3.1	-0.9	-0.8	-0.4	43
1952	-0.1	0.1	0.1	2.7	4.9	15.9	28.8	15.4	12.6	0.5	-1.0	-0.5	79
1953	-0.2	-0.1	0.0	0.1	6.1	10.0	26.3	20.5	15.8	-0.8	-1.6	-0.9	75
1954	-0.4	-0.2	-0.1	0.5	11.2	7.9	30.1	19.6	9.8	-1.6	-1.4	-0.7	75
1955	-0.3	-0.1	0.0	1.9	8.6	14.3	34.5	19.7	8.8	0.1	-1.4	-0.8	85

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	-0.4	-0.1	0.0	0.0	10.9	27.5	19.1	15.3	12.7	-0.4	-1.6	-0.9	82
1957	-0.5	-0.3	-0.1	-0.1	1.6	9.1	31.0	17.5	10.9	-1.4	-1.3	-0.7	66
1958	-0.3	-0.1	0.1	0.1	18.0	12.3	15.6	28.4	15.4	0.0	-1.9	-1.0	87
1959	-0.5	-0.3	-0.1	0.2	3.3	22.3	27.9	27.1	2.5	-1.3	-1.3	-0.7	79
1960	-0.4	-0.2	0.0	0.0	3.9	13.8	27.6	20.3	9.0	0.0	-1.4	-0.8	72
1961	-0.4	-0.1	0.0	0.9	2.2	18.3	28.5	22.2	6.0	-0.5	-1.3	-0.7	75
1962	-0.4	-0.2	-0.1	1.1	0.3	6.6	16.0	22.4	11.0	-0.3	-1.3	-0.7	54
1963	-0.3	-0.1	0.0	0.1	7.8	11.1	21.9	26.1	3.5	0.4	-1.3	-0.7	69
1964	-0.3	-0.1	0.0	0.0	9.7	13.4	25.4	21.9	11.5	0.2	-1.6	-0.9	79
1965	-0.5	-0.3	-0.2	-0.1	4.5	9.1	19.5	22.4	-1.8	0.3	-0.9	-0.4	51
1966	-0.2	0.0	0.1	0.1	18.6	17.0	24.9	11.5	4.6	-0.9	-1.1	-0.6	74
1967	-0.3	-0.1	0.0	1.6	6.1	5.6	31.1	23.6	11.1	-0.9	-1.5	-0.8	75
1968	-0.5	-0.2	-0.1	0.0	4.9	8.6	28.5	15.8	8.2	-0.2	-1.2	-0.7	63
1969	-0.3	-0.1	0.0	1.4	12.4	11.8	20.5	23.8	12.4	-2.4	-1.5	-0.8	77
1970	-0.4	-0.2	0.0	0.0	8.4	17.5	28.5	22.7	9.6	-1.0	-1.0	-0.5	84
1971	-0.2	0.0	0.0	0.1	6.5	20.4	23.9	26.4	7.9	-1.5	-1.1	-0.5	82
1972	-0.3	-0.1	0.0	0.0	1.9	16.2	16.0	21.1	13.1	-1.2	-1.4	-0.8	65
1973	-0.3	-0.2	0.0	0.0	4.9	20.7	24.0	20.7	-1.0	-0.7	-1.0	-0.5	67
1974	-0.2	0.0	0.1	0.1	5.0	19.5	26.9	22.3	13.0	-0.2	-1.7	-0.9	84
1975	-0.4	-0.2	-0.1	0.0	11.1	10.9	33.2	21.5	8.1	-0.8	-1.3	-0.7	81
1976	-0.3	-0.1	0.0	0.2	10.8	23.1	25.7	20.8	10.4	-0.4	-1.0	-0.5	89
1977	-0.3	-0.1	0.0	0.9	7.8	21.1	22.0	14.5	5.8	-1.2	-1.2	-0.6	69
1978	-0.2	-0.1	0.0	0.0	5.6	17.6	22.5	24.2	14.8	-0.3	-1.6	-0.9	82
1979	-0.4	-0.2	-0.1	0.2	9.2	16.9	16.5	15.5	15.3	-1.6	-1.5	-0.8	69
1980	-0.3	-0.1	0.0	1.9	15.1	17.5	28.6	11.8	11.5	-1.1	-1.1	-0.5	83
1981	-0.2	-0.1	0.0	2.5	8.2	17.3	20.4	22.5	15.5	-1.9	-1.7	-0.9	82
1982	-0.5	-0.3	-0.2	0.4	-0.1	14.6	21.1	19.3	3.2	-1.6	-0.9	-0.5	54
1983	-0.2	0.0	0.1	0.1	3.7	9.6	26.1	29.1	9.1	-1.5	-1.5	-0.8	74
1984	-0.4	-0.2	-0.1	0.0	7.2	12.5	22.1	19.3	9.9	-1.5	-1.3	-0.7	67
1985	-0.3	-0.2	-0.1	0.2	16.8	14.7	22.5	11.5	0.5	-0.2	-0.9	-0.5	64
1986	-0.2	-0.1	0.0	0.0	8.1	13.7	25.7	19.6	0.1	-0.5	-1.0	-0.5	65
1987	-0.2	-0.1	0.0	1.2	9.2	17.0	20.8	15.7	8.2	-0.5	-1.3	-0.7	69
1988	-0.3	-0.1	0.0	0.9	0.9	21.8	27.1	23.5	5.1	0.2	-0.9	-0.4	78
1989	-0.1	0.0	0.1	0.8	15.5	20.6	23.2	22.6	6.3	0.4	-1.4	-0.7	87
1990	-0.4	-0.2	-0.1	0.2	1.9	14.7	19.6	21.4	16.2	-0.6	-1.6	-0.9	70
1991	-0.4	-0.2	-0.1	0.0	1.1	11.3	30.3	22.5	7.9	-1.9	-1.3	-0.7	69
1992	-0.4	-0.1	0.0	1.4	19.6	10.2	9.1	16.1	7.7	0.3	-1.2	-0.6	62
1993	-0.4	-0.2	-0.2	-0.1	6.5	5.3	10.5	22.0	3.5	0.0	-0.9	-0.5	45
1994	-0.2	-0.1	0.0	0.1	16.8	7.4	16.3	16.2	7.9	-1.0	-1.2	-0.6	62
1995	-0.3	-0.2	-0.1	0.0	0.1	12.3	25.3	17.1	6.9	-1.8	-1.1	-0.6	58
1996	-0.3	-0.1	0.0	0.5	0.0	16.6	20.3	21.8	0.9	-1.1	-0.9	-0.5	57

Table A-33. Current Level Depletions Between Fort Randall and Gavins Point Dams (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	-2.5	-0.8	0.3	0.6	4.2	210.5	263.1	240.9	83.2	-19.5	-11.7	-5.9	762
1899	-2.4	-0.7	0.3	0.7	18.9	135.9	351.2	176.3	134.6	-11.6	-12.9	-6.9	783
1900	-2.9	-0.8	0.2	0.7	19.1	277.4	248.5	323.2	-8.0	-19.2	-10.6	-4.9	823
1901	-2.3	-0.6	0.4	0.5	16.9	81.0	501.8	228.4	-11.7	-9.8	-5.7	-2.4	796
1902	-1.9	-0.4	0.2	0.2	47.6	77.0	253.2	140.9	-10.8	-5.1	-5.9	-2.9	492
1903	-1.0	0.2	0.7	0.7	4.6	157.3	247.0	155.7	51.9	-11.4	-8.5	-4.4	593
1904	-1.8	-0.4	0.2	0.5	11.4	118.3	264.2	142.9	89.0	-15.4	-9.3	-4.9	595
1905	-2.5	-1.0	-0.3	0.0	3.7	88.7	231.0	185.3	-5.6	-8.9	-6.4	-3.1	481
1906	-1.0	0.3	0.8	0.9	11.9	124.4	325.3	175.0	-3.7	-14.0	-7.3	-3.6	609
1907	-1.4	0.0	0.6	0.6	11.6	71.2	258.9	334.7	-8.8	-11.1	-9.4	-4.4	643
1908	-2.2	-0.5	0.5	4.2	7.7	82.8	319.2	185.4	89.3	-17.4	-10.3	-5.4	653
1909	-1.7	0.0	0.9	1.2	4.9	89.8	325.4	331.9	106.1	-20.1	-13.9	-7.0	817
1910	-3.5	-1.2	0.1	4.1	14.9	247.5	281.4	211.3	40.5	-14.8	-10.4	-5.2	765
1911	-2.1	-0.5	0.3	0.5	26.1	300.7	278.8	203.5	-8.1	-16.3	-8.9	-4.3	770
1912	-1.7	-0.3	0.4	4.1	7.6	292.9	259.0	181.5	38.6	-13.8	-9.8	-5.0	753
1913	-1.7	-0.2	0.5	0.8	4.1	113.1	394.2	207.0	120.1	-11.6	-8.1	-3.8	814
1914	-1.0	0.6	1.3	5.2	12.3	201.6	386.2	303.0	-20.8	-16.8	-10.5	-5.0	856
1915	-2.7	-0.7	0.2	0.2	3.9	59.7	230.6	347.7	126.2	-4.3	-14.5	-7.5	739
1916	-1.8	0.4	1.9	103.7	114.3	284.1	441.3	283.6	-10.7	-11.0	-7.9	-3.2	1195
1917	-2.3	-0.7	0.0	0.4	0.8	122.6	430.6	238.7	27.1	-4.5	-11.1	-5.8	796
1918	-3.0	-0.8	0.1	0.3	7.6	100.6	374.7	169.1	93.2	-15.5	-10.9	-5.8	710
1919	-2.6	-0.7	0.1	0.5	7.8	100.7	340.1	279.5	-7.4	-17.3	-9.1	-4.3	687
1920	-1.9	-0.1	0.7	0.8	8.1	112.8	323.7	237.5	83.8	-10.5	-11.8	-6.1	737
1921	-2.4	-0.4	0.6	4.6	4.4	287.1	278.1	202.4	87.6	-13.8	-12.2	-6.3	830
1922	-2.4	-0.6	0.3	3.9	33.2	215.0	228.7	290.9	112.0	-12.3	-8.8	-3.9	856
1923	-2.0	-0.6	0.2	0.5	4.3	101.3	433.3	134.6	-5.1	-11.5	-7.3	-3.9	644
1924	-1.2	0.5	0.9	4.6	29.9	111.3	360.1	256.6	22.8	-12.6	-10.4	-5.2	757
1925	-2.5	-0.6	0.3	0.5	48.0	118.9	275.6	328.0	-8.3	-15.3	-10.0	-4.6	730
1926	-2.3	-0.5	0.5	4.2	26.0	146.8	408.6	197.1	-13.8	-13.6	-8.6	-4.3	740
1927	-2.4	-0.6	0.1	0.1	7.5	79.9	349.1	147.0	67.6	-7.0	-9.4	-5.1	627
1928	-1.5	0.3	1.0	8.6	15.5	162.5	419.6	273.8	-8.8	-19.6	-10.2	-5.0	836
1929	-0.5	0.6	1.3	3.1	20.3	68.5	263.9	345.8	6.9	-10.9	-5.5	-2.0	692
1930	0.0	1.2	1.9	1.9	7.1	123.5	405.6	186.6	124.3	-12.7	-7.0	-3.1	829
1931	-0.2	1.2	1.9	7.3	38.6	181.5	342.5	292.4	101.4	-0.2	-6.8	-2.7	957
1932	-0.9	0.5	1.2	4.1	26.5	128.6	299.8	226.6	143.4	-12.0	-7.5	-3.3	807
1933	-0.5	0.8	1.6	4.5	12.3	266.9	297.0	159.1	142.8	11.7	-7.8	-3.7	884
1934	-0.6	0.8	1.5	8.6	80.0	144.2	334.2	306.5	52.9	8.4	-6.2	-2.4	928
1935	-0.6	0.8	1.5	1.7	4.5	74.3	365.8	261.9	151.8	7.9	-8.8	-4.2	856
1936	-0.4	1.3	2.2	5.0	41.2	164.4	466.1	299.6	116.4	7.9	-4.7	-1.3	1098
1937	0.1	1.3	1.9	3.7	32.1	111.2	357.3	294.0	130.2	-6.3	-4.3	-1.1	920
1938	0.3	1.3	1.9	2.1	5.6	136.1	259.3	355.1	74.6	16.7	-7.0	-3.0	843
1939	-0.5	0.9	1.8	5.4	33.3	134.7	336.3	249.6	153.3	-9.9	-7.0	-2.9	895
1940	0.0	1.3	2.1	2.4	91.1	155.7	364.2	282.2	115.9	0.8	-4.2	-1.0	1011
1941	-0.3	0.8	1.3	1.5	48.2	63.5	287.8	296.8	53.3	-10.6	-6.1	-2.4	734
1942	-0.7	0.5	1.2	2.2	3.2	88.6	288.4	292.4	54.7	-5.9	-6.3	-2.6	716
1943	-0.4	0.9	1.6	5.2	24.1	66.8	348.2	274.0	96.3	-9.9	-7.3	-3.1	796
1944	-1.5	-0.1	0.7	2.6	21.6	57.1	208.0	229.6	120.1	5.3	-7.1	-3.4	633
1945	-1.1	0.1	0.9	2.9	20.2	34.9	298.4	204.3	69.8	13.0	-6.0	-2.9	634
1946	-0.8	0.5	1.1	9.1	7.1	111.2	266.5	262.0	18.9	-9.9	-5.0	-1.9	659
1947	0.4	1.5	2.0	3.7	21.3	28.0	332.8	367.2	107.5	7.2	-5.8	-2.1	864
1948	-0.5	0.8	1.5	6.0	45.9	59.1	257.3	275.7	136.5	3.5	-8.0	-3.7	774
1949	-1.0	0.4	1.3	1.6	9.1	141.3	310.9	289.4	73.1	-7.9	-4.3	-1.3	813
1950	-0.8	0.2	0.8	0.9	12.1	114.9	176.5	189.9	44.0	14.6	-5.1	-2.3	546
1951	-1.3	-0.3	0.2	2.1	12.5	24.6	178.1	132.2	53.1	-5.0	-3.7	-1.6	391
1952	1.8	2.5	2.9	3.8	11.0	204.1	352.0	208.4	163.0	16.8	-4.7	-1.6	960
1953	-0.1	1.0	1.5	1.8	28.6	99.8	212.4	293.4	176.8	-6.5	-8.8	-3.9	796
1954	-1.6	-0.2	0.8	2.9	31.3	61.5	356.4	192.4	71.7	-4.6	-5.9	-2.6	702
1955	-0.1	1.2	1.8	7.5	24.1	54.8	375.2	306.1	81.5	15.7	-4.1	-1.2	863

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	0.6	1.8	2.3	4.2	39.2	211.5	315.0	225.9	144.0	-5.3	-6.7	-2.7	930
1957	-1.3	0.0	0.7	1.0	4.5	64.8	288.1	253.7	74.4	-8.0	-6.2	-2.7	669
1958	-0.2	1.0	1.7	1.8	56.9	85.4	123.0	364.4	165.0	20.0	-9.7	-4.5	805
1959	-1.7	-0.1	1.0	3.2	8.5	179.5	332.3	226.0	60.8	-8.4	-6.2	-2.6	792
1960	-0.8	0.4	1.0	2.1	7.2	64.1	344.6	213.0	77.3	10.8	-6.7	-3.2	710
1961	-1.1	0.3	1.0	4.7	3.7	110.5	263.5	259.3	44.0	7.5	-6.1	-2.7	685
1962	-1.1	0.1	0.8	6.1	5.1	35.6	187.2	277.6	97.9	-3.2	-5.2	-3.1	598
1963	-0.7	0.5	1.3	3.3	23.2	115.7	243.7	258.2	53.8	13.0	-6.3	-2.8	703
1964	-0.8	0.5	1.2	1.4	47.4	74.9	288.6	237.4	71.7	15.4	-6.9	-3.2	728
1965	-1.8	-0.4	0.3	2.3	7.6	34.0	235.2	285.1	-9.5	-5.0	-4.5	-1.7	542
1966	0.3	1.3	1.9	3.6	81.4	110.3	353.4	166.4	50.9	-4.5	-4.2	-1.5	759
1967	0.0	1.0	1.4	6.7	5.8	37.9	304.7	284.1	113.3	-8.6	-7.3	-3.2	736
1968	-1.0	0.4	1.2	2.3	11.9	90.4	269.2	236.1	128.8	-1.1	-7.3	-3.4	728
1969	-0.8	0.5	1.3	4.7	42.7	69.8	216.0	336.0	120.6	-9.4	-5.1	-1.7	775
1970	0.3	1.3	2.0	2.2	23.9	161.1	302.6	282.6	97.6	-11.7	-7.5	-3.1	851
1971	-1.2	0.2	1.0	1.2	7.3	132.0	236.5	292.7	85.6	-10.5	-6.9	-2.9	735
1972	-1.2	0.0	0.8	1.0	6.2	78.5	155.9	285.0	123.8	-7.8	-7.2	-3.2	632
1973	-0.6	0.6	1.4	1.7	10.4	189.6	239.7	342.7	-12.7	-9.9	-5.3	-1.8	756
1974	0.3	1.4	2.1	4.6	22.4	177.5	358.4	231.1	123.4	-0.1	-5.0	-1.7	914
1975	0.2	1.3	1.9	3.7	47.5	87.8	355.3	255.6	129.1	11.2	-5.4	-2.0	886
1976	0.2	1.4	2.0	3.1	30.7	228.3	287.8	314.1	64.9	4.3	-3.8	-0.8	932
1977	-0.3	0.6	1.2	1.3	10.9	118.2	276.0	178.8	81.0	-5.1	-5.6	-2.4	654
1978	0.1	1.1	1.7	1.9	14.1	162.4	202.7	266.0	160.5	10.4	-8.7	-4.1	808
1979	-1.8	-0.3	0.6	2.7	7.9	73.5	206.0	271.5	133.0	-10.8	-7.5	-3.3	671
1980	-0.3	0.9	1.7	7.6	19.0	133.4	380.2	180.3	143.3	-6.7	-4.7	-1.7	853
1981	-0.5	0.6	1.1	9.1	10.6	141.6	174.7	213.6	126.1	-9.8	-6.5	-2.9	657
1982	-1.1	-0.1	0.6	2.6	2.6	76.8	216.7	232.8	51.0	-9.2	-5.0	-2.0	566
1983	0.0	1.0	1.5	1.7	5.2	23.2	192.5	383.2	109.4	-4.5	-7.9	-3.4	702
1984	-1.2	0.2	1.2	1.5	9.2	92.6	201.5	312.4	112.8	-3.1	-7.6	-3.3	716
1985	-1.2	0.0	0.9	2.9	55.4	113.0	299.9	190.5	17.1	-5.1	-4.5	-1.8	667
1986	-0.1	0.9	1.4	1.5	12.9	113.5	319.9	272.9	16.0	-9.7	-5.2	-2.0	722
1987	-0.1	1.1	1.7	7.7	21.7	143.3	302.6	215.2	108.4	0.6	-6.1	-2.6	794
1988	0.0	1.2	1.8	4.7	13.1	192.7	335.5	262.8	74.1	10.9	-6.4	-2.7	888
1989	-0.4	1.0	1.7	7.9	51.6	151.6	313.6	262.6	108.2	6.4	-6.8	-2.8	895
1990	-0.6	0.8	1.5	3.5	6.2	156.5	275.0	276.2	169.0	2.1	-9.1	-4.2	877
1991	-1.3	0.2	1.2	1.6	8.4	98.8	307.1	301.5	153.0	-10.3	-7.4	-3.1	850
1992	-1.8	-0.4	0.4	5.1	49.6	75.6	163.2	158.6	118.6	4.8	-6.0	-2.9	565
1993	-0.8	0.2	0.8	1.1	36.6	74.3	187.1	247.0	66.1	-7.4	-5.6	-2.3	597
1994	-0.1	0.9	1.6	3.5	70.2	98.1	211.6	235.8	150.4	-8.4	-7.6	-3.4	753
1995	-0.6	0.6	1.4	1.7	3.6	122.9	317.5	347.6	54.0	-13.3	-7.1	-2.8	825
1996	-1.0	0.4	1.2	4.0	5.6	148.9	293.9	321.4	0.4	-7.9	-5.6	-2.1	759

Table A-34. Current Level Depletions Between Gavins Point Dam and Sioux City (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	0.6	1.3	1.7	1.8	3.0	82.1	112.4	103.0	35.2	-6.1	-3.0	-0.7	331
1899	0.6	1.4	1.8	1.9	7.7	53.8	149.0	75.9	55.8	-3.0	-3.4	-1.1	340
1900	0.6	1.4	1.8	2.0	7.8	108.0	106.9	137.8	-1.3	-6.0	-2.5	-0.3	356
1901	0.8	1.5	1.9	1.9	7.2	33.4	212.4	97.6	-3.2	-2.5	-0.7	0.6	351
1902	0.2	0.8	1.0	1.0	16.3	30.9	107.6	60.4	-3.2	-1.1	-1.3	-0.2	212
1903	0.8	1.3	1.5	1.5	2.7	61.4	105.0	66.8	22.2	-3.3	-2.1	-0.5	258
1904	0.5	1.1	1.3	1.4	4.9	46.6	112.2	61.4	37.0	-4.8	-2.4	-0.7	259
1905	0.0	0.6	0.9	1.0	2.2	35.0	97.8	78.7	-1.3	-2.7	-1.6	-0.3	210
1906	0.8	1.3	1.6	1.6	5.1	49.0	137.7	74.9	-0.2	-4.4	-1.7	-0.2	266
1907	0.7	1.3	1.6	1.6	5.1	28.7	109.8	141.4	-2.4	-3.4	-2.5	-0.5	281
1908	0.4	1.1	1.5	2.7	3.9	33.1	135.1	79.1	37.2	-5.6	-2.7	-0.8	285
1909	1.0	1.7	2.0	2.2	3.3	36.1	137.9	140.6	44.2	-6.4	-3.8	-1.1	358
1910	0.1	1.0	1.6	2.9	6.4	96.4	120.4	90.8	18.1	-4.3	-2.4	-0.4	331
1911	0.7	1.4	1.7	1.8	10.0	116.9	119.6	87.9	-1.3	-4.8	-1.9	-0.1	332
1912	0.8	1.5	1.7	2.9	4.1	113.7	111.1	78.5	17.4	-3.9	-2.2	-0.3	325
1913	1.1	1.7	2.0	2.0	3.1	45.9	167.3	88.7	51.3	-3.1	-1.6	0.1	358
1914	1.3	1.9	2.2	3.5	5.8	79.0	164.0	129.1	-6.5	-5.1	-2.4	-0.3	373
1915	0.4	1.2	1.6	1.6	2.8	24.4	98.1	146.9	52.1	-0.5	-4.2	-1.4	323
1916	1.6	2.5	3.1	35.9	40.0	115.5	190.3	123.2	-1.1	-1.7	-0.6	1.2	510
1917	0.9	1.5	1.8	1.9	2.0	48.5	181.9	101.8	12.4	-0.5	-2.8	-0.7	349
1918	0.2	1.1	1.5	1.6	3.9	40.0	158.4	72.5	38.9	-4.7	-2.8	-0.8	310
1919	0.4	1.1	1.5	1.6	4.0	40.0	143.9	118.6	-1.7	-5.6	-2.3	-0.4	301
1920	0.7	1.4	1.8	1.8	4.1	44.7	137.2	101.2	35.2	-2.8	-3.1	-0.9	321
1921	0.7	1.5	1.9	3.2	3.2	111.6	119.1	87.4	37.3	-3.7	-3.0	-0.7	359
1922	0.8	1.5	1.9	3.1	12.5	86.0	98.8	124.5	48.3	-3.2	-1.7	0.2	373
1923	0.5	1.1	1.5	1.6	2.8	40.1	182.7	58.0	-0.8	-3.4	-1.6	-0.2	282
1924	1.0	1.7	1.9	3.1	11.2	44.5	152.7	109.3	10.7	-3.6	-2.6	-0.5	329
1925	0.5	1.3	1.6	1.7	16.9	47.5	117.6	139.2	-1.8	-4.7	-2.5	-0.4	317
1926	0.6	1.3	1.7	2.9	9.9	58.0	173.0	84.6	-4.0	-4.0	-1.9	-0.2	322
1927	0.3	1.1	1.3	1.3	3.7	31.9	147.4	63.0	28.4	-1.7	-2.4	-0.7	274
1928	1.1	1.8	2.1	4.6	6.8	64.1	177.8	116.8	-1.8	-6.2	-2.4	-0.3	365
1929	1.1	1.5	1.7	1.7	8.0	43.3	98.1	102.2	5.4	-1.6	-0.4	0.6	262
1930	1.4	1.8	2.0	2.1	7.5	33.8	148.6	84.8	15.1	-1.2	0.2	1.0	297
1931	2.1	2.5	2.6	3.0	16.9	76.6	146.8	96.5	20.9	-0.2	0.7	1.6	370
1932	1.6	1.9	2.1	2.3	9.7	58.9	146.4	67.8	17.8	-0.6	0.3	1.1	309
1933	1.7	2.1	2.2	3.1	12.0	104.4	100.4	66.7	23.9	3.5	0.4	1.2	321
1934	1.6	1.9	2.0	3.3	48.7	51.7	103.8	85.7	3.5	0.0	0.3	1.2	304
1935	1.5	1.8	2.0	2.0	5.6	42.1	139.0	63.5	38.6	0.9	-0.1	0.8	298
1936	2.4	2.8	2.9	3.2	18.6	76.2	189.1	85.8	27.6	1.8	0.8	1.8	413
1937	1.8	2.1	2.3	2.3	13.7	37.1	144.9	101.5	35.5	-0.7	0.1	1.2	342
1938	1.4	1.7	1.9	2.0	3.3	53.9	98.4	122.7	5.0	2.9	-0.5	0.7	293
1939	1.4	1.8	2.1	2.4	14.6	31.0	128.5	91.5	39.3	0.6	0.0	1.0	314
1940	1.4	1.8	2.0	2.0	30.2	39.1	114.9	66.9	42.3	-1.0	-0.4	0.7	300
1941	1.5	1.8	2.0	2.1	22.5	34.7	130.0	115.7	5.1	-1.1	0.4	1.3	316
1942	0.8	1.1	1.3	1.7	2.0	33.7	85.8	80.9	0.7	0.7	-0.3	0.5	209
1943	1.4	1.7	1.9	2.7	5.2	23.3	112.2	93.3	32.4	-2.1	-0.8	0.4	272
1944	0.4	0.8	1.0	1.1	9.1	26.0	80.2	53.1	15.4	1.3	-0.4	0.3	188
1945	1.0	1.3	1.5	1.5	2.4	10.7	101.1	85.2	15.1	2.0	-0.6	0.4	221
1946	1.1	1.4	1.6	2.8	7.3	28.8	115.3	90.7	0.3	-1.9	-0.3	0.7	248
1947	1.8	2.1	2.3	2.3	15.8	15.7	144.1	133.7	13.2	-1.4	0.0	1.1	331
1948	1.0	1.4	1.6	1.7	13.5	15.8	94.0	101.6	20.3	-1.9	-0.6	0.5	249
1949	1.2	1.6	1.8	3.0	10.7	53.4	113.4	85.4	2.0	-1.4	-0.2	0.7	272
1950	1.3	1.6	1.8	1.8	5.2	71.6	86.3	103.3	3.5	-0.7	-0.4	0.7	276
1951	0.4	0.8	1.0	1.0	6.2	14.3	91.3	56.9	11.2	-1.5	-0.4	0.4	182
1952	2.1	2.3	2.5	3.5	18.3	56.7	126.4	75.2	50.2	2.7	-0.2	0.9	340
1953	1.0	1.4	1.6	1.7	8.0	28.8	109.4	83.5	33.8	1.2	-0.8	0.4	270
1954	1.0	1.4	1.6	2.1	9.0	34.6	124.0	75.0	16.0	-1.6	-0.5	0.6	263
1955	1.7	2.1	2.3	3.0	15.1	34.0	114.7	125.6	37.2	1.4	0.3	1.3	339

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	1.5	1.8	2.0	2.2	16.0	87.3	86.1	64.8	37.7	1.1	-0.3	0.7	301
1957	1.1	1.4	1.5	1.6	3.4	28.2	131.7	80.9	8.1	-2.1	-0.4	0.6	256
1958	1.8	2.1	2.3	2.3	24.9	58.1	72.6	136.1	30.8	4.4	-0.2	1.0	336
1959	1.4	1.8	2.0	2.7	5.1	64.2	147.2	77.2	9.5	-1.6	0.1	1.0	311
1960	1.3	1.6	1.8	1.8	8.4	31.9	155.1	63.4	11.2	-0.4	-0.2	0.7	277
1961	1.4	1.8	2.0	2.4	4.2	45.6	114.6	120.8	8.7	-2.2	-0.5	0.7	299
1962	0.2	0.7	0.9	1.0	2.6	19.7	55.6	86.7	4.9	0.3	-0.5	0.3	172
1963	1.5	1.8	1.9	2.0	9.8	55.6	83.2	102.8	13.9	0.9	-0.6	0.6	273
1964	1.4	1.7	1.9	2.0	18.4	68.7	121.7	65.1	13.4	3.2	0.1	1.0	299
1965	0.7	1.1	1.2	1.2	4.3	16.7	103.4	82.4	-3.1	-1.8	-0.3	0.5	206
1966	1.4	1.7	1.8	1.8	16.0	55.4	115.1	63.9	10.0	-1.1	0.1	0.9	267
1967	1.6	1.9	2.0	2.4	16.4	20.2	137.7	89.5	25.6	-1.1	-0.6	0.6	296
1968	0.7	1.1	1.4	1.4	9.0	28.2	101.3	87.8	3.5	-1.7	-0.3	0.6	233
1969	1.0	1.3	1.5	1.7	7.8	22.4	80.8	86.5	26.4	-2.1	-0.7	0.4	227
1970	1.5	1.9	2.1	2.1	8.6	51.8	111.5	119.0	9.5	-1.8	-0.4	0.8	307
1971	1.4	1.8	2.1	2.1	13.7	49.1	102.7	127.7	17.3	-2.7	-0.7	0.7	315
1972	0.7	1.1	1.4	1.4	3.1	61.0	62.3	93.7	19.8	-2.0	-0.6	0.5	243
1973	1.5	1.8	2.0	2.1	13.7	74.9	98.2	112.1	-2.5	-2.1	-0.2	0.9	302
1974	1.5	1.8	2.0	2.2	4.8	55.3	139.7	64.2	39.9	-0.2	-0.1	0.9	312
1975	1.5	1.9	2.1	2.1	15.1	25.1	169.4	69.9	23.4	1.7	0.2	1.0	313
1976	2.3	2.7	2.9	3.3	22.9	85.0	134.1	118.5	30.9	0.0	0.7	1.7	405
1977	1.3	1.6	1.8	1.9	18.0	74.5	119.8	58.2	3.4	-1.5	0.0	0.8	280
1978	1.5	1.8	1.9	1.9	7.4	64.9	88.9	93.6	33.6	1.0	-0.4	0.7	297
1979	0.8	1.2	1.4	1.4	7.2	47.0	81.8	60.7	30.4	-1.7	-0.5	0.4	230
1980	1.4	1.7	1.9	2.9	16.0	50.4	120.4	49.5	37.3	-1.2	-0.3	0.7	281
1981	1.4	1.7	1.9	3.4	22.2	59.2	95.0	72.1	35.8	-1.1	-0.3	0.8	292
1982	0.9	1.2	1.4	1.5	2.5	59.9	88.1	64.1	11.1	-1.6	-0.3	0.6	229
1983	1.6	1.9	2.0	2.1	10.2	15.6	118.1	135.4	12.9	-2.4	-0.5	0.8	298
1984	1.3	1.8	2.0	2.0	9.0	42.0	117.5	108.7	22.3	-2.5	-0.6	0.6	304
1985	0.6	1.0	1.2	1.4	13.4	45.5	101.8	51.0	-0.5	-0.6	0.0	0.6	215
1986	1.3	1.6	1.7	1.7	11.5	54.0	108.0	77.7	-1.8	-1.2	-0.1	0.7	255
1987	1.5	1.9	2.0	3.2	13.6	70.2	104.0	83.7	15.6	0.4	-0.1	0.9	297
1988	2.1	2.4	2.6	2.9	16.3	112.1	144.0	81.7	5.1	3.2	0.9	1.7	375
1989	1.9	2.2	2.3	2.5	18.7	53.7	134.9	94.7	18.7	3.4	0.5	1.4	335
1990	1.6	2.0	2.1	2.1	5.5	38.8	103.1	110.8	45.1	-1.5	-0.4	0.8	310
1991	1.1	1.5	1.7	1.8	4.2	28.0	114.0	109.8	9.5	-1.7	-0.5	0.6	270
1992	0.2	0.6	0.8	0.9	22.6	38.4	35.5	50.7	5.5	-0.6	-0.2	0.4	155
1993	0.6	0.7	0.8	0.9	6.0	10.6	35.3	73.9	10.1	-0.6	-0.5	0.2	138
1994	1.2	1.4	1.6	1.6	20.9	26.4	82.5	75.5	10.9	-1.5	-0.4	0.5	221
1995	1.1	1.4	1.5	1.6	2.1	53.6	99.2	67.8	9.7	-1.7	-0.3	0.6	237
1996	1.1	1.4	1.5	2.3	1.5	57.0	86.8	83.9	1.2	-1.5	-0.3	0.6	236

Table A-35. Current Level Depletions Between Omaha and Nebraska City (1000 acre-feet)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1898	41.9	81.5	128.0	256.8	360.5	1114.6	1154.5	1206.3	400.7	23.4	-8.4	22.5	4782
1899	43.8	83.2	129.6	266.4	616.4	1174.2	925.9	1103.9	695.5	40.0	-19.8	16.0	5075
1900	40.1	79.9	126.9	191.5	972.9	1298.0	944.3	1116.0	374.8	12.5	0.2	29.6	5187
1901	46.4	83.5	128.8	210.7	758.6	888.5	1680.0	1196.2	99.2	16.8	9.7	32.6	5151
1902	42.4	81.3	126.0	261.7	716.7	898.6	825.6	1014.3	106.0	13.0	16.6	36.0	4138
1903	49.0	85.1	129.4	249.1	684.7	904.3	844.3	853.8	498.2	68.0	-3.0	24.5	4388
1904	41.8	79.9	125.4	258.7	553.6	949.5	738.6	991.0	358.0	17.9	5.7	28.9	4149
1905	44.8	81.8	127.2	200.5	465.3	972.5	671.0	1174.8	378.6	-15.2	1.8	29.4	4132
1906	46.1	82.9	128.7	249.8	645.8	1028.7	895.6	915.3	287.0	-43.8	8.3	33.2	4278
1907	46.8	82.8	132.7	227.7	466.8	884.8	743.5	990.4	374.5	158.2	-2.4	23.5	4129
1908	40.5	79.6	125.4	262.4	402.1	795.7	643.2	694.3	803.8	-28.3	0.3	26.7	3846
1909	48.2	84.3	129.8	223.5	584.2	722.4	934.9	1323.6	386.9	40.8	-6.8	23.9	4496
1910	44.8	84.1	138.0	274.6	694.3	1101.3	1408.7	854.9	363.7	146.8	-4.6	20.9	5127
1911	15.5	52.0	99.6	185.0	953.5	1751.9	898.9	788.8	348.5	-65.0	-28.1	1.8	5002
1912	16.4	69.1	112.3	355.2	1013.9	1341.8	814.4	757.9	-209.7	-277.9	-52.6	15.1	3956
1913	32.4	83.6	138.5	522.2	922.6	1246.7	912.8	1503.8	257.2	37.4	12.6	21.2	5691
1914	41.0	75.3	144.6	369.6	1030.0	1337.6	1249.5	932.7	377.6	-92.4	-4.3	18.2	5480
1915	27.3	62.5	106.3	273.6	555.8	784.0	492.3	593.0	259.9	113.3	24.2	37.3	3330
1916	55.7	93.1	224.1	325.3	677.3	1184.5	1411.1	776.4	505.7	2.3	5.0	29.4	5290
1917	43.5	74.8	119.1	437.2	619.1	1193.7	1664.6	848.4	135.3	68.3	11.8	32.3	5248
1918	48.7	79.4	156.0	233.0	794.4	1698.8	930.0	948.0	199.1	-4.2	13.8	35.7	5133
1919	41.5	78.7	129.7	318.8	903.6	852.5	898.7	1247.8	343.3	-104.9	-0.5	26.7	4736
1920	42.0	86.5	154.0	306.6	1040.9	1230.5	1158.3	759.0	532.4	-34.4	1.9	14.9	5293
1921	43.7	81.2	182.9	194.7	876.1	1208.0	1155.0	1004.0	428.9	-15.4	-11.7	17.0	5164
1922	37.8	68.8	145.7	275.8	588.8	1424.8	856.4	1135.4	556.0	15.6	-3.0	17.2	5119
1923	38.2	70.1	109.8	256.8	795.8	1142.9	1111.2	707.9	101.1	7.7	36.6	28.7	4407
1924	44.6	87.8	118.5	335.9	427.1	1177.3	829.0	1001.5	-73.3	49.4	19.6	30.5	4048
1925	47.6	84.6	179.1	359.5	874.3	941.1	1153.2	760.0	427.2	4.8	18.7	33.6	4884
1926	37.4	86.2	165.3	543.4	949.7	1090.6	927.7	982.8	-30.1	30.3	-1.1	11.8	4794
1927	15.5	69.7	125.2	325.8	1249.7	713.8	1013.0	651.3	232.4	152.3	29.6	17.4	4596
1928	28.0	82.8	191.0	339.1	941.0	468.0	594.2	1185.3	433.9	-109.0	2.7	20.7	4178
1929	29.7	69.4	116.5	437.8	922.0	1172.2	1211.5	1032.2	-176.1	4.0	11.9	38.3	4869
1930	33.6	82.0	138.4	423.3	626.3	1158.0	1127.6	593.2	482.4	9.8	-11.4	15.9	4679
1931	37.3	79.6	116.9	335.4	711.7	1190.3	1171.1	812.6	538.3	10.9	-13.0	18.3	5010
1932	37.7	78.4	133.8	437.5	1202.6	1052.7	918.6	1026.3	425.8	-31.8	-10.0	5.2	5277
1933	35.5	64.5	135.9	270.2	701.0	1924.2	1053.0	357.0	296.2	199.3	4.7	15.2	5057
1934	45.8	84.1	127.7	316.1	988.1	1135.2	1472.2	1123.8	182.0	74.2	7.4	29.8	5586
1935	42.5	79.2	110.2	183.0	403.6	1238.7	1560.3	941.5	409.9	81.7	-4.6	10.1	5056
1936	38.2	75.7	138.0	356.5	966.3	1249.6	1546.4	1138.1	430.9	41.0	0.3	18.5	6000
1937	15.4	64.9	143.3	420.9	768.1	998.4	1262.9	1258.4	289.7	1.0	1.4	28.7	5253
1938	40.3	59.6	133.2	317.9	707.2	1237.1	995.3	1130.4	236.7	217.0	-4.9	21.9	5092
1939	42.5	67.4	150.9	230.7	695.9	896.4	1342.1	1062.5	769.4	48.0	-21.3	3.7	5288
1940	78.6	104.2	129.5	250.5	954.3	1081.7	1248.2	1168.1	403.3	33.9	32.2	54.3	5539
1941	78.9	98.5	120.5	274.1	992.3	653.3	913.8	1212.5	100.8	70.1	68.2	75.3	4659
1942	123.8	123.0	151.9	336.2	869.5	906.5	1305.2	961.2	59.0	65.6	69.1	63.5	5034
1943	86.9	138.5	197.6	217.8	287.0	1016.4	1142.4	1384.1	537.3	-20.4	-27.7	50.1	5010
1944	75.8	131.2	167.9	227.8	777.5	801.8	778.7	1135.9	559.8	131.6	19.6	2.3	4810
1945	86.3	109.2	150.5	157.4	769.8	828.6	1171.0	819.2	286.1	285.7	74.7	36.2	4775
1946	148.4	145.9	193.8	307.0	332.2	971.4	1286.9	658.2	197.3	153.6	93.2	103.3	4591
1947	111.9	113.0	164.6	301.4	618.0	925.2	1335.0	1498.6	398.1	68.5	50.7	111.3	5696
1948	109.6	131.0	216.6	327.2	620.4	636.1	984.0	941.2	670.1	76.2	58.4	64.6	4836
1949	73.3	130.4	199.5	340.7	758.9	942.6	1235.5	1014.2	377.4	45.2	5.0	37.1	5160
1950	96.5	132.4	138.8	263.4	429.5	1237.9	551.8	825.2	375.7	240.4	41.4	75.5	4409
1951	74.8	109.3	91.2	86.2	711.7	711.0	662.0	763.2	257.2	56.7	64.1	55.3	3643
1952	86.9	42.5	71.6	340.2	684.8	1619.1	1005.5	666.4	513.0	147.0	29.5	96.6	5303
1953	151.8	126.9	136.0	118.9	620.0	949.0	762.7	894.4	722.7	85.2	49.9	104.9	4722
1954	112.9	103.7	144.3	283.6	539.3	884.1	1281.3	721.8	587.5	74.6	3.2	44.9	4781
1955	95.5	109.6	140.2	302.4	513.7	675.0	1481.3	1240.8	253.8	138.1	8.5	62.6	5021

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1956	126.0	121.3	160.8	231.4	869.5	1018.6	598.3	946.2	766.3	42.8	57.1	106.9	5045
1957	96.9	129.3	86.1	244.1	613.2	1319.7	1342.0	841.0	310.3	70.1	83.3	85.0	5221
1958	76.5	113.5	169.6	197.7	987.3	840.3	669.0	1413.7	470.4	129.0	-29.5	52.5	5090
1959	57.3	69.4	97.3	231.0	439.7	1079.5	1351.8	1207.4	149.8	-20.7	-14.9	42.5	4690
1960	54.7	82.6	177.4	291.1	650.0	899.3	1195.2	1171.2	545.3	51.8	-54.6	-2.3	5062
1961	39.9	72.3	88.2	172.9	511.6	1164.4	919.6	1355.5	57.6	148.6	40.1	54.8	4625
1962	76.1	133.7	154.1	506.2	652.1	992.5	1003.3	1522.7	365.6	42.5	-26.2	4.1	5427
1963	41.2	111.8	128.7	218.1	649.1	1056.9	1272.3	830.1	228.2	81.8	-22.1	13.4	4609
1964	50.2	68.4	90.5	212.2	840.6	841.3	1460.1	1026.0	381.4	75.2	-18.5	11.1	5039
1965	45.7	57.8	79.1	177.5	700.6	1109.2	1068.1	1163.1	-72.4	146.2	40.5	53.0	4568
1966	54.7	104.2	165.7	156.1	848.1	634.7	1151.4	962.7	489.9	69.6	-47.0	28.9	4619
1967	63.4	65.4	106.1	148.5	236.9	908.6	1319.7	1312.8	531.5	49.3	-49.5	8.2	4701
1968	62.0	91.3	76.3	232.1	560.0	1387.4	1172.1	783.0	563.5	6.4	-75.3	-18.2	4841
1969	73.1	87.2	90.6	300.1	667.9	734.3	1175.1	1286.4	571.1	-67.6	-10.3	31.9	4940
1970	61.5	104.1	91.8	206.2	1246.9	1234.6	1515.6	1367.3	198.7	0.8	-3.2	-27.2	5997
1971	66.7	96.5	159.5	266.2	839.3	1240.1	1288.5	1442.4	233.8	11.7	-17.7	-30.3	5597
1972	3.6	50.5	58.1	229.5	667.7	1048.0	842.4	1159.6	331.4	-45.1	17.1	27.7	4390
1973	54.3	76.6	113.8	287.6	1273.4	1204.2	920.9	1510.4	-217.2	-67.1	-34.3	-15.3	5107
1974	47.7	26.2	-130.0	141.7	1081.0	1006.9	1232.8	934.3	550.9	68.6	36.4	19.1	5016
1975	66.2	67.1	162.5	231.6	407.4	1080.7	1362.9	1236.1	478.2	147.9	9.3	41.0	5291
1976	77.2	122.9	132.0	237.4	691.1	1126.1	1210.1	1175.4	327.9	48.1	-12.8	37.4	5173
1977	31.4	92.2	127.5	269.6	590.1	1119.1	957.7	784.2	465.7	37.6	-34.4	13.6	4454
1978	45.1	83.9	165.5	200.9	518.7	1477.1	1330.8	981.6	754.3	62.8	-34.8	14.6	5600
1979	39.6	75.1	170.8	304.0	598.0	1002.0	1029.8	1171.5	862.6	4.0	-13.3	30.0	5274
1980	44.7	114.6	125.5	245.7	863.3	1357.0	1432.1	967.0	644.0	0.4	-20.9	31.3	5805
1981	59.7	70.3	111.9	188.9	348.5	1041.6	912.3	1042.6	794.3	-19.6	-47.2	4.0	4507
1982	25.5	73.9	98.3	133.0	496.6	861.2	1276.0	1087.3	373.2	51.3	10.8	23.1	4510
1983	62.6	72.0	160.9	261.2	891.0	1004.8	1644.1	1301.7	466.9	154.2	13.3	-78.5	5954
1984	11.0	-51.3	-144.0	66.9	1396.2	897.4	1420.5	1317.0	480.1	-36.5	-78.0	-61.8	5217
1985	27.7	35.2	17.0	256.8	822.3	855.5	970.6	1330.2	64.5	37.9	-13.7	54.9	4459
1986	90.9	128.3	90.4	252.6	739.5	1389.5	1423.0	1234.6	151.7	-99.4	-57.8	16.1	5359
1987	26.6	-33.8	250.1	260.0	461.4	1111.4	1370.7	821.8	706.6	-18.5	-58.5	-20.3	4877
1988	39.3	99.1	128.7	304.4	603.3	1228.2	1172.6	1246.2	319.8	126.3	-23.9	20.6	5264
1989	66.4	79.8	163.4	199.9	611.2	585.0	1334.8	1028.1	284.3	90.6	-11.7	20.3	4452
1990	84.1	80.7	132.8	166.6	499.7	1201.1	609.4	1221.4	834.9	-4.3	-12.8	10.6	4824
1991	53.9	93.2	103.9	186.4	761.2	1098.1	1087.1	1308.1	603.2	21.6	13.6	42.9	5373
1992	58.1	85.3	141.6	245.3	755.0	672.8	736.3	724.3	873.9	-23.4	-27.4	13.7	4256
1993	48.1	67.8	165.5	251.2	1000.5	1028.9	943.3	1242.6	465.1	1.5	-21.6	28.5	5221
1994	63.6	72.1	147.7	213.6	774.5	799.5	912.0	1334.5	667.9	-46.8	-23.3	56.1	4971
1995	71.3	92.9	115.1	125.6	746.5	1576.6	1734.9	1591.3	331.7	-12.3	-16.4	25.1	6382
1996	40.9	102.2	88.0	243.4	629.2	1376.3	1090.3	1144.2	87.9	112.2	-28.4	-1.4	4885

Table A-36. Comparison of Unregulated Peak Values Between 1960 Study and This Study (Years 1898-1960), 1000 cfs

Year	Sioux City			Omaha			Nebraska City			St. Joseph		
	1960 Study	Current Study	Diff	1960 Study	Current Study	Diff	1960 Study	Current Study	Diff	1960 Study	Current Study	Diff
1898	210	175	-35	145	168	23	214	206	-8	153	199	46
1899	258	254	-4	225	242	17	274	273	-1	166	260	94
1900	133	131	-2	61	122	61	177	178	1	97	151	54
1901	180	151	-29	166	144	-22	180	182	2	142	178	36
1902	132	133	1	134	125	-9	*N V*	167	167	116	180	64
1903	173	153	-20	181	153	-28	231	223	-8	263	348	85
1904	204	180	-24	198	185	-13	171	184	13	152	200	48
1905	252	239	-13	210	175	-35	226	245	19	204	238	34
1906	177	184	7	164	201	37	151	196	45	166	220	54
1907	176	184	8	170	195	25	187	231	44	184	277	93
1908	197	188	-9	202	232	30	238	260	22	212	308	96
1909	183	175	-9	162	217	55	209	236	27	201	307	106
1910	210	205	-5	187	232	45	187	207	20	171	236	65
1911	145	142	-4	138	158	20	169	175	6	113	161	48
1912	197	195	-3	162	204	42	256	226	-30	193	268	75
1913	180	201	21	166	208	42	231	206	-25	163	233	70
1914	160	159	-1	143	141	-2	244	239	-5	144	230	86
1915	170	181	11	147	178	31	264	210	-54	177	266	89
1916	170	187	17	153	177	24	277	212	-65	121	228	107
1917	229	201	-28	200	207	7	315	224	-91	212	317	105
1918	187	183	-4	135	189	54	158	211	53	121	209	88
1919	141	142	1	118	152	34	122	151	29	150	171	21
1920	197	201	4	220	234	14	231	270	39	212	284	72
1921	170	180	10	164	216	52	177	297	120	163	239	76
1922	149	164	15	149	181	32	120	216	96	118	200	82
1923	207	157	-50	195	190	-5	200	231	31	217	237	20
1924	117	135	18	130	151	21	144	213	69	214	235	21
1925	141	174	33	158	206	48	144	218	74	195	217	22
1926	80	115	35	65	122	57	96	157	61	136	135	-2
1927	200	209	9	202	234	32	243	250	7	237	256	19
1928	162	154	-8	182	170	-12	167	192	25	182	200	18
1929	188	191	3	212	219	7	234	252	18	207	240	33
1930	88	89	1	88	87	-1	98	127	29	107	136	29
1931	57	83	26	55	86	31	57	131	74	68	137	69
1932	140	151	11	138	158	20	146	183	37	160	193	33
1933	107	133	26	101	130	29	110	145	35	110	147	37
1934	50	79	29	90	91	1	82	134	52	81	150	69
1935	132	161	29	103	133	30	111	164	53	121	167	46
1936	88	102	14	88	101	13	113	122	9	110	123	13
1937	107	130	23	118	133	15	114	145	31	105	149	44
1938	145	172	27	145	165	20	153	217	64	152	203	51
1939	210	170	-40	187	146	-41	191	160	-31	186	162	-24

Year	Sioux City			Omaha			Nebraska City			St. Joseph		
	1960 Study	Current Study	Diff	1960 Study	Current Study	Diff	1960 Study	Current Study	Diff	1960 Study	Current Study	Diff
1940	65	91	26	65	94	29	70	153	83	76	158	82
1941	130	151	21	118	138	20	116	147	31	123	158	35
1942	149	153	4	149	154	5	178	224	46	184	234	50
1943	248	222	-26	244	218	-26	231	237	6	212	237	25
1944	197	208	11	183	189	6	231	296	65	187	237	50
1945	121	133	12	116	129	13	142	172	30	170	195	25
1946	109	127	18	101	122	21	118	161	43	121	165	44
1947	259	195	-64	231	187	-44	230	248	18	233	244	11
1948	164	173	9	166	174	8	178	225	47	183	223	40
1949	200	192	-8	208	202	-6	203	208	5	191	209	18
1950	255	248	-7	223	227	4	212	221	9	205	210	5
1951	170	161	-9	176	164	-13	175	225	50	206	254	48
1952	521	479	-42	490	469	-21	498	488	-10	490	467	-23
1953	208	263	55	214	272	58	217	284	67	223	278	55
1954	84	105	21	109	139	30	136	185	49	129	176	47
1955	76	107	31	82	116	34	86	137	51	102	145	43
1956	94	160	66	97	162	65	98	181	83	99	178	79
1957	118	161	43	130	170	40	174	274	100	176	286	110
1958	76	149	73	76	153	77	89	179	90	158	204	46
1959	184	136	-48	182	140	-42	194	200	6	192	210	18
1960	308	256	-52	334	274	-60	387	329	-58	384	353	-31

N V = No value contained in 1960 Study report.

Table A-37. Comparison of Computed and Observed End-Of-Month Mainstem Storage, 1000 acre-feet

Month	Computed	Observed	Month	Computed	Observed	Month	Computed	Observed	Month	Computed	Observed
Oct-37	24174	3	May-41	19455	1480	Dec-44	51804	11340	Jul-48	56796	17820
Nov-37	23841	30	Jun-41	19981	2005	Jan-45	50904	11060	Aug-48	57029	16720
Dec-37	23462	77	Jul-41	20778	1690	Feb-45	50369	11340	Sep-48	61341	15430
Jan-38	23535	141	Aug-41	20771	1222	Mar-45	50051	11780	Oct-48	62181	14100
Feb-38	23434	274	Sep-41	22943	1339	Apr-45	49949	12050	Nov-48	60806	13720
Mar-38	22971	70	Oct-41	22855	1686	May-45	50741	12550	Dec-48	58863	13480
Apr-38	22795	335	Nov-41	22742	1970	Jun-45	53496	13760	Jan-49	57484	13320
May-38	22761	1025	Dec-41	23619	2255	Jul-45	53638	14170	Feb-49	56344	13190
Jun-38	23913	2090	Jan-42	24610	2470	Aug-45	52884	13770	Mar-49	55674	13750
Jul-38	23466	2427	Feb-42	25260	2707	Sep-45	54442	12970	Apr-49	55427	13940
Aug-38	22991	1801	Mar-42	25346	3161	Oct-45	54563	12380	May-49	55269	14570
Sep-38	24886	1223	Apr-42	25528	3800	Nov-45	53227	12380	Jun-49	57792	15280
Oct-38	26717	1165	May-42	25535	4829	Dec-45	51740	12530	Jul-49	60265	14800
Nov-38	25490	813	Jun-42	26631	6827	Jan-46	50615	12790	Aug-49	60138	13620
Dec-38	25527	512	Jul-42	27120	7151	Feb-46	49945	13140	Sep-49	60924	12590
Jan-39	25944	484	Aug-42	29989	6659	Mar-46	49858	13510	Oct-49	59875	11940
Feb-39	26019	481	Sep-42	33699	6142	Apr-46	50043	13890	Nov-49	57786	11950
Mar-39	25720	750	Oct-42	34247	5735	May-46	50375	14420	Dec-49	56174	11880
Apr-39	25857	508	Nov-42	33170	5731	Jun-46	51516	15100	Jan-50	54923	11900
May-39	25861	485	Dec-42	32324	5961	Jul-46	50957	15380	Feb-50	54331	12100
Jun-39	28088	513	Jan-43	31921	6235	Aug-46	50267	14460	Mar-50	53826	12550
Jul-39	27976	320	Feb-43	32469	6817	Sep-46	50996	13890	Apr-50	53507	13160
Aug-39	27599	128	Mar-43	32437	7561	Oct-46	50943	13610	May-50	53440	13520
Sep-39	28468	116	Apr-43	32721	8622	Nov-46	49112	13780	Jun-50	54826	15180
Oct-39	27854	159	May-43	33500	9651	Dec-46	48421	13970	Jul-50	59825	15710
Nov-39	26260	159	Jun-43	35944	12530	Jan-47	48423	14140	Aug-50	60523	15070
Dec-39	24509	255	Jul-43	39824	13410	Feb-47	48388	14470	Sep-50	62139	14350
Jan-40	24532	400	Aug-43	40135	12880	Mar-47	48333	15600	Oct-50	62690	13520
Feb-40	24611	588	Sep-43	44472	12010	Apr-47	48640	15840	Nov-50	61808	13190
Mar-40	24512	866	Oct-43	46397	11220	May-47	49325	16570	Dec-50	60331	13120
Apr-40	24230	1061	Nov-43	45254	10750	Jun-47	52026	17530	Jan-51	58953	13050
May-40	24154	1532	Dec-43	44036	10250	Jul-47	54368	17360	Feb-51	57192	13050
Jun-40	23847	2080	Jan-44	43017	10040	Aug-47	55219	16320	Mar-51	56745	13580
Jul-40	23466	1622	Feb-44	42440	10120	Sep-47	58103	15150	Apr-51	56870	14020
Aug-40	22637	810	Mar-44	42331	10740	Oct-47	58321	14100	May-51	56877	14910
Sep-40	22874	780	Apr-44	42508	11120	Nov-47	57027	13820	Jun-51	57672	16060
Oct-40	21633	837	May-44	42840	11590	Dec-47	55250	13700	Jul-51	60420	16420
Nov-40	19971	905	Jun-44	43873	13330	Jan-48	54131	13750	Aug-51	60957	15540
Dec-40	19378	1098	Jul-44	47258	13950	Feb-48	53403	13810	Sep-51	63021	14610
Jan-41	19658	1254	Aug-44	47400	13280	Mar-48	53078	14060	Oct-51	63677	13460
Feb-41	19613	1422	Sep-44	51966	12790	Apr-48	53080	14400	Nov-51	63258	12740
Mar-41	19511	1631	Oct-44	53889	12210	May-48	53090	15350	Dec-51	62209	12430
Apr-41	19453	1383	Nov-44	52920	11750	Jun-48	54972	18000	Jan-52	60405	12210

Table A-37 (continued). Comparison of Computed and Observed End-Of-Month Mainstem Storage, 1000 acre-feet

Month	Computed	Observed	Month	Computed	Observed	Month	Computed	Observed	Month	Computed	Observed
Feb-52	58304	12310	Sep-55	51692	14343	Apr-59	44014	23955	Nov-62	49219	35309
Mar-52	57421	13010	Oct-55	51244	13209	May-59	44218	24409	Dec-62	48470	35225
Apr-52	57315	14250	Nov-55	49270	13311	Jun-59	47034	26216	Jan-63	48069	35532
May-52	57905	15540	Dec-55	47625	13563	Jul-59	47074	26383	Feb-63	47537	36538
Jun-52	59414	16280	Jan-56	46340	14020	Aug-59	47113	25098	Mar-63	47242	38072
Jul-52	67520	16410	Feb-56	46371	14327	Sep-59	48291	23914	Apr-63	47239	37732
Aug-52	67345	15480	Mar-56	46464	15011	Oct-59	47880	23284	May-63	48285	38245
Sep-52	67678	14480	Apr-56	46688	14060	Nov-59	46294	23400	Jun-63	49581	42021
Oct-52	65677	13490	May-56	46875	15343	Dec-59	45141	24355	Jul-63	49691	42153
Nov-52	63085	13240	Jun-56	48241	17053	Jan-60	44533	27425	Aug-63	50049	41059
Dec-52	60376	13094	Jul-56	48444	16689	Feb-60	44016	24771	Sep-63	52542	40131
Jan-53	58297	13092	Aug-56	48564	15704	Mar-60	44469	28632	Oct-63	52271	38921
Feb-53	56567	13266	Sep-56	50090	14436	Apr-60	44693	30553	Nov-63	50806	37946
Mar-53	55844	13453	Oct-56	49517	13610	May-60	45157	31276	Dec-63	49849	37706
Apr-53	55615	13387	Nov-56	48167	13978	Jun-60	48520	32214	Jan-64	48915	38258
May-53	55672	14201	Dec-56	46541	14010	Jul-60	50414	31104	Feb-64	47933	38695
Jun-53	57177	17254	Jan-57	45315	14014	Aug-60	50658	29986	Mar-64	47390	38873
Jul-53	57148	17374	Feb-57	44586	14362	Sep-60	51321	28680	Apr-64	47602	39169
Aug-53	58102	16633	Mar-57	44460	15728	Oct-60	49760	27685	May-64	47831	40983
Sep-53	62995	15086	Apr-57	44325	16284	Nov-60	48294	27177	Jun-64	47995	45891
Oct-53	62710	13881	May-57	44510	17221	Dec-60	46869	26807	Jul-64	48457	47468
Nov-53	61198	14233	Jun-57	45392	20788	Jan-61	45861	26945	Aug-64	49652	46397
Dec-53	58855	14196	Jul-57	45787	21832	Feb-61	45116	27393	Sep-64	53871	45375
Jan-54	56875	14200	Aug-57	46846	20650	Mar-61	44564	27973	Oct-64	54948	44169
Feb-54	55481	14690	Sep-57	49612	19963	Apr-61	44515	27194	Nov-64	53599	43139
Mar-54	54964	14861	Oct-57	49756	19233	May-61	44813	26772	Dec-64	52634	42859
Apr-54	54639	15245	Nov-57	48349	19718	Jun-61	45300	27283	Jan-65	51441	43456
May-54	55195	15629	Dec-57	47573	19964	Jul-61	44710	25096	Feb-65	50367	44182
Jun-54	55449	17139	Jan-58	46920	20105	Aug-61	44109	24878	Mar-65	50077	45001
Jul-54	55612	16422	Feb-58	46803	20515	Sep-61	44432	23838	Apr-65	50443	47837
Aug-54	55238	15680	Mar-58	46806	21560	Oct-61	42679	23767	May-65	50867	50645
Sep-54	55923	14617	Apr-58	46763	22127	Nov-61	40634	24339	Jun-65	51500	54683
Oct-54	55081	14084	May-58	47044	22339	Dec-61	39571	23917	Jul-65	54519	57131
Nov-54	53625	14623	Jun-58	47624	23363	Jan-62	38543	24115	Aug-65	57279	56582
Dec-54	52155	14593	Jul-58	47962	23931	Feb-62	38068	24747	Sep-65	60955	56089
Jan-55	51373	14520	Aug-58	47775	22608	Mar-62	37470	26539	Oct-65	63048	55823
Feb-55	50576	14688	Sep-58	48757	21435	Apr-62	37586	27929	Nov-65	62139	55135
Mar-55	50334	15509	Oct-58	48744	20503	May-62	38056	30525	Dec-65	60935	55054
Apr-55	49984	16318	Nov-58	46961	20803	Jun-62	39446	35309	Jan-66	59783	54721
May-55	50003	16340	Dec-58	45474	20893	Jul-62	41046	37492	Feb-66	58083	54772
Jun-55	50448	17377	Jan-59	44511	21003	Aug-62	43668	37296	Mar-66	57577	57942
Jul-55	50978	17477	Feb-59	44001	21066	Sep-62	47986	36578	Apr-66	57377	58231
Aug-55	50890	15949	Mar-59	43994	24095	Oct-62	49902	35976	May-66	57641	58136

Table A-37 (continued). Comparison of Computed and Observed End-Of-Month Mainstem Storage, 1000 acre-feet

Month	Computed	Observed	Month	Computed	Observed	Month	Computed	Observed	Month	Computed	Observed
Jun-66	60656	58415	Jan-70	58976	59645	Aug-73	60630	63047	Mar-77	55471	58721
Jul-66	60967	57456	Feb-70	58053	59373	Sep-73	61317	61490	Apr-77	55273	59484
Aug-66	60775	56123	Mar-70	57432	59676	Oct-73	60299	60751	May-77	55610	59150
Sep-66	61161	54744	Apr-70	57145	59862	Nov-73	58201	60138	Jun-77	56407	58790
Oct-66	60298	53181	May-70	57441	61075	Dec-73	57660	59286	Jul-77	56037	58638
Nov-66	58570	51949	Jun-70	57733	64043	Jan-74	57151	59011	Aug-77	55699	57058
Dec-66	56850	51755	Jul-70	59151	66871	Feb-74	56528	59113	Sep-77	55660	55322
Jan-67	55301	51890	Aug-70	61930	67051	Mar-74	56284	59504	Oct-77	54257	54387
Feb-67	54017	52519	Sep-70	63909	65022	Apr-74	56541	60033	Nov-77	52546	53303
Mar-67	53530	54324	Oct-70	62883	63339	May-74	56941	60616	Dec-77	51844	51931
Apr-67	53177	54973	Nov-70	60580	61639	Jun-74	57199	61436	Jan-78	51213	51758
May-67	53293	55841	Dec-70	59280	60151	Jul-74	57685	64246	Feb-78	50263	51463
Jun-67	55173	62325	Jan-71	58385	59611	Aug-74	58430	64774	Mar-78	50200	51620
Jul-67	56043	64414	Feb-71	57559	59660	Sep-74	60828	63713	Apr-78	50055	58870
Aug-67	57358	63105	Mar-71	57131	61139	Oct-74	60841	62303	May-78	50219	62261
Sep-67	63343	61760	Apr-71	56607	64156	Nov-74	59535	60827	Jun-78	57451	65733
Oct-67	64543	61734	May-71	57365	65520	Dec-74	57798	59917	Jul-78	61265	68017
Nov-67	62483	60374	Jun-71	60426	66183	Jan-75	56513	59752	Aug-78	65024	69067
Dec-67	60266	59502	Jul-71	61381	68597	Feb-75	55682	59171	Sep-78	66662	67139
Jan-68	59008	58882	Aug-71	62022	68015	Mar-75	55533	59102	Oct-78	67255	65550
Feb-68	57911	59106	Sep-71	65159	65809	Apr-75	55082	59941	Nov-78	64961	63031
Mar-68	57084	59414	Oct-71	64431	63928	May-75	54999	62816	Dec-78	63083	60383
Apr-68	57274	60614	Nov-71	61860	62542	Jun-75	55972	66647	Jan-79	60250	59666
May-68	57574	60575	Dec-71	60086	60516	Jul-75	59031	70136	Feb-79	57921	59324
Jun-68	58297	60273	Jan-72	59406	59564	Aug-75	62595	71832	Mar-79	57467	59027
Jul-68	58187	63314	Feb-72	58541	59176	Sep-75	65723	69765	Apr-79	57344	62494
Aug-68	57702	63332	Mar-72	57755	59460	Oct-75	67076	66789	May-79	56918	66144
Sep-68	60304	62568	Apr-72	57337	64588	Nov-75	64765	64029	Jun-79	60343	66777
Oct-68	60076	61653	May-72	57407	64426	Dec-75	62001	61335	Jul-79	64234	67350
Nov-68	59189	60793	Jun-72	62327	66174	Jan-76	59957	60951	Aug-79	64536	66905
Dec-68	58079	59931	Jul-72	61647	68526	Feb-76	58099	60784	Sep-79	65181	65590
Jan-69	57143	59350	Aug-72	63384	68031	Mar-76	58052	61366	Oct-79	64648	63967
Feb-69	56655	59444	Sep-72	65361	66531	Apr-76	57789	62225	Nov-79	62989	62145
Mar-69	56186	59604	Oct-72	64487	64447	May-76	58166	62343	Dec-79	60984	60513
Apr-69	56389	62205	Nov-72	62817	62450	Jun-76	59098	63706	Jan-80	59361	59686
May-69	56602	65643	Dec-72	60903	61021	Jul-76	59476	65842	Feb-80	58228	58904
Jun-69	59036	66294	Jan-73	59499	60395	Aug-76	60834	65774	Mar-80	57544	58927
Jul-69	63153	67282	Feb-73	58254	60482	Sep-76	63069	64266	Apr-80	56899	59303
Aug-69	63528	68956	Mar-73	57646	60613	Oct-76	63152	62550	May-80	56906	59187
Sep-69	64575	66391	Apr-73	57831	61994	Nov-76	61452	61008	Jun-80	57225	58923
Oct-69	65551	63731	May-73	58088	62176	Dec-76	59560	59401	Jul-80	57357	60236
Nov-69	62632	61625	Jun-73	60013	62936	Jan-77	57705	58799	Aug-80	57145	59545
Dec-69	60210	60142	Jul-73	60216	64011	Feb-77	55920	58407	Sep-80	58169	57882

Table A-37 (continued). Comparison of Computed and Observed End-Of-Month Mainstem Storage, 1000 acre-feet

Month	Computed	Observed	Month	Computed	Observed	Month	Computed	Observed	Month	Computed	Observed
Oct-80	57097	56366	May-84	58693	62329	Dec-87	60339	56928	Jul-91	41902	47563
Nov-80	55865	55371	Jun-84	60079	63952	Jan-88	58548	56285	Aug-91	43239	48127
Dec-80	54552	54128	Jul-84	61871	67735	Feb-88	57241	55776	Sep-91	47031	46847
Jan-81	53748	53715	Aug-84	63327	67444	Mar-88	56492	55414	Oct-91	47581	45711
Feb-81	52872	53841	Sep-84	66249	65516	Apr-88	56047	55692	Nov-91	46107	44635
Mar-81	52500	54127	Oct-84	66135	63549	May-88	55997	54833	Dec-91	44885	44899
Apr-81	52685	54075	Nov-84	63850	61808	Jun-88	56507	54803	Jan-92	43867	44815
May-81	52953	52835	Dec-84	61398	59926	Jul-88	55756	54279	Feb-92	43483	44880
Jun-81	53306	54087	Jan-85	59933	59003	Aug-88	55483	52788	Mar-92	43487	45399
Jul-81	52418	56122	Feb-85	58313	58793	Sep-88	54960	50603	Apr-92	43673	45833
Aug-81	53114	55937	Mar-85	57531	58745	Oct-88	53504	48770	May-92	44113	45275
Sep-81	55119	54775	Apr-85	57474	60329	Nov-88	51210	46958	Jun-92	44653	44869
Oct-81	54949	52946	May-85	57659	60219	Dec-88	49483	46164	Jul-92	44110	45038
Nov-81	53920	51543	Jun-85	58787	59859	Jan-89	47967	45693	Aug-92	43630	45474
Dec-81	52440	51286	Jul-85	58890	59398	Feb-89	46970	45504	Sep-92	43914	44805
Jan-82	51461	50942	Aug-85	58382	57870	Mar-89	46503	45323	Oct-92	44274	43855
Feb-82	50983	50593	Sep-85	58120	56852	Apr-89	46349	46974	Nov-92	43341	43385
Mar-82	50637	51589	Oct-85	56707	55726	May-89	46328	47316	Dec-92	42562	43730
Apr-82	50338	53752	Nov-85	55731	54941	Jun-89	47750	47696	Jan-93	42016	42726
May-82	51320	55643	Dec-85	54870	53462	Jul-89	48299	47845	Feb-93	41737	42774
Jun-82	53579	58312	Jan-86	54460	53244	Aug-89	48712	47004	Mar-93	40942	42996
Jul-82	55739	61862	Feb-86	53548	53481	Sep-89	49026	45373	Apr-93	41049	45426
Aug-82	58300	63818	Mar-86	53522	54026	Oct-89	48303	44188	May-93	41287	46084
Sep-82	61655	63235	Apr-86	53816	58376	Nov-89	46732	42981	Jun-93	43963	47562
Oct-82	63623	62158	May-86	54440	60538	Dec-89	45751	43092	Jul-93	44796	50293
Nov-82	62846	61908	Jun-86	59355	63002	Jan-90	44576	42621	Aug-93	46116	55617
Dec-82	61062	60324	Jul-86	61953	64947	Feb-90	44122	43140	Sep-93	48823	57163
Jan-83	60282	59692	Aug-86	64920	64832	Mar-90	43799	43390	Oct-93	53474	57138
Feb-83	58539	59427	Sep-86	66533	63083	Apr-90	44300	44453	Nov-93	54763	56932
Mar-83	58136	59859	Oct-86	66136	63131	May-90	44596	44082	Dec-93	54797	56634
Apr-83	58123	61217	Nov-86	63852	62184	Jun-90	45377	44209	Jan-94	54566	56728
May-83	58745	61858	Dec-86	63681	60654	Jul-90	45066	45234	Feb-94	54429	56632
Jun-83	60646	62927	Jan-87	62035	59545	Aug-90	45034	45017	Mar-94	54626	56786
Jul-83	61653	64800	Feb-87	59979	58910	Sep-90	45920	43958	Apr-94	54727	60713
Aug-83	62733	65978	Mar-87	59692	59048	Oct-90	45698	42533	May-94	55022	61015
Sep-83	64065	64571	Apr-87	59314	62100	Nov-90	44522	41382	Jun-94	59342	61575
Oct-83	65064	62839	May-87	59715	63107	Dec-90	43224	41547	Jul-94	59823	62130
Nov-83	63580	61674	Jun-87	62763	63338	Jan-91	42106	40904	Aug-94	60635	61140
Dec-83	61179	60606	Jul-87	63646	62943	Feb-91	41475	41025	Sep-94	61316	59456
Jan-84	59679	59439	Aug-87	63903	62143	Mar-91	40961	41488	Oct-94	60300	58025
Feb-84	58287	59684	Sep-87	63512	60920	Apr-91	41229	42097	Nov-94	58570	57261
Mar-84	57360	60392	Oct-87	62744	59694	May-91	41694	41849	Dec-94	57113	55936
Apr-84	57779	61266	Nov-87	61500	58100	Jun-91	41982	43441	Jan-95	56438	55630

Table A-37 (continued). Comparison of Computed and Observed End-Of-Month Mainstem Storage, 1000 acre-feet

Month	Computed	Observed	Month	Computed	Observed	Month	Computed	Observed	Month	Computed	Observed
Feb-95	55066	55215	Nov-95	64714	61183	Aug-96	65122	67706	May-97	61714	67129
Mar-95	54882	55902	Dec-95	62211	59045	Sep-96	68053	65217	Jun-97	65847	67616
Apr-95	54509	57207	Jan-96	60344	58402	Oct-96	67217	63048	Jul-97	67357	71155
May-95	55223	58698	Feb-96	58605	58131	Nov-96	64834	60767	Aug-97	67931	71158
Jun-95	56927	63143	Mar-96	58000	60162	Dec-96	62513	58442	Sep-97	71153	69080
Jul-95	58531	66664	Apr-96	57555	62289	Jan-97	60181	57785	Oct-97	71122	66230
Aug-95	62734	68019	May-96	59339	63315	Feb-97	58258	57744	Nov-97	68963	62947
Sep-95	65389	65942	Jun-96	61478	65352	Mar-97	59006	59377	Dec-97	65910	59824
Oct-95	66491	63329	Jul-96	62634	68453	Apr-97	59909	64609			

Upper Mississippi River System
Flow Frequency Study

Appendix F-B
Descriptions of Gages and Derivation of Flow from Stage Records

Stream flow Records

The first river stage station on the Missouri River was established on January 1, 1872 at Fort Leavenworth, Kansas, which is currently located in the Kansas City District. Within the current boundaries of the Omaha District, the first stage gage on the Missouri River was established on April 10, 1872 at Omaha, Nebraska. Other river stage gages were established at Plattsmouth, Nebraska on April 19, 1873; at Nebraska City on August 1, 1878; and at Sioux City, Iowa on September 2, 1878. These river stage stations were operated by the Corps of Engineers from the date of their establishment to December 31, 1899. On January 1, 1900, the work of securing a record of river stages was taken over by the United States Weather Bureau, who maintained daily river stage records until 1930. At that time, the USGS had taken over the responsibility of collecting and recording river gage records. Available records at key stations are shown in Table B-1.

Table B-1 Missouri River Main Stem Streamgage Records

Yankton, SD	805.8	279,500	1139.7	32	USGS	1921 – date	1930 - 1995
Sioux City, Ia	732.3	314,600	1057.0	36	USGS	1878 – date	1928-1931 1938 - date
Decatur, Ne	691.0	316,200	1010.0	35	COE	1987-date	None
Blair, Ne	648.3	321,400	987.3	19	COE	1881-1899 1905-date	None
Omaha, Ne	615.9	322,800	948.2	29	USGS	1872-date	1928-date
Plattsmouth, Ne	591.5	323,500	938.8	16	COE	1872-1928 1932-date	None
Nebraska City, Ne	562.6	414,400	905.4	18	USGS	1878-1900 1929-date	1929-date
Rulo, Ne	498.1	418,900	837.2	17	USGS	1929-date	1949-date
St. Joseph, Mo	448.2	420,300	788.2	17	USGS	1873-date	1928--date
Kansas City, Mo	366.1	485,200	706.4	32	USGS	1873-date	1928-date
Waverly, Mo	293.4	487,200	646.0	20	USGS	1879-1900 1915-date	1929-date
Boonville, Mo	197.1	501,700	565.4	21	USGS	1875-date	1925-date
Hermann, Mo	97.9	524,200	481.6	21	USGS	1873-date	1928-date
St. Charles, Mo	28.2	529,200	413.6	25	COE	1878-1899 1917-date	None

Gage Description

Descriptions of each gage in the Omaha District used for this study are listed below:

Missouri River At Sioux City, Iowa

Presently, the U.S. Geological Survey (USGS) operates gaging station number 06486000, Missouri River at Sioux City, Iowa. The gage is located on the right bank on the upstream side of the U.S. Highway 20 and 77 bridge at South Sioux City, Nebraska, 1.9 miles downstream from the Big Sioux River at mile 732.2, lat. $42^{o}29'09"$, long. $96^{o}24'49"$, in sec. 16, T. 29 N., R. 9E. At the gage site, the drainage area is approximately 314,600 square miles. The gage is a water stage encoder with a datum of 1,056.98 ft above sea level.

Daily gage-height records from September 2, 1878, to December 31, 1899, have been published in "Stages of the Missouri River for the Period 1872-1899". The U.S. Weather Bureau obtained and published fragmentary gage-height records from July 1, 1889, to December 31, 1905. According to records compiled by the Missouri River Commission, the US Corps of Engineers (USCOE) established the river gage station at Sioux City, Iowa on September 2, 1878 just below the mouth of Perry Creek. The gage was 1.5" x 8" pine, attached to a clump of piling; it was painted white, with black markings with the graduations running from –1.8' to 20.2'. At times, due to shore sand bar filling, this gage could not be read and a supplementary gage was located at the foot of Pearl Street, about 500' below the original gage, the graduations running from 0' to 12.2'. The supplementary gage was a 2" x 4" scantling, with markings cut into it; the gage was spiked to the piling of a government dike, with the zero elevation 0.07 feet lower than the Perry Creek gage.

From November 8, 1882 to some time early in May 1883, the readings were taken on a gage about 400' below the Perry Creek gage. The readings from these gages are continuous from September 2, 1878, to October 26, 1888, inclusive. The gage was abandoned by the USCOE on that date, and a new gage was established on the Omaha Bridge, due to sand bar accretion along the left bank interfering with the readings. At this time, the Missouri River Commission established a standard cable and weight gage over the channel span (first from left bank) of the Chicago, St. Paul, Minneapolis and Omaha Bridge, 1.7 miles downstream from the Perry Creek gage. The readings on the gage at this bridge (known locally as the "Omaha Bridge") began on October 27, 1888, and are complete through December 31, 1899. At and about the 5-foot stage, the records show that there is an average slope of 1.3 feet from Perry Creek to the "Omaha Bridge" and at high stages the average slope is 1.6 feet between gages. This gage was graduated to read elevations above St. Louis Directrix.

The Signal Corps, U.S. Army, established a river station at Sioux City, Iowa, on July 1, 1887 and readings were taken on the USCOE gage at the mouth of Perry Creek, with the following exceptions, until a new gage was installed by the USWB in March 1900. Readings from March 1, 1888 to September 30, 1888 and from April 1, 1889 to June 30, 1889, which were taken by the Signal Corps, are published on pages 242 and 243, "Stages of the Mississippi River and of its principal tributaries, except the Ohio River, 1860-1889, Part II". From August 5 to October 7, 1889 and from August 20 to 31, 1890, readings were made from a temporary gage at the foot of Douglas Street. From September 1, 1890 to October 20, 1890, the readings were taken from a temporary gage on the Pacific Short Line Bridge or what was later known as the Combination Bridge. From September 1, 1891 to November 13, 1891 readings were taken from a temporary gage on a clump of piles in the middle of the river on the west side of pontoon bridge, which was located at the foot of Pearl Street, just below the Combination bridge, which was then under construction. The USWB assumed charge of the gages on the Missouri River on January 1, 1900, and the Missouri River Commission abandoned the service.

On December 31, 1899, at the time of the discontinuance of the reading of the gage by the USCOE, the records state that the reference BM is 466 "A", described as "under side of marked brick in water table, southeast corner of Sanborn and Follett's brick building on southwest corner of Third and Water Streets; elevation 694.02' above St. Louis Directrix; also that the elevation of zero on the gage is 665.08', or a difference of 28.94' between the BM and the zero of the gage." 665.08' above St. Louis Directrix corresponds to 1,076.94' MSL, USC&GS 1929 adjustment. A careful check of the records indicates that the Perry Creek gage, USCOE, was kept at a zero elevation of 28.94' below the BM 466 "A". Published elevations in some of the early reports are not always in agreement, which may be explained by different determinations from several surveys, the first of which was made in 1878-1879; a recheck was made in 1880, and a third survey was run in 1892-1893, after the USCOE abandoned the gage.

In March, 1900, a new river gage was installed by the USWB. It was located at the mouth of Perry Creek and spiked to the surface of the old gage, which was attached to a clump of white oak piling. It was made of a 2" x 6" yellow pine, painted white, with graduations cut into the wood and painted black, ranging from 0 to 20'. Zero elevation was the same as the USCOE gage, or 665.08' above St. Louis Directrix, which corresponds to 1,076.94' MSL.

On account of changes made by river improvements, it became necessary on September 28, 1900 to remove the supplementary USCOE gage, and it was accordingly fastened to the dike, or shore protection of the north end of the Combination bridge about 500' above the Perry Creek gage. The graduations on this gage ranged from –1.0' to 15.0'.

The USWB abandoned the Perry Creek gage on December 31, 1905, and beginning with January 1, 1905, readings were made on a new gage of the USGS pattern, which was installed 0.1 mile upstream on the Combination Bridge. It was located on the north, or draw-span, being bolted to the east face of the east guardrail of the street car and railroad portion of the bridge, 35' south of the north and of the bridge. The gage was set by the USCOE but the leveling notes were destroyed in an office fire of the USWB, Sioux City, Iowa, on January 26, 1911. The City Engineer checked the river gage on October 2, 1928, and an error of 0.36 feet appeared to have developed in the gage since the new chain was installed on May 25, 1925. The gage-box was raised that amount on October 4, 1928 to correct the error. As there had been some changes in many of the early BM, which were used as reference points when the gage was originally set on September 2, 1878, the advisability of establishing new BMs in the vicinity of the gage was apparent. A complete circuit of levels was run in the fall of 1930, which tied the gage in with all the early BMs located within two to three miles on both sides of the river that had not been destroyed. This thorough check showed that the zero of the gage was now 0.219 feet high and that the gage-box should not have been raised on October 4, 1928. A blue print showing the circuit of levels is on file at the Central Office, USWB, Washington, D.C., and a copy is retained at the USWB office, Sioux City, Iowa. The USGS began making discharge measurements at Sioux City in September, 1928, using the USWB gage in connection with their work. The chain length was measured by the USGS and the gage checked at frequent intervals after that date, until the gage was corrected and set at correct datum on December 31, 1930, by the USCOE.

The stages for the year 1930 were corrected before being published. A careful study of the measurements of the chain and checking of the gage by the USGS from September, 1928 to

March 29, 1930 and the checking of the BM's and the gage by the USCOE disclosed that the following corrections should be applied to the published stages in the USWB Daily River Stages, years 1925 to 1929, inclusive, for the Sioux City River gage from September 1, 1925 to December 31, 1929: Subtract 0.2 feet from September 1, 1925 to May 31, 1928; subtract 0.3 feet from June 1, 1928 to October 4, 1928, and add 0.1 feet from October 5, 1928 to December 31, 1929.

On September 2, 1931, the 53rd anniversary of the establishment of the river station, a new short-box pattern chain and weight gage was installed 73 feet from the right bank abutment by the USGS, at a zero elevation of 665.1' above St. Louis Directrix, which corresponds to 1076.96', USC&GS 1929 adjustment. On December 2, 1936, the USGS installed a Type A wire-weight gage on the Combination Bridge for the USWB. This gage was set to the same datum as the former chain gage and has been in use since that date.

USGS used a chain gage located 160 feet from left end of bridge on which present gage is located from September 1, 1928, to September 30, 1931. This chain gage was the property of the Weather Bureau and was used by them also. From October 1, 1931, to July 31, 1938, the collection of discharge records was discontinued by the USGS. During this period, the Weather Bureau installed a recording gage on February 14, 1935. This gage was maintained for the Weather Bureau by the USGS until the gage was reestablished as a USGS gaging station on September 1, 1938. It remained at this location, 227 feet downstream from the present site, at a datum 20 feet higher than present until September 30, 1970 and until Jan 30, 1981 at the present datum.

Maximum stage recorded by the Weather Bureau was 22.5 feet on April 23, 1881. However, according to the station description for Missouri River at Sioux City, Iowa, dated March 24, 1934, which was prepared by the War Department, a stage of 25.0 feet occurred on May 18, 1892 as a result of backwater from the Floyd River. A maximum discharge of 441,000 cfs occurred on April 14, 1952 at a gage height of 24.28 feet.

Missouri River At Omaha, Nebraska

The U.S. Geological Survey (USGS) presently operates gaging station number 06610000, Missouri River at Omaha, Nebraska. The gage is located on the right bank on the left side of the concrete floodwall, at the foot of Douglas Street, 275 ft. downstream from the Interstate 480 Highway Bridge in Omaha, and at river mile 615.9, lat. 41°15'32", long 95°55'20", in SE ¼ NW ¼ sec.23, T. 15 N., R. 13 E., Douglas County. Drainage area above the gage is approximately 322,800 square miles. Present gage datum is 948.24 feet above sea level. From Oct. 1, 1936 to Sept. 30, 1982 the gage datum was 10 feet higher.

Daily gage-height records have been collected from April 10, 1872, to date by U.S. Army Engineers and U.S. Weather Bureau. The records from April 10, 1872, to December 11, 1899, were published by the Missouri River Commission in "Stages of the Missouri River." The records since January 1, 1900, have been published by the U.S. Weather bureau in "Daily River Stages of Principal Rivers of the United States". The gages used at or near this site were as follows:

From April 10, 1872, to August 31, 1878, the Union Pacific Railroad (UPRR) used a cable gage on their bridge about 0.6 miles below present gage on Douglas Street Bridge, which was demolished Dec. 1968.

From September 1, 1878, to February 28, 1907, the U.S. Corps of Engineers collected records from the several gages. From Sept. 1, 1878, to Apr. 26, 1879, readings were at the UPRR gage site. From April 27, 1879, to May 20, 1886, a staff gage 700 ft. upstream at the foot of Farnam Street was used. The gage heights were corrected for slope to correspond with readings on the UPRR gage. From May 21, 1886, to Feb. 28, 1907, gage heights were obtained from the UPRR gage, except for the period Nov. 19, 1886, to Mar. 9, 1887, during which time the gage was moved to a temporary bridge while repairs were being made to old bridge.

From March 1, 1907, to date, the U.S. Weather Bureau has obtained gage heights from the several gages. A chain and weight gage bolted to the downstream guardrail on the Douglas Street Bridge was used from March 1, 1907, to September 21, 1934. According to letter, dated April 7, 1930, from the U.S. Weather Bureau, the zero of this chain gage was 0.43 feet higher than the zero of the UPRR gage in order to compensate for slope of river. From September 22, 1934 to May 2, 1968, the U.S. Weather Bureau Type A wire-weight gage was located on the upstream truss of the main span of the Ak-Sar-Ben (Douglas Street) Bridge at Sta. 135. Standard check bar elevation was 76.83 ft. above zero of gage.

From September 1, 1928, to date, the U.S. Geological Survey has obtained gage heights from several gages. From September 1, 1928, to November 30, 1929, readings were made from the chain gage attached to the Illinois Central R.R. Bridge, about two miles upstream from former Douglas Street Bridge. The zero of this gage was 2.97 feet higher than the zero of the present gage. From December 1, 1929, to May 26, 1930, readings were made from the Douglas Street gage. From May 27, 1930, to October 18, 1931, a Canfield wire-weight gage was used near the chain gage on the Douglas Street Bridge and set to the same datum as that gage. From October 19, 1931, to September 30, 1936, a Stevens recording gage in a 36-inch corrugated iron pipe bolted to Nebraska Power and Light Company's concrete intake wall was used. This gage was set to the same datum as the Douglas Street gage and was located 1900 feet downstream from that gage. From October 1, 1936, to February 4, 1952, Eriez and Stevens recording gages in 36" corrugated house and 18" galvanized spiral-welded pipe well attached to the downstream end of the pier at the left end of the main truss span of the Douglas Street Bridge at station 396 were used. The recorders were set to read the same as the outside gage. On February 7, 1952, the recorder was moved to the current gage location and was used until September 30, 1965. A digital punched-tape water stage recorder with 15 minute punch interval was installed to be used beginning Oct. 1, 1965. It is driven by means of sprocket and chain from the Stevens A-35 water stage recorder. Reference gage is the inside float tape, which is an integral part of the Stevens A-35 recorder. A Stevens A-35 continuous water-stage recorder with gage-height ratio 1:6 and 2.4" per day is operated as an auxiliary recorder. The gage is housed in a reinforced concrete house and well, 6 ft. 4 inches square with two 3-inch intakes, both connected to a flushing system equipped with an electric pump. The outside gage is a staff gage attached to the downstream landward side of the right pier of the Interstate 480 Highway bridge and was installed May 2, 1968, at which time the wire-weight gage was removed prior to demolition of Ak-Sar-Ben Bridge on Dec. 14, 1968.

The gage height for April 25, 1881, is given as 569.4 feet St. Louis Directrix. On page 6 of the Missouri River Commission book “Stages of the Missouri River from its Mouth to Sioux City, Iowa, 1890-1894”, the table of corrections shows that 1.003 feet must be added to the 1881 datum in order to transfer it to St. Louis Directrix correctly. Therefore, the true elevation of the 1881 high water at the Union Pacific Bridge, referred to the St. Louis Directrix is 570.403 feet. The 1929 Adjustment of the Primary Level Net of the U.S. Coast and Geodetic Survey gives a difference between the St. Louis Directrix and the U.S. Coast and Geodetic Survey datum at Omaha of 412.057 ft. Therefore, the true elevation of the 1881 flood referred to the 1929 Adjustment of the Primary Level Net by the U.S. Coast and Geodetic Survey at Omaha would be (570.403 plus 412.057) 982.460 feet, m.s.l. The zero of the gage on the Union Pacific Railroad bridge used from 1872 to 1907 was 957.807 feet above mean sea level, U.S.C. & G.S. General Adjustment of 1929, as determined by the following method: On page 7 of the Missouri River Commission Report of “Stages of the Missouri River for 1895 to 1899”, the adjusted elevation of the zero of the gage is given as 545.75 feet above St. Louis Directrix. In order to convert this to mean sea level elevation, 1929 adjustment, it is necessary to add 412.057 feet, which gives 957.807 feet. Therefore, the flood of April 25, 1881, corresponded to a stage of 24.65 feet (982.460 – 957.807) on the gage on the Union Pacific Railroad bridge, which was used from 1872 to 1907. With the USWB chain gage installed on the Douglas Street bridge in 1907 set to read the same as the gage on the Union Pacific Railroad bridge and the U.S.W.B. wire gage on the Douglas Street bridge set to the same datum as the chain gage located there, it is assumed that the flood of April 25, 1881, corresponded to a stage of 24.65 feet on both the USWB chain and wire gages on the Douglas Street bridge, which were used by the USWB from 1907 to date. As the present USGS recording gage is set to read the same as the USWB wire weight gage, the flood of April 25, 1881 also reached a stage of 24.65 feet on the present U.S.G.S. recording gage. Maximum stage at this gage of 30.20 feet occurred on April 16, 1952 with a peak discharge of 396,000 cfs.

Missouri River At Nebraska City, Nebraska

The USGS currently operates gaging station number 0680700, Missouri River at Nebraska City, Nebraska. The gage is located on the right bank 2 miles upstream from the Highway 2 Bridge at mile 562.6, lat. 40°40’55”, long. 95 °50’48”. Drainage area upstream from the gage is approximately 414,400 square miles. The current datum of the gage is 905.36 feet above sea level.

The U.S. Corps of Engineers obtained daily gage heights from an inclined masonry gage 2700 feet downstream from the C.B. & Q.R.R. bridge from August 1, 1878, to October 30, 1888, and from the cable gage on the bridge from October 31, 1888, to December 31, 1899. The Missouri River Commission published these records in “Stages of the Missouri River.” The C.B. & Q.R.R. obtained daily gage heights from the cable gage on the railroad bridge from November 1917 to August 12, 1929.

The USGS obtained daily gage heights from a chain gage on the C.B. & Q.R.R. bridge from August 12, 1929, to June 27, 1930 and from a Canfield wire-weight gage on that bridge from June 27, 1930, to October 22, 1931. From October 22, 1931, to Apr 1, 1963, a recording gage on the Waubonsie Highway Bridge was used. The Canfield wire-weight gage was moved from the railroad to highway bridge on August 1, 1932. All these USGS gages were set and maintained to the same datum.

During the flood of 1881, the maximum stage occurred April 27, 1881. In "Stages of the Missouri River" the stage recorded for that date was 509.1 ft. According to pages V and VI of this report for 1895 to 1899, 0.36 ft. must be added to this figure in order to make it refer to correct St. Louis directrix. According to page XII of report for 1886 to 1889, the gage maintained during 1881 was an inclined masonry gage located 2700 feet downstream from C.B. & Q.R.R. bridge and the fall in water surface between the bridge and inclined gage at a stage of 499 feet was 0.37 feet. Therefore, the correct elevation for the maximum stage of April 27, 1881, at the railroad bridge was (509.1+0.36+0.37) 509.83 feet. The zero of USGS gages on railroad and highway bridges is 491.80 feet above St. Louis directrix. Therefore, the maximum stage of April 27, 1881 was (509.83-491.80) 18.03 feet, referred to the present USGS gage. The maximum flood of record occurred on April 19, 1952 with a discharge of 414,000 cfs and a peak stage of 27.66 feet.

Additional gages along the Missouri River in the Omaha District used in this study are briefly described below:

Yankton-
LOCATION.--Lat 42 51'58", long 97 23'37", in SW¼ SW¼ sec.18, T.93 N., R.55 W., Yankton County, Hydrologic Unit 10170101, near left bank in downstream end of left pier of Meridian Highway Bridge on U.S. Highway 81, 5.2 mi downstream from Gavins Point Dam, 6.0 mi upstream from James River, and at mile 805.8.
DRAINAGE AREA.--279,500 mi2, approximately.
PERIOD OF RECORD.--October 1995 to current year, daily gage-height records. October 1930 to September 1995, daily discharge determined. Monthly discharge only for some periods, published in WSP 1309. Gage-height records collected at same site March 1873 to November 1886, March 1905 to May 1908 (fragmentary), August 1921 to September 1950 (except winter months prior to 1932), are contained in reports of the National Weather Service.
GAGE.--Water-stage recorder. Datum of gage is 1,139.68 ft above National Geodetic Vertical Datum of 1929. Prior to Sept. 20, 1932, nonrecording gage, and Sept. 20, 1932, to Mar. 9, 1967, water-stage recorder at present site and at datum 20.0 ft higher.

Decatur-
LOCATION.--Lat 42 00'26", long 96 14'29", in NE¼ SW¼ sec. 36, T.24 N., R.10 E., Burt County, Hydrologic Unit 10230001, on right bank 0.1 mi upstream from Iowa Highway 175 bridge at Decatur, and at mile 691.0.
DRAINAGE AREA.--316,200 mi2, approximately. The 3,959 mi2 Great Divide basin are not included.
PERIOD OF RECORD.--October 1987 to current year.

GAGE.--Water-stage encoder. Datum of gage is 1010.00 ft above sea level, supplementary adjustment of 1954.

Historical Discharge Records

The first discharge measurement of record in the basin was made of the Missouri River at St. Joseph on June 25, 1875. Within the Omaha District boundaries, the first discharge measurements of the Missouri River were made at Omaha in 1877. Discharge measurements were also made at Sioux City, Omaha and Nebraska City during the period of 1878 to 1882.

Early discharge measurements of the Missouri River were made by means of either double floats or weighted poles (rod floats). The measuring sections were located in a reach of river having uniform flow conditions, and the floats, or poles, were generally run over from 3 to 5 ranges, located approximately 250 feet apart. Soundings were made after each float and the sections were also sounded each day before running the floats. The majority of the measurements were made with double floats, the lower float being run at approximately mid-depth. The discharge was then calculated by the "graphic method". It consisted of plotting on cross section paper from the water line of the middle section, the three curves: cross section, normal velocity, and elements of discharge.

The ordinates of the elements of discharge curve are the products of the depth and velocity at every point where velocity is observed and at pronounced points of flexure in the cross section. The area of this curve gives the discharge. These three curves, with the upper and lower cross sections when sounded and the path of floats through the discharge ranges constituted the graphic record of a discharge, and with reference maps and tabulations the record shadows a series of observations. The graphic method was used at that time for two reasons: First, because it gave the most accurate determination of the discharge and second, because the final graph contained a diagram of both the observations and computations.

In addition to the sporadic, early discharge measurements, the USGS has published streamflow records at various gages for many years. The following Table B-2 summarizes the dates of USGS streamflow measurements used for this study.

Table B-2. Dates of Published USGS Streamflow Data Used for This Study

Gaging Station	Dates of Published Data Used for This Study
Yankton	October 1, 1930 to September 30, 1995
Sioux City	October 1, 1929 to September 30, 1931 and October 1, 1939 to September 30, 1997
Decatur	October 1, 1987 to September 30, 1997
Omaha	September 1, 1928 to September 30, 1997
Nebraska City	August 11, 1929 to September 30, 1997

Estimating Discharge from Historical Stage Records

Since daily discharge records were not available for the entire study period, discharge values were estimated from stage records as described below.

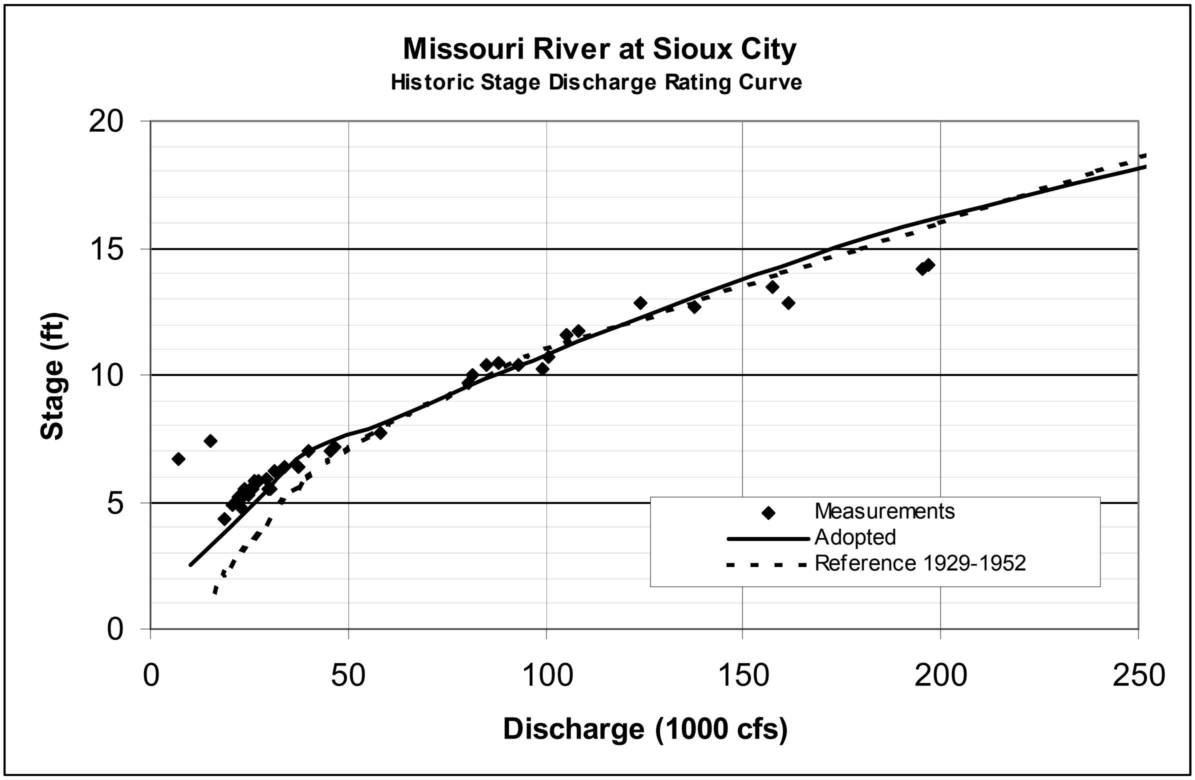
Missouri River At Sioux City At Sioux City, daily stage records were generally available from early March through November during 1898-1904 and 1909. All other years had daily stage records available for the entire year. These records were obtained from "U.S. Department of Agriculture, Weather Bureau. Daily River Stages at River Gage Stations of the Principal Rivers of the United States. Parts VI through XXVI." For the years 1898 through 1905, the records were obtained at the gage below Perry Creek, while the years 1906 through 1928 were obtained at the Combination Bridge. Datums for the gages published in the reports were 1077.8 ft msl in 1898, 1078.9 ft msl in 1900, 1078.2 in 1911, and 1078.6 in 1920.

The first attempt to develop a historical flow record at Sioux City utilized the family of rating curves developed for previous studies in the mid-forties and the 1962 Hydrology Study. Search of our files found the original rating curves as well as a listing of which curves were used for each year. However, no rational was found on how the different rating curves were selected for each year as well as how the family of rating curves was developed. In general, rating curve numbers 5, 6, and 7 were used for most years. Rating curve number 5 was used for 1898, 1901, 1903, 1911, and 1928. Rating curve number 6 was used for 1900, 1902, 1904-05, 1908-09, 1912-14, 1917-18, and 1921-22. Rating curve number 4 was used for 1927. Rating curve number 7 was used for all remaining years. After computing the daily flows from this approach, they were compared to the USGS estimates of monthly flows obtained from USGS Circular 108. In most years, the monthly flow volumes derived from the daily flow estimates were significantly higher than the USGS estimates of the monthly flow volumes.

Therefore, an alternative approach was used to compute the historical flows. This consisted of developing a stage discharge rating curve based on historical measurements. As shown in Table 8, measurements were made in 1878 and 1879 at a location about 700 feet downstream from Perry Creek. These measurements were obtained from the report "Missouri River Study of Effects of Navigation and Channel Stabilization Works", dated April 1954. In that report, the discharge measurements were plotted along with a reference curve. The Reference curve was derived from USGS discharge measurements made during the period of 1928 through 1952. In order to derive the reference curve, upper and lower limit curves were drawn to bound the discharge measurements and the reference curve was drawn midway between the upper and lower limits.

Table B-3. Missouri River at Sioux City, Iowa - Historic Discharge Measurements

No.	Date	Width (feet)	Area (sq ft)	Velocity (fps)	Gage Height (feet)	Discharge (kcfs)	Method
1	9/17/1878	1130	8,643	3.51	5.50	30.3	DOUBLE FLOAT
2	9/18/1878	1130	8,453	3.56	5.50	30.1	DOUBLE FLOAT
3	9/19/1878	1125	8,613	3.46	5.50	29.8	ROD FLOAT
4	9/21/1878	1127	8,398	3.52	5.90	29.5	ROD FLOAT
5	9/26/1878	1125	7,958	3.46	5.80	27.5	ROD FLOAT
6	9/30/1878	1150	8,107	3.22	5.80	26.1	ROD FLOAT
7	10/02/1878	1115	7,779	3.31	5.60	25.7	ROD FLOAT
8	10/03/1878	1120	7,565	3.41	5.50	25.8	DOUBLE FLOAT
9	10/04/1878	1120	7,743	3.28	5.50	25.4	ROD FLOAT
10	10/05/1878	1125	7,600	3.12	5.50	23.6	ROD FLOAT
11	10/07/1878	1125	7,054	3.13	5.20	22.1	ROD FLOAT
12	10/09/1878	1120	7,194	3.15	5.10	22.6	ROD FLOAT
13	10/11/1878	1123	7.551	3.04	5.10	22.9	ROD FLOAT
14	11/01/1878	1125	5,951	3.53	4.90	21.0	ROD FLOAT
15	7/01/1879	1390	26,284	7.48	14.30	196.7	DOUBLE FLOAT
16	7/02/1879	-	26,263	7.43	14.20	195.1	DOUBLE FLOAT
17	7/05/1879	-	24,850	6.34	13.50	157.6	DOUBLE FLOAT



No.	Date	Width (feet)	Area (sq ft)	Velocity (fps)	Gage Height (feet)	Discharge (kcfs)	Method
18	7/07/1879	-	24,830	6.50	12.80	161.5	DOUBLE FLOAT
19	7/09/1879	-	23,068	5.96	12.70	137.4	DOUBLE FLOAT
20	7/10/1879	-	20,497	6.05	12.80	124.0	DOUBLE FLOAT
21	7/14/1879	-	20,394	5.32	11.70	108.5	DOUBLE FLOAT
22	7/15/1879	-	20,120	5.24	11.60	105.5	DOUBLE FLOAT
23	7/16/1879	-	19,967	5.27	11.60	105.3	DOUBLE FLOAT
24	7/22/1879	-	16,943	5.20	10.50	88.1	DOUBLE FLOAT
25	7/23/1879	-	15,840	5.37	10.40	85.0	DOUBLE FLOAT
26	7/24/1879	-	16,387	4.97	10.00	81.4	DOUBLE FLOAT
27	7/25/1879	1335	15,733	5.13	9.70	80.7	DOUBLE FLOAT
28	7/28/1879	-	18,654	5.32	10.20	99.2	DOUBLE FLOAT
29	7/30/1879	-	17,706	5.68	10.70	100.5	DOUBLE FLOAT
30	8/01/1879	1390	14,871	6.27	10.40	93.2	DOUBLE FLOAT
31	8/08/1879	-	10,927	5.34	7.70	58.3	DOUBLE FLOAT
32	8/13/1879	-	10,993	4.22	7.20	46.4	DOUBLE FLOAT
33	8/14/1879	-	10,912	4.18	7.00	45.6	DOUBLE FLOAT
34	8/15/1879	-	10,705	3.76	7.00	40.2	DOUBLE FLOAT
35	8/20/1879	-	9,007	4.14	6.40	37.3	DOUBLE FLOAT
36	8/21/1879	-	7.930	4.29	6.40	34.0	DOUBLE FLOAT
37	8/26/1879	-	8,138	3.86	6.20	31.4	DOUBLE FLOAT
38	9/06/1879	-	6,425	3.84	5.30	24.7	DOUBLE FLOAT
39	9/13/1879	-	6,354	3.59	4.80	22.8	DOUBLE FLOAT
40	9/19/1879	1080	5,548	3.37	4.30	18.7	DOUBLE FLOAT
41	11/02/1895	-	4,655	3.24	7.40	15.1	DOUBLE FLOAT
42	2/18/1905	-	3,515	1.97	6.70	6.9	CURRENT METER

Figure B-1. Historic Stage-Discharge Rating Curve at Sioux City

To develop the rating curve for use in this study, an eye fit curve was drawn through the 1878-1879 measurements and transitioned to the reference curve at a discharge of about 100,000 cfs. A first attempt used the eye fit curve for all points but that resulted in an unreasonably high estimate of the 1881 peak. This is consistent with a study completed by the St. Louis District that concluded that historic discharge measurements based on surface floats tended to overestimate discharges that exceeded bank full capacity by about 4 to 20 percent. Therefore, for the high flows the reference curve was used. Figure XX shows the adopted curve compared to the reference curve and actual discharge measurements. Since these curves were based on a site about 1,200 feet downstream from the USWB gage, an adjustment of 0.3 to 0.4 feet was made to transfer the curve the USWB site at the Combination Bridge. For flows less than 100,000 cfs, 0.3 feet was added to the stage, while 0.4 feet was added for flows above 100,000 cfs when computing the final stage discharge curve. This would have the same effect of subtracting like amounts from the stage records. These values were based on USGS studies comparing stages at the USWB gage and the USGS gage made in 1939, which indicated that the water surface slope was 1.3 feet from Perry Creek to the Omaha Bridge (a distance of 1.7 miles) at average flows and 1.6 feet at high flows.

The USWB records were also researched for periods of ice cover. During those periods, an ice affected rating curve was applied, as stages are higher for the same discharge during periods of partial or complete ice cover. The ice curve was derived by first adjusting computed discharges to match monthly USGS volumes. Dates of ice cover were determined based on notes in the USWB stage records, as well as checking meteorological records from Nebraska, Iowa, South Dakota and North Dakota. Volumes for those months with ice cover were noted from the USGS and compared to those computed using the historic rating curve. The average monthly computed discharge was plotted against the ratio of USGS monthly flow volume and computed monthly flow volume. The bulk of the ratio values fell between 0.2 and 0.6, so a value of 0.4 was used to factor the historic rating curve to determine an average ice-affected rating curve during those periods of noted ice cover. The same factor was used to determine the ice-affected rating curve at downstream stations for periods, or duration, of noted ice cover (the period of ice cover decreased with distance downstream).

Missing records were estimated based on comparison of the USGS monthly estimates of flows and eye fitting the missing discharge hydrograph to preserve the monthly volumes. A comparison was made with the USGS monthly volumes and the flows appeared reasonable. A comparison was also made with the previous estimates of discharges and the use of the single rating curve seemed to match the USGS monthly estimates much better than using a family of rating curves.

Missouri River At Omaha At Omaha, daily stage records were generally available from early March through mid to late December during 1900-1908 and 1912-1915. All other years had daily stage records available for the entire year. These records were obtained from “U.S. Department of Agriculture, Weather Bureau. Daily River Stages at River Gage Stations of the Principal Rivers of the United States. Parts VI through XXVI.” For the years 1898 through 1906, the records were obtained at the gage on the UPRR Bridge, while the years 1907 through 1928 were obtained at the Douglas Street Bridge. Datums for the gages published in the reports were 958.5 ft msl in 1898, 959.6 ft msl in 1900, 958.9 in 1911, 958.2 in 1916, and 959.3 in 1920.

The first attempt to develop a historical flow record at Omaha utilized the family of rating curves developed for previous studies in the mid-forties and the 1962 Hydrology Study. These curves included the family of rating curves at Sioux City and a relationship between stage at Omaha and Stage at Sioux City, which varied by time period. These curves were combined to form individual rating curves for each year at Omaha. Search of our files found the original rating curves as well as a listing of which curves were used for each year. However, no rational was found on how the different rating curves were selected for each year as well as how the family of rating curves was developed. In general, rating curve numbers 5, 6, and 7 were used for most years. Rating curve number 5 was used for 1898, 1901, 1903, 1911, and 1928. Rating curve number 6 was used for 1900, 1902, 1904-05, 1908-09, 1912-14, 1917-18, and 1921-22. Rating curve number 4 was used for 1927. Rating curve number 7 was used for all remaining years. After computed the daily flows from this approach, they were compared to the USGS estimates of monthly flows obtained from. In most years, the daily flow estimates were significantly higher than the USGS estimates of the monthly flow volumes.

Therefore, an alternative approach was used to compute the historical flows. This consisted of developing a stage discharge rating curve based on historical measurements. As shown in Table B-4, measurements were made in 1877, 1878, 1879, 1880, 1882 and 1895 at a location believed to the UPRR bridge, about 0.6 miles downstream from the Douglas Street Bridge. These measurements were obtained from the report "Missouri River Study of Effects of Navigation and Channel Stabilization Works", dated April 1954. In that report, the discharge measurements were plotted along with a reference curve. The Reference curve was derived from USGS discharge measurements made during the period of 1928 through 1952. An additional reference curve was developed using data for the 1929 through 1933 period.

Table B-4. Missouri River at Omaha, Nebraska - Historic Discharge Measurements

No.	Date	Width (feet)	Area (sq ft)	Velocity (fps)	Gage Height (feet)	Discharge (kcfs)	Method
1	-/-/1877	-	5,008	3.29	7.06	20.2	DOUBLE FLOAT
2	10/01/1878	1000	8,644	3.68	8.66	31.9	DOUBLE FLOAT
3	10/02/1878	955	8,717	3.40	8.66	29.7	DOUBLE FLOAT
4	10/03/1878	845	7,285	3.62	8.46	26.4	DOUBLE FLOAT
5	10/10/1878	810	6,532	2.66	7.96	17.4	DOUBLE FLOAT
6	10/111878	820	7,332	2.92	7.96	21.6	DOUBLE FLOAT
7	10/12/1878	670	5,426	4.25	7.86	23.1	DOUBLE FLOAT
8	10/14/1878	620	5,312	3.50	7.96	19.6	DOUBLE FLOAT
9	10/18/1878	680	5,858	4.15	7.86	24.3	DOUBLE FLOAT
10	10/22/1878	740	6,850	2.78	7.76	19.1	DOUBLE FLOAT
11	10/28/1878	434	4,397	5.60	7.86	24.6	DOUBLE FLOAT
12	11/06/1878	485	5,426	3.86	7.86	21.0	DOUBLE FLOAT
13	11/09/1878	470	4,892	4.62	7.86	22.6	DOUBLE FLOAT
14	11/12/1878	675	5,316	4.15	7.86	22.1	DOUBLE FLOAT
15	11/14/1878	675	5,838	4.17	7.86	24.3	DOUBLE FLOAT
16	11/15/1878	675	6,344	3.83	7.86	24.3	DOUBLE FLOAT
17	11/16/1878	680	7.179	3.44	7.86	24.7	DOUBLE FLOAT
18	11/19/1878	1260	6,745	3.40	7.86	22.9	DOUBLE FLOAT
19	11/21/1878	595	4,658	5.11	7.86	24.0	DOUBLE FLOAT
20	11/22/1878	595	4,585	5.52	7.76	25.3	DOUBLE FLOAT
21	8/26/1879	932	7,681	4.91	8.86	37.7	DOUBLE FLOAT
22	8/30/1879	920	6,789	4.53	8.56	30.6	DOUBLE FLOAT
23	9/02/1879	910	7,368	3.72	8.16	27.4	DOUBLE FLOAT
24	9/04/1879	890	7,351	3.65	8.06	26.8	DOUBLE FLOAT
25	9/22/1879	1055	5,479	3.23	6.76	17.7	DOUBLE FLOAT
26	9/27/1879	980	5,171	3.16	6.56	17.3	DOUBLE FLOAT
27	10/03/1879	1238	5,502	3.13	6.76	17.2	DOUBLE FLOAT
28	10/10/1879	973	4,849	3.01	6.76	14.6	DOUBLE FLOAT
29	4/16/1880	633	9,880	4.70	9.46	46.5	ROD FLOAT
30	4/22/1880	633	9,421	6.12	10.36	57.5	ROD FLOAT
31	5/03/1880	1270	7,477	5.23	8.66	39.1	DOUBLE FLOAT
32	5/05/1880	770	5,919	5.67	8.36	33.6	DOUBLE FLOAT
33	11/01/1880	797	4,582	4.17	6.86	19.1	DOUBLE FLOAT

No.	Date	Width (feet)	Area (sq ft)	Velocity (fps)	Gage Height (feet)	Discharge (kcfs)	Method
34	6/13/1882	1119	13,927	7.85	11.56	109.4	DOUBLE FLOAT
35	6/15/1882	1093	14,502	7.82	11.56	113.5	DOUBLE FLOAT
36	7/10/1882	1160	16,168	7.01	12.96	113.4	DOUBLE FLOAT
37	7/11/1882	1160	16,659	8.12	13.16	135.3	DOUBLE FLOAT
38	7/19/1882	1160	13,898	7.70	12.56	107.0	DOUBLE FLOAT
39	7/22/1882	1160	12,541	6.43	11.46	80.7	DOUBLE FLOAT
40	7/25/1882	1097	12,385	5.56	10.56	88.8	DOUBLE FLOAT
41	7/26/1882	1096	11,455	5.66	10.26	64.8	DOUBLE FLOAT
42	7/27/1882	1093	11,102	6.10	10.36	67.7	DOUBLE FLOAT
43	8/28/1882	1045	7,623	4.03	7.96	31.6	DOUBLE FLOAT
44	8/29/1882	1034	7,922	4.22	7.86	33.5	DOUBLE FLOAT
45	8/30/1882	1035	7,584	4.11	7.86	31.2	DOUBLE FLOAT
46	8/31/1882	1048	7,953	4.35	7.76	34.7	DOUBLE FLOAT
47	9/01/1882	1046	7,636	4.01	7.66	30.6	DOUBLE FLOAT
48	9/02/1882	1049	7,429	4.39	7.56	32.7	DOUBLE FLOAT
49	9/04/1882	1041	6,853	4.27	7.36	29.5	DOUBLE FLOAT
50	9/05/1882	1049	7,246	3.99	7.26	28.9	DOUBLE FLOAT
51	9/11/1882	1045	7,145	3.30	6.76	23.6	DOUBLE FLOAT
52	9/12/1882	1051	7,270	3.38	6.66	24.6	DOUBLE FLOAT
53	9/13/1882	1044	7,261	3.39	6.56	24.6	DOUBLE FLOAT
54	9/16/1882	1044	6,731	3.62	6.56	24.4	DOUBLE FLOAT
55	9/26/1882	1060	6,251	3.55	6.26	21.9	DOUBLE FLOAT
56	9/27/1882	1055	4,920	3.42	6.26	16.8	DOUBLE FLOAT
57	9/28/1882	1053	5,802	3.39	6.28	19.7	DOUBLE FLOAT
58	9/29/1882	974	6,762	3.43	6.26	19.4	DOUBLE FLOAT
59	9/30/1882	914	6,673	3.12	6.26	20.8	DOUBLE FLOAT
60	10/02/1882	900	6,030	3.35	6.16	21.1	DOUBLE FLOAT
61	11/08/1895		5,590	2.77	7.18	16.5	DOUBLE FLOAT

To develop the rating curve for use in this study, an eye fit curve was drawn through the 1877-1895 measurements and compared with the reference curve developed from measurements in 1929 through 1933. Adjustments were made to this rating curve to provide consistent flows with those computed at Sioux City and Omaha. These adjustments were made by trial and error based on inspection of the computed hydrographs at Sioux City, Omaha, and Nebraska City for each year of the period 1898 through 1928. As shown on Figure 2, the final adopted stage discharge curve resulted in an increase of the stage of about 4 feet for discharges less than 20,000 cfs, slightly lowering the curve for discharges in the 50,000 to 120,000 cfs range, and a gradual increase in the curve by up to 2.5 feet at discharges of 350,000 cfs. Datum shifts were added to the gage records as follows: For the period of 1898-1899, 1.7 feet was added which includes a datum change of 1.1 feet and 0.6 feet for a change of location of 0.6 river miles, assuming 1 foot per mile slope; For the period 1900 to 1906, 1.0 feet was added to the stage records which includes a datum change of 0.4 feet and 0.6 feet for change in gage location; for the period of 1920 to 1929, 0.2 feet was subtracted from the gage records to account for shift due to channel changes.

Missing records were estimated by routing the Sioux City flows using lag average routing coefficients of 1 day lag and averaging two days flows. Missing records only occurred during the ice season or low flow conditions. A comparison was made with the USGS monthly volumes at Sioux City and the computed flows at Sioux City and the flows appeared reasonable. A comparison was also made with the previous estimates of discharges and the use of the single rating curve seemed to match the computed flows at Sioux City much better than using a family of rating curves.

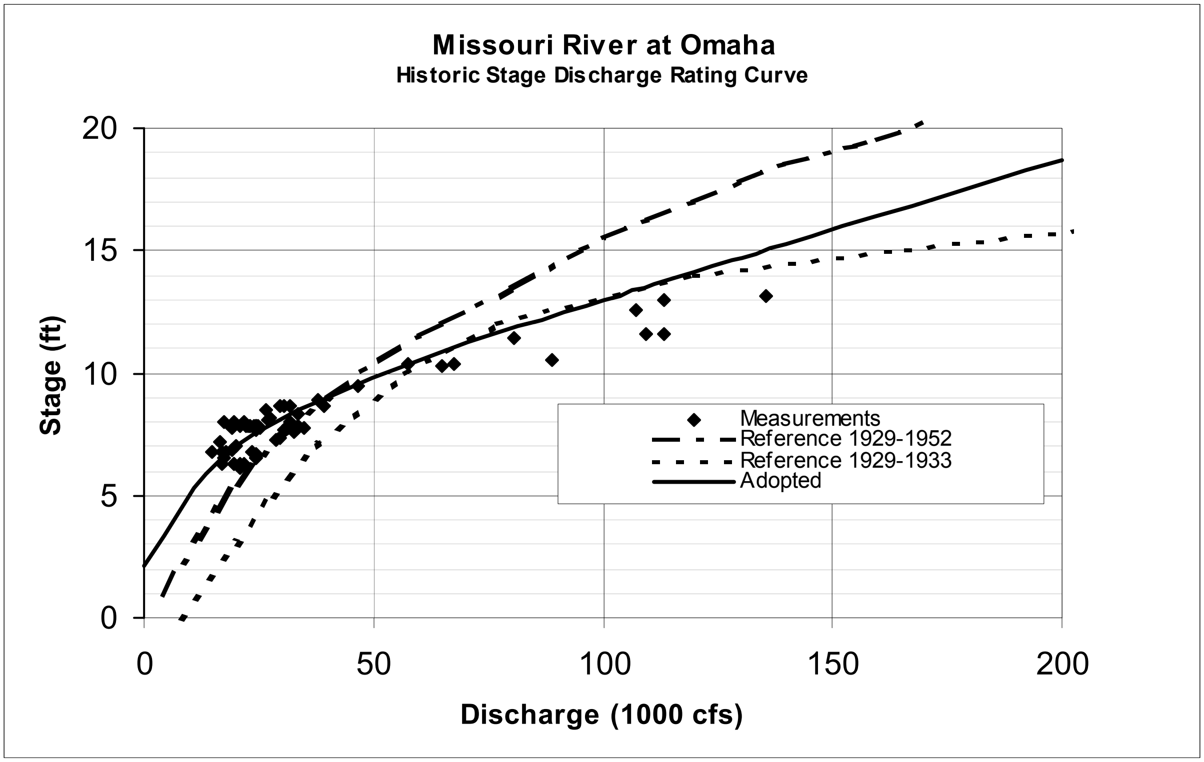


Figure B-2. Historic Stage-Discharge Rating Curve at Omaha.

Missouri River At Nebraska City

At Nebraska City, stage records were available from 1878 to 1899 and 1929 to present. For the period 1900 through 1928, stage records at the Plattsmouth gage were used to estimate stages at Nebraska City. A relationship between stage at Plattsmouth and stage at Nebraska City was developed for the 1945 Hydrology study using daily stage data from 1888 to 1899. This curve was verified for this study using April through October daily stage data from 1895 through 1899. As shown on Figure 3, the adopted relationship fits the data well except for the lower stages. At the lower stages, the adopted curve predicts higher stages at Nebraska City, which would tend to overestimate the lower flows. Since the stages at Plattsmouth during the period 1900 through 1928 were published as feet above local datum and the stages prior to 1900 were published as feet above St. Louis Directrix, a value of 529 feet was added to the stages at Plattsmouth to convert to the St. Louis datum. Once the Plattsmouth stages were converted to the St. Louis Directrix, Figure 3 was used to estimate the stages at Nebraska City. At Nebraska City, a value of 490.4 feet should be subtracted from readings in the St Louis Directrix to obtain gage readings in local datum.

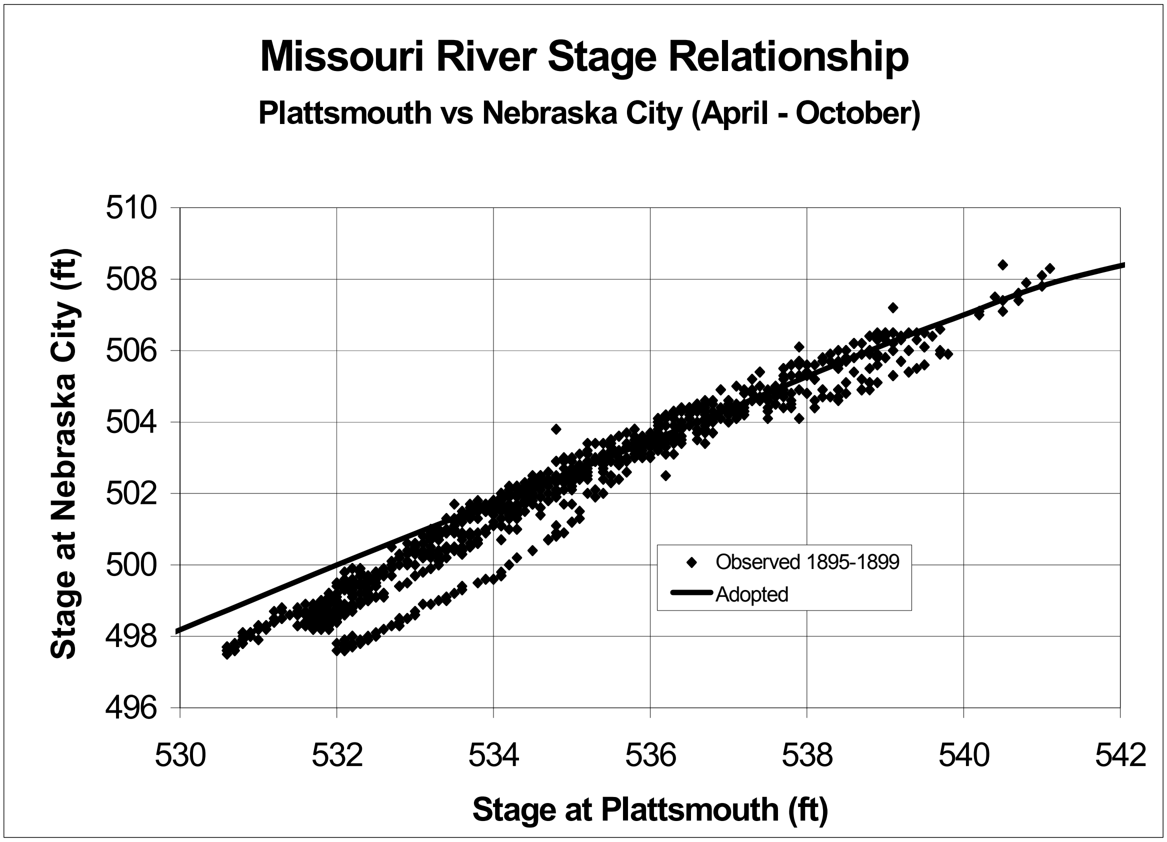


Figure B-3. Relationship Between Plattsmouth and Nebraska City Stages

To compute the historical flows at Nebraska City from the estimated stages, a stage discharge rating curve was developed based on historical measurements. As shown in Table B-5, measurements were made in 1878. These measurements were obtained from the report “Missouri River Study of Effects of Navigation and Channel Stabilization Works”, dated April 1954. In that report, the discharge measurements were plotted along with a reference curve. The Reference curve was derived from USGS discharge measurements made during the period of 1928 through 1952.

To develop the rating curve for use in this study, an eye fit curve was drawn through the 1877 discharge measurements. Two stage-discharge rating curves were found in the files that were developed in 1945. The first rating curve was identified as the 1903 curve and closely fit the upper bound of the discharge measurements. The second rating curve was identified as the 1908 rating curve and had about 25 percent less discharge for flows exceeding about 100,000 cfs when compared to the 1903 rating curve. The 1903 stage discharge rating curve was used for the period of 1898-1905, while the 1908 rating curve was used for the period of 1906-1928. These rating curves are shown on Figure 4 along with the 1882 measurements and the reference curve for the period of 1929-1952. The reference curve was based on the mid-point of the USGS discharge measurements obtained during the period of 1929 through 1952. For stage readings in the St Louis Directrix a value of 490.4 feet is added to the stage at Nebraska City.

Since the Plattsmouth stages were generally only available during the March through July period, the flows at Nebraska City during the missing periods were based on those estimated at Omaha and routed to Nebraska City. USGS discharge records from 1929 through 1995 were used to compute the average flow during the period of October through February at Omaha and Nebraska City. Next, the ratio of the flow at Nebraska City to the flow at Omaha during this period was computed as 1.2. Therefore, the missing flows at Nebraska City were based on increasing the Omaha flows by 20 percent and routing to Nebraska City using the lag average method by averaging 2 days of flows with no lag.

Table B-5. Missouri River at Nebraska City, Nebraska - Historic Discharge Measurements

No.	Date	Width (feet)	Area (sq ft)	Velocity (fps)	Gage Height (feet)	Discharge (kcfs)	Method
1	5/10/1878	1890	13,173	3.69	8.86	48.6	DOUBLE FLOAT
2	5/24/1878	2195	18,530	4.96	10.56	92.0	DOUBLE FLOAT
3	5/29/1878	2340	23,040	4.96	10.96	114.3	DOUBLE FLOAT
4	5/31/1878	2060	21,130	4.95	10.76	104.7	DOUBLE FLOAT
5	6/02/1878	2020	20,040	4.44	10.06	88.9	DOUBLE FLOAT
6	6/05/1878	2045	20,200	3.70	9.56	74.8	DOUBLE FLOAT
7	6/07/1878	1490	14,900	4.18	9.26	62.2	DOUBLE FLOAT
8	6/10/1878	1470	14,260	4.23	9.26	60.3	DOUBLE FLOAT
9	6/13/1878	2135	18,220	6.41	10.86	116.8	DOUBLE FLOAT
10	6/15/1878	2160	18,580	6.36	11.16	118.2	DOUBLE FLOAT
11	6/20/1878	2800	31,340	6.37	13.56	199.6	DOUBLE FLOAT
12	6/22/1878	2810	30,580	6.84	13.86	209.3	DOUBLE FLOAT
13	6/24/1878	2820	30,340	6.64	14.16	201.6	DOUBLE FLOAT
14	6/26/1878	2810	29,140	7.37	14.36	214.7	DOUBLE FLOAT
15	6/28/1878	2830	29,800	7.10	14.36	239.6	DOUBLE FLOAT
16	6/30/1878	2825	28,660	7.32	14.46	209.8	DOUBLE FLOAT
17	7/03/1878	2840	27,460	6.04	14.26	175.9	DOUBLE FLOAT
18	7/07/1878	2850	28,440	5.05	13.06	143.1	DOUBLE FLOAT
19	7/10/1878	2850	28,840	4.35	12.76	125.4	DOUBLE FLOAT
20	7/12/1878	2840	30,560	4.91	12.76	150.0	DOUBLE FLOAT
21	7/14/1878	2845	30,860	4.63	12.76	143.0	DOUBLE FLOAT
22	7/17/1878	2850	28,440	5.14	12.76	146.2	DOUBLE FLOAT
23	7/19/1878	2850	26,580	4.65	12.06	123.5	DOUBLE FLOAT
24	7/21/1878	2840	23,900	4.55	11.66	108.6	DOUBLE FLOAT
25	7/24/1878	2840	20,920	4.25	10.96	88.8	DOUBLE FLOAT
26	7/31/1878	2825	19,860	3.65	10.16	72.6	DOUBLE FLOAT
27	8/12/1878	2660	14,760	3.41	8.96	50.4	DOUBLE FLOAT
28	8/24/1878	2240	11,565	3.97	7.86	40.9	DOUBLE FLOAT
29	8/28/1878	2260	11,025	3.13	7.76	34.5	DOUBLE FLOAT
30	8/31/1878	2320	10,860	3.28	7.56	35.7	DOUBLE FLOAT
31	9/04/1878	2800	10,710	2.92	7.36	31.3	DOUBLE FLOAT
32	9/07/1878	2480	9,750	3.10	7.16	30.3	DOUBLE FLOAT
33	9/26/1878	1560	8,920	2.42	6.16	21.6	DOUBLE FLOAT

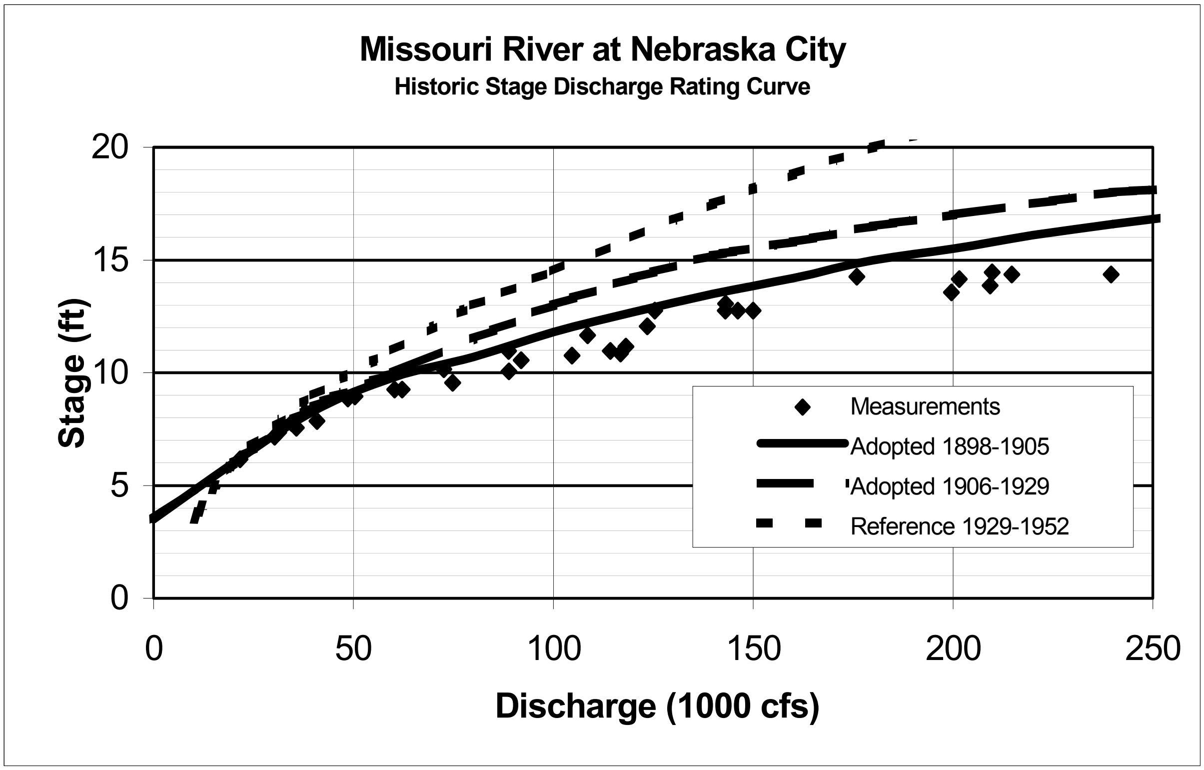


Figure B-4. Historic Stage-Discharge Rating Curve at Nebraska City

The following table summarizes the dates of available stage records used for reconstructing the flow record.

Table B-6. Dates of Published Stage Records Used for This Study

Station	Dates of Published Data Used for This Study
Sioux City	3/8/1898-11/21/1898, 4/5/1899-12/4/1899, 3/25/1900-11/20/1900, 3/13/1901-12/8/1901, 3/10/1902-12/4/1902, 3/12/1903-11/17/1903, 3/18/1904-12/31/1908, 3/21/1909-12/6/1909, 1/1/1910-9/30/1929
Omaha	2/25/1898-11/22/1898, 3/26/1899-12/31/1899, 1/21/1900-1/22/1900, 3/13/1900-2/23/1901, 3/1/1901, 12/13/1901, 3/1/1902-12/4/1902, 3/2/1903-12/25/1903, 3/19/1904-9/30/1904, 3/1/1905-12/3/1905, 12/24/1905-2/15/1906, 2/21/1906-3/22/1906, 3/26/1906-6/18/1906, 6/20/1906-12/19/1906, 3/1/1907-11/30/1907, 2/1/1908, 2/12/1908-12/1/1908, 12/25/1908-1/7/1909, 2/28/1909-12/9/1909, 12/14/1909-12/17/1909, 12/31/1909-1/2/1911, 3/1/1911-12/27/1911, 2/19/1912-3/15/1912, 3/19/1912-12/11/1912, 2/17/1913-12/25/1913, 1/6/1914-2/5/1914, 2/9/1914-12/11/1914, 1/11/1915-12/29/1915, 12/3/1916-8/31/1928
Plattsmouth	Mar. 1 – July 31, 1900-1928
Nebraska City	1/1/1898-12/31/1899, 1/1/1929-8/10/1929

Upper Mississippi River System
Flow Frequency Study

Appendix F-C

A Study to Determine the

Historic and Present-Level Streamflow Depletions

in the

Missouri River Basin

Above Hermann, Missouri

Prepared by:

Water Resources Service Group

Great Plains Regional Office

Bureau of Reclamation

Billings, Montana

August, 1999

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A Study to Determine the Historic and Present-Level Streamflow Depletions in the Missouri River Basin Above Hermann, Missouri

August, 1999

I. Introduction

In April 1998, the Corps of Engineers (COE) requested that the Bureau of Reclamation determine monthly streamflow depletion estimates for selected node basins throughout the Missouri River Basin. These node basins included:

Missouri River above Ft Peck Dam, Montana
Missouri River - Ft Peck Dam to Garrison Dam, North Dakota
Missouri River - Garrison Dam to Oahe Dam, South Dakota
Missouri River - Oahe Dam to Big Bend Dam, South Dakota
Missouri River - Big Bend Dam to Ft Randall Dam, South Dakota
Missouri River - Ft Randall Dam to Gavins Point Dam, South Dakota
Missouri River - Gavins Point Dam to Sioux City, Iowa
Missouri River - Sioux City to Omaha, Nebraska
Missouri River - Omaha to Nebraska City, Nebraska
Missouri River - Nebraska City to St Joseph, Missouri
Missouri River - St Joseph to Kansas City, Missouri
Kansas River Basin
Missouri River – Kansas City to Boonville, Missouri
Osage River Basin
Missouri River – Boonville to Hermann, Missouri

The COE planned to use these depletions to determine natural flow and present level streamflows in the Upper Mississippi, Lower Missouri River, and Illinois River Flow Frequency Study. A requirement of this analysis was to provide depletion estimates, both historic and present-level, for the period 1898 to 1996 for all node basins in the Missouri River above Boonville, Missouri, the mouth of the Missouri River. The following is a summary of the process used to calculate irrigation acres, consumptive use, historic and present-level depletions in this study.

The intent of this document is to explain data sources, methodologies, and assumptions used to develop the depletion estimates. Backup data and input files are all being archived at the Regional Office of the Bureau of Reclamation in Billings, Montana.

II. Use of Existing Data - 1982 Missouri Basin States Association

In 1977, the Bureau of Reclamation, along with state agencies within the Missouri River Basin states, and 10 Federal agencies, formed work teams to evaluate and determine the depletion effects of development on streamflows in the Missouri River Basin. This 4-year study effort was initiated originally by the Missouri River Basin Commission, later to be known as the Missouri Basin States Association (MBSA). The MBSA study identified 16 depletion categories to be evaluated in the determination of total depletions in the basin. Categories besides irrigation included municipal, industrial, rural domestic, livestock, forest accretions, stock ponds, large and small reservoir evaporation, and conservation land practices (contour farming, tillage, and border grading).

It was not feasible in the time frame of the present study to collect and compile information for all these categories. Therefore, it was decided to concentrate on the irrigated acres depletions, since the majority of the depletions can be attributed to this use. The other depletions would be generally accounted for by using the data developed during the MBSA study and adding an appropriate adjustment to the irrigation depletions.

III. Irrigated Acres Used in the MBSA Study

Irrigated acres were taken from the U.S. Agricultural Census (Ag Census) and the Soil Conservation Service, now the Natural Resources Conservation Service (NRCS). The study period for this study was 1944 to 1978. County data was published in the Ag Census for years 1944, 1949, 1954, 1959, 1964, 1969, 1974, and 1978 census years.

IV. Determination of Irrigated Acres for Years not included in the MBSA Study

It needs to be noted that like in many studies, the data is only as good as its source. It is recognized that the procedure to collect agricultural irrigated acres varied throughout time as did the definitions of the data requested. Since the Ag Census is the largest complete data source available for irrigated acres, it was decided to use this data source exclusively for all county data throughout the period of record.

The MBSA study only looked at the 1944 to 1978 period of record. In order to evaluate depletions for the 1898 to 1996 period, it was necessary to locate county information from all available U.S. Ag Census reports. From 1900 to 1940, the Ag Census was coordinated with the population census and collected on 10 year intervals. Beginning in 1944 through 1997, the Ag Census deviated from the population census and began data collection on five year intervals. Irrigated acres for each county in the study period were recorded. Annual values were determined by straight line interpolation between known Ag Census values.

Several problems with the early Ag Census data were discovered. In the 1900 and 1910 Ag Census periods, some states were only recognized as territories; and counties, as we know them today, had different boundaries or did not exist. Note: the 1900 Ag Census data reported irrigated acres for the 1889 and 1899 periods. In Montana, only 24 counties were identified in the 1900 Ag Census whereas, in the 1930 Ag Census, Montana had 56 reporting counties. In

Wyoming, only 13 counties were identified in the 1900 Ag Census, while in the 1930 Ag Census, 24 counties were reporting irrigated acres. In Colorado, 56 counties were identified in the 1900 Ag Census as opposed to 63 counties in the 1930 Ag Census.

Along with Nebraska and Kansas, these were the only states that reported irrigated acres in Ag Census Year 1900 within the study area. For all the other states, irrigated acres by county were assumed to be zero for all Ag Census periods until actual data was displayed.

Since the number of counties in Montana and Wyoming changed between the 1900 and 1930 Ag Census periods, it was necessary to establish a methodology of assigning irrigated acres to node basins rather than trying to work with individual counties. The following methodology describes the procedure used to compute irrigated acres between major river reaches for the period 1898 to 1929.

V. Determination of 1898 to 1928 Irrigated Acres by Major Node Basin.

Irrigated acreage estimates by county were made based upon the relative size of the county and its location. Only Montana, Nebraska, Colorado, Kansas and Wyoming had any data presented in the 1900 Ag Census. In these states, only county data was displayed where actual irrigation took place. All other county figures were not listed, thus it was assumed that the acreage was zero. For the rest of the states within the Missouri River drainage, it was assumed the irrigated acres were zero. In addition, the 1900 Ag Census data also contained simple maps showing relative size of irrigated acreages located in each county. These maps were used to visually estimate the percentage of irrigated acres in each county to be distributed to the different basins.

Missouri River Above Ft Peck, Montana

Using the 1898 county data, and subtracting the counties within the Yellowstone River Basin, the total irrigated acres for the contributing counties in this reach was 581,931 acres.

County	1898 Irrigated Acres
Beaverhead	138,022
Broadwater	30,144
Cascade	27,593
Chouteau	49,086
Teton	30,784
Valley	9,878
Fergus	71,152
Gallatin	60,267
Jefferson	16,149
Lewis and Clark	30,663
Madison	74,980
Meagher	43,213
Total	581,931

1929 Total Irrigated Acres - from accumulated node basins - 1,141,763 Acres

Irrigated acres for the years between 1898 and 1929 was determined by straight line interpolation between the two known values. (1,141,763 -581,931)/31 equals annual increment.

Missouri River - Ft Peck to Garrison, North Dakota

In the reach Missouri River - Ft Peck and Garrison Dams, a similar process was used. The irrigated acres for Ag Census year 1898 for selected counties in Montana and Wyoming were summed.

Montana Counties	
County	1898 Irrigated Acres
Custer	18,659
Dawson	999
Carbon	51,287
Park	29,917
Sweetgrass	37,494
Yellowstone	35,364
Total Montana Acres	173,270
Wyoming Counties	
Bighorn	50,465
Fremont	26,620
Sheridan	49,263
Johnson	25,217
Total Wyoming Counties	151,565

Total of Montana and Wyoming - 325,285 Acres

The 1900 Ag Census did not provide any estimates for North Dakota in year 1889 or 1899. However, North Dakota served 19,540 acres of irrigation in 1929. It was assumed that there was irrigation in this node basin from the state of North Dakota for the 1898 to 1929 period. It was also assumed that the irrigation came on line in the same manner as it did in Montana and Wyoming. The following equation was used to determine North Dakota s portion of irrigated land for the period for each year 1898 to 1928.

1898 Acres (MT+WY)/1929 Acres(MT+WY) * (1929 ND Acres)
325,285 / 1,136,772 * 19,540 = 5,597 Acres

The 5,597 acres would be North Dakota share of irrigated acres for year 1898. This value is then added to the Montana and Wyoming total of 325,285 acres for a grand total of 330,882 acres. This process was repeated for each year 1898 to 1928.

Missouri River - Garrison to Oahe

In the reach Missouri River - Garrison to Oahe, portions of North Dakota. South Dakota and Wyoming contributed to the irrigated lands within the reach.

The irrigated acres for Ag Census year 1898 for selected counties in Wyoming were summed.

County	1898 Irrigated Acres
Crook	3,208
Weston	3,472
Total Wyoming Acres	6,680

Irrigated acres were not available for North and South Dakota in 1898, but we did have some county acreage figures in Ag Census Year 1920 (1919 data). The irrigated acres for Ag Census year 1920 for selected counties in South Dakota were summed.

County	1898 Irrigated Acres
Butte	57,856
Custer	5,527
Fall River	2,891
Lawrence	6,219
Meade	9,969
Pennington	16,994
Total South And North Dakota Acres	99,456

For the Wyoming acres for the period 1898 to 1928, simply straight line interpolation was used between the 1898 and the 1928 values. For North and South Dakota, it was assumed that the 1898 acres were the same as the 1919 acres *(99,456)* and for the period 1920 through 1929, straight line interpolate between the 1919 value (99,456) and the total acres accumulated for the node basin in 1929 (65,171). The annual total is the sum of the two numbers.

Missouri River - Oahe to Big Bend

The cumulative total of irrigated acres for year 1929 was 0 acres. Since there were no county irrigated acreage data for Ag Census years 1900 to 1930, it was assumed that there were no irrigation in this reach for the period 1898 to 1928.

Missouri River - Big Bend to Ft Randall

Irrigated acres for the period 1898 to 1928 in this node basin was assumed to be the same as was irrigated in year 1929. An annual figure of 8,609 acres was used for all years 1898 to 1928.

Missouri River - Ft Randall to Gavins Point

Irrigated acres for the period 1898 to 1928 in this node basin was assumed to be the same as was irrigated in year 1929. An annual figure of 8,248 acres was used for all years 1898 to 1928.

Missouri River - Gavins Point to Sioux City

The cumulative total of irrigated acres for year 1929 was 0 acres. Since there were no county irrigated acreage data for Ag Census years 1900 to 1930, it was assumed that there were no irrigation in this reach for the period 1898 to 1928.

Missouri River Sioux City to Omaha

The cumulative total of irrigated acres for year 1929 was 0 acres. Since there were no county irrigated acreage data for Ag Census years 1900 to 1930, it was assumed that there were no irrigation in this reach for the period 1898 to 1928.

Missouri River - Omaha to Nebraska City

Irrigated acres in the 1900 Ag Census were available for the State of Wyoming. Counties in the Platte River drainage included:

County	1898 Irrigated Acres
Carbon	108,806
Natrona	17,601
Albany	104,260
Converse	18,015
Laramie	64,901
Total Wyoming Acres	313,583

Since Wyoming was the only state to provide 1900 Ag Census data, all other county data was assumed to be zero.

Missouri River - Nebraska City to St Joseph

Irrigated acres for the period 1898 to 1928 was assumed to be zero for this reach.

Missouri River - St. Joseph to Kansas City

Irrigated acres for the period 1898 to 1928 was assumed to be zero for this reach.

Kansas River Basin

Irrigated acres for the period 1898 to 1928 was assumed to be zero for this reach.

Missouri River - Kansas City to Boonville

Irrigated acres for the period 1898 to 1928 was assumed to be zero for this reach.

Osage River Basin

Irrigated acres for the period 1898 to 1928 was assumed to be zero for this reach.

Missouri River - Boonville to Hermann

Irrigated acres for the period 1898 to 1928 was assumed to be zero for this reach.

VI. Accumulation of County Irrigated Acres to Node Basin Irrigated Acres.

U.S. Ag Census county data for the 1944, 1949, 1954, 1959, 1964, 1969, 1974 and 1978 Ag Census was used in the MBSA Hydrology Study. Yearly data for the period 1979 to 1982 was provided to the MBSA by the NRCS for all counties in the study area. In several cases, individually states had performed agriculture surveys in the 1970 s, thus resulting in better estimates and were used accordingly.

The Missouri River basin was originally delineated into 93 node basins of interest where depletions would be calculated. A portion of the Upper Missouri was further broken down to evaluate depletions at smaller node basin boundaries, bringing the total number of node basins in the study to 118. Since all of the U.S. Ag Census is reported on a county wide basis, it was necessary to aggregate the county data into node basin data. In many cases, the irrigated acres within a county would need to be distributed into one or several different node basins, depending upon the geographical layout of the lands within the county. In addition, as acres became irrigated throughout the years, the distribution of acres to each node basin would change.

In order to use the best and most current data available at the time, i.e., 1978 data, the MBSA Agricultural Work Group requested that each Soil Conservation Service District Conservationist provide their best estimate of irrigation use within their county. This information would include locations of irrigated lands, types of irrigation, confirmation of actual irrigated lands, efficiencies of conveyance and on-farm systems and crop distributions. Information packets were sent to each District and the following information was requested.

Based upon the number of node basins represented within the county:

1. Verify the 1978 irrigated acre value for their county

2. Determine the acreage value for each node basin in 1978. (See sample worksheet Number 1)

3. Determine a crop distribution for the acres within each node basin. (See sample worksheet Number 1)

4. Estimate the irrigation water source in percent for the periods 1944, 1964 and 1978. (See sample worksheet Number 2)

5. Determine type of irrigation and estimate the efficiency of that type of irrigation. (See sample worksheet Number 2)

This information was accumulated for all 493 counties within the Missouri River Basin. Worksheets were prepared for the 118 node basins that displayed the number of counties represented in each node, the percentage of irrigated lands found within that basin and the distribution of crops. In some cases, only one county or a portion of that county, was represented in the node basis, or in some cases in excess of 20 counties were inclusive within the node basin. Using the data, averages of crop distributions, efficiencies, and types of irrigation were calculated.

Using the information provided by the District Conservationists in the MBSA study and the annual irrigation values established for each county, it was possible to accumulate node basin acreages for the node basins from the county data. A computer program, TOTAL4, was written to perform the task.

Because of time constraints, it was not possible to collect new information for 1996 conditions, therefore it was assumed the percent distribution provided in the MBSA for year 1978 would be the same for all years in the study.

The TOTAL4 program provides the following functions based upon the information provided by the NRCS:

1. Separates the county data into the node basin. During the MBSA study, the lower basin states provided information about distribution of county to the node basin throughout the study period. In other words, the percentage distribution in 1944 was different than it was in 1964 and 1978. The TOTAL4 program was modified to be able to redistribute this data throughout the study period in accordance with the data provided by the states. The upper basins states did not provide data of this sort.

2. Separates irrigation according to source of irrigation, surface water supply or groundwater supply.

3. Separates both the surface water acres and groundwater acres into types of irrigation. These types include furrow/border, full and partial; water-spreaders, full and partial; center pivot sprinklers, full and partial; and other sprinklers, full and partial. All of these categories were established in an attempt to analysis depletion estimates based upon different efficiencies for different types of irrigation.

4. Sums all the individual county data together into the node basin.

Since all of the information about irrigation types and uses were taken from data provided at only one point in time, 1978, it was necessary to logically evaluate the data and make adjustments that were reasonable for the times. For example, it is not realistic to assume that extensive groundwater pumping took place in the 1890 s and early 1900 s. Although some areas were probably irrigated from windmills, etc., the majority of the irrigation would be from surface gravity flow systems. Therefore, it was necessary to make adjustments to account for changes in irrigations practices. The program was modified to shift all acres from any type of sprinkler irrigation to gravity systems at a predesignated year. This year varies depending upon the node basin and the available data.

The original purpose behind defining the types of irrigation was to improve the accuracy of the depletion estimates. It was assumed that each different type of system would have a unique efficiency, conveyance and on-farm, associated with it. However, the information provided by the District Conservationists indicated that there was not a significant difference in many of the irrigation systems. In order to avoid multiple consumptive use runs, irrigated acres, within the node basin, with the same or similar efficiencies were added together.

In Montana, the state had performed actual field verification of irrigated acres at two time intervals, 1975 and 1987. In order to use their information, it was necessary to compare the data estimated by the U.S. Ag Census and the actual data provided by the state, determine the relative difference as a ratio and adjust the previous records accordingly. In this case, the Montan county data was first adjusted for the period 1929 to 1975 using the ratio of 1975 Actual data to 1975 Ag Census data and then again for the period 1976 to 1987 period using the ratio of 1987 actual data to 1987 Ag Census data. This ratio was used for the period 1987 to 1992 also.

During the MBSA study, several states, North Dakota, South Dakota, Colorado, Missouri, and Nebraska, elected to use the Ag Census for the 1944 to 1974 period while providing their own county figures for the ensuing years. The following describes the data and years where actual data was used. These values were used in our analysis. Whenever possible, field verified data was used.

North Dakota	1974 to 1996	Data from State
South Dakota	1970 to 1977	Data from the State
	1978 to 1996	US Ag Census
Colorado	1974 to 1978	Data form the State
	1978 to 1996	US Ag Census
Missouri	1974 to 1978	Data from the State
	1978 to 1996	US Ag Census
Nebraska	1974 to 1978	Data from the State
	1978 to 1996	US Ag Census

1997 U. S Ag Census data was not available at the time of this study. Data for the period 1993 to 1996 was assumed to be the same as the 1992 data for each county.

The biggest drawback of this process is the fact that, in most cases, a single value provided by the District Conservationist in 1978 was used throughout the entire period of record. This process would assume that if 50 percent of Gallatin County was contributing to the Madison River Basin in 1978, that 50 percent was also contributing in 1929 as well as in 1996. Historical records of land use within each county by drainage basin is unavailable and unknown, so for a lack of better information, an assumption was made to use the 1978 data for all years. As mentioned earlier, time constraints of this analysis did not allow for the investigations of more updated data as each node basin, so again the same figures were used for the 1978 to 1996 period.

VII. Calculation of Irrigation Depletions

In order to determine the effects of irrigation on a watershed, it is necessary to compute the crop irrigation requirement, the diversion requirement, and a return flow component of the irrigation. The difference between the diversion need and the return flow is the water loss, or depletion. This value is the sum of the crop use, the transmission losses, the non beneficial consumptive uses, and the return flow losses.

A computer program to calculate the crop evapotranspiration was written for the MBSA study. Although several modifications have been made to the program, it is essential the same uses in this analysis. This program combines several programs and allows the user to select either the Blaney-Criddle methodology or the Jensen-Haise methodology to calculate crop consumptive use. Input requirement for these programs include monthly mean temperature, total monthly precipitation, monthly solar radiation, crop data, which includes plant dates, cover dates, and harvest dates. The results of this program is the crop irrigation requirement. The crop irrigation requirement is the amount of water needed in addition to natural precipitation in order to aid the crops to grow to maturity.

A. Climatological/Meteorological Data

For each of the 118 node basins, a representative climatological station, or in some cases more than one, were selected based upon the relative location of the station within the node basin and the years of recorded data available at that station. All data was taken from National Weather Service recorded data.

In the upper portion of the region, above Sioux City, missing data was filled in by using a station with data in the same general area. This was done for both temperature and precipitation data. In the lower portion of the region, below Sioux City, the Corps of Engineers provided complete records for the period 1898 to 1996 for all representative station in the node basins.

In the Jensen-Haise consumptive use methodology, solar radiation is a required input item. The data is read in as percent of possible sunshine data. A subroutine program within the main program converts the percent of possible sunshine data into usable solar radiation data. Across the Missouri River Basin, there are only a few National Weather Service stations that record percent of possible sunshine data. Especially in the early years, 1898 to 1929, data was not available at some of the stations. In these cases, the average monthly percent of possible sunshine data for the 1929 to 1996 period was used for the 1898 to 1928 period.

The percent of possible sunshine stations that were used included:

Helena WSO AP, Montana
Cheyenne WSO AP, Wyoming
Williston WSO AP, North Dakota
Bismarck WSO AP, North Dakota
Rapid City WSO AP, South Dakota
Huron WSO AP, South Dakota
Sioux City WSO AP (with Valentine), Nebraska
Valentine WSO AP, Nebraska
North Platte WSO AP, Nebraska
Lincoln WSO AP, Nebraska
Concordia WSO AP, Kansas

A complete listing of the climatological used for each node basin is included in Appendix A.

B. Crop Distribution Percentages

Based upon the information received from the District Conservationists in the MBSA study, an average crop distribution percentage was calculated for each node basin. It was assumed that the cropping pattern would not change throughout the period of record since no other data was available. Although it is recognized that this assumption may lead to inaccuracies in the crop irrigation requirement over time, it is also known that major changes in the cropping patterns are necessary to significantly alter the monthly consumptive use requirements.

Planting dates and harvest dates were taken from the NRCS s Crop Irrigation Guides and information accumulated in the MBSA study. Cover dates were determined based upon the planting date and information from the NRCS.

Using the temperature, precipitation, and cropping data described above, the CONUSE5 program then calculates the crop irrigation requirement (CIR). The CIR is used as an input item in the DEPOPS subroutine of the program to calculate the following:

Diversion requirement in Acre-feet per acre
Return flow requirement in Acre-feet per acre
Depletion requirement in Acre-feet per acre

Additional input data is required, including conveyance and on-farm efficiencies, return flow distribution patterns, and non-beneficial consumptive use.~

C. Conveyance and On-Farm Efficiencies (or losses)

The conveyance system is that portion of the delivery system that provide water from the source of supply to the farm lateral. As the water moves through this system, inherent losses will take place, those being canal seepage, deep percolation, and evaporation. Data for each of the node basin was taken from estimates provided by the District Conservationists in the MBSA study. Conveyance losses were estimates for a variety of systems, i.e., open channel, pipe, or a combination of both. In addition, monthly losses were estimated to account for the early season build up of seepage in the canal prism, to minimal losses during the height of the irrigation season, to additional losses as they would occur at the end of the season to account for canal draw down and late season irrigations.

The on-farm system is that portion of the delivery of the system that provides water from the farm delivery lateral to the farms and crops itself. Losses include deep percolation, operational waste, and in the case of sprinklers, wind drift and spray losses. Data for each of the node basin was taken from estimates provided by the District Conservationists in the MBSA study. Conveyance losses were estimates for a variety of systems, i.e., open channel, pipe, or a combination of both. Monthly losses were estimated to account for more efficient operation during the irrigation season.

D. Return Flow Distribution Patterns

Irrigation water that is not consumptively used or lost in other ways is available to be returned to the river system and used again downstream. The return of this water is not instantaneous in many cases, and may require several months to work it way back to the river. In this study, it was assumed that all return flows would occur within the node basin of the diversion.

Hydrogeologists from the Montana Department of Natural Resources and Conservation provided estimates of return flow patterns for all node basins in the reach above Ft Peck Reservoir. This was done for a joint study between Reclamation and the State in 1989. For the rest of the node basins, a representative pattern was used based upon information used in the MBSA study.

The return flows are broken into two portions. It is assumed that a portion of the diversion will return immediately in the same month of the diversion. The remaining portion is then lagged throughout a 12-month period at a rate established as an input item. Return flow values at accumulated throughout the year for the entire period of record. For example, assume that of the diverted amount in July of this irrigation season, 1.0 acre-foot is available for return in the month of the diversion. Assume the following return flow pattern.

Available return flow in diversion month	60%
Month one following diversion	50%
Month two following diversion	15%
Month three following diversion	13%
Month four following diversion	8%
Month five following diversion	4%
Month six following diversion	3%
Month seven following diversion	2%
Month eight following diversion	1%
Month nine following diversion	1%
Month ten following diversion	1%
Month eleven following diversion	1%
Month twelve following diversion	1%

Based upon an example of an available return flow of 1.0 acre-foot for July, the return flow would be lagged in the following pattern.

Month	Available Return Flow (in acre-feet)
July	.60
August	.20(50% of the remaining 40%)
September	.06(15% of the remaining 40%)
October	.05 (13% of the remaining 40%)
November	.03 (8% of the remaining 40%)
December	.02(4% of the remaining 40%)
January	.01 (3% of the remaining 40%)
February	.01 (2% of the remaining 40%)
March	.01 (1% of the remaining 40%)
April	.01 (1% of the remaining 40%)
May	.00 (1% of the remaining 40%)
June	.00 (1% of the remaining 40%)
July	.00 (1% of the remaining 40%)

E. Non-Beneficial Consumptive Use

Non-beneficial consumptive use is a loss that occur within the irrigation system. It is primarily weeds, trees and other vegetation that grows along canals, ditches, return flow ditches and waste ditches and uses water that would normally be returned to the stream as return flow. The available return is adjusted to account for these losses. Although accurate figures are very difficult to measure and studies on these water losses in this area have not been done, a common values that is used is 15 to 20%. In this study, the non-beneficial consumptive use value of 20 % for both conveyance and on-farm losses was used for all the node basins.

VIII. Calculation of the Historic Depletions

Using the monthly diversion, return flow and depletion figures calculated from the process mentioned above, the monthly and annual historic depletion are calculated by applying the annual irrigated acres to the monthly depletion number. Of primary concern is the historical depletions. The irrigated acres, taken from the TOTAL 4 program, are multiplied by the monthly depletions value to determine the monthly depletion. The program also computes historic diversion and historic return flows.

As mentioned earlier, in each node basin, several consumptive runs may have been made to account for the different type of irrigation that was taking place within that basin. The CONUSE5 program will make multiple runs and combine all of the total historical depletions into one monthly value for the period of record.

Adding the historical irrigation depletions and other depletions identified below to the historic streamflow will represent an estimate of potential natural or virgin flow within the node basin. Graphs of estimated historic total depletions (irrigation + major reservoir + other depletions) are shown in Appendix B.

IX. Calculation of the Present-Level Depletions

The concept of present level depletions is defined as the impact that today's development would have on the development of any past year. For example, how would the irrigation development of today effect the development in 1935 assuming 1935 climatological conditions? How much additional depletion would take place?

Present-level irrigation depletions are calculated the same way as historical depletions, with the exception that the irrigated acres for all years from 1898 thru 1996 were the same as the number of acres irrigated in 1996. The resultant depletions can then be applied to the historic natural flow record to get present-level depleted streamflows.

A typical example of the determination of the present-level depletion would be:

Assume:
1929 Irrigated acres for node basin X is 10,000 Acres
1996 Irrigated acres for node basin X is 25,000 Acres

July, 1929 Irrigation Depletion for July is .87 acre-feet per acre
(Depletion is diversion minus return flow)

1996 Effect on July 1929 would be 25,000 times .87 equals 21,750 Acre-feet

This means that had 25,000 acres of irrigation been in place in a climatological year such as July, of 1929 that the depletion for that month would have bee 21,750 acre-feet. Historically, only 8,700 acre-feet of depletion took place. (10,000 acres times .87 acre-feet pe acre)

As mentioned previously, there are many other depletions that affect the streamflow in the basin. The following sections describe the methodology used to project these other depletions to the historic and present level.

X. Historic Depletions Due to Irrigation by Ground Water

Large capacity wells located near streams can reduce streamflow significantly by reducing aquifer discharge to streams or by inducing flow out of the stream. Factors controlling the degree of depletions include, but are not limited to, the hydraulic connection between the aquifer and stream, distance of well from stream, quantity and duration of water pumped. Time and financial constraints did not allow for the collection of data to calculate those depletions. The U.S. Agricultural Census data does not differentiate between ground water and surface water irrigated acreage, it is all lumped to one annual value. Because of these constraints, assumptions were drawn from the MBSA study which looked into and utilized simplified methods for estimating ground water depletions.

In general, the Kansas and Platte river basins have much more extensive well development than other basins because of the occurrence aquifer systems of large areal extent. For the present study, it was assumed that for all drainage basins other than the Kansas and Platte River basins, any irrigation wells in those basins are located in narrow river valley alluvial channels. Most of the water pumped by the wells is essentially assumed to be coming from the streams. With those assumptions, ground water irrigated acreage was assumed to be the same as surface-water acreage using sprinkler system efficiencies. Therefore, ground water depletions for basins other than the Kansas and Platte are inclusive of the surface-water depletion calculations described in previous sections.

The Kansas and Platte river basins have a large number of irrigated acres supplied by wells completed in aquifers that have minimal hydraulic connections with streams, or are located quite distant from perennial streams. Generally, the further a well is from a stream, the less impact it will have on stream flows. For the present study, net ground water usage was approximated using ground water irrigated acreage estimated from U.S. Agriculture Census data. Again, since the Ag Census data does not differentiate between surface and ground water irrigated acreage, it was assumed for the Platte and Kansas basins that all acreage using sprinklers was the same as ground water acreage. Sprinkler acreage was defined using percentages of total irrigated acreage. Those percentages were taken from the MBSA study for each node basin.

The ground water acreage (sprinkler acres) was input to the CONUSE5 program to estimate net aquifer withdrawals. These are 'net' withdrawals since the CONUSE5 program takes into account return flows. Although the return flows are originally intended to be returning to a stream, we are assuming that the return flows are returning in a similar fashion to the aquifer.

Although we now have estimated net withdrawals, we do not have any information on where the ground-water irrigated acreage is located, and how far that acreage is from a stream. A procedure needed to be developed to adjust the ground water usage output by CONUSE5 to reflect reduced depletionary effects of ground water irrigated acreage located distant from the main streams.

The 1982 MBSA study addressed this concern by utilizing analytic groundwater models and well locations in the Kansas and Platte River basins to delineate the reduced depletionary effects of wells as they became more distant from streams. That study developed depletionary data for 1944 through 1978. We did not have the time in the present study to build upon those techniques and extend the database. Instead, a simplified procedure outlined below was developed to approximate the percentage of groundwater usage that could be depleting nearby streams utilizing data developed in the MBSA study:

Tables 31, 32, *35,* and 36 of the MBSA study report "Technical Paper, Ground Water Depletion, February 1982" list annual streamflow depletions and ground water pumpage for sub-basins in the Kansas and Platte River basins. For each sub-basin, the ratio of depletions to pumpage were developed for each year from 1944-1978.

Example: Republican River below Harlan County Dam, data from MBSA Study

Year	Pumpage	Depletion	Depletion/Pumpage Ratio
1944	33954	7569	0.22
1945	26075	8477	0.33
1946	28742	9744	0.34
1947	42688	13074	0.31
1948	43815	14604	0.33
1949	45117	15859	0.35
1950	47339	16623	0.35
1951	28197	13240	0.47
1952	76509	21119	0.28
1953	92797	26422	0.28
1954	90407	27901	0.31
1955	114764	30944	0.27
1956	127941	32049	0.25
1957	115453	31620	0.27
1958	125341	31957	0.25
1959	171612	40872	0.24
1960	210000	47449	0.23
1961	180801	46622	0.26
1962	146294	40335	0.28
1963	226171	48968	0.22
1964	291785	54886	0.19
1965	173649	44480	0.26
1966	290288	51334	0.18
1967	280876	49466	0.18
1968	440102	61993	0.14

1969	469650	65472	0.14
1970	698344	86252	0.12
1971	570915	81491	0.14
1972	630050	84160	0.13
1973	608688	84003	0.14
1974	925203	101795	0.11
1975	1118070	119183	0.11
1976	1315126	140698	0.11
1977	1440094	154706	0.11
1978	1773101	184031	0.10

These annual ratios were then applied to 1944-1978 annual net ground water irrigation withdrawals calculated by the CONUSE5 program, to arrive at approximate depletions for each year from 1944-1978. Since ultimately we need monthly depletions, it was assumed that the monthly ratios were the same as the annual ratios, and were applied to monthly withdrawals output from the CONUSE5 program.

In many cases, the ratios calculated from the MBSA study indicated that a higher percentage of groundwater pumpage depleted the streams earlier in the historic period (as shown in the above example). This is probably because, initially, more wells were constructed nearer the streams to begin with. With time, more wells are developed further from the streams because of remaining available irrigable land. To account for this change, the depletion-to-pumpage ratios for 1944-1953 were averaged into a single ratio and applied to all CONUSE5 calculated pumpage prior to 1944. The ratios for 1969-1978 were averaged to a single value and applied to CONUSE5 calculated pumpage after 1978. Using the above example data for the Republican River below Harlan County Dam, the average depletion-to-pumpage ratio for 1944-1953 was 0.33, and the ratio for 1969-1978 was 0.12. These ratios were developed for each sub-basin of the Kansas and Platte basins.

For the North Fork Republican, Arikaree, and South Fork Republican River sub-basins, the MBSA study did not use any analytic groundwater models to determine streamflow depletions via groundwater pumpage. This could have been because that study did **not** feel there was significant groundwater usage to justify a more detailed analysis. For this study, it was assumed that groundwater usage in these three subbasins would be adjusted using the same depletion-to-pumpage ratios utilized for the Republican River below Harlan County Dam sub-basin.

Using the above steps, the monthly depletions due to net groundwater withdrawals were estimated for 1898-1996. The monthly groundwater depletions were then summed with surface water depletions calculated by the CONUSE5 program to arrive at total irrigation depletions by sub-basin.

XI. Present-Level Depletions Due to Irrigation by Ground Water

Since the surface-water depletions already include ground water depletions for all basins, except Kansas and Platte rivers, then the present-level surface water depletions are inclusive of ground water depletions. As for the Kansas and Platte basins, the present-level ground water depletions were calculated the same way as historic, with the exceptions that the annual average depletion-to-pumpage ratio for 1969-78 was applied to every month for 1898 thru 1996, and using present level net withdrawals from the CONUSE5 program.

XII. Historic Major Reservoir Depletions:

Using data from Reclamation s HYDROMET database, the monthly operational depletions for the major Reclamation reservoirs were developed. These depletions are also termed holdouts and can include the net effects of storage changes, reservoir evaporation, precipitation on reservoir, and seepage. It would be more accurate to remove the theoretical effects of evaporation and rainfall on the pre-development river channel covered by the reservoir, but that was beyond the resources of this study. Major reservoirs are those defined as generally having storage in the range of 200,000 acre-feet or more (same criteria as used in MBSA study). For the most part, the depletions were calculated as monthly total reservoir inflow minus total reservoir discharge (includes any canal discharge from reservoir). If those data were not available, then the monthly change in end-of-month storage were used. Not all basins had major reservoirs, the basins that did and associated reservoirs are as follows:

Basin Reach	Major Reservoirs
Missouri River above Ft. Peck	Clark Canyon, Canyon Ferry, Lake Elwell
Missouri River - Ft. Peck to Garrison	Fresno, Boysen, Buffalo Bill, Bighorn Lake
Missouri River - Garrison to Oahe	Keyhole, Belle Fourche, Angostura
Missouri River - Omaha to Nebraska City	Seminoe, Pathfinder, Alcova, Glendo, Guernsey, Horsetooth, McConaughy, Sherman

Holdouts or depletions for minor reservoirs (<200,000 acre-feet) were included in ‘other’ depletion values which will be defined below.

XIII. Present-Level Major Reservoir Depletions

The preferred method for determining present-level depletions (holdouts) for each major reservoir would have been to utilize monthly reservoir operations models driven by present-level depleted inflows. The time and resources necessary to develop such models and inflows for all reservoirs in the study area were not available.

Existing operations models has been established for other studies to calculate present-level depletions back to 1929 for Canyon Ferry, Bighorn, Boysen, and Buffalo Bill reservoirs. Since holdouts back to 1898 were needed, it was assumed that the median monthly holdouts for the l929-‘96 period could be used to fill in the respective monthly holdouts for 1898-1929. It is felt that this would be a valid assumption since, over the long term, reservoir operations have a tendency to be the same as to when water is stored and released, and hydrologic cycles tend to be the same. Hence long-term depletions would have a tendency to be in the same range for different periods during the year. There did not appear to be any correlation between reservoir inflows and reservoir depletions.

For the remainder of the major reservoirs where we did not have models, historic holdouts were used to represent present-level, and used the median monthly historic holdouts for years prior to historic data. Validity in using those procedures was based on comparisons of historic and present-level holdouts for Canyon Ferry. Those comparisons did not suggest a large difference between the two conditions. In addition, the difference is a small percentage of overall depletions (inclusive of irrigation depletions) in the basins and therefore would have minimal impact on total depletions. For example, in the basin reach above Ft. Peck reservoir, the ratio of annual historic reservoir depletions to total depletions for 1953 to 1996 averaged about 2 percent. For the Platte River basin, ratio of annual historic reservoir depletions to total depletions for 1910 to 1996 averaged about 3 percent.

Because historic holdouts are usually large when a reservoir initially fills, the historic holdouts during the first year the reservoir filled were not used to represent present-level conditions. Following is an explanation of how present-level holdouts were estimated for each major reservoir:

Missouri Basin above Ft. Peck:

Clark Canyon Reservoir: 1965-1996 are historic holdouts, 1898-1964 are monthly median historic holdouts.

Canyon Ferry Reservoir: 1929-1996 are present-level holdouts, 1898-1928 are monthly median of the present-level holdouts.

Lake Elwell: 1957-1996 are historic holdouts, 1898-1956 are monthly median historic holdouts.

Ft. Peck to Garrison:

Fresno Reservoir: 1940-1996 are historic holdouts, 1898-1939 are monthly median historic holdouts.

Boysen Reservoir: Used 1990-level depletion study and 1988-1996 historic holdouts for the period 1929-1996, 1898-1928 are monthly median historic holdouts.

Buffalo Bill Reservoir: 1914-1996 are historic holdouts, 1898-1913 are monthly median historic holdouts.

Bighorn Reservoir: Used 1990-level depletion study and 1988-1996 historic holdouts for the period 1929-1996, 1898-1928 are monthly median historic holdouts.

Garrison to Oahe:

Keyhole Reservoir: 1953-1996 are historic holdouts, 1898-1952 are monthly median historic holdouts.

Belle Fourche Reservoir: 1952-1996 are historic holdouts, 1898-1951 are monthly median historic holdouts.

Angostura Reservoir: 1953-1996 are historic holdouts, 1898-1952 are monthly median historic holdouts.

Oahe to Big Bend:

No major reservoirs**.**

Big Bend to Fort Randall:

No major reservoirs.

Fort Randall to Gavins Point:

No major reservoirs.

Gavins Point to Sioux City:

No major reservoirs.

Sioux City to Omaha:

No major reservoirs.

Omaha to Nebraska City:

Seminoe Reservoir: 1940-1996 are historic holdouts, 1898-1939 are monthly median historic holdouts.

Pathfinder Reservoir: 1911-19.96 are historic holdouts, 1898-19 10 are monthly median historic holdouts.

Alcova Reservoir: 1946-1996 are historic holdouts, 1898-1945 are monthly median historic holdouts.

Glendo Reservoir: 1958-1996 are historic holdouts, 1898-1957 are monthly median historic holdouts.

Guernsey Reservoir: 1929-1996 are historic holdouts, 1898-1928 are monthly median historic holdouts.

Horsetooth Reservoir: 1953-1996 are historic holdouts, 1898-1952 are monthly median historic holdouts.

McConaughy Reservoir: 1942-1996 are historic holdouts, 1898-1941 are monthly median historic holdouts.

Sherman Reservoir: 1964-1996 are historic holdouts, 1898-1963 are monthly median historic holdouts.

Remainder of basins:

COE did not want major reservoir holdouts included in present-level depletions.

XIV. Historic ‘Other Depletions

Other depletions include the effects of conservation tillage practices, farm ponds, small reservoirs 1 (those less than 200,000 acre-feet normal storage), livestock, municipal, energy, industrial, and rural domestic uses. The MBSA study had compiled annual depletion data for 1944 -1978 for each usage category by sub-basin. This data had been collected by field personal from each state and is summarized for each major basin in the MBSA study report “Missouri River Basin Hydrology Study Final Report, May 1983”. Data is also listed in computer printouts for each sub-basin by year.

Apparently for the MBSA study, small reservoir depletions were developed using an average reservoir surface area and a net evaporation value. For the eastern Missouri basins, that net evaporation value is sometimes negative because of higher precipitation than evaporation. This results in negative reservoir depletions that are accruals to streamflow.

It would have been desirable for the present study to add to the existing database. However, to collect and compile similar data for the present study for 1898-1943 and 1979-1996 would be difficult and time consuming to do. It is doubtful any detailed early years data can be found. One potential source of data is USGS estimated use of water in the United States. The USGS has been compiling that data on approximate five year intervals from 1950 to present. However, their data is presented as water withdrawals and consumptive use, as they don t directly calculate depletions to streamflow. The USGS data also did not evaluate depletion effects from farm ponds and soil conservation practices, which can be significant. Also their, database doesn’t help with the need for data prior to 1944.

Simplified procedures were needed to estimate the other depletions for the present study. Methods selected to estimate other depletions include using a percentage of irrigation depletions and using MBSA data for the time period it covered, and to define the trend of other depletions for extended years. In some instances, the USGS estimated water use data were used to quantify relationships between consumed water for other uses and consumed irrigation water.

Following is a breakdown of how historic other depletions were developed by basin reach. Also note that the estimated annual depletion was distributed evenly to all 12 months of the year.

All Reaches above Gavins Point:

Based on MBSA other depletions, the river basins above Gavins Point generally had other depletions that were about 7 percent of the irrigation depletions. Therefore, for all basins above Gavins Point, the other depletions were calculated as 7 percent of annual irrigation depletions.

Missouri River - Gavins Point to Sioux City:

Since the population density was felt to increase significantly in this reach, it was felt that using 7 percent of irrigation depletions to represent other depletions may not be valid, and a new method was developed to estimate what the percentage of other depletions to irrigation depletions would be. Depletions from other uses was calculated as 15 percent of annual irrigation depletion. This percentage was determined from USGS estimated water use data for 1985 and 1990. For the two sub-basins in this reach, the USGS water-use categories for total-irrigation consumptive use and total-all-water consumptive use were subtracted, with remainder assumed to be consumed other-water. Ratio of consumed other-water to irrigation consumed was established, and the average for two time periods was calculated to be 15 percent.

Missouri River - Sioux City to Omaha:

In this reach, depletions from other uses is much greater than irrigation depletions. A review of 1985 and 1990 USGS water use data for Blackbird and Soldier drainage basins showed an average ratio of 205% for ‘other consumed water versus irrigation consumed water (total consumed water minus irrigation consumed divided by irrigation consumed). A review of 1978 annual ‘other depletions compared to irrigation depletions from the MBSA study showed a ratio of 67% for the two node basins in this reach. From the MBSA study, depletions in 1944 showed ‘other’ depletions, but no irrigation depletions. Because there are no irrigation depletions in the earlier years, it became apparent that using a percentage relationship between ‘other’ and irrigation depletions would not work for earlier years. Therefore, the annual ‘other’ depletion data for 1944 to 1978 from the MBSA was used as the ‘other depletions for this reach. It was assumed that depletions from 1978 to present would be the same as year 1978 from the MBSA study. Due to the lack of usage data for earlier year, it was assumed that ‘other’ depletions in 1898 were the same as the 1944 MBSA livestock depletions and would ramp up linearly from 1898 to the 1944 MBSA ‘other’ depletion. Use of 1944 livestock depletions to represent 1898 total other depletions is a very arbitrary decision. It was felt that there had to be some water being consumed in 1898, but depletions from municipalities, reservoirs, industry, conservation practices, etc. were probably very small. It was assumed that livestock would have been one of the more significant other depletions during the earlier years.

Missouri River - Omaha to Nebraska City

Selected other depletion data for 1944, 1960, and 1978 from the MBSA study (final summary report) were used to establish a ratio of other depletion to irrigation depletions for those same years. Ratios were linearly ramped between those years to get additional ratios.

	‘Other’ depletions from MBSA study	Total irrigation depletions from present study	Ratio of ‘other depletions to irrigation depletions
1944	288.80 Kaf	3286.297 Kaf	.09
1960	485.68Kaf	4336.5lIKaf	.11
1978	759.00 Kaf	4481.721 Kaf	.17

The ratio for 1978 was applied to all years from 1979 thru 1996, thereby assuming no changes in recent years. It was also assumed that 1944 livestock depletions were equivalent to other depletions in 1898, therefore, the ratio of 1944 livestock depletions to average irrigation depletions for 1898 thru 1907 was used to define the 1898 ratio of .01. Ratios were ramped from 1898 to 1944 to get intervening years ratios. All ratios are then multiplied by the calculated irrigation depletions for each year to get annual other depletions.

Missouri River Reaches: Nebraska City to St. Joseph, St. Joseph to Kansas City, Kansas City to Booneville, and Booneville to Herman Subbasins

‘Other’ depletions previously developed for other basins in this study were based on establishing a relationship between irrigation depletions and MBSA ‘other’ depletions for selected years. However, these basins have very little irrigation depletions in earlier years, thereby making it difficult to establish relationship for the early years. Therefore, a different approach was used to develop ‘other’ depletions for these basins.

The annual ‘other’ depletions calculated for the MBSA study were used to develop ‘other’ depletions for this analysis. This includes the depletion categories of: conservation measures, farm ponds, livestock, municipal, energy, industrial, and rural domestic. These categories from the MBSA study were summed to a total depletion for each year from 1944 to 1978. The 1944-1978 totals from the MBSA study were directly applied to the corresponding years in the present analysis.

Since the present analysis covers the period 1898 to 1996, several assumptions were made to extend the MBSA study data. From 1898 to 1944, it was assumed that the depletions historically ramped up linearly from some starting level to the 1944 value. Upon reviewing the individual depletion categories and trends with time, it was assumed that the livestock depletions for 1944 were representative of livestock depletions in 1898, whereas the other depletions were assumed to be minimal. Therefore, the 1998 ‘other’ depletions were assumed to be the same as the 1944 livestock depletions, and the 1898-1944 depletions ramped up linearly to the total 1944 ‘other’ depletions from the MBSA report.

To extend the MBSA data from 1978 to 1996, it was assumed that the annual depletions after 1978 would be the same as the 1978 ‘other’ depletion from the MBSA report.

Kansas and Osage River Basins

Annual other depletions were estimated by sub-basin using MBSA data (data from computer printouts for each sub-basin). All other usage categories were summed to a total value for each year for 1944 to 1978. Other depletion for 1898 was assumed to be same as 1944 livestock depletion from MBSA study. Values were then linearly ramped from 1898 to 1944. 1979 and later were assumed to be same as 1978.

XV. Present-Level 'Other Depletions

Based on a conversation with COE, the 'other depletion ratio of 7% of irrigation depletions used for historic depletion estimates in the upper Missouri River basin was lowered to 5%. The COE felt that it would be better to err on the low side of depletions for present-level conditions. Therefore, an 'other' depletion ratio of 5 percent was used for all Missouri basin reaches above Gavins Point.

Below Gavins Point, the influence of larger population centers, which have higher municipal and industrial depletions, required that different 'other' depletion ratios were needed versus what was used above Gavins Point. Following are those ratios selected by reach:

Gavins Point to Sioux City:

A 15% ratio of 'other' to irrigation depletions was used for historic depletions. That ratio was based on 1985 and 1990 USGS water-use compilations of sub-basins in this reach. Following the COE's request to use 5% vs. 7% in basins above Gavins Point for present-level depletions, it was decided to use a present-level 'other' depletion ratio of 11% (5/7ths of 15%) for this reach.

Sioux City to Omaha:

A review of 1985 and 1990 USGS water use data for Blackbird and Soldier drainages showed an average ratio of 205% for 'other' consumed water versus irrigation consumed water (total consumed water minus irrigation consumed divided by irrigation consumed). A review of 1978 annual 'other' depletions compared to irrigation depletions from the MBSA study showed a ratio of 67% for the two node basins in this reach. It was decided to use the MBSA derived ration of 67% of irrigation depletions to represent annual 'other' depletions for present-level conditions.

Omaha to Nebraska City:

A review of 1978 total 'other' and irrigation depletions fro the Platte-Niobrara basin from the MBSA study indicated that the ratio of 'other' to irrigation depletions is 176%. A review of 1985 and 1990 USGS water use data fro sub-major hydrologic units of 1018, 1019, 1020, 1021, and 1022 suggested that the average ration of other-consumed water to irrigation consumed water is about 6%. It was arbitrarily decided to use 6% as a present-level ration of 'other' depletions to irrigation depletions.

Remainder of Missouri Reaches:

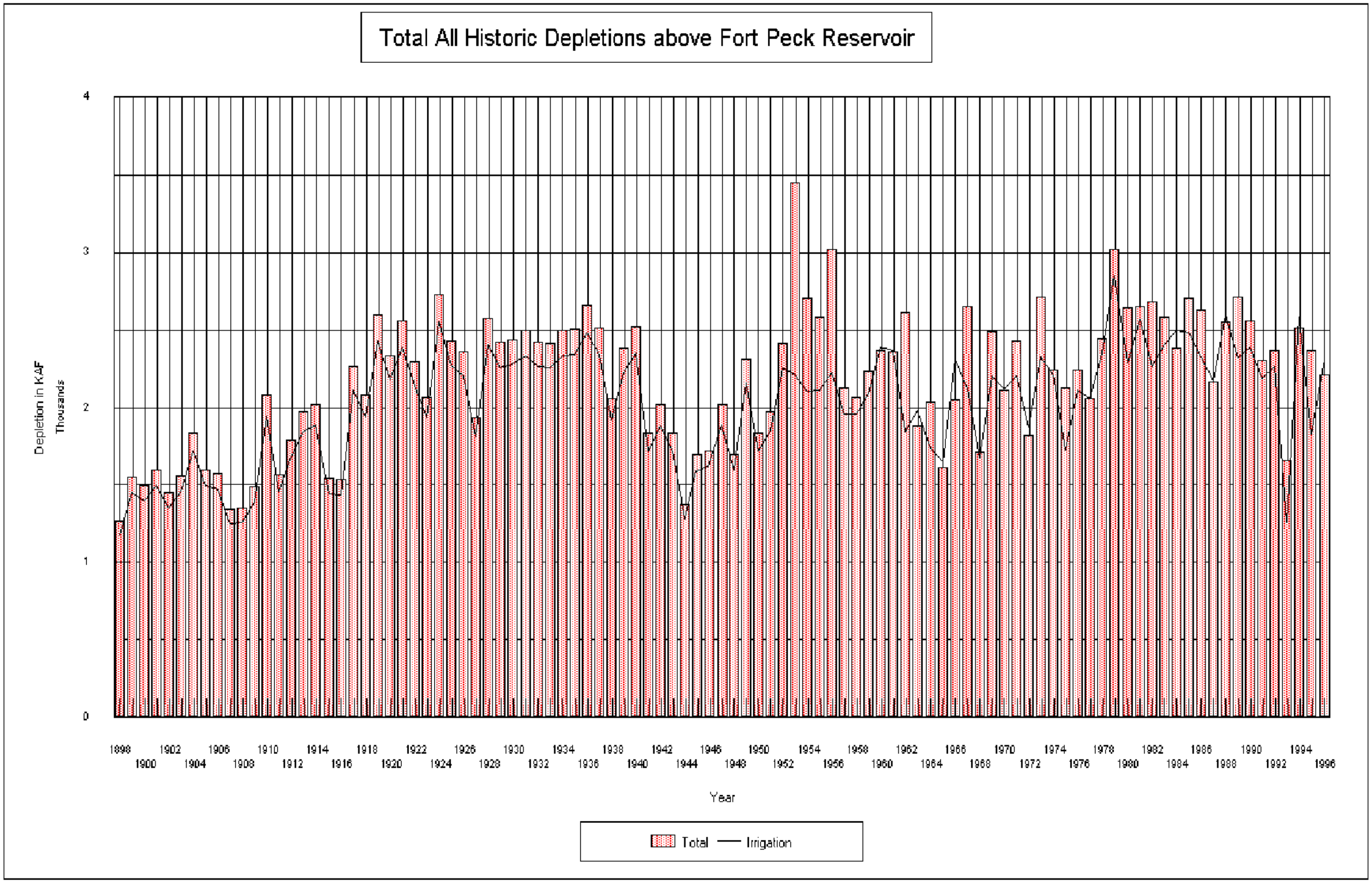
COE did not want ‘other’ depletions to be included in basins below Nebraska City for present-level depletions. Therefore, no present-level other depletions estimates were made.

XVI. Other Impacts to Streamflow

There were other factors which alter streamflow from natural conditions or impact natural flow calculations but were not addressed in this study because of time and funding constraints;

Inter-basin transfers of water.

If historic natural flows are to be calculated by adding historic depletions to recorded streamflow, then there may be an additional seepage and evaporation losses from having more water in the stream. Those additional seepage losses were not determined.

Total All Historic Depletions above Fort Peck Reservoir
Depletion in KAF
Thousands
4
3
2
1
0
1898
1900
1902
1904
1906
1908
1910
1912
1914
1916
1918
1920
1922
1924
1926
1928
1930
1932
1934
1936
1938
1940
1942
1944
1946
1948
1950
1952
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1956
1958
1960
1962
1964
1966
1968
1970
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1982
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1986
1988
1990
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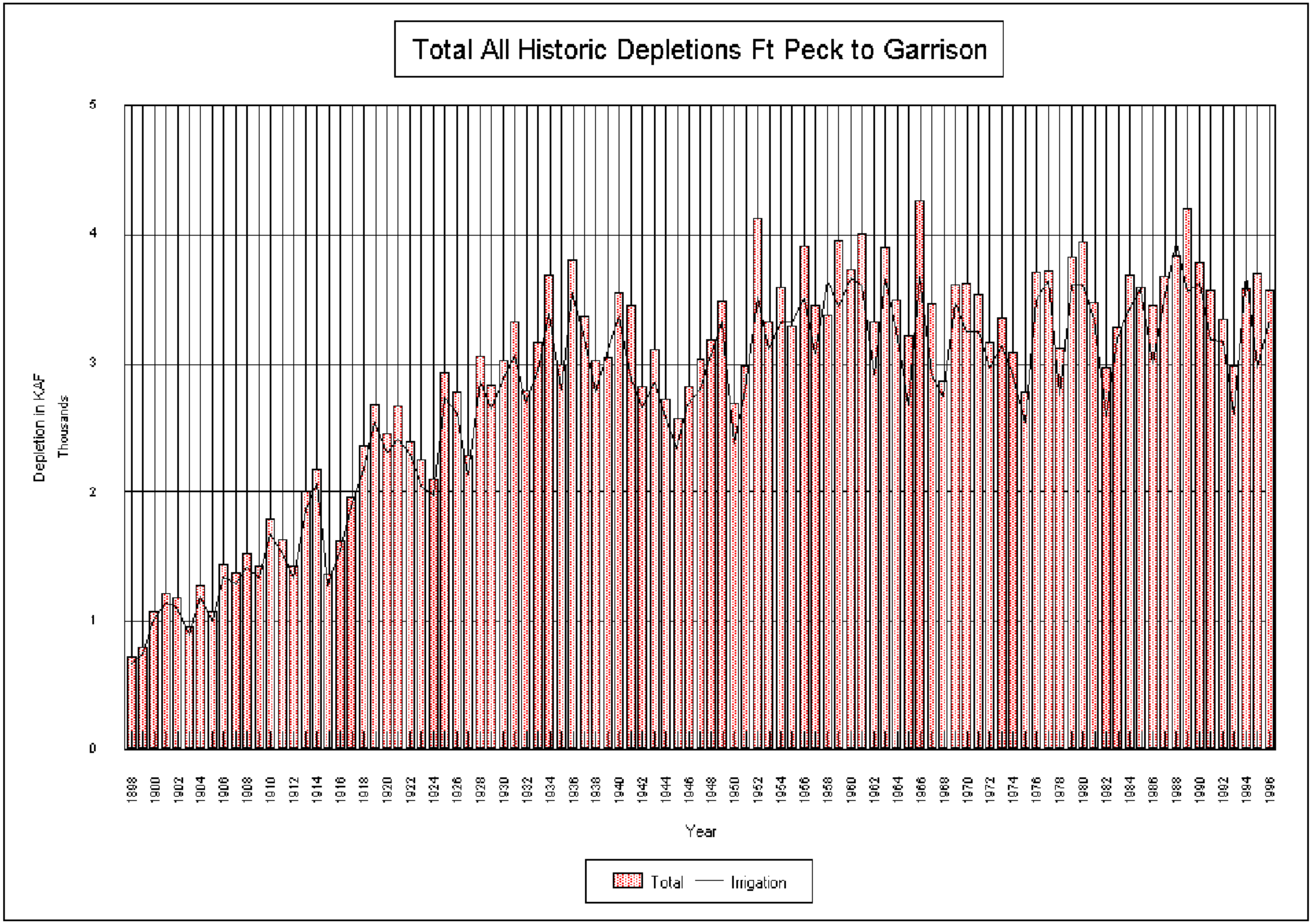
1994
1996
Year
Total
Irrigation


Total All Historic Depletions Ft Peck to Garrison
Depletion in KAF
Thousands
0
1
2
3
4
5
1898
1900
1902
1904
1906
1908
1910
1912
1914
1916
1918
1920
1922
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1928
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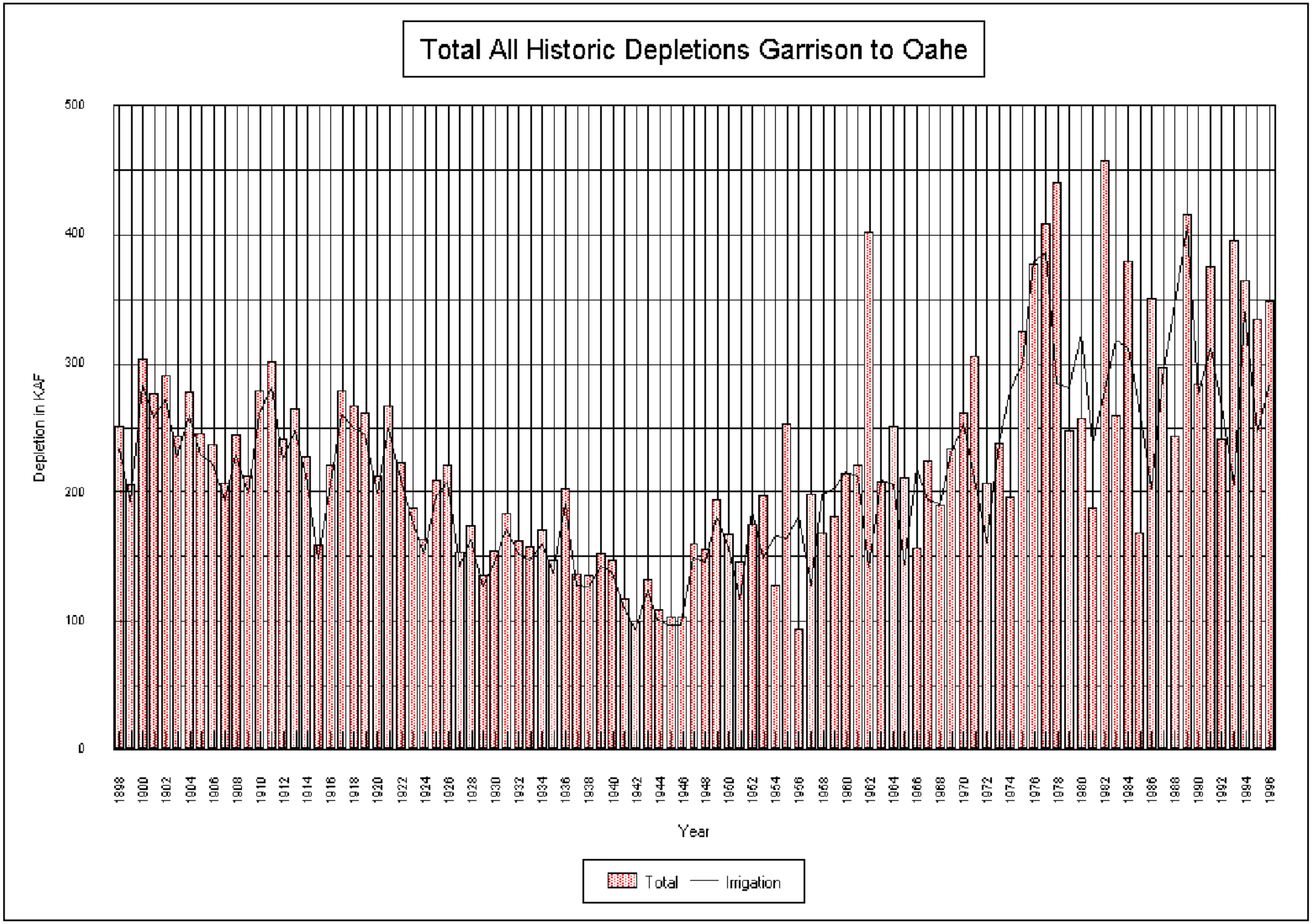
1996
Year
Total
Irrigation


Total All Historic Depletions Garrison to Oahe
Depletion in KAF
500
400
300
200
100
0
1898
1900
1902
1904
1906
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1910
1912
1914
1916
1918
1920
1922
1924
1926
1928
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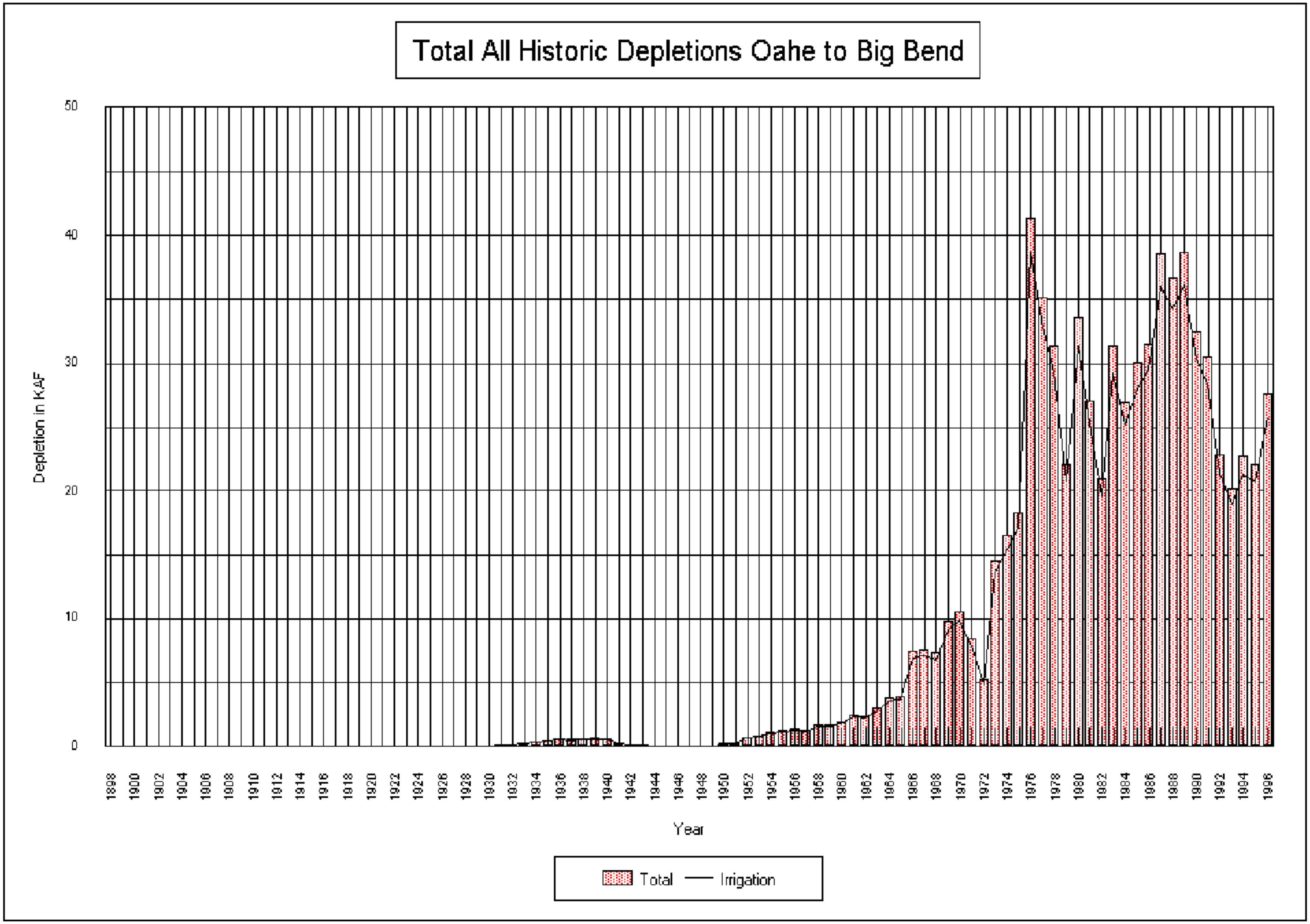
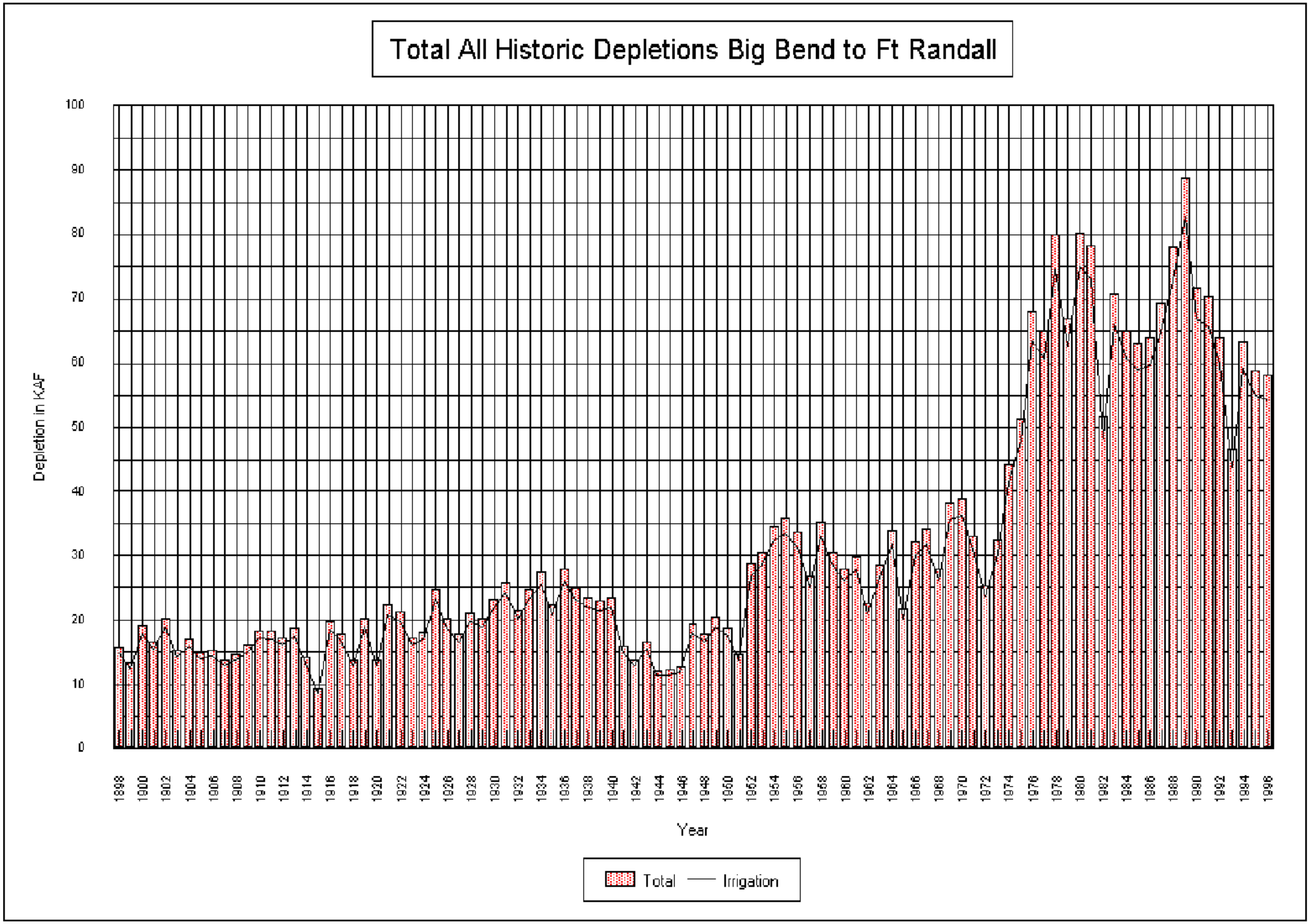
1996
Year
Total
Irrigation

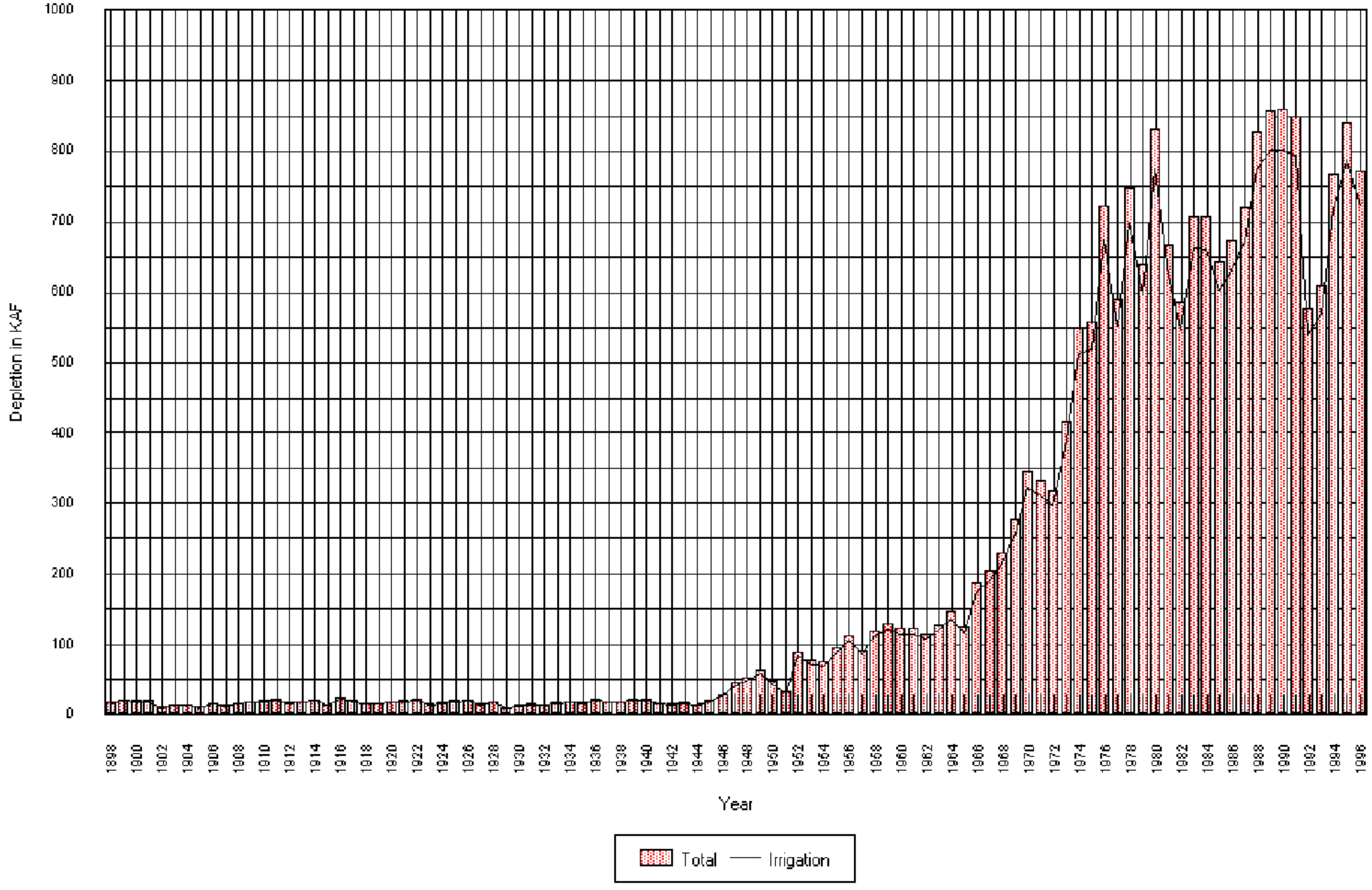


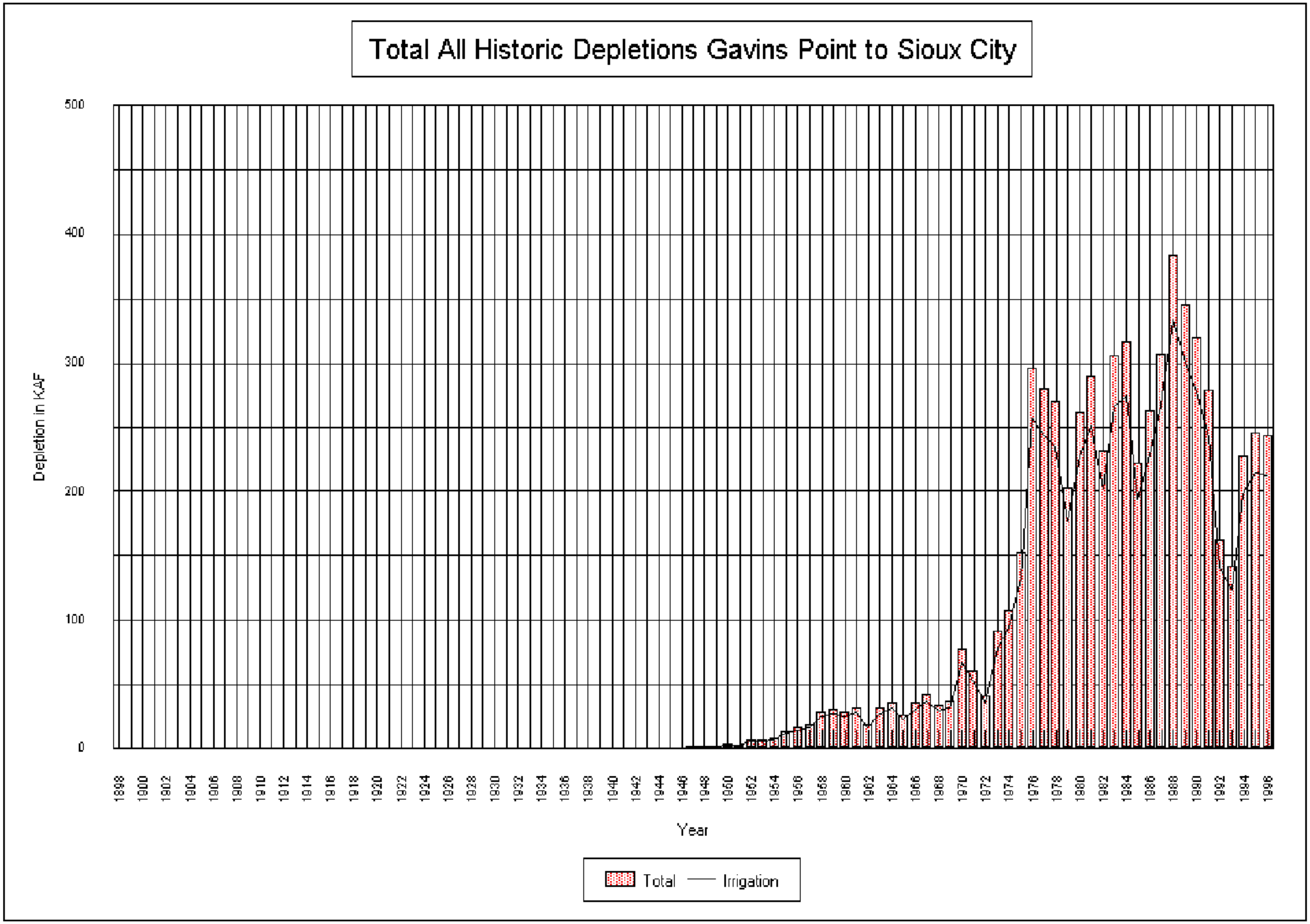
Total All Historic Depletions Oahe to Big Bend



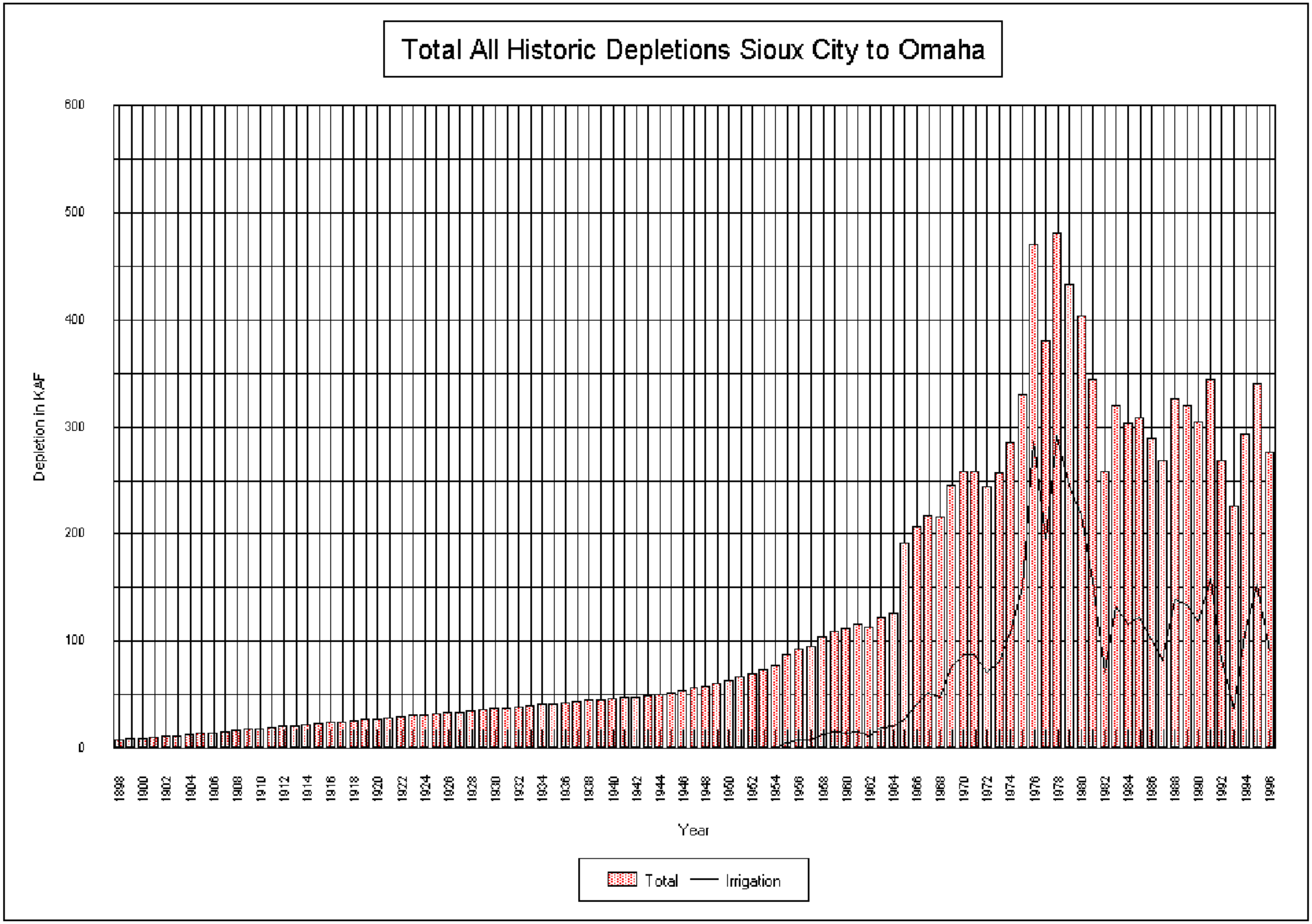
Total All Historic Depletions Big Bend to Ft Randall

Total All Historic Depletions Ft Randall to Gavins Point

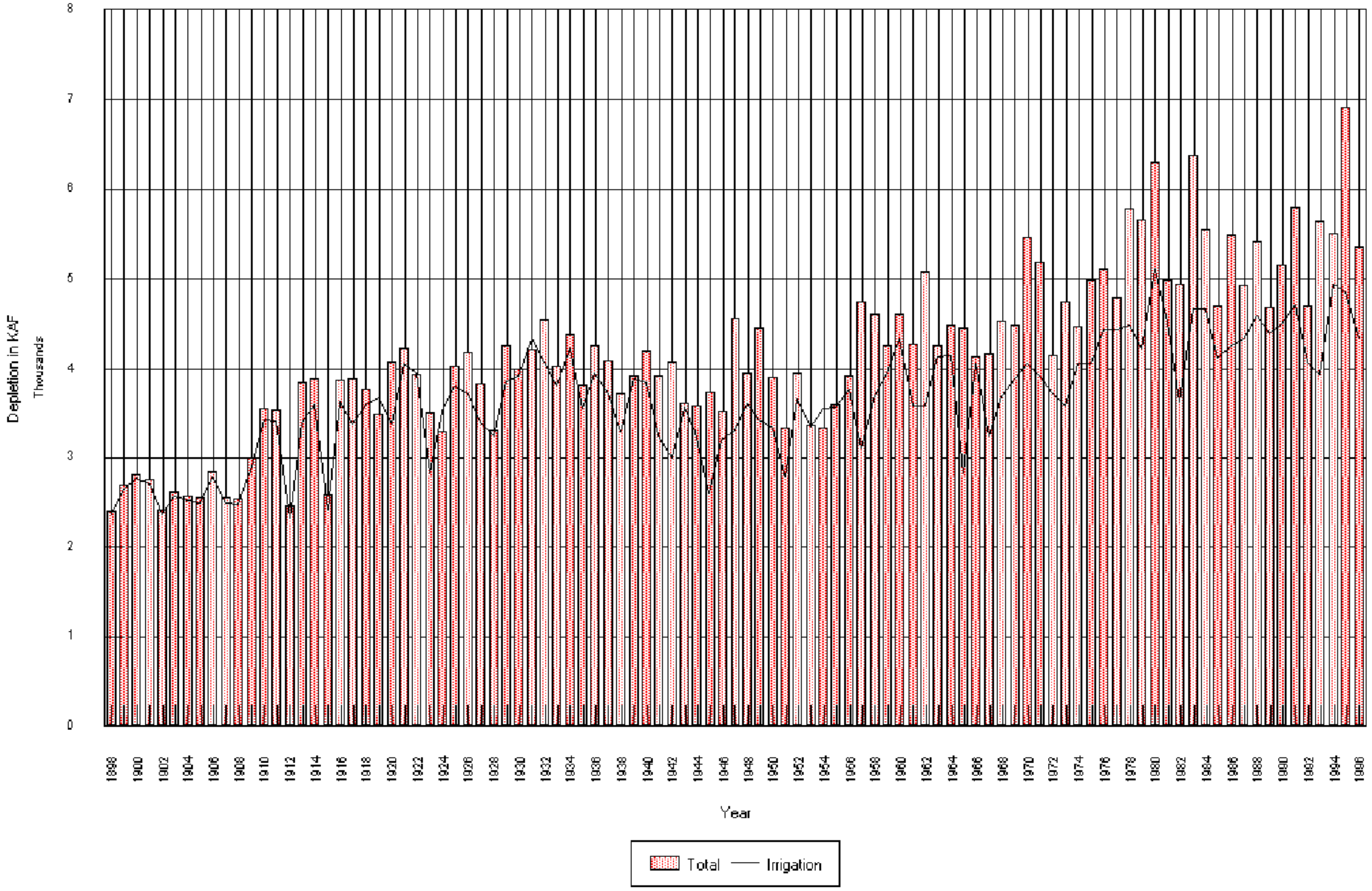




Total All Historic Depletions Gavins Point to Sioux City



Total All Historic Depletions Sioux City to Omaha


Total All Historic Depletions Omaha to Nebraska City
Depletion in KAF
Thousands
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1
2
3
4
5
6
7
8
1898
1900
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1904
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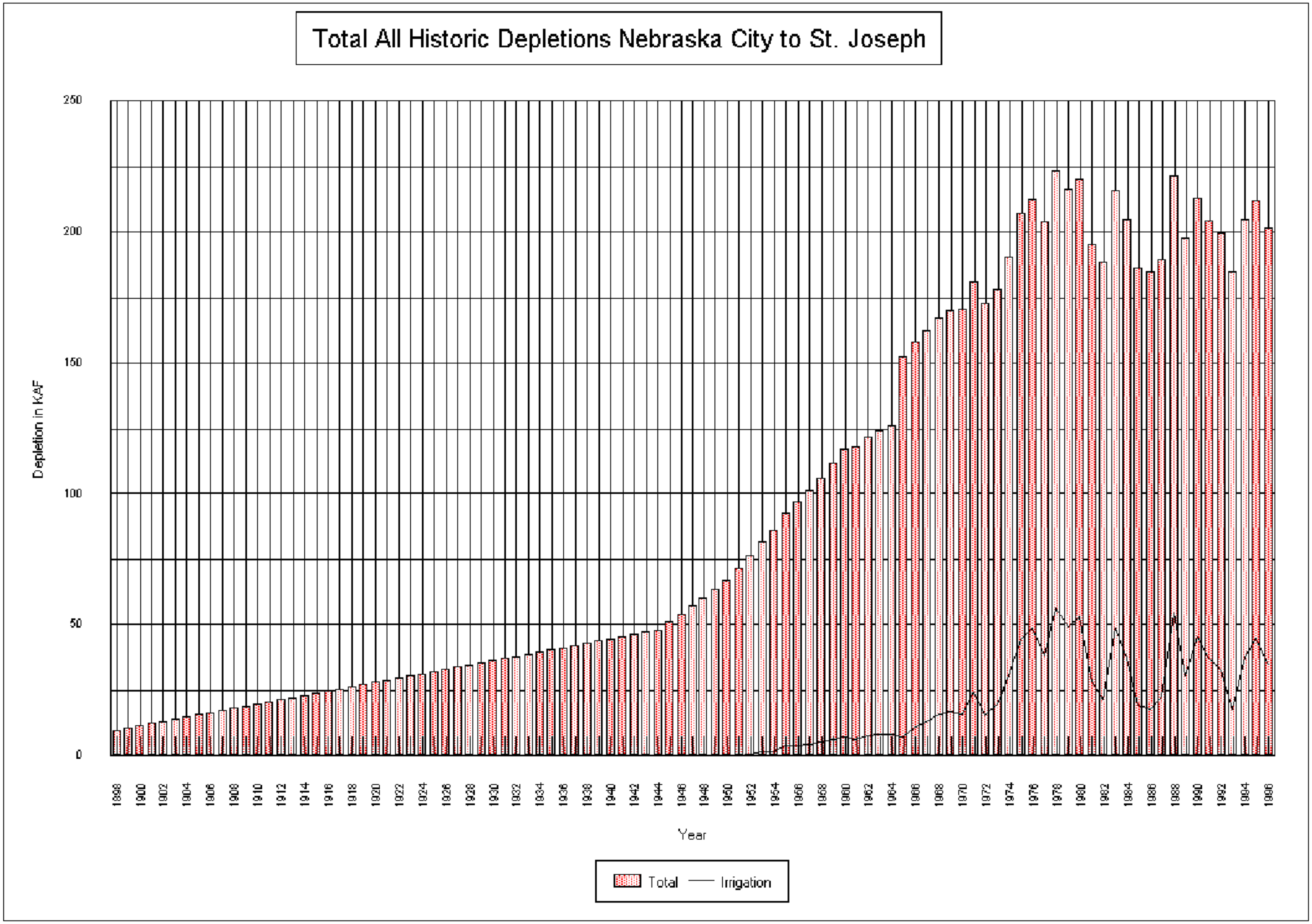
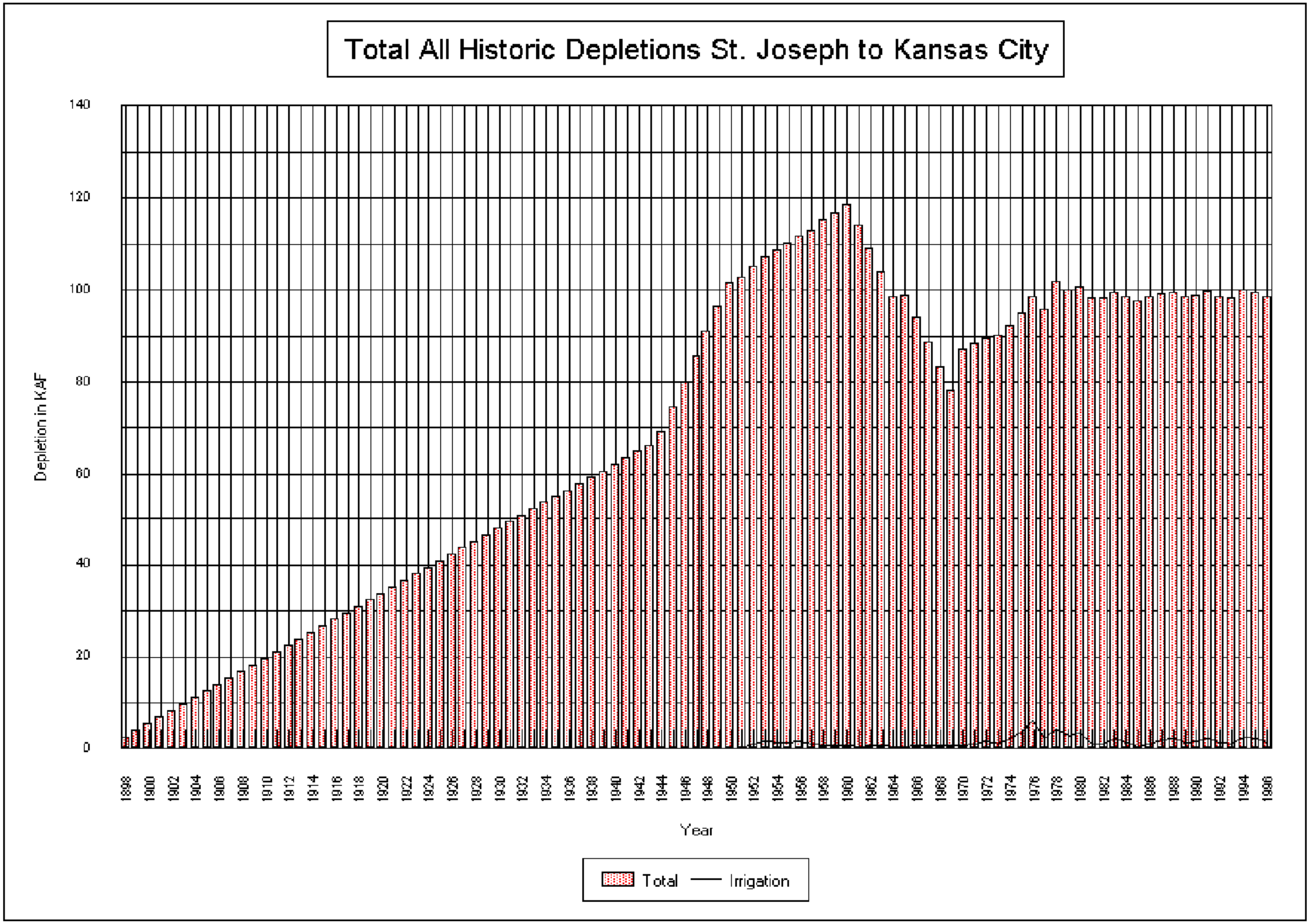
1994
1996
Year
Total
Irrigation



Total All Historic Depletions Nebraska City to St. Joseph

Total All Historic Depletions St. Joseph to Kansas City
Depletion in KAF
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40
60
80
100
120
140
1898
1900
1902
1904
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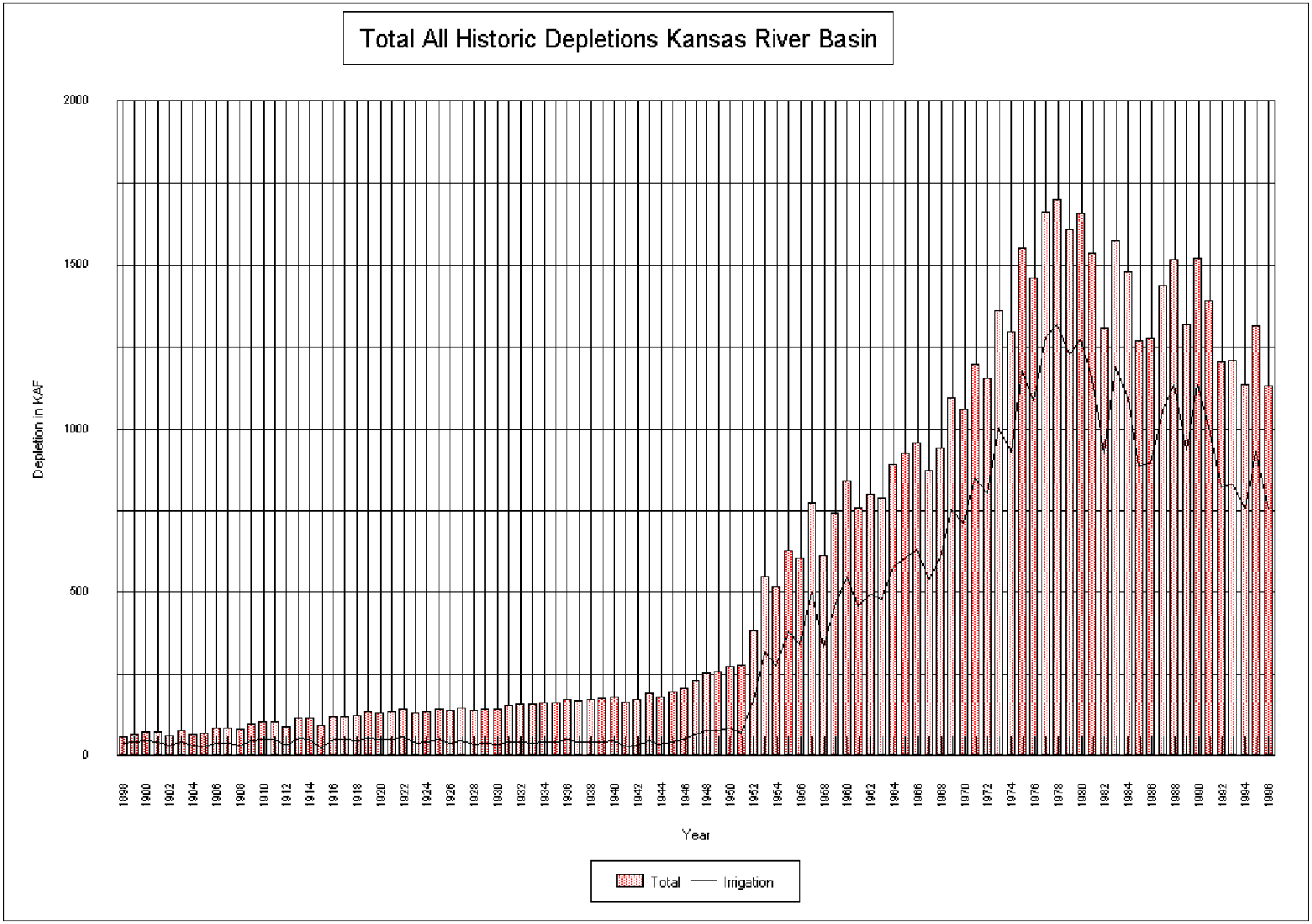
1996
Year
Total
Irrigation


Total All Historic Depletions Kansas River Basin
Depletion in KAF
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1500
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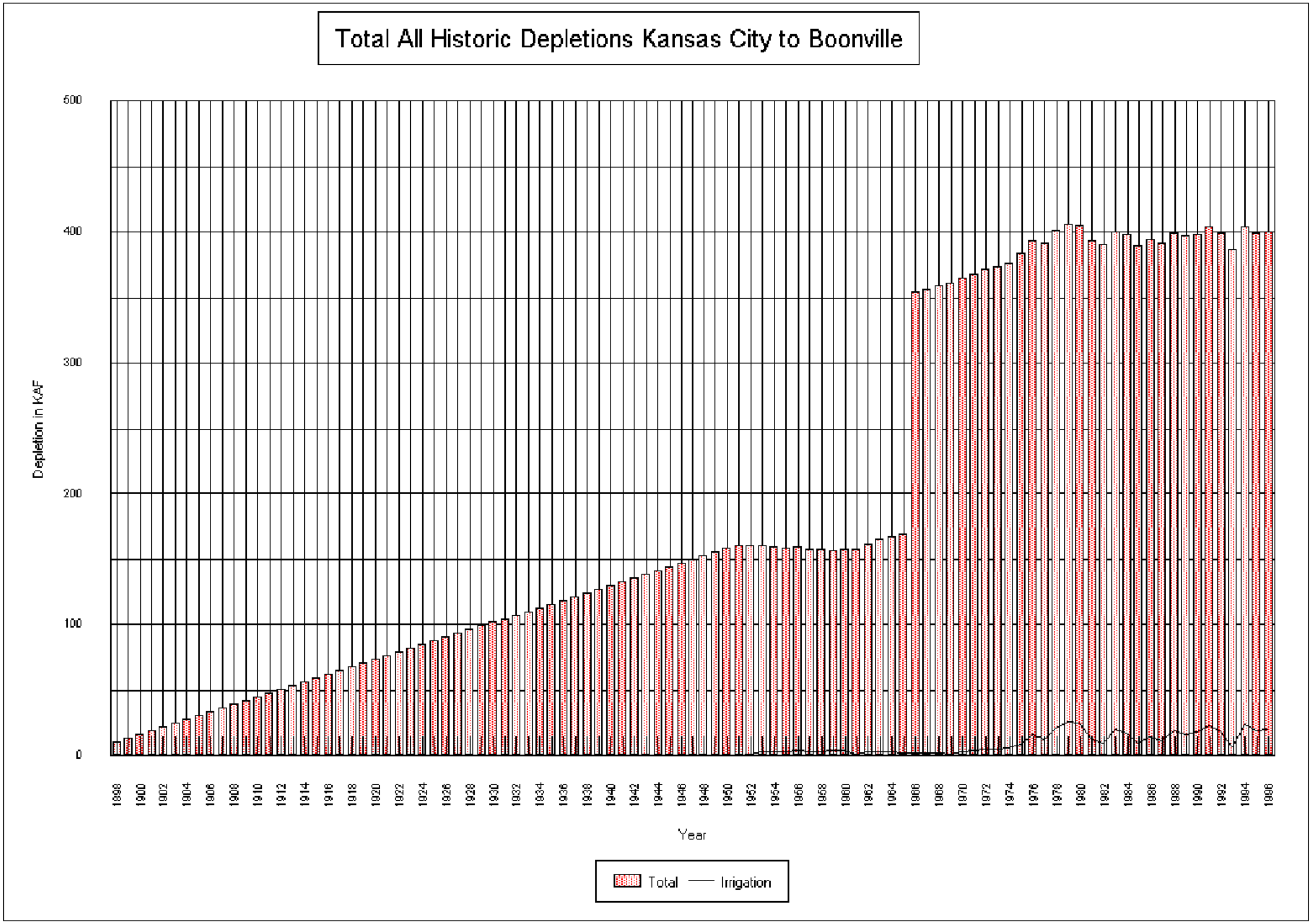
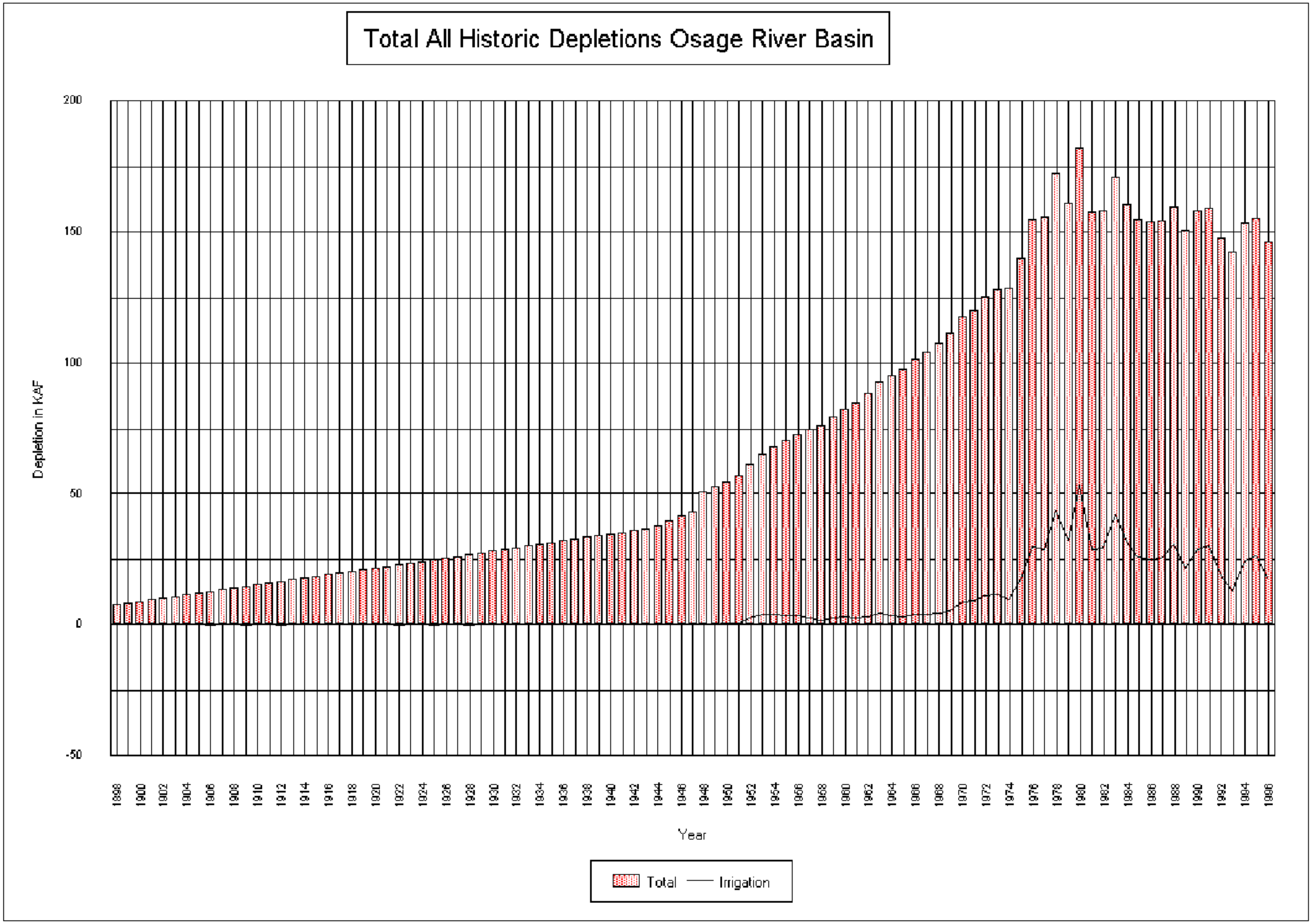
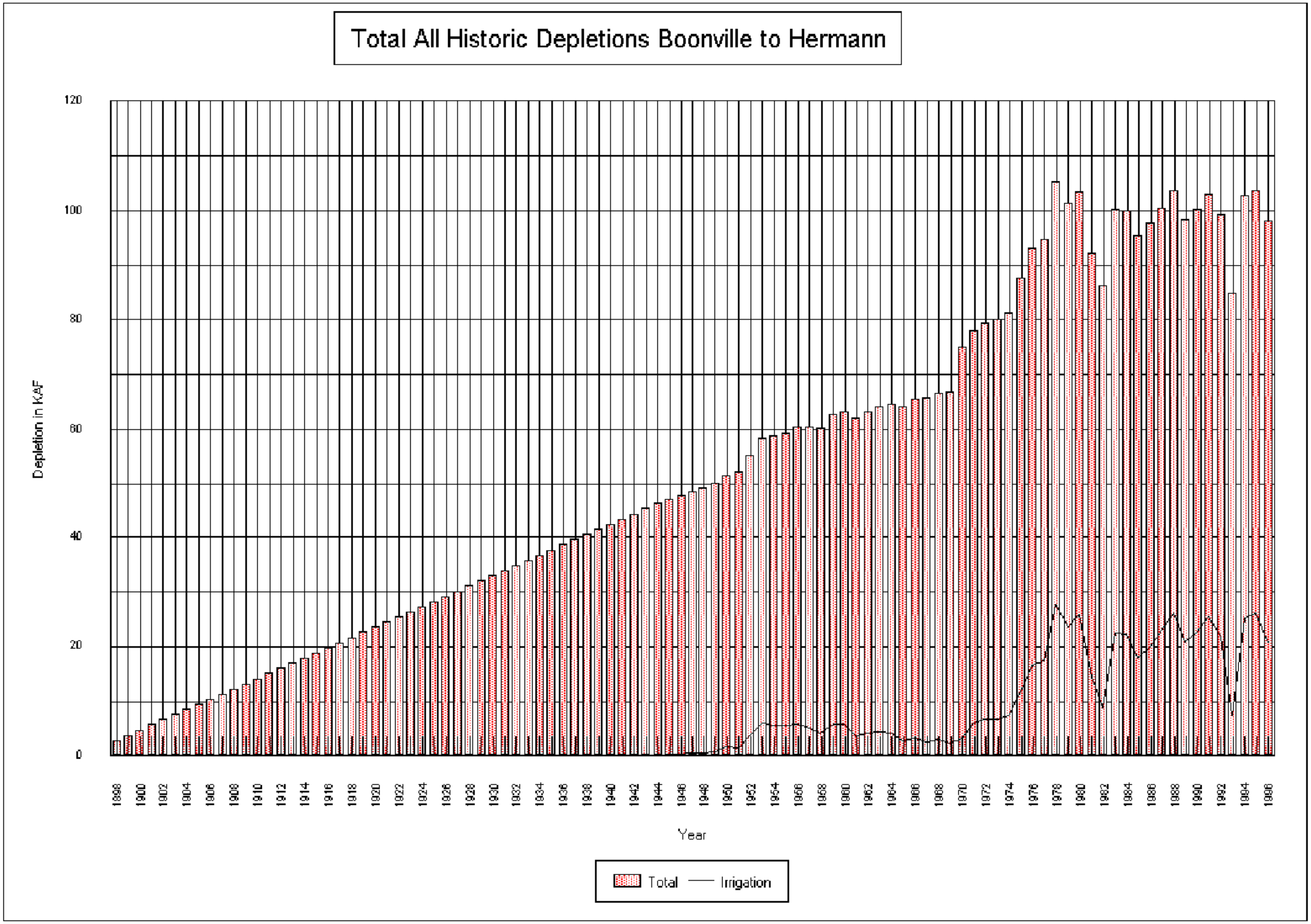
1996
Year
Total
Irrigation



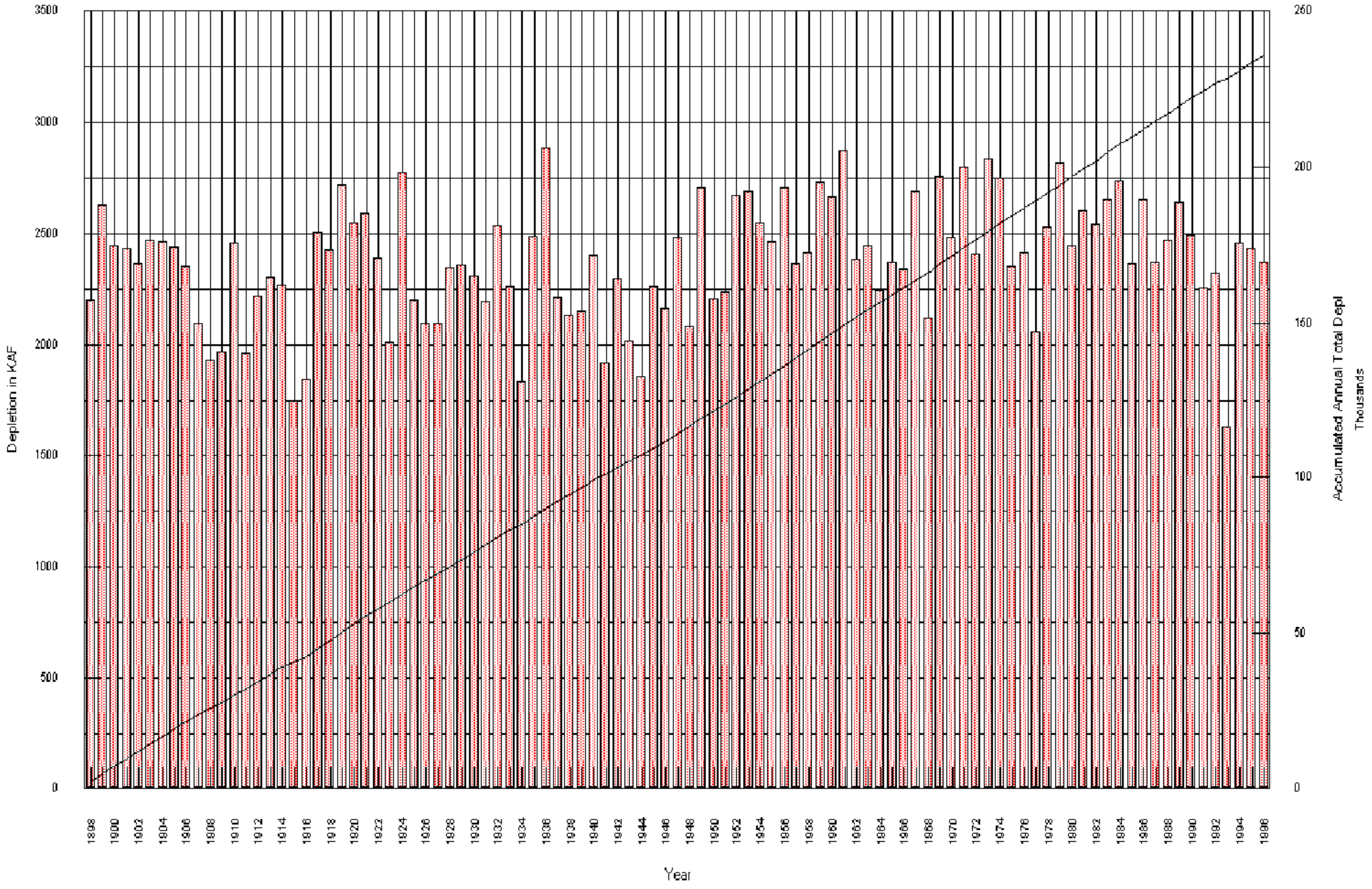
Total All Historic Depletions Kansas City to Boonville



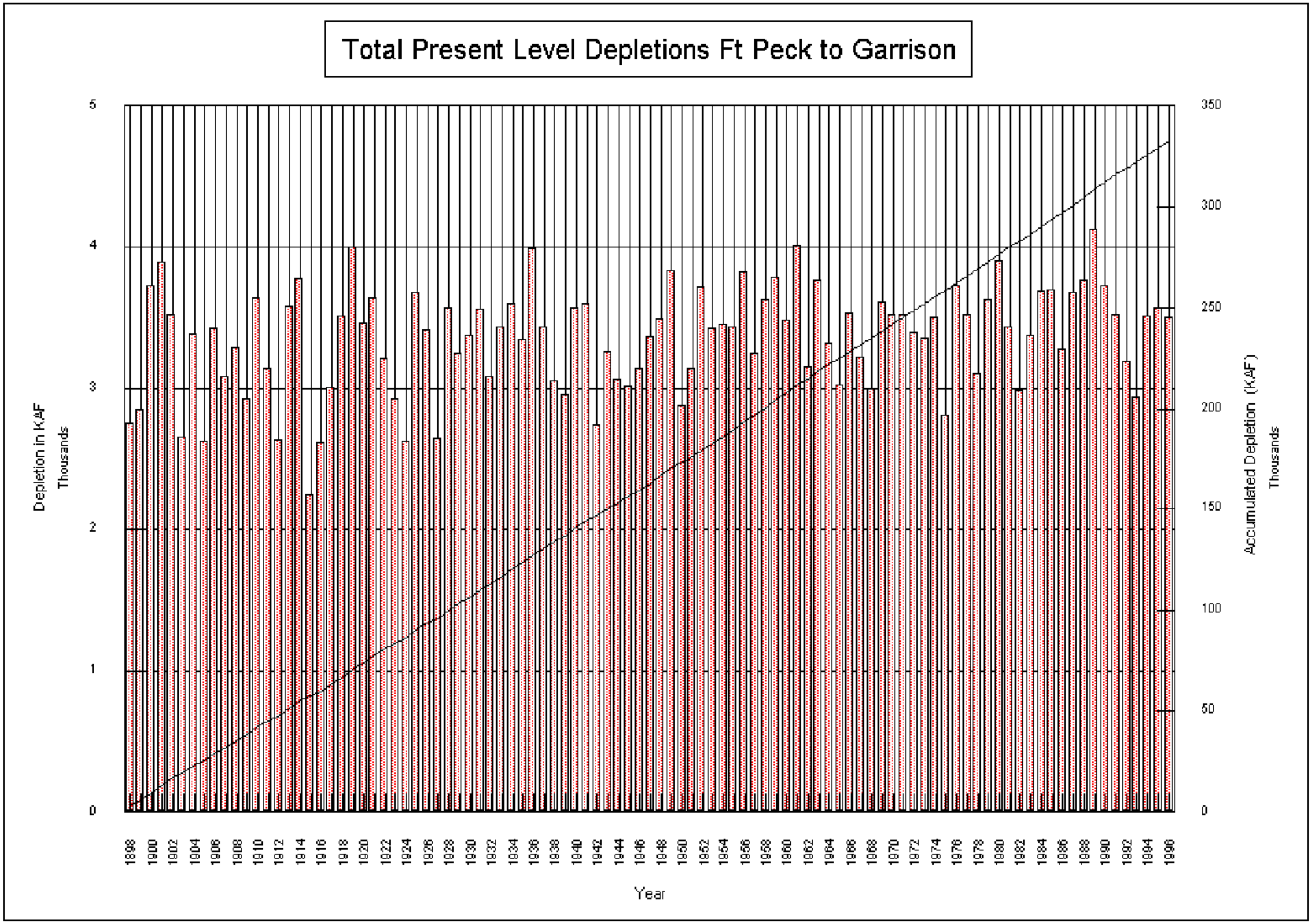
Total All Historic Depletions Osage River Basin



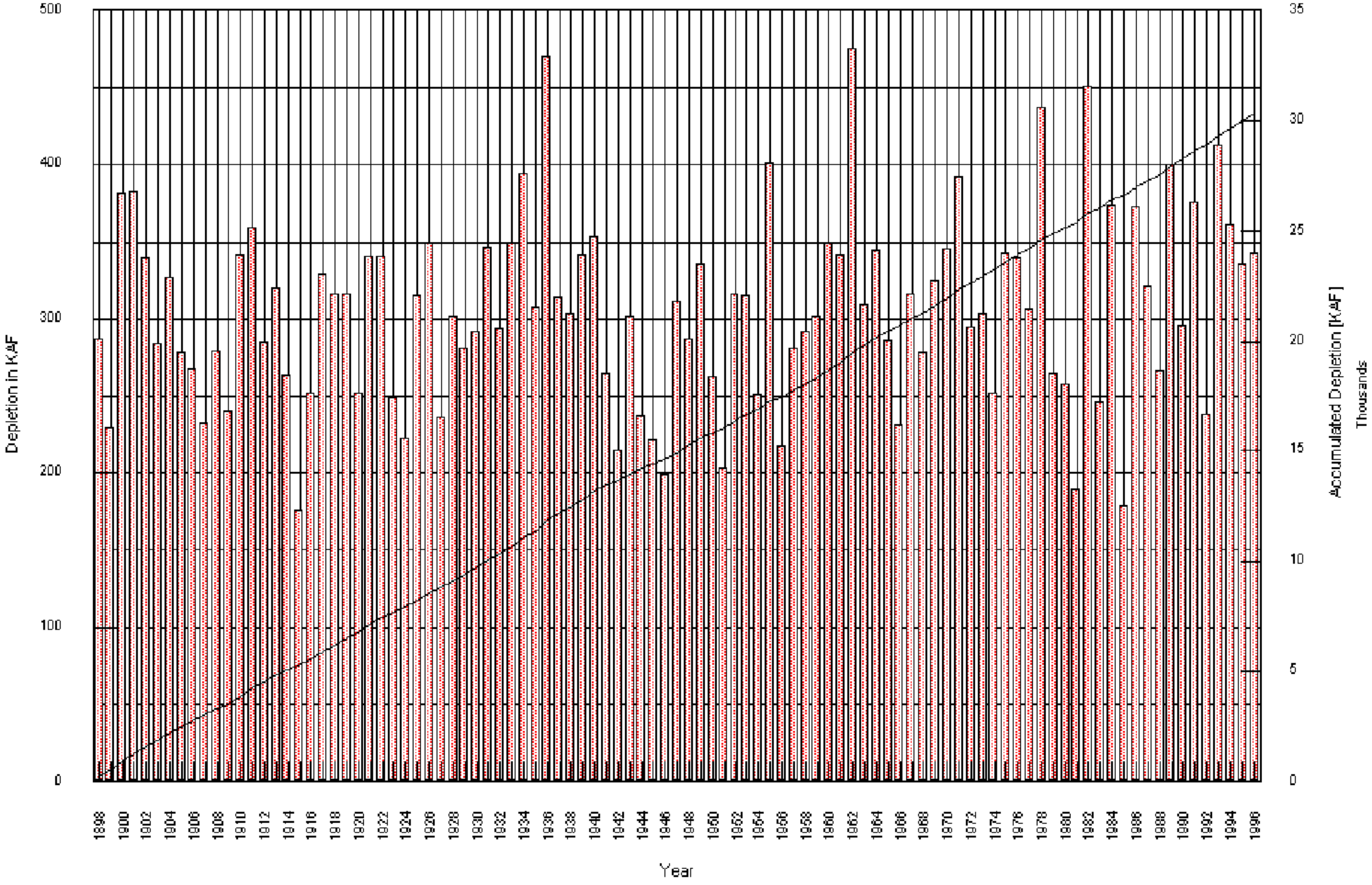
Total All Historic Depletions Boonville to Hermann



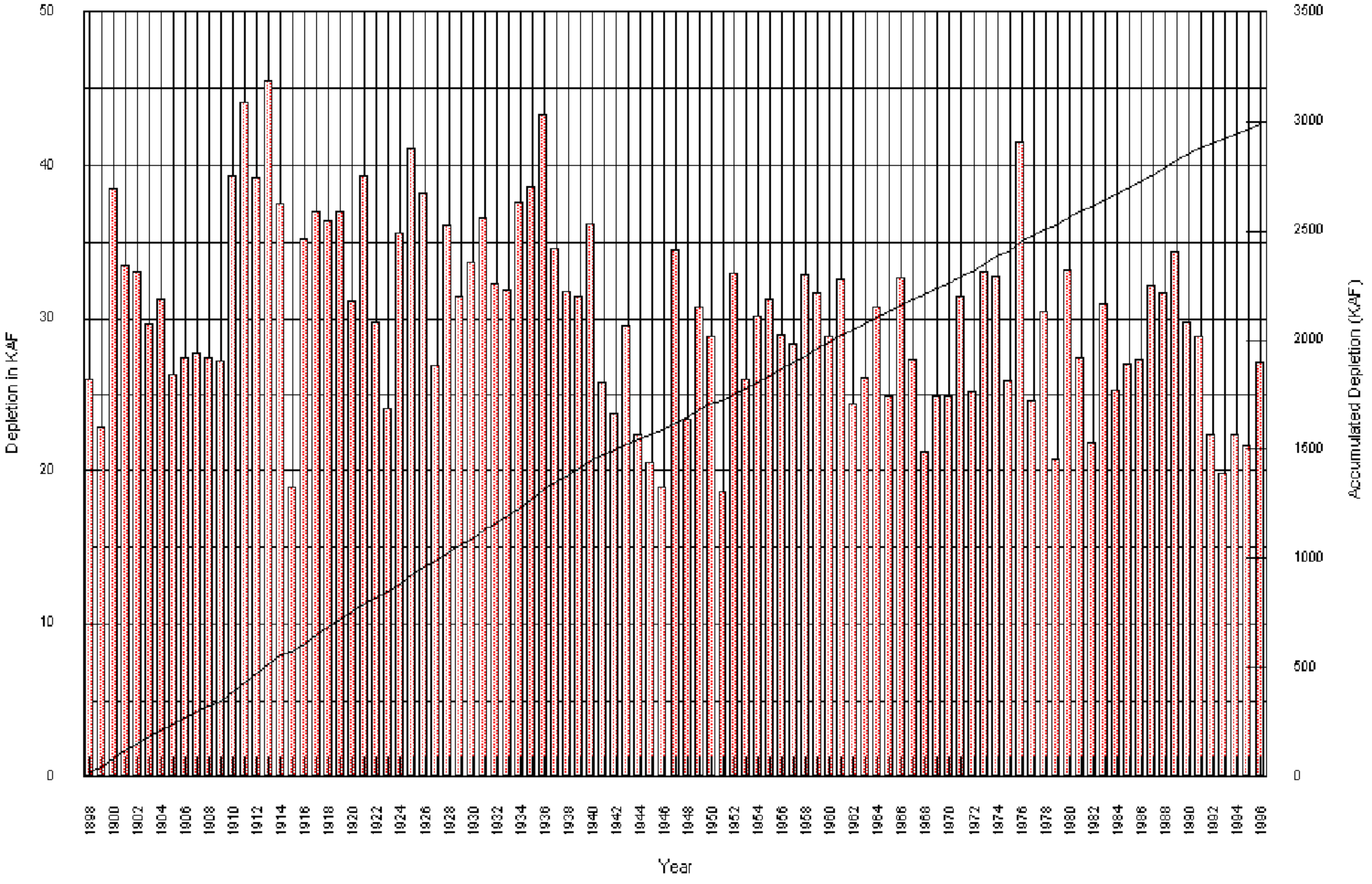
Total All Present-Level Depletions above Fort Peck Reservoir

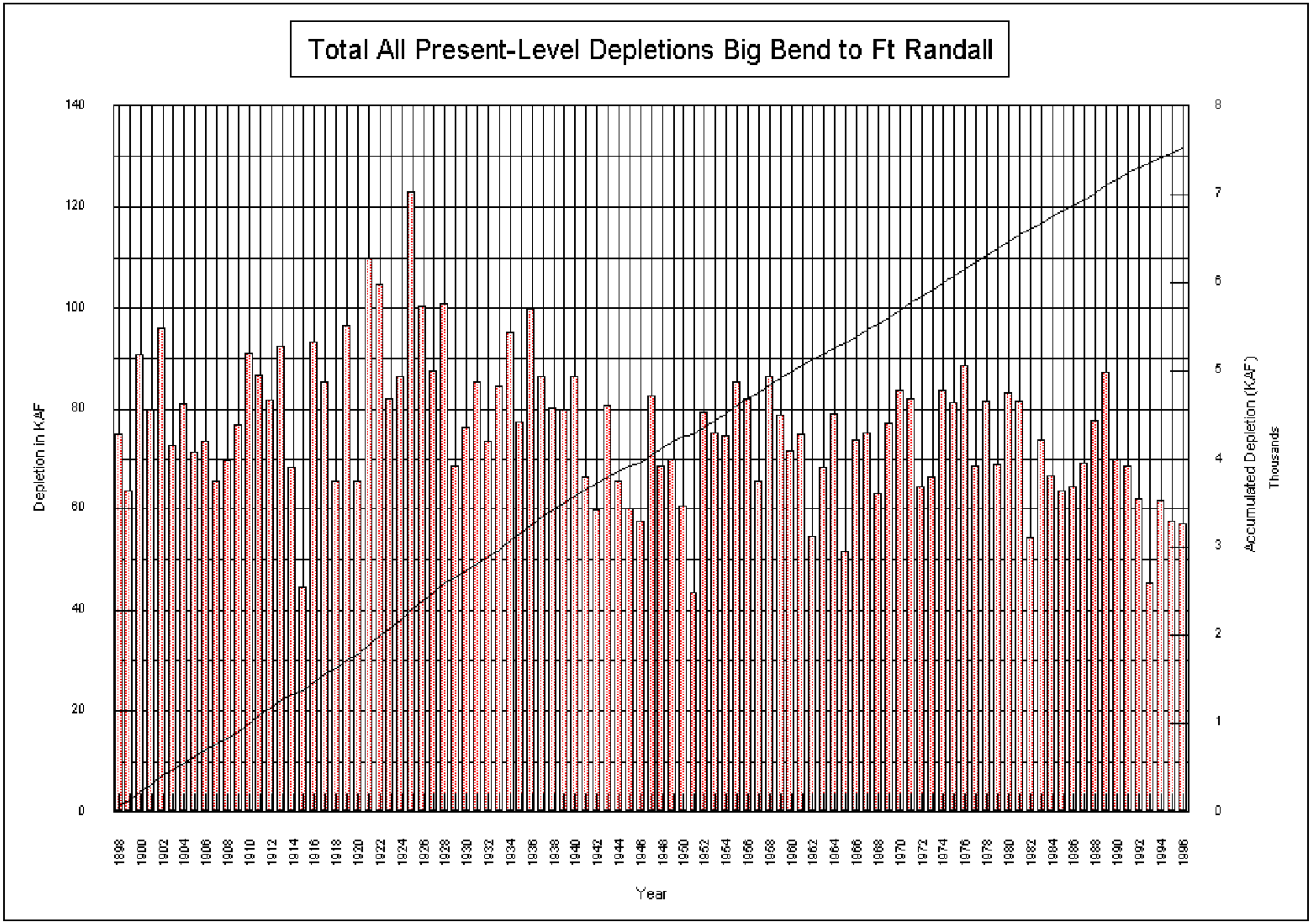

Total Present Level Depletions Ft Peck to Garrison

Total All Present-Level Depletions Garrison to Oahe



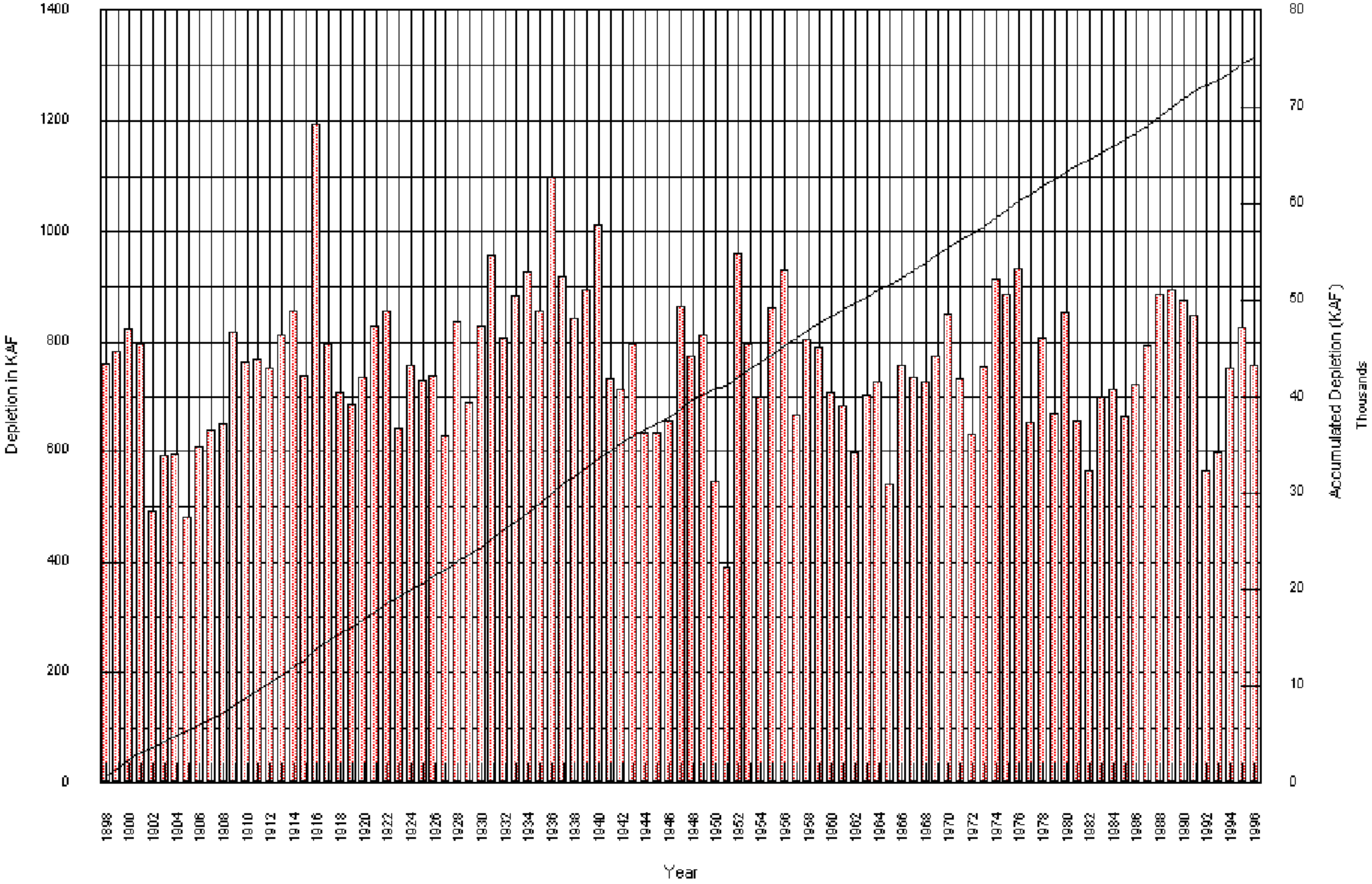
Total All Present-Level Depletions Oahe to Big Bend

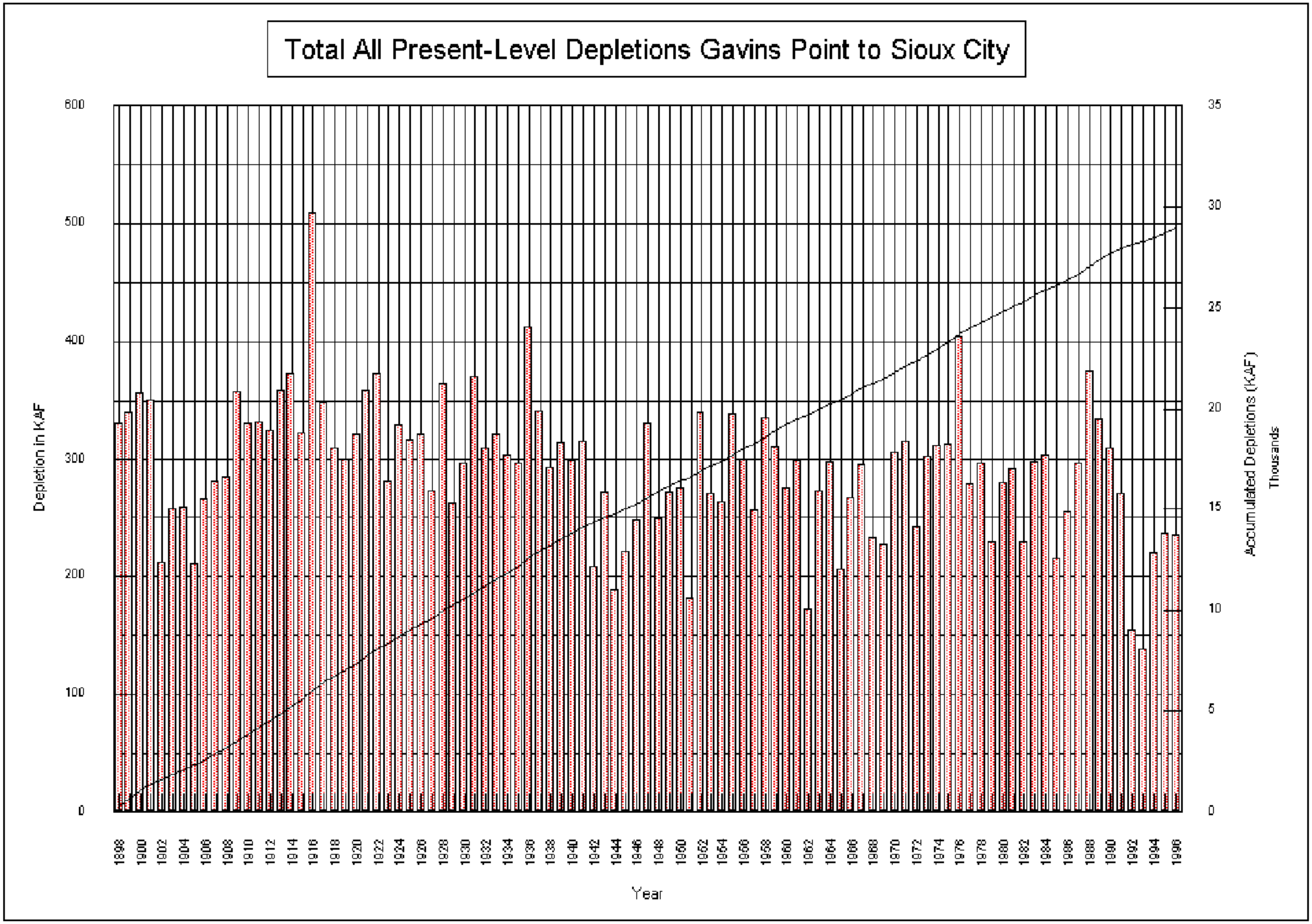




Total All Present-Level Depletions Big Bend to Ft Randall

Total All Present-Level Depletions Ft Randall to Gavins Point




Total All Present-Level Depletions Gavins Point to Sioux City
Depletion in KAF
600
500
400
300
200
100
0
Accumulated Depletions (KAF)
Thousands
35
30
25
20
15
10
5
0
1898
1900
1902
1904
1906
1908
1910
1912
1914
1916
1918
1920
1922
1924
1926
1928
1930
1932
1934
1936
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1954
1956
1958
1960
1962
1964
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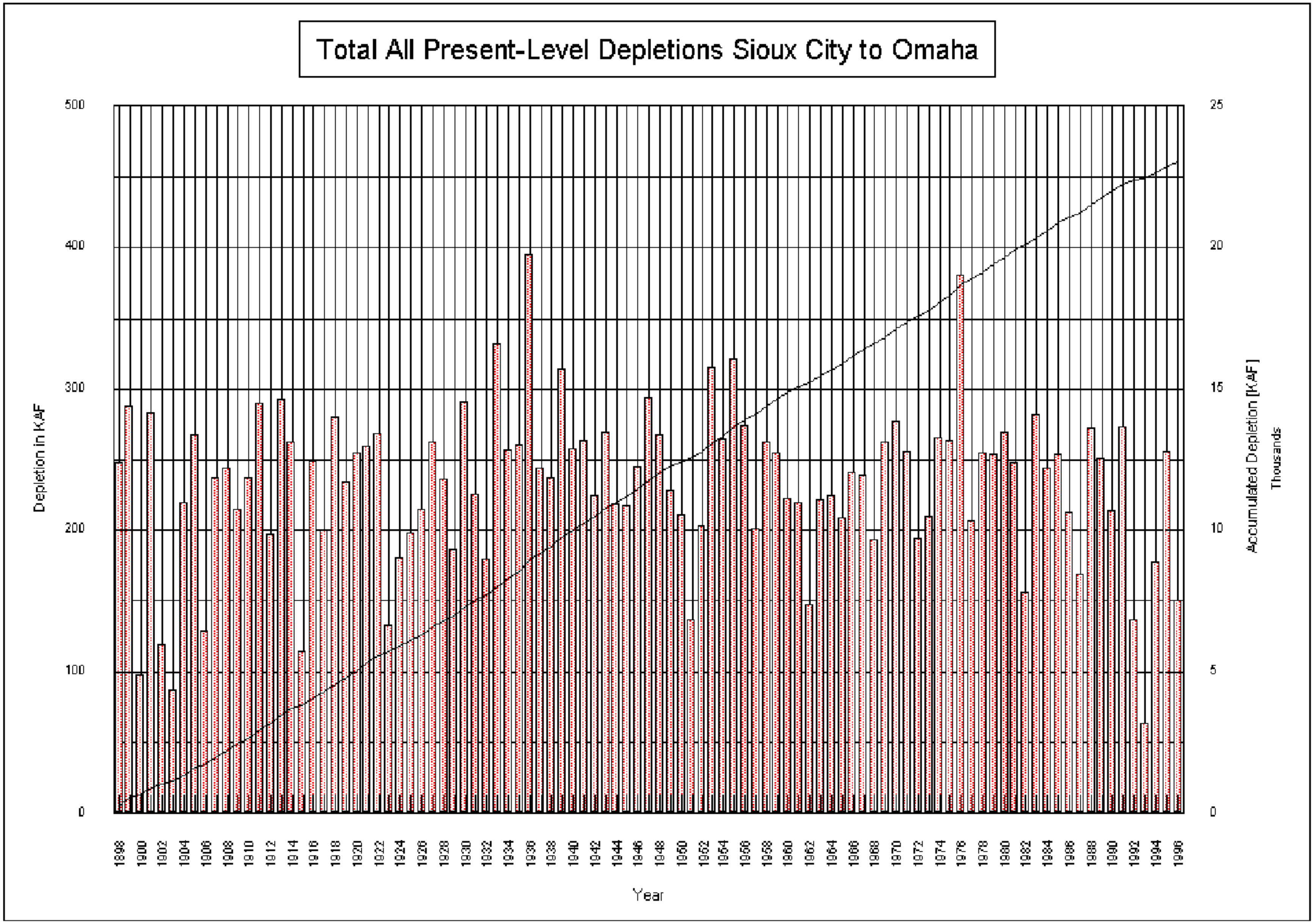
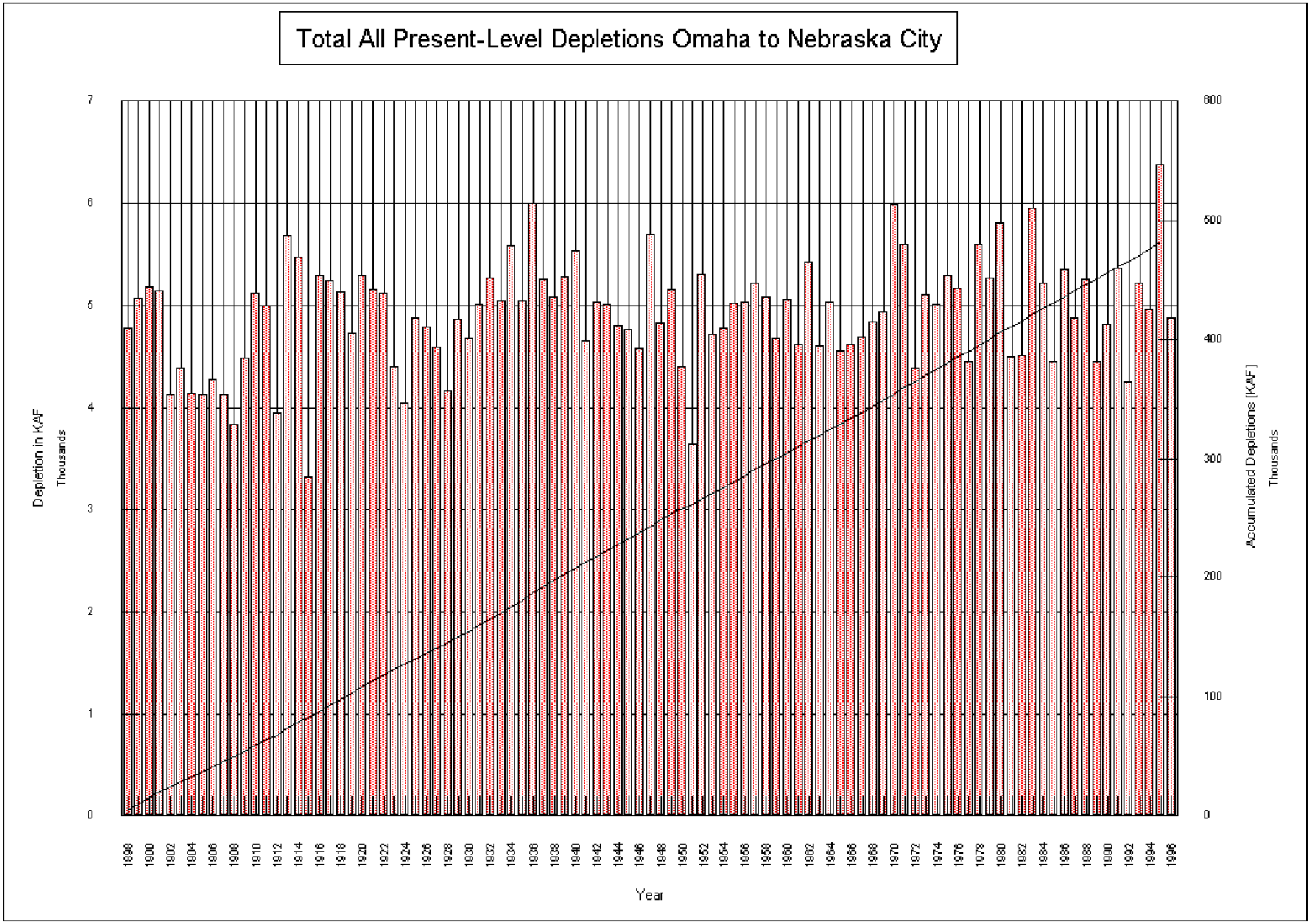
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
Year

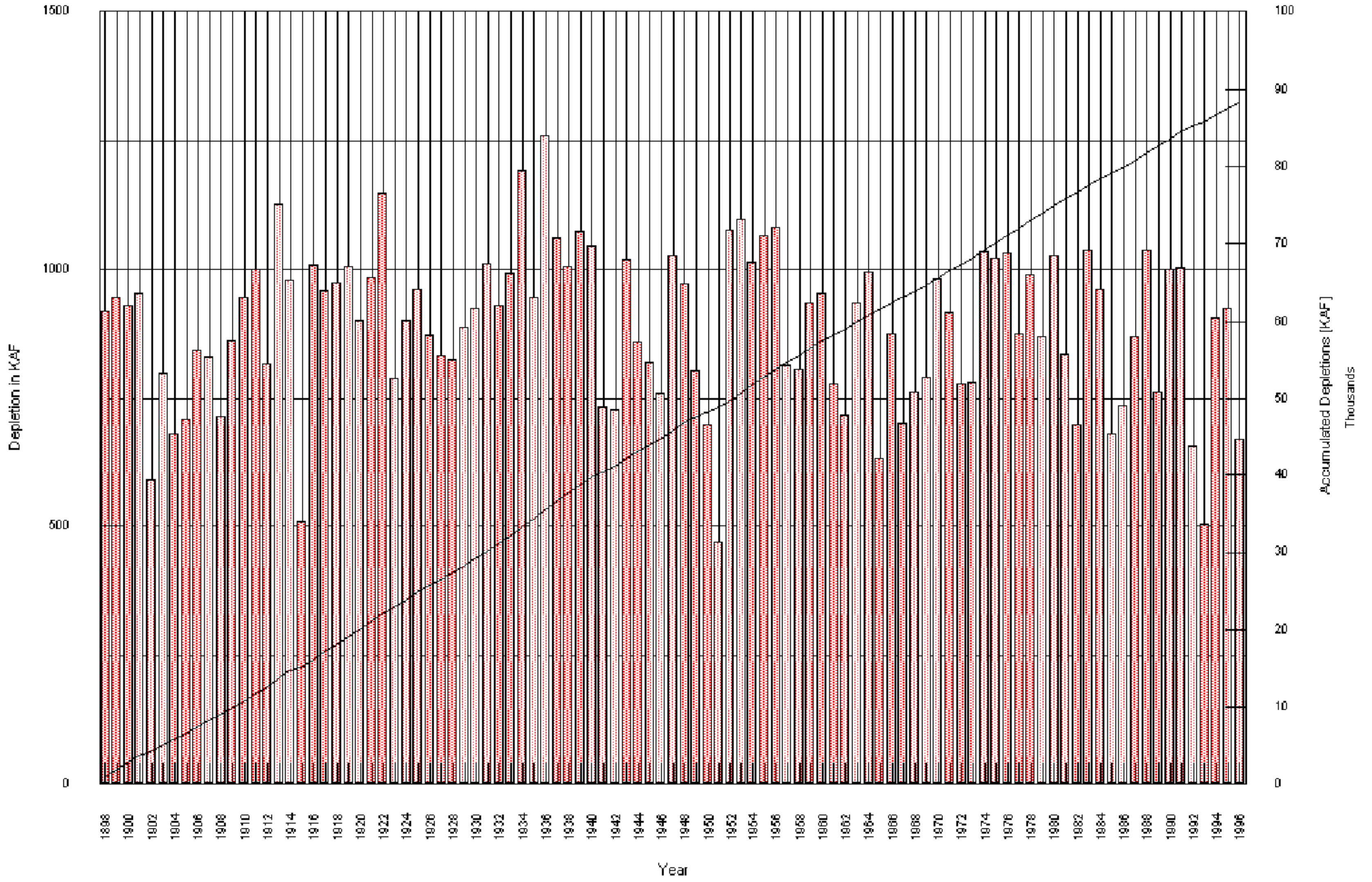


Total All Present-Level Depletions Sioux City to Omaha



Total All Present-Level Depletions Omaha to Nebraska City

Irrigation Only Present-Level Depletions Kansas River Basin



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Appendix F-D
Auxiliary Programs Developed for Use in Data Processes

Executable Programs – Unless otherwise noted, all executable programs were compiled with Microsoft Fortran PowerStation Version 4.0.

converter.exe – Program takes data from USBR (in format as submitted) at each reservoir location and converts it into format that will be readable by creator.exe. Program prompts user for input file name, output file name, type of data (inflow, outflow, storage, or elevation), and the 4-letter code for the reservoir. Input data is by water year and must be converted to calendar year.

creator.exe – Program that creates one or more years of input data for the UFDM model (starting with reservoir and station data) using files created by DSSconvert.exe or converter.exe. Program prompts user whether one or multiple years of data files are desired to be created, what year(s), and whether or not reach inflow data is to be built into the input files. The program then goes station by station prompting the user for: the name of the input file for flows (gage stations only); whether reservoir records are based on records of inflow and outflow, storage, or both; whether reach inflow records at each mainstem reservoir are to be included (if user previously answered yes); and whether the reservoir should have precipitation and evaporation records built into the input file. The program automatically creates a file named HOLDxxxx.in1, where xxxx stands for the year of each file.

DSSconvert.exe – Program takes data from DSS format and converts it to format readable by creator.exe. As written, the data must first be written to a text file from DSSUTL using the WR.T command, but the program could be modified to read directly from a DSS file. Program prompts user for the desired station, the type of data being input, the beginning date of data, as well as the ending year for data. The program automatically names the output file based on station name and type of data.

evap.exe – Program reads climate data (evaporation) and computes monthly evaporation. Missing daily data is filled in from monthly average values supplied by user.

freq.exe - This program will read in a file, freqhold.in, containing years and the names of files created with DSSMATH macros (see maxYYYY.txt below) that have the maximum unregulated flow values for each gaging station below Gavins Point for each year as determined using UFDM. The program then outputs the maximum flow values in a text-format file (can be imported into EXCEL).

freqreg.exe - This program will read in a file, freqreg.in, containing the names of files created with DSSMATH macros (see regYYYY.txt) that have the maximum regulated flow values for each gaging station below Gavins Point for each year. The program then outputs the maximum flow values in a text-format file (can be imported into EXCEL). The program is very similar to freq.exe, except for the number of stations that are processed.

janstore.exe - This program will read in a file, janstore.in, containing the names of files created with DSSMATH macros (see storjan.bat) that have storage values for each reservoir project on January 1 of each year. The program will then output the storage values in a format for the UFDM program.

mixtest.exe – Program developed by HEC to take results from two populations of flow data and combine into one final frequency curve. Unknown compiler.

plotter.exe - This program will prompt the user for the type of plot desired (single station with multiple years for a single parameter, multiple stations for a single parameter for a single year, or multiple parameters for a single station in a single year) from the HOLDOUT.DSS file created by UFDM. The program then creates a macro file (macro.plt) that will plot the desired parameters/stations/years using d.bat and DSPLAY. The stations for which parameters can be plotted include: Fort Peck, Wolf Point, Culbertson, Garrison Dam, Bismarck, Oahe Dam, Big Bend Dam, Fort Randall Dam, Gavins Point Dam, Yankton, Sioux City, Decatur, Omaha, Nebraska City, Rulo, St. Joseph, Kansas City, Waverly, Boonville, and Hermann. Parameters that can be plotted include: unregulated flow; depletions; holdouts – all; holdouts - mainstem; holdouts - above Fort Peck; total inflow (or actual flow at gage stations); and reach inflow; which are all available at all stations, along with holdouts from each reservoir as they are routed downstream.

precip.exe – Same as evap.exe, except using precipitation data

regulate.exe – Program reads in text output files created by DRM (abaa10.eld, abaa10.q1d, and abaa10.q2d), and writes the daily values at each station to a DSS file. Once the output is converted to DSS, annual maximums can be extracted with freqreg.exe.

regvolume.exe - This program will read in a file, regvolum.in, containing the names of files created with regXXX.bat that have maximum flow volume values for various durations for each gaging station below Gavins Point for each year. The program then outputs the maximum flow values in a text-format file (can be imported into EXCEL). There are slightly different versions of this use on unregulated and regulated data due to the differing number of stations

Batch Files

combine.bat – Batch file creates input files for UFDM for each year by combining files containing the reservoir-storage relationships and routing parameters, the depletion data, and the reservoir and gaging station info for each year.

d.bat – Batch file used in conjunction with plotter.exe to call the proper DSS macro to create plots displayed by DSPLAY.

maxall.bat – Batch file used to call DSS macros (see maxYYYY.txt) to create input files for freq.exe.

monthreach.bat – Batch file used to call DSS macros (see XXXmohld.txt and XXXmornf.txt) to create a DSS file with monthly incremental flow data at each station.

monthvolumes.bat - Batch file used to call DSS macros (see XXXmovol.in) to create a DSS file with monthly flow volumes for unregulated flow at each station.

omadist.bat - Batch file used to call DSS macros (see XXXreduc.in) to divide convert observed flows from cfs to Kcfs, so that a direct comparison between observed flows and DRM computed flows can be made.

peakperiods.bat - Batch file used to call DSS macros (see XXXvolum.in) to create a DSS file with 1-, 3-, 7-, 15-, 31-, 91-, and 181-day moving averages of unregulated or regulated flows for use in determining volume-duration relationships.

regall.bat - Batch file used to call DSS macros (see regYYYY.txt) to create input files for freqreg.exe.

regXXX.bat - Batch file used to call DSS macros (see XXXYYYY.txt) to retrieve maximum annual values for various durations of regulated flow and create input files for use by regvolume.exe. XXX stands for the station being processed (i.e. YKN=Yankton, SUX=Sioux City, DEN=Decatur, OMA=Omaha, NCN=Nebraska City, RUN=Rulo, STJ=St. Joseph, MKC=Kansas City, WVM=Waverly, BNM=Boonville, HEM=Hermann).

storjan.bat - Batch file used to call DSS macros (see storYYYY.txt) to create that will be read by janstore.exe for use in UFDM input files.

values.bat - Batch file used to call DSS macros (see XXXvolum.in) to create volume-duration relationships for design floods.

DSS Macros

4kc.in – Macro that retrieves the daily unregulated flow record for NWK gages created by UFDM from HOLDOUT.DSS and writes to a new DSS file.

4kcobs.in - Macro that retrieves the daily observed flow record for NWK gages from HOLDOUT.DSS and writes to a new DSS file.

adjbend.in – Macro used with monthly.in to smooth out oscillating reach inflow values for Big Bend inflow.

adjftra. in – Macro used with monthly.in to smooth out oscillating reach inflow values for Fort Randall inflow.

adjplne.in – Macro that retrieves USGS daily and monthly observed flow record on Platte (NE) River and patterns the monthly depletion data after the observed hydrograph

ashmonth.in – Macro to convert observed USGS daily observed Platte (NE) River flows to mean monthly flow values; used with adjplne.in.

conhist.txt - Macro used to convert USBR historic monthly depletion data to daily flows for DRM model input.

convert.txt – Macro used to convert USBR current level monthly depletion data to daily flows for DRM model input.

denecom2.in – Macro used with denecomp.in to compute Decatur flows prior to USGS records by routing Sioux City flows to Decatur, then to Omaha, and then computing the incremental inflow from Sioux City to Omaha. It then ratios the inflow by incremental drainage areas, and back-route the Sioux City to Decatur incremental inflow to determine the Decatur flows.

denecomp.in - Macro used with denecom2.in to compute Decatur flows prior to USGS records by routing Sioux City flows to Decatur, then to Omaha, and then computing the incremental inflow from Sioux City to Omaha. It then ratios the inflow by incremental drainage areas, and back-route the Sioux City to Decatur incremental inflow to determine the Decatur flows.

differ.txt – Macro used to compute difference between historic and current level depletions for input into DRM model; used after conhist.txt and convert.txt.

dplmonth.in – Macro to convert daily Platte (NE) River depletions to mean monthly values; used to help determine ratio of monthly depletions and monthly observed flow.

dplsmoth.in – Macro used to smooth Platte (NE) River depletions using 3- and 7-day moving averages.

gavinmax.txt – Macro used to retrieve maximum annual Gavins Point flow over period of record from DRM output.

maxYYYY.txt - Macro used to retrieve the maximum unregulated flow at each station for each year. Used in conjunction with freq.exe. YYYY stands for the year (1898-1997).

monthly.in - Macro used with adjbend.in and adjftra.in to smooth out oscillating reach inflow values for Big Bend and Fort Randall inflow. This is necessary as the computed reach inflow in high flow periods can oscillate due to the short travel times into Big Bend and Fort Randall. Otherwise, the oscillating reach inflows into these reservoirs will be routed downstream in the UFDM as part of the computed holdouts, and cause the computed unregulated flow values to oscillate downstream.

platcomb.in – Macro that combines the Platte (NE) River observed flows and depletions to produce an unregulated flow data set for the Platte River at either Ashland or Louisville.

plnem2da.in – Macro that prorates Platte River depletions from monthly values to daily values prior to 1928.

reachall.txt – Macro that retrieves all daily computed reach inflow values from HOLDOUT.DSS and places in another DSS file.

reachXXX.txt – Macros used to retrieve computed reach inflows and multiply by a given percent for use in computing design floods. XXX stands for the percent the values are increased by (i.e. 25=25%, 50=50%, 75=75%, 100=100%)

rechinf2.txt – Macro similar to reachall.txt, except Yankton and Sioux City reach inflows are combined and Decatur and Omaha reach inflows are combined for use with DRM data.

regYYYY.txt – Macros used to retrieve the annual maximum regulated flow at each gaging station. Used with regall.bat and freqreg.exe. YYYY stands for the year being processed (1898-1997).

runecom2.in - Macro used with runecomp.in to compute Rulo flows prior to USGS records by routing Nebraska City flows to Rulo, then to St. Joseph, and then computing the incremental inflow from Nebraska City to St. Joseph. It then ratios the inflow by incremental drainage areas, and back-route the Nebraska City to Rulo incremental inflow to determine the Rulo flows.

runecomp.in – Macro used with runecom2.in to compute Rulo flows prior to USGS records by routing Nebraska City flows to Rulo, then to St. Joseph, and then computing the incremental inflow from Nebraska City to St. Joseph. It then ratios the inflow by incremental drainage areas, and back-route the Nebraska City to Rulo incremental inflow to determine the Rulo flows.

storYYYY.txt- Macros used to retrieve storage values at each reservoir on 1Jan of each year for input into UFDM. Used with storjan.bat. YYYY stands for the year being processed (1910-1997).

sumYYYY.txt - Macros used to retrieve the maximum unregulated daily flow at each station for the period 1May to 31Dec for each year for use in mixed population analysis. Similar to winYYYY.txt. YYYY stands for the year (1898-1997).

unreg.in – Macro to retrieve daily unregulated flow values at all gages from HOLDOUT.DSS file.

usbrmnth.in – Macro to convert Platte (NE) River depletions from acre-feet (as supplied by USBR) to d-sf before manipulation by other macros.

winYYYY.txt - Macros used to retrieve the maximum unregulated daily flow at each station for the period 1Jan to 30Apr for each year for use in mixed population analysis. Similar to sumYYYY.txt. YYYY stands for the year (1898-1997).

XXfloinY.txt – Macros used to increase flow at gaging stations to correspond with increased reach inflows for use in modeling design floods with UFDM and DRM to extend the regulated-unregulated relationships. XX stands for the % increase in reach inflow (i.e. 25=25%, 50=50%, 75=75%, 00=100%). Y designates various design flood years (i.e. 1960, 1978, 1984, 1993, 1997).

XXX19YY.txt - Macros used to retrieve maximum flow value for various durations of flow from regulated flow data set; used with regXXX.bat. XXX represents the station being processed (i.e. YKN-Yankton, SUX-Sioux City, DEN-Decatur, OMA-Omaha, NCN-Nebraska City, RUN-Rulo, STJ-St. Joseph, MKC-Kansas City, WVM-Waverly, BNM-Boonville, HEM-Hermann). YY stands for the last two digits in the year being processed.

XXXmornf.txt - Macros that extract computed reach inflow at each station form HOLDOUT.DSS and converts daily values to monthly values.

XXXmovol.in – Macro that converts daily unregulated flow to mean monthly flows for analysis of monthly flows over various periods.

XXXreduc.in – Macro to convert observed flows from cfs to Kcfs, to compare against DRM output. XXX stands for station (i.e. SUX-Sioux City, OMA-Omaha, NCN-Nebraska City, and RUN-Rulo).

XXXvolum.in – Macros used to retrieve daily flow from UFDM and DRM output and compute mean flow for various periods (1-, 3-, 7-, 15-, 31-, 91-, & 181-days) at each station. Values used to assist in volume-duration analysis; used with peakperiods.bat. XXX stands for station being processed.

XXXXevap.txt – Macros to convert pan evaporation to lake evaporation at tributary reservoirs. XXXX is 4-letter symbol for tributary reservoir (ANGA-Angostura, BOHA-Bowman-Haley, BOYN-Boysen, BUBI- Buffalo Bill, BULA-Bull Lake, CAFE-Canyon Ferry, CLCA-Clark Canyon, FDMT-Fresno, GDMT-Gibson, HEBN-Hebgen, HEBU-Heart Butte, JATO-Jamestown, KEYO-Keyhole, PACA-Pactola, PIPE-Pipestem, SHHI-Shade Hill, TIBR-Tiber, YETL-Yellowtail).

XXXXmoev.in – Macros used to convert pan evaporation to lake evaporation at each mainstem dam. XXXX stands for the dam (i.e. FTPK-Fort Peck, GARR-Garrison, OAHE-Oahe, BEND-Big Bend, FTRA-Fort Randall, GAPT-Gavins Point).

XXXYYYY.txt – Macro used to retrieve annual maximum unregulated or regulated flow volumes for various durations at each station. XXX stands for the station being processed (i.e. YKN=Yankton, SUX=Sioux City, DEN=Decatur, OMA=Omaha, NCN=Nebraska City, RUN=Rulo, STJ=St. Joseph, MKC=Kansas City, WVM=Waverly, BNM=Boonville, HEM=Hermann). YYYY stands for the year being processed (1898-1997).

yknsux.in - Macro to subtract incremental inflow data from DRM input data at Sioux City from the observed Sioux City flows and back-route to Yankton to obtain pre-USGS period Yankton flows.

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Appendix F-E
Null Internal Boundary Condition Ungaged Inflow Optimization

Null Internal Boundary Condition

The Null Internal Boundary Condition (NIBC) is a tool for estimating ungaged lateral inflow in a river system. The NIBC feature is used by the Omaha District to reproduce flow at the USGS gage locations at Sioux City, Decatur, Omaha, Nebraska City, and Rulo. Use of the NIBC is an important component of calibrating the model to both flow and stage.

The technique optimizes ungaged inflow to reproduce either a stage hydrograph or a flow hydrograph at the NIBC station. When optimizing the stage hydrograph, the reproduction of flow is secondary, being dependent on the calibration of the model. Likewise, when optimizing the flow hydrograph, the reproduction of stage is secondary, being dependent on the calibration of the model. Optimizing stage is generally used for a flood forecast model, where stage accuracy is the primary goal. Optimizing flow is used whenever the observed flow record must be maintained, such as a period-of-record frequency analysis. In either case, the ungaged inflow compensates for all the errors in the measurement of stage and flow and for systematic changes in roughness and geometry, that may not be included in the model. As a result, the ungaged inflow determined using the NIBC procedure includes both flow and an error correction term.

Using the observed flow hydrographs, the river routing reach is divided into two routing reaches that are bounded by two streamflow gages. For example, Omaha to Nebraska City forms a routing reach bounded by gage stations. Flow is routed from the upstream station to the downstream station using the upstream flow . This flow does not include the ungaged flow. Next, to determine the flow at the downstream location with the ungaged included, the flow upstream based on a stage boundary condition is computed from the hydrodynamics and the geometry reach downstream. The ungaged inflow hydrograph is determined using DSSMATH procedures. The hydrograph is estimated by subtracting the routed hydrograph from the computed hydrograph. The computed difference is lagged backward in time and inserted into the model as a uniform lateral inflow. The lag time varies according to travel time between the gage stations. Ungaged inflow between the gaging stations is distributed according to drainage area. The ungaged drainage area is summarized within plate 1.

UNET Application of NIBC.

Within the UNET model, the NIBC is inserted between two identical cross-sections that are separated by a small distance. NIBC flags were inserted at Sioux City, Decatur, Omaha, Nebraska City, and Rulo within the Omaha District model. Both a flow and stage hydrograph are required at all NIBC locations.

Insertion of NIBC flags is implemented within the UNET graphical user interface. NIBC flags are inserted within the cross section file. A typical format for the NIBC is as follows:

```
!NIBC START
IX732.38                               1       1       1
Z0 0
OH \MROPOR\MORHIST.DSS:/MISSOURI RIVER/SIOUX CITY/ELEV//1DAY/OBS/
OH \MROPOR\OMADAILY.DSS:/MISSOURI/SUX/FLOW//1DAY/OBS/
HY SIOUX CITY US - RM 732.38

uq \MROPOR\oma_uq.DSS:/MISSOURI RIVER/YANKTON TO SIOUX CITY/UNGAGED INFLOW//1DAY/EST/
lg    -1    -901       0  -15000      -1           10000    3432       0       0
pq       798      1158                   JAMES UNGAGED
pq     787.6       304                       BOW CREEK
pq     745.2       222                      AOWA CREEK
pq     737.3       132                       ELK CREEK
pq       735      1146               BIG SIOUX UNGAGED
NI SUX

IX732.38                               1       1       1
OH \MROPOR\OMADAILY.DSS:/MISSOURI/SUX/FLOW//1DAY/OBS/
HY SIOUX CITY DS - RM 732.38
!NIBC END
```

The NIBC assumes that the stage and flow at the two cross-sections are the same; hence, if the upstream cross-section is number j, then

$$\begin{aligned} Z_j^n &= Z_{j+1}^n \\ Q_j^n &= Q_{j+1}^n \end{aligned} \qquad (1)$$

in which Z is the stage and Q is the flow.

When optimizing stage, the river routing reach is effectively broken into two routing reaches. The stage hydrograph is used as the downstream boundary for the upstream reach and the stage hydrograph is used as the upstream boundary for the downstream reach; cross-sections j and $j+1$ are downstream and upstream boundaries respectively. Figure 1 shows the upstream and downstream routing reaches.

When optimizing flow, the flow hydrograph is applied as the upstream boundary at cross-section $j+1$ and serves as the upstream boundary of the downstream reach. The stage hydrograph is still applied at cross-section j and serves as the downstream boundary of the upstream reach. All optimization within the Omaha District was performed with flow.

After running the model, the flow at j is the routed flow from upstream. Since the ungaged inflow is unknown and not entered, the flow at j is missing the ungaged inflow. For the downstream reach, the flow at $j+1$ contains the ungaged inflow. If the flow at $j+1$ is computed from a stage boundary condition, the flow is generated by the hydrodynamics and the geometry of the reach downstream. The ungaged inflow is the difference between the flow hydrographs at j and the flow at j+1,

$$Q_U^1 = Q_{j+1}^n - Q_j^n \qquad (2)$$

in which Q_U^1 is the ungaged inflow for iteration 1.

The ungaged inflow enters from the upstream boundary of the upstream reach to cross-section j , the downstream boundary. To use the ungaged inflow in a model, the flow is lagged backward in time (usually one day) and inserted in the model as point and uniform lateral inflow. Point inflow occurs a known ungaged tributaries and uniform inflow is the remainder. The inflow is normally distributed by drainage area. The backward lag is adjusted by distance. For example, if a one day lag is assumed, the upper one-half of the reach has a lag of one day and the lower one-half of the reach has no lag.

The NIBC is inserted at the principal gage locations where the stage or flow records are the most accurate. Generally, these locations are the USGS (U. S. Geological Survey) gaging stations. If a reach includes k interior gages, inserting NIBC at each of the gages creates k routing reaches.

Ungaged Inflow Optimization.

Optimization is performed using a series of UNET runs to iteratively improve the estimated ungaged inflow based on replicating the observed hydrograph at the gaging station. Ungaged inflow is optimized by successively applying ungaged inflow to the upstream reach. The initial estimate of ungaged inflow is computed using equation 2 and ungaged inflow is successively corrected using:

$$Q_U^k = Q_U^{k-1} + \left(Q_{j+1}^n - Q_j^n\right) \qquad (3)$$

This iterative procedure usually requires three to five iterations to converge. For a free flowing river, the ungaged inflow can be optimized for the routing reaches simultaneously, since, the flow computation at j+1 is not impacted by the ungaged inflow downstream. This procedure is called simultaneous optimization.

For flat streams, when a stage hydrograph is applied, backwater from downstream of the NIBC will impact the convergence of the ungaged inflow for the upstream reach. The flow at cross-section j+1 is computed from the stage hydrograph. If cross-section j+1 is impacted by backwater, the flow changes with the degree of backwater. Hence, the flow at j+1 changes as ungaged inflow is applied downstream and the optimization of ungaged inflow begins to oscillate. The computed flow at cross-section j+1 is dependent on the ungaged inflow downstream. Generally, this problem occurs on streams with a gradient less than 0.2 feet per mile. Optimizing the reaches one reach at a time can eliminate this problem. This procedure is called sequential optimization.

After ungaged inflow is optimized simultaneously, an error still exists in the routed flow hydrograph at cross-section j. Simultaneous optimization of all gaging stations preserves this error, which can be significant after the stage hydrographs at the NIBC's are released. However, sequential optimization corrects these errors as the optimization moves downstream. Therefore, after simultaneous optimization, the model should be optimized sequentially to correct the residual errors.

The NIBC is inserted into the UNET cross-section file using the NI card between cross-section j and j+1. Cross-section j is a repeat of cross-section j+1 and the reach length between the cross-sections is very small, usually one foot. The only parameter on the NI card is a eight character name which uniquely defines the name of the NIBC when attaching an observed stage or flow hydrograph in the boundary condition file. HY cards must be inserted at cross-sections j and j+1 to define output hydrographs. The OH cards upstream and downstream attach the USGS hydrograph to the plot macro. Within the Omaha District, all null interior boundary simulations were optimized with flow.

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Appendix F-F
Ungaged Inflow Computation

<u>Historic UNET Model</u>. The Missouri River has undergone major changes in its planform and length in the 20th century. In order to conduct a period-of-record UNET analysis of the desired 100-year period, it is necessary to be able to estimate the ungaged local inflow to the river for the entire period. Since the hydraulic characteristics of the river changed during the century, it was necessary to develop several UNET geometry models of the Missouri River to simulate historic hydraulic routings for the entire study period. A Missouri River historic UNET model was developed expressly for the purpose of computing the ungaged inflow for the early 1900's. The geometry of this model reflects the natural conditions of the Missouri River before canalization, and the construction of dikes and levees. The natural channel was wide, braided, and shallow, and meandered freely back and forth across the floodplain. Geometry data from the early 1900's is inexact and incomplete. No data could be located for bluff to bluff overbank geometry. Maps were found for several hydrographic surveys in the early 1900's. In order to compile channel geometry for the entire reach of the Missouri River from RM 498 to the mouth, data from different surveys had to be used. The data used were from surveys conducted in the early 1920's.

The maps of the 1920's hydrographic surveys show the channel and the near overbanks, and depict depth below water surface elevation. Thus, the location of the channel in the floodplain cannot be ascertained from these maps. Also, the locations of the depth measurements along the river are known only approximately, since river miles along the Missouri River have been revised several times over the years. Additionally, the vertical datum, which was used in the early 1900's, is obscure. Its elevation could never be precisely verified.

The channel geometry from the 1920's mapping was merged with the overbank geometry from the 1998 UNET model at each cross section in the 1998 model. The 1920's channel was centered on the channel location in the 1998 model's cross sections. The 1920's channel geometry, which was inserted into each 1998 cross section, was selected according to what was determined to be the closest 1920's depth measurements to that particular 1998 cross section. Following preparation of the historic model's cross sections, the model was calibrated to reproduce flow volumes using flow data from the early 1900's.

<u>Computation of Ungaged Lateral Inflow</u>

In order to perform a period-of-record analysis using UNET, it is first necessary to determine the sources and amounts of historic inflows to the Missouri River that have occurred in the past. This was done by using the historic records at each gage, and an automated routine that has been built into UNET. The automated UNET flow calibration technique was also used for these computations.

Null Internal Boundary. Ungaged tributary inflow and other sources of inflow between the mainstem USGS gages must be accounted for in the UNET model. Estimates of ungaged inflow are computed using the Null Internal Boundary Condition (NIBC) procedure of the UNET program. To use NIBC, the UNET model was automatically calibrated using rating curves at the mainstem USGS gaging stations listed in Table E-19. The exception is the St. Charles gage, which is a stage gage in the backwater of the Mississippi River. Rating curves are derived for the gages from the observed data. The automatic calibration routine of the UNET program derives the rating curves and calibrates the model by adjusting the rating curves to reproduce stage at the USGS gages, based on observed flows.

Then the NIBC procedure in UNET is used to estimate ungaged lateral inflow throughout the model by optimizing to USGS observed flow. In the cross section file, the NIBC feature is inserted at each of the mainstem gage locations between two identical cross sections. The two cross sections are exact duplicates separated for computational purposes by an extremely small distance, such as one foot. The first cross section is the downstream boundary of a mainstem routing reach, and the second cross section is the upstream boundary of the subsequent mainstem routing reach. Flow data at the upstream cross section is flow computed from routing through the upstream reach. Flow data at the downstream cross section is the target USGS observed flow data.

The NIBC procedure requires iterative executions of UNET until the flow is the same at both the upstream and downstream cross sections. The first execution results in computed flow at the cross section just upstream of each NIBC. The differences in the computed and observed flows at these locations are calculated to get the residual or ungaged inflows for each reach. To achieve flow continuity at the NIBC locations, the ungaged inflows are then distributed throughout the upstream reach and lagged in time as appropriate. The second execution uses these ungaged inflows as lateral and/or point inflow hydrographs. The differences in computed and observed flows are again calculated, and the procedure is repeated until the differences in flow approach zero. The last execution removes the NIBC and runs with the final computed ungaged lateral inflows.

Computation of Ungaged Lateral Inflow. Ungaged inflow for the period of record analysis was developed by Dr. Robert Barkau using the three different Missouri River UNET models – the historic UNET model for 1900 through 1940, the 1998 UNET model without levees for 1940 through 1961, and the 1998 UNET model with levees for 1961 through 2000. The three models used to calculate the ungaged inflows, were each calibrated using the UNET processes. These steps in the calibration process are the Null Internal Boundary Condition (NIBC), Manning's *n*, fine tuning, and levee performance for the 1961 – 2000 model, which is the only model with levees.

To compute the ungaged inflow with UNET, several boundary conditions files were needed. Each boundary conditions file was for a different time period, ranging from five to ten years. This was needed to accommodate the establishment of tributary gaging stations as they were brought into service at different times.

Using the historic and current condition UNET models, the ungaged inflows were calculated for the period of record. These calculations occasionally produced negative inflows. To avoid instability in the current conditions UNET model, some of these negative inflows were eliminated from the data files. The ungaged inflows were then added to the boundary conditions file of the current conditions UNET model for use in the period of record analysis. In the boundary conditions file of the current conditions model, the ungaged inflows were distributed by average flow at the tributary gages.

UNET has the capacity to distribute this ungaged lateral inflow at various tributaries, or to uniformly distribute lateral inflow through the reach, or a combination of the two methods. Initially the allocation of flow was based on the drainage areas of the major tributaries. Later on, it was found that the ratio of the mean annual discharges at the tributaries gave more satisfactory results. This capacity was used to extend the inflow records at the tributary gages, none of which was long enough to conduct the period of record analysis.

The net result of this procedure is a .dss file for historic inflows to the Missouri River at points between the principal gaging stations. This file served as an input flow file in the period-of-record analysis.

Upper Mississippi River System
Flow Frequency Study

UNET Model Parallel Flow Algorithm
Prepared by Dr. Robert L. Barkau
Appendix F-G

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March 14, 2001

Mr. John Burant
Hydraulics Branch
Rock Island District, Corps of Engineers
Clock Tower Building
P.O. Box 2004
Rock Island, Illinois 61204-2004

Re: UNET Parallel Flow Algorithm.

Dear John,

This letter describes the parallel flow algorithm that I wrote for the UNET program.

The parallel flow algorithm writes the flow behind a levee system to DSS, including the parallel levee flow in the total river flow. The algorithm functions with simple (SF) and complex (EF) levee breaches. The levee storage must be modeled as a storage cell. Figure 1 demonstrates a typical problem. After the upstream and downstream breaches have failed, water flows parallel to the river from the upstream breach to the downstream breach. The river flow between the breaches is reduced by the flow into the upstream breach. In the original UNET formulation, the flow output to DSS is the computed river flow without the parallel river flow. The new program combines the parallel river flow behind the levee with the parallel flow behind the levee and outputs the total flow to DSS.

At a hydrograph location between levee breaches, with the parallel flow option on, the following information is output:

Parameter	**DSS C Part**
Flow in the river	RIVER FLOW
Parallel flow behind the levee	LEVEE FLOW
Total river and levee flow	TOTAL FLOW

Figure 2 shows a sample hydrograph plot between the upstream and downstream breaches of the Elsberry Levee system. In addition to the river stage hydrograph, the program output river flow, levee flow, and total flow hydrographs.

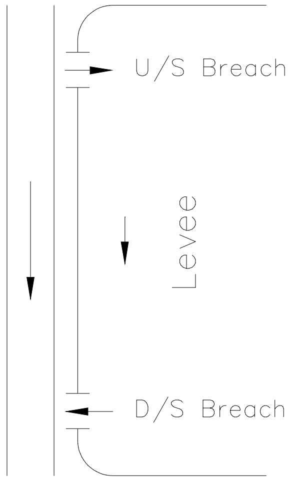


Figure 1. A typical levee system with parallel flow. Flow enters the levee through the upstream breach and exits through the downstream breach. The parallel flow is the minimum of the inflow and the outflow.

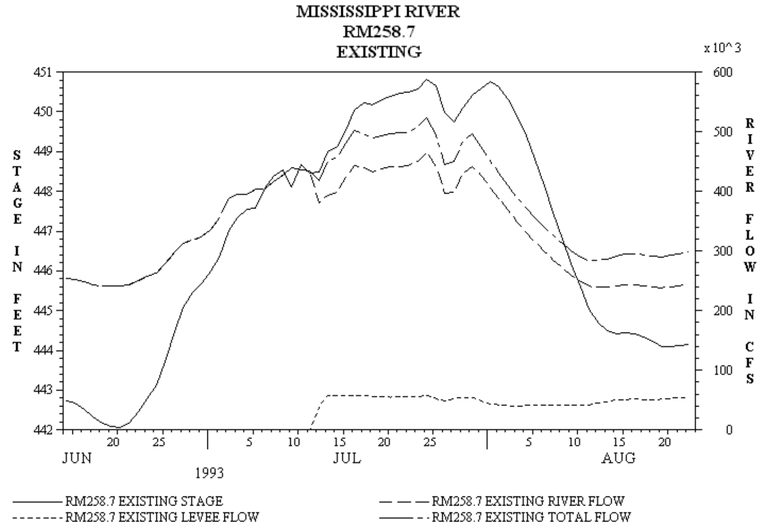


Figure 2. Hydrograph at RM 258.7, which is between the upstream and downstream breaches of the Elsberry Levee. The river flow, the levee flow, and the total flow, the sum of river and levee flow are plotted.

With the parallel flow option on, the maximum flow profile includes both river and levee flow. Figure 3 shows the maximum flow profile for the Mississippi River. The flow profile is relatively smooth. In contrast, Figure 4 shows the maximum river flow profile, with and without parallel levee flow. The profile shows the diversions into the Riverland, Elsberry, Columbia, and Harrisonville Levees.

Figure 6 shows a more complex levee system. Flow enters Levee 1 through the upstream and downstream breaches and exits through a breach in the flank levee, entering Levee 2. Water from Levee 2 exits through the downstream breach. This system is similar to the Columbia-Harrisonville complex south of St. Louis.

To solve this system and other more complex systems, the following parallel flow algorithm is defined:

1. Parallel flow only occurs when inflow and outflow occur.

2. The maximum parallel flow for any river system is the minimum of the total inflow and the total outflow – the flux of water from storage does not count; hence,

$$Q_{PMin} = \mathrm{Min}(Q_{In}, Q_{Out})$$

3. Between breaches the parallel flow is the minimum between the total sum of inflow and outflow and the maximum parallel flow; hence,

$$Q_P = \text{Min}\left(Q_{P\,\text{Max}},\ \sum_{i=1}^{k} Q_{B\,i} \right)$$

in which $Q_{B\,i}$ is the breach flow through breach i and k is the current breach number. The breach flow uses the normal UNET sign convention – positive toward the cell and negative away from the cell. The sum is the flux of water up to breach k.

The Columbia-Harrisonville Levee failure occurred at the crest of the 1993 flood. The Columbia Levee failed first and flow accelerated toward the upstream breach. Parallel flow developed upstream, through the Columbia Levee early. When the flank levee failed, at RM 156, the flow from the Columbia Levee filled the Harrisonville Levee storage downstream. By the time parallel flow developed behind the Harrisonville Levee, the peak flow had passed along the river; hence there is a step in the maximum flow profile at RM 156. Figure 5 confirms this scenario. Failures of simple levee systems such as the Elsberry Levee, which fail long before the crest of a major event will produce the smooth flow profile shown in Figure 4.

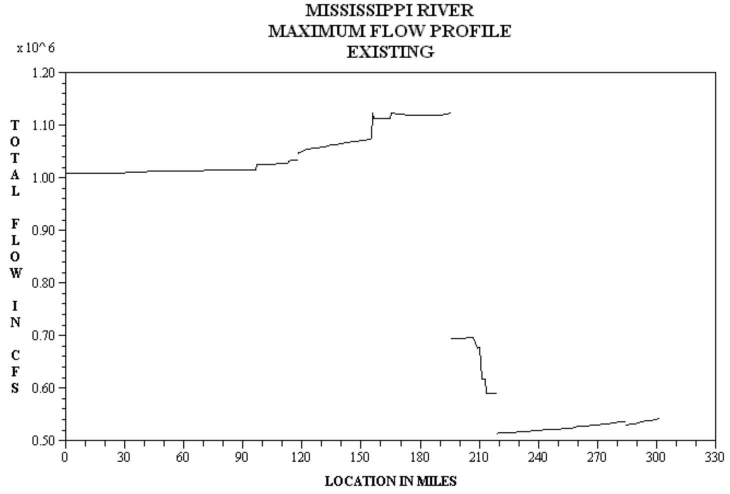


Figure 3. Maximum flow profile with parallel river flow. The significant jumps in flow are located at the Missouri River Crossover and the Missouri River.

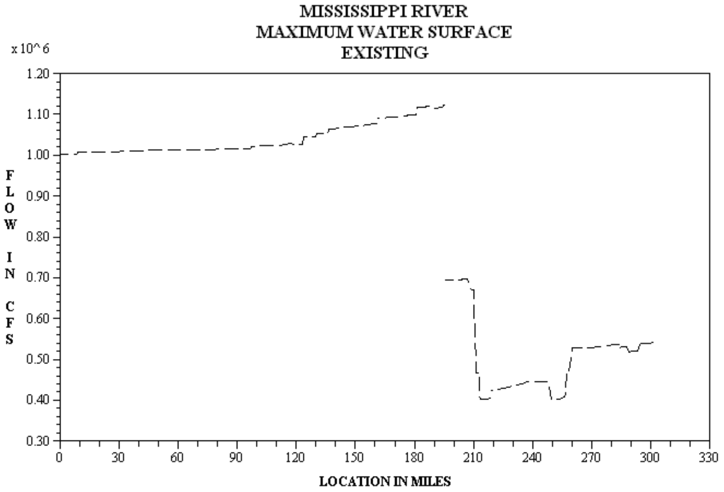


Figure 4. Comparison of maximum flow profiles of total flow and of river flow. The most dramatic impacts are the diversion of water through the Elsberry Levee system, from RM 250 to 260. Because of the timing of the levee failures, the parallel flow behind the Harrisonville Levee has no impact on peak flow.

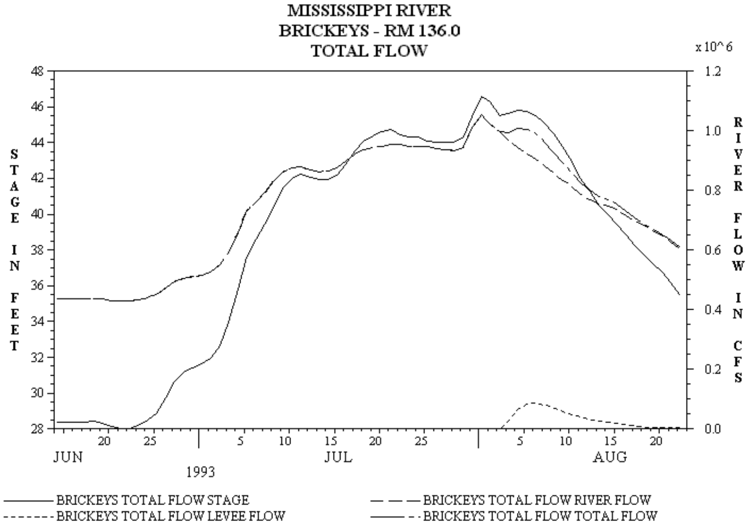


Figure 5. Stage and flow at Brickeys Landing, which is between the upstream and downstream breaches of the Harrisonville Levee. Because of the timing of the failure, the parallel flow behind the levee started after the peak flow. This explains the reduction in flow at RM 156 in Figure 4.

The parallel flow computation is called by including the following line in the boundary condition file:

```
PARALLEL=ON
```

The line can appear anywhere in the BC file before the EJ card.

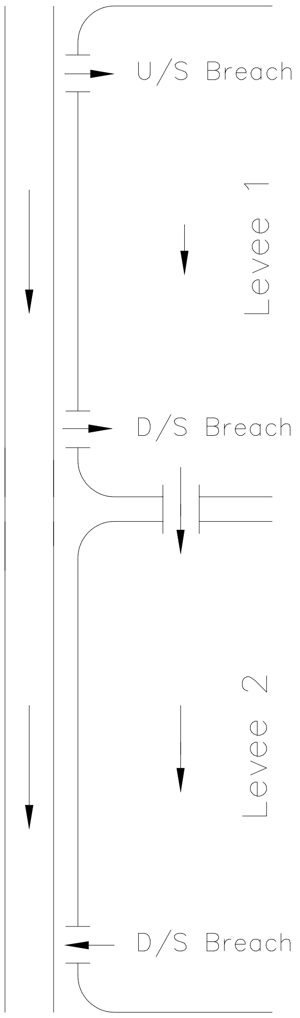


Figure 6. Complex levee systems, similar to the Columbia-Harrisonville Levees downstream of St. Louis.

Final comments: The parallel flow algorithm smoothes the flow profile in the vicinity of levee systems where the levee fails before the flood crest. This scenario is illustrated by the Elsberry and Riverland systems in Figure 4. But also consider this: The stage between the levee crests results from the river flow not the total flow. Therefore, the water surface elevation is different at the river than inside the levee; hence using the total flow and the river stage will not produce a representative rating curve.

Secondly, if the levee fails near the flood crest, water accelerates toward the levee breach as demonstrated for the Columbia Levee as a step in the maximum flow profile in Figure 3. The acceleration is real and upstream of the breach. The acceleration cannot be removed by computing parallel flow.

If you have questions or comments, please call. If you send a E-mail, please follow-up with a telephone call. I am still uncertain that I am receiving all my E-mail.

Kindest regards,

Bob Barkau

Upper Mississippi River System
Flow Frequency Study

Appendix F-H
Stage Frequency Analysis From UNET POR Results

1. Introduction to Stage-Frequency Analysis

For the Omaha District, the stage-frequency analysis at each cross section are determined using the POR analysis and HEC developed suite of software. Using the output from the UNET POR analysis, stage-frequency relationships may be determined at all UNET model cross section locations. The POR analysis does not generate a traditional 100-year profile. Several additional steps are required using software analysis programs developed by the Hydrologic Engineering Center (HEC). The POR analysis determines input files that may also be used to determine stage-frequency at a cross section using a spreadsheet approach developed by Dr. Robert Barkau. The steps for both procedures are explained in the following sections. Prior to executing either procedure, the UNET period of record results are required.

Run the UNET period of record using the final csect and boundary condition files. Set the following flags within the model:

```
PERAVG=ON
PARALLEL=ON
ANNUAL MAXIMUM=ON
annual.dss 5 5 5
```

The output from the POR analysis is a series of files used by HEC software to determine final profiles. Output files are as follows:

Annual.amx – ascii text file that summarizes POR results.

```
                       MISSOURI
             ANNUAL MAXIMUM STAGE AT 1S810.870

                   Max      Prob   Assoc                   Comp
    Rank    Year   Elev       %     Flow        Date        Elev
    ****    ****   ****     ****   *****    **********     ****
       1    1952 1183.13   0.980 472000.     4/12/1952 1182.98
       2    1943 1177.14   1.961 274000.     4/ 8/1943 1177.30
       3    1905 1175.38   2.941 232900.     7/ 5/1905 1175.41
       4    1950 1175.22   3.922 229000.     4/23/1950 1174.53
       5    1913 1173.78   4.902 202100.     4/11/1913 1174.04
       6    1927 1173.69   5.882 202100.     5/11/1927 1173.73
       7    1910 1173.39   6.863 195000.     3/19/1910 1173.51
       8    1917 1173.36   7.843 193712.     4/11/1917 1173.34
       9    1912 1172.94   8.824 187200.     4/ 9/1912 1173.18
      10    1929 1172.91   9.804 188000.     3/30/1929 1173.04
…..
Continue to rank the max elevation for the entire POR.
```

```
                        MISSOURI
            ANNUAL MAXIMUM FLOW AT 1S810.870

                 Max      Prob   Assoc                 Comp
 Rank    Year    Flow      %      Elev       Date      Flow
 ****    ****    ****     ****   *****   **********    ****
    1    1952 472000.   0.980 1183.13     4/12/1952 497983.
    2    1943 274000.   1.961 1177.14     4/ 8/1943 265972.
    3    1905 232900.   2.941 1175.38     7/ 5/1905 220981.
    4    1950 229000.   3.922 1175.22     4/23/1950 205537.
    5    1913 202100.   4.902 1173.78     4/11/1913 199121.
    6    1927 202100.   5.882 1173.69     5/11/1927 196170.
    7    1910 195000.   6.863 1173.39     3/19/1910 194634.
    8    1917 193900.   7.843 1173.17     4/11/1917 193621.
    9    1929 188000.   8.824 1172.91     3/30/1929 192708.
   10    1912 187200.   9.804 1172.94     4/ 9/1912 191688.
…..
Continue to rank the max flow for the entire POR.
Continue further for every cross section within the model.
```

Annual.dss – dss file of results from POR at each cross section used by HEC analysis. Pathnames within the dss file, repeated for every cross section, are as follows:

```
     1  T2739     /MISSOURI/11S635.230/PROB-MAX FLOW/1900-2000//NEW/
     2  T2737     /MISSOURI/11S635.230/PROB-MAX STAGE/1900-2000//NEW/
     3  T2742     /MISSOURI/11S635.230/STAGE-COMP FLOW/1900-2000//NEW/
     4  T2741     /MISSOURI/11S635.230/STAGE-FLOW/1900-2000//NEW/
```

Annual.eqq – Results from POR at each cross section including the exponents to define a fifth order polynomial curve fit used by Barkau spreadsheet analysis. The file contains tab delimited data for import to a spreadsheet.

Annual.eqr– Results from POR at each cross section including the exponents to define a fifth order polynomial curve fit used by Barkau spreadsheet analysis. The file contains tab delimited data for import to a spreadsheet.

Annual.eqz– Results from POR at each cross section including the exponents to define a fifth order polynomial curve fit used by Barkau spreadsheet analysis. The file contains tab delimited data for import to a spreadsheet.

Annual.plt – plot macro file for reviewing POR results at each cross section through the UNET interface PLTCON. The file assigns macros to plot data from the annual.dss file.

2. HEC Method for Stage-Frequency Analysis Using UNET POR Results

A. Copy the annual maximum dss files from the POR analysis (annual.dss or etc.) into the stage-frequency analysis directory. Use dssutl to delete the pathnames C=PROB-MAX COMP FLOW and C=PROB-MAX COMP STAGE (the pathnames conflict with the store rating program). Squeeze and catalog the dss file. Also, make sure the dss file has data from only 1 event (the D path should be only for 1 run, not combined runs). Combined runs have to be stored in different output files.

B. Run the store_rating program:
Execute with the run_store_rating.bat file. The file command line is:

```
store_rating.exe i=storerate_input.dat o=store_rating.out w=storate.dss
```

The storerate_input.dat file has the .dss filename specified. Edit the .dss file name in the storerate_input.dat file. The file format is:

```
0 1
annual???.dss
```

For multiple POR dss files, change the 1 to the number of files and add the name of the dss file after the annual.dss name.

The batch file specifies the text output file store_rating.out and the output file for the paired data (omarate.dss). The output is paired data of with path stage-flow at each cross section in the omarate.dss file. The rating curve data for the input dss files are combined into a single output dss file called Rating_data.dss (this file name is written automatically and cannot be changed –watch out for data overwriting). This file can then be used for subsequent curve fitting by the module RATING_CURVE.

C. Run the rating_curve program:

Execute with the run_rating_curve_all.bat. Files are:

rating_curve.exe i=oma_rate_all.dat o=omrating.out d=rating_data.dss **w=crv???.dss**

Rename the W=??curve file name for each alternative.

The input file contains data as:

```
flag  spline fit, ifix (fix last point -1,0-no),nwidth no pts avg width
1,1,6
top of levee followed by pathnames (o for no levee)
0.0
/MISSOURI/13S616.030/FLOW-STAGE/1991-2000//NEW/
```

and etc. repeated for all sections.

Pathnames are provided for all the section locations. All output data is stored in the rcurve.dss file. The paths in the input data files (oma_rate_…) can be built by cataloging the file created from the store_rating program. For combined runs, the pathname contains the F part from a single file, but output data is from the combined files. The store_rating program uses the path from the last dss file. All analysis was performed using a 0.0 specified to indicate no levee. The software option to set a levee elevation allows curve fitting to consider the specified elevation. Output data did not indicate a improved curve fit by specifying a levee. Therefore, this option was not included. When initially formatting the input file, the 0.0 elevation must be inserted between all paths.

D. Run the area_vs_stats program:

This step was originally separated into spring and summer statistics but has been combined in the final version of the software used by the Omaha District. Execute with the omaha_area_vs_stats.bat. This program interpolates the hydrologic stats by drainage area. The sole purpose of this program is to provide a file format that is easily used to construct the input file for the Omaha_stage-Freq_area program. Results from this program are not used for any other purpose. After building the input file, this program is no longer required. The station values MUST correspond with the stations from the rating_curve program. If new cross sections are added, the data must be revised.

E. Run the reg-vs-unreg program:

NOTE: This step was not performed by the Omaha District. The regulated-unregulated relationship was previously developed during the hydrologic analysis. The reg-unreg dss file developed contains the pathnames and data for each gage station to define the flow-flow relationship. The reg-unreg relationship for each gaging station location is a critical component of the analysis that is incorporated in the final stage-frequency program.

F. Run the Omaha_stage_freq_area.exe and the Omaha_interpolate_quantile.exe program:

Omaha_stage_freq_area.exe:

Execute with the run_Omaha_stage_freq_area.bat The file is:
omaha_stage_freq_area.exe i=omaha_stage_freq_area.dat **o=omaha_stage_freq_area_??.out d=??curve.dss** w=omaha.dss

Copy the regunreg.dss file data into the rcurve dss file prior to running the program (this step must be done once for each new rcurve file).
The .dat file is built from the drainage area spreadsheet and then cut and pasted together. Sort into the right order that goes with the data in the .dat file. **Once built, this only requires revision if the cross section number is revised and can be used with multiple ??rcurve files for different POR runs.** Check the .out to be sure that the section numbers correspond in the output file and that the input data tables (in the .dat) was correctly formatted (the first tables must match the sequence of the path names in the 2nd half of the file). Output is to the .out file specified in the batch file.

Omaha_interpolate_quantile.exe

Execute with the run_Omaha_quantile.bat The file is:
omaha_interpolate_quantile.exe i=omaha_interp_quantile.dat **o=freq_quantile_??.out d=quant_comb_??.dss**
The .dat file accesses the quant_comb.dss file that is a combined file with data from several different programs. Pathnames within the .dss file are as follows:

1) All regulated gage flow data such as:
`/MISSOURI/YKN/FREQ-FLOW//22AUG2002/REGULATED/`

2)The UNET POR output from the regulated analysis at each cross section such as:
`/MISSOURI/1S810.870/PROB-MAX FLOW/1900-1997//REGFLOW/`

3) The spline rating curve determined at each cross section from the UNET POR analysis using the observed inflow data such as:
`/MISSOURI/1S810.870/FLOW-STAGE/1900-2000//SPLINE RATING/`

If revised analysis alters the UNET POR analysis of either the regulated or the observed data, then the quant_comb.dss file must be revised prior to running the Omaha_interpolate_quantile program. Once built, the .dat file only requires revision if the cross section number is revised and can be used with multiple files for different POR runs. Check the .out to be sure that the section numbers correspond in the output file and that the input data tables (in the .dat) were correctly formatted (the first tables must match the sequence of the path names in the 2nd half of the file). Output is to the .out file specified in the batch file.

G. Final Profile.

Output to the .out file will have the tabulated flow-freq and stage-freq values for each section. Combine the output from the two programs for above and below Sioux City. The output file from each program can be imported into the final profile plotting spreadsheet. Final stage-flow and stage-frequency values are determined at each cross section after performing spreadsheet profile smoothing and backwater adjustments. A series of spreadsheets are required to perform these operations. Each spreadsheet contains directions for updating the values. The spreadsheets that should be accessed are as follows:

1) freq_prog_import_tables.xls

Import the stage and flow values from the frequency .out files to the spreadsheet. The spreadsheet combines the stage and flow values from above Sioux City (the quantile method) and below Sioux City (the drainage area method) into a single table.

2) flow_final_plot.xls

Copy the combined flow from freq_prog_import_tables.xls to this spreadsheet. The flow values are compared to previous values.

3)profiles_stage_smooth.xls

Copy the combined stage and flow from freq_prog_import_tables.xls to this spreadsheet. The spreadsheet smooths the stage profile with the smoothing algorithm and the RAS profile at the tributary confluences. The final stage profiles for the 8 flow events are developed in this spreadsheet.

4)profile_interpolation_tabulate_rm.xls

Copy the combined flow from the freq_prog_import_tables.xls to this spreadsheet. Copy the smoothed stage from profiles_stage_smooth.xls to this spreadsheet. The spreadsheet interpolates the values to river mile from the cross section location to be used with the final stage-flow tables by river mile for the report.

5)

A portion of the output file is included to illustrate format and is as follows:

Sample Output File Format:

```
    -----DSS---ZOPEN:  Existing File Opened,  File: CRVEKR1.DSS
                       Unit:  71;  DSS Version: 6-JG
    -----DSS---ZOPEN:  Existing File Opened,  File: OMAHA.DSS
                       Unit:  72;  DSS Version: 6-JG
unregulated-regulated relationship (0=yes), 2 stations, no mixed analysis (0=no)
           0           6           1
first distribution         xsec    area    mean   std dev
    810.87  279500.     5.000      .2560     -.05
    805.77  279501.     5.000      .2560     -.05
    732.30  314580.     5.014      .2490     -.05
    616.03  322800.     5.031      .2430     -.05
    562.60  410000.     5.083      .2210      .08
    498.03  414900.     5.084      .2230      .08
second distribution       xsec    area    mean   std dev
    810.87  279400.     5.162      .1230     -.43
    805.77  279501.     5.162      .1230     -.43
    732.30  314580.     5.171      .1190     -.43
    616.03  322800.     5.190      .1210     -.43
    562.60  410000.     5.298      .1110     -.09
    498.03  414900.     5.306      .1170     -.09
number of x-sections for interpolation
         827
x-section    area      mean    std dev     skew
    810.87  279500.
    810.67  279500.
    810.29  279500.
```

… repeated with section and drainage area for all sections …

```
     498.06  414900.
    498.04  414900.
gage pathnames
/MISSOURI/YKN/FLOW-FLOW//22AUG2002/UNREG-REG/
/MISSOURI/1S810.870/FLOW-STAGE/1900-2000//QUANTILE RATING/
/MISSOURI/YKN/FLOW-FLOW//22AUG2002/UNREG-REG/
/MISSOURI/1S805.760/FLOW-STAGE/1900-2000//QUANTILE RATING/
/MISSOURI/SUX/FLOW-FLOW//22AUG2002/UNREG-REG/
/MISSOURI/7S732.370/FLOW-STAGE/1900-2000//QUANTILE RATING/
/MISSOURI/OMA/FLOW-FLOW//22AUG2002/UNREG-REG/
/MISSOURI/13S616.030/FLOW-STAGE/1900-2000//QUANTILE RATING/
/MISSOURI/NCNE/FLOW-FLOW//22AUG2002/UNREG-REG/
```

```
/MISSOURI/17S562.740/FLOW-STAGE/1900-2000//QUANTILE RATING/
/MISSOURI/RUNE/FLOW-FLOW//22AUG2002/UNREG-REG/
/MISSOURI/21S498.030/FLOW-STAGE/1900-2000//QUANTILE RATING/
interpolated section pathnames
/MISSOURI/1S810.870/FLOW-STAGE/1900-2000//SPLINE RATING/
/MISSOURI/1S810.670/FLOW-STAGE/1900-2000//SPLINE RATING/
```

… repeated section pathnames …

```
-----DSS---ZWRITE Unit  72; Vers.    3:  /MISSOURI/21S498.040/FREQ-FLOW/1900-
2000//UNREGULATED/
 -----DSS---ZWRITE Unit  72; Vers.    3:  /MISSOURI/21S498.040/FREQ-STAGE/1900-
2000//STAGE/

          exceedance probability vs flow gages
    sta      0.500     0.200     0.100     0.040     0.020     0.010     0.005     0.002
    810.87   45266.    63009.    65017.    69129.    74723.    84879.    98027.   123460.
    805.77   45266.    63009.    65017.    69129.    74723.    84879.    98027.   123460.
    732.30   49539.    66820.    78335.    93925.   113799.   133759.   155008.   185400.
    616.03   64182.    85318.   123554.   132687.   147927.   174713.   204465.   247940.
    562.60   88034.   118656.   149766.   189924.   206378.   236694.   275891.   345400.
    498.03   94705.   132349.   160874.   188576.   217315.   252221.   296913.   370700.

          exeedance probability vs flow sections
    sta      0.500     0.200     0.100     0.040     0.020     0.010     0.005     0.002
    810.87   45266.    63009.    65017.    69129.    74723.    84879.    98027.   123460.
    810.67   45266.    63009.    65017.    69129.    74723.    84879.    98027.   123460.
```

… repeated with tabulated flow at all sections …

```
498.04   94705.   132349.   160874.   188576.   217315.   252221.   296913.   370700.

          exceedance probability vs stage gages
    sta      0.500     0.200     0.100     0.040     0.020     0.010     0.005     0.002
    810.87  1160.9    1163.0    1163.2    1163.7    1164.3    1165.3    1166.4    1168.5
    805.77  1156.5    1158.7    1158.9    1159.4    1159.9    1160.9    1162.0    1163.7
    732.30  1076.8    1080.2    1081.6    1082.9    1084.2    1085.8    1086.8    1088.5
    616.03   971.2     974.2     978.1     978.8     979.5     980.4     981.6     983.6
    562.60   924.1     927.5     929.8     932.0     932.5     933.2     934.3     935.4
    498.03   856.1     859.7     860.4     860.8     861.1     861.8     862.4     862.6



          exceedance probability vs stage sections
    sta      0.500     0.200     0.100     0.040     0.020     0.010     0.005     0.002
    810.87  1160.9    1163.0    1163.2    1163.7    1164.2    1165.2    1166.4    1168.5
    810.67  1160.8    1162.8    1163.0    1163.4    1164.0    1165.0    1166.1    1168.1
```

… repeated with tabulated stage at all sections …

```
    498.06   856.1     859.6     860.4     860.9     861.2     861.9     862.6     863.0
    498.04   856.1     859.6     860.4     860.8     861.2     861.8     862.5     862.9
```

3. Barkau Spreadsheet Method

The Barkau spreadsheet method was used to evaluate the results from the HEC software program. The method uses a similar theory and allows an independent verification of results obtained with the HEC software. The steps required are as follows:

A. Copy the files from the POR analysis to the stage-freq\ directory for the spreadsheet analysis. This includes the files as follows:
   Annual.dss
   Annual.eqq
   Annual.eqr

Annual.eqz

B. Open the profile spreadsheet – oma_profiles_dec02_barkau.xls, enable macros. Open each of the .e?? files from excel, the files are tabulated delimited. Copy and paste the data into the appropriate page of the master profiles spreadsheet.
C. Check the flow data in the TAG flow column for the 10, 50, 100, 500 profile worksheets. Update if needed from the HEC output file above. This step is not needed unless drainage area is changed.
D. Run the visual basic macro to update the computations for the 10, 50, 100, and 500 yr profile sheets. The macro is run from the tools – macro button. In visual basic, click run and pick the run sub/user form. NOTE: If the path is changed, the macro will not work. Check the path in the freq_profiles module, in the sub frequency profiles routine.
E. Copy the computed profile, under the TAG stage heading, into the final spreadsheet for comparison to the HEC method final profiles. Note that the computed elevations are prior to performing any smoothing operations.

Upper Mississippi River System
Flow Frequency Study

Appendix F-I
Stage Frequency Profile Smoothing

1. Stage Frequency Profile Smoothing

Stage frequency profile smoothing follows the technique developed by John Burant of the Rock Island District, U.S. Army Corps of Engineers. This appendix describes the preferred 5-point distance-weighted smoothing method. The smoothing is intended to eliminate the "jumps" across the confluences and eliminate any other minor fluctuations in the profiles. In the vicinity of tributary junctions and bridges, where section spacing is extremely small, the smoothing method was reduced from 5 point to 3 point to preserve the bridge profile impacts.

2. Distance-Weighted Average Profile Smoothing

This method uses the two nearest upstream cross sections and the two nearest downstream cross sections in addition to the subject cross section. The stage value at the subject cross section location is averaged with the distance-weighted average of the other four stages. The weighting technique used is described below (refer to Figure 1 for a diagram).

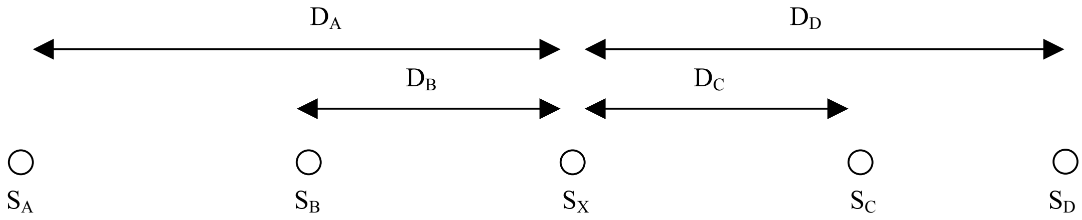


Figure 1

A. Distance Weighting Factors

The distance weighting factors are based on a ratio of the distance from the subject cross section to the sum of the four distances, $(D_A + D_B + D_C + D_D) = D_T$. This ratio is subtracted from 1 to give cross sections that are closer to the subject cross section more "weight" when averaging. For example, the weighting factor F_A for the stage value S_A would be calculated as follows:

$$F_A = 1 - \left(\frac{D_A}{D_A + D_B + D_C + D_D} \right) = 1 - \left(\frac{D_A}{D_T} \right)$$ or with some algebraic manipulation,

$$F_A = \left(\frac{D_B + D_C + D_D}{D_T} \right)$$

B. Distance Weighting

The weighting factor is then multiplied by its respective stage value for each of the four cross sections:

$F_A * S_A$, $F_B * S_B$, $F_C * S_C$, and $F_D * S_D$

C. Distance Weighted Average of Non-Subject Cross Sections

The final value to be averaged with the actual stage value at the subject cross section is determined as follows:

$$\left[(F_A * S_A) + (F_B * S_B) + (F_C * S_C) + (F_D * S_D) \right] / 3$$

Note: The distance weighted values are divided by 3, not 4 because each weighting factor accounts for an average of ¾ of the total distance, D_T, as can be seen in section A above.

D. Final Smoothed Value

The final smoothed value is simply the arithmetic average of the stage value at the subject cross section and the calculated value from section C above.

E. Example

The following is an example calculation for one cross section using the 100-Year profile.

Cross Section	Elevation	F_A	F_B	F_C	F_D	F_A*S_A	F_B*S_B	F_C*S_C	F_D*S_D	Sum of (Factors*S_n)/3	Final Smoothed Value
810.87	1165.20										
810.67	1165.00										
810.29	1164.70	0.730	0.823	0.814	0.633	850.83	959.14	947.98	736.49	1164.81	1164.75
809.89	1164.60										
809.5	1164.30										

$$F_A = 1 - \left(\frac{D_A}{D_T}\right) = 1 - \left(\frac{(810.87 - 810.29)}{(810.87 - 810.29) + (810.67 - 810.29) + (810.29 - 809.89) + (810.29 - 809.5)}\right)$$

$$F_A * S_A = 0.730 * 1165.20$$

Sum of (Factors*S_n)/3=(850.83+959.14+947.98+736.49)/3

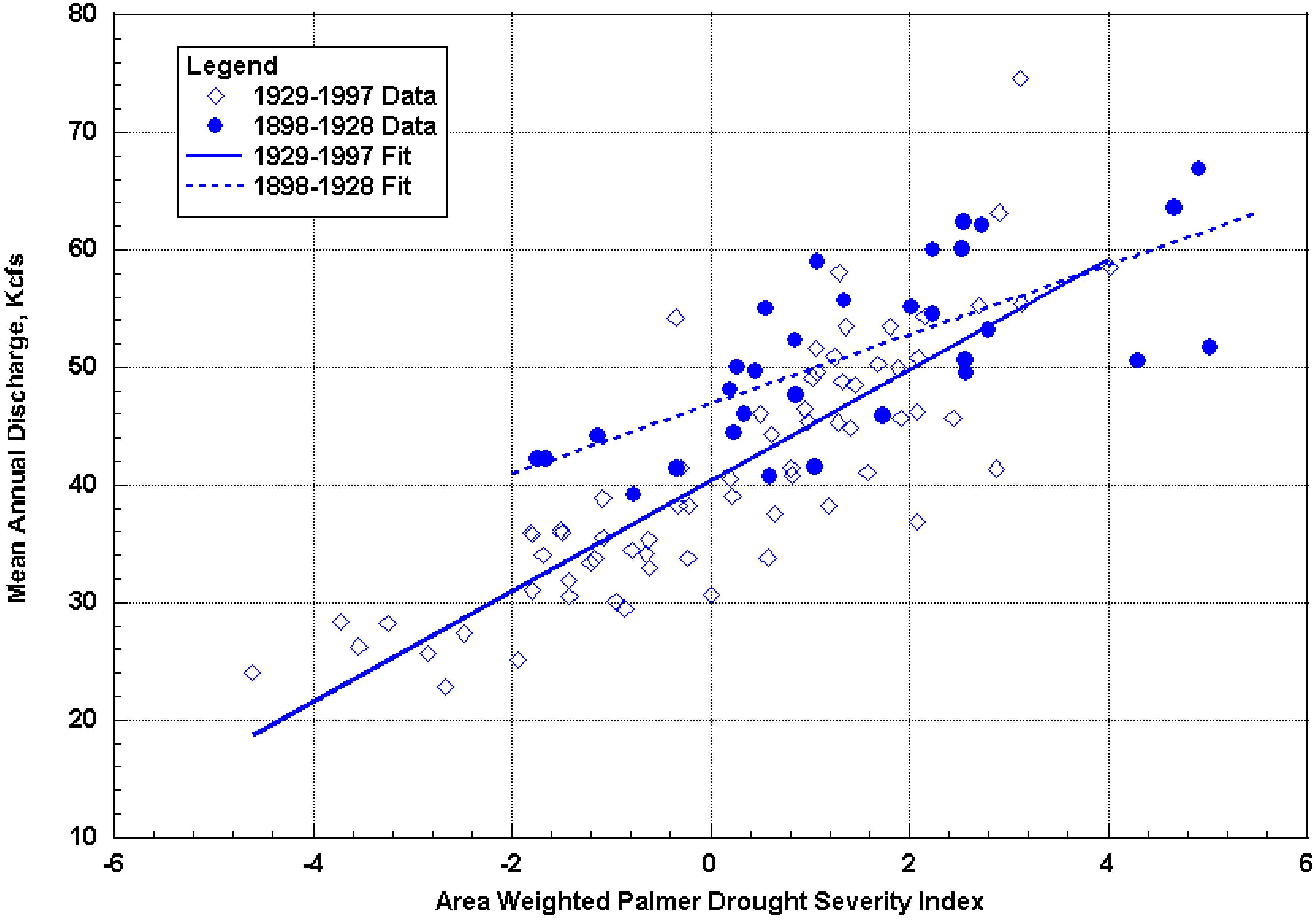
Final Smoothed Value=(1164.81+1164.70)/2

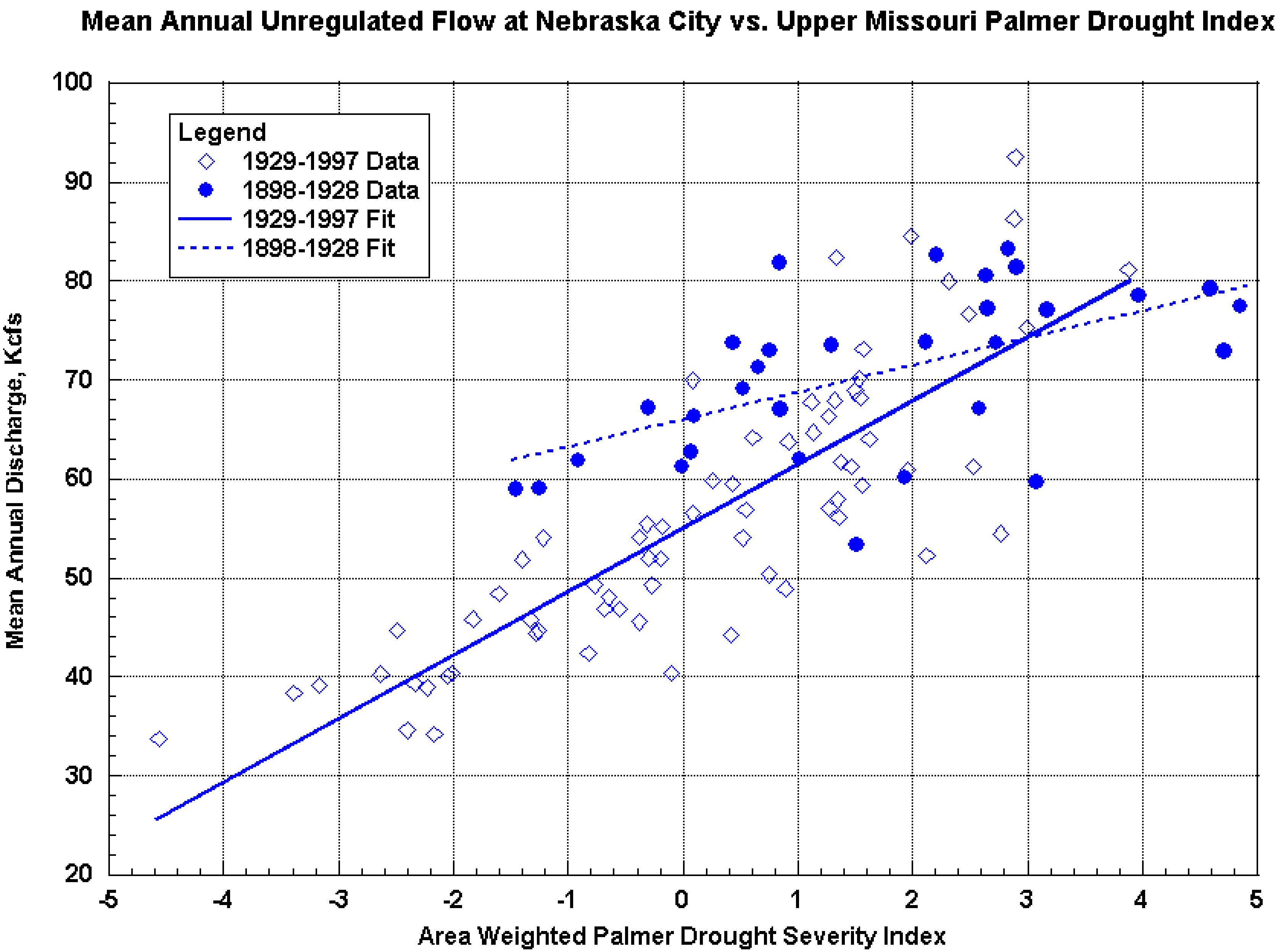
Upper Mississippi River System
Flow Frequency Study

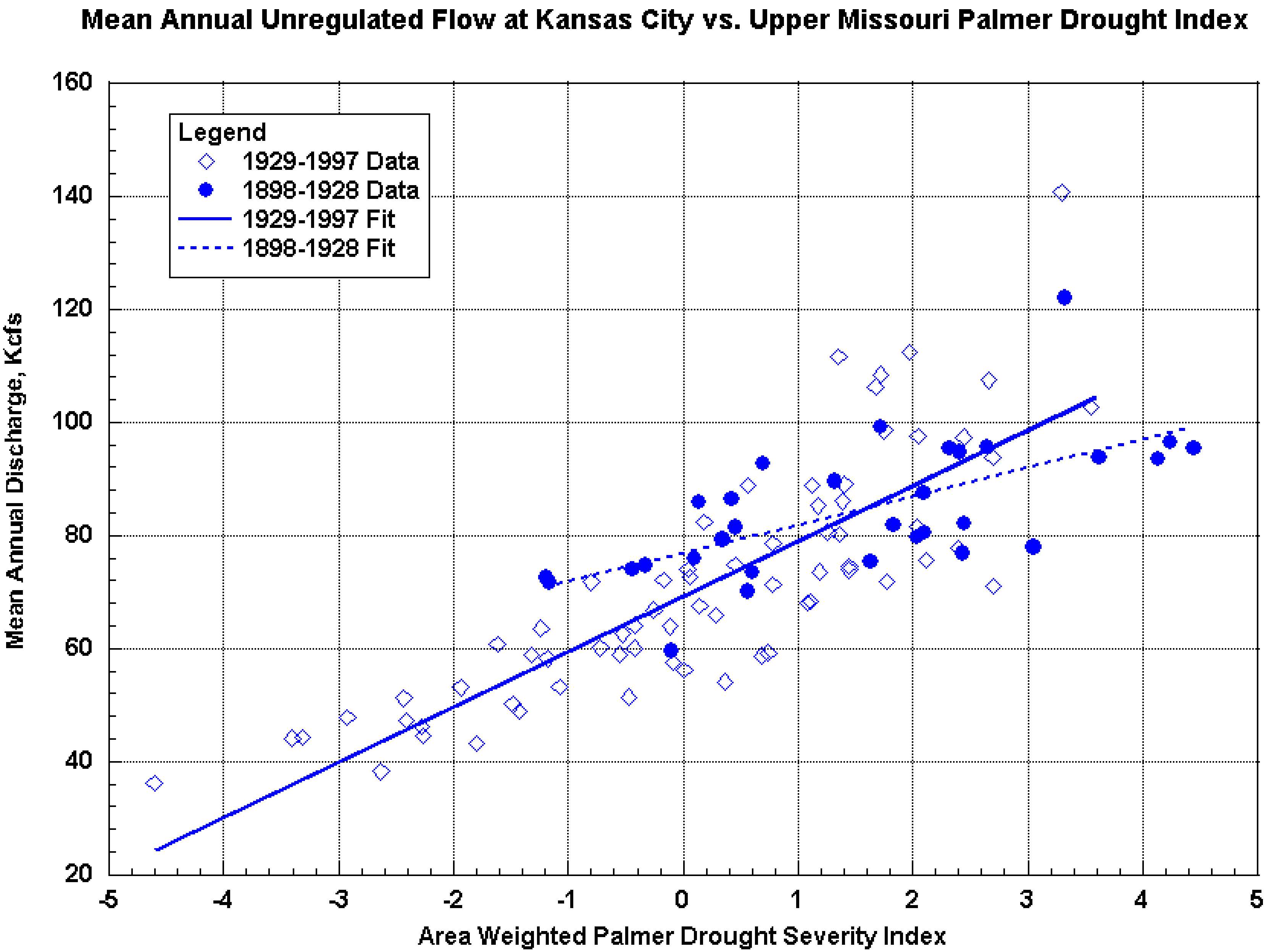
Appendix F

Plates

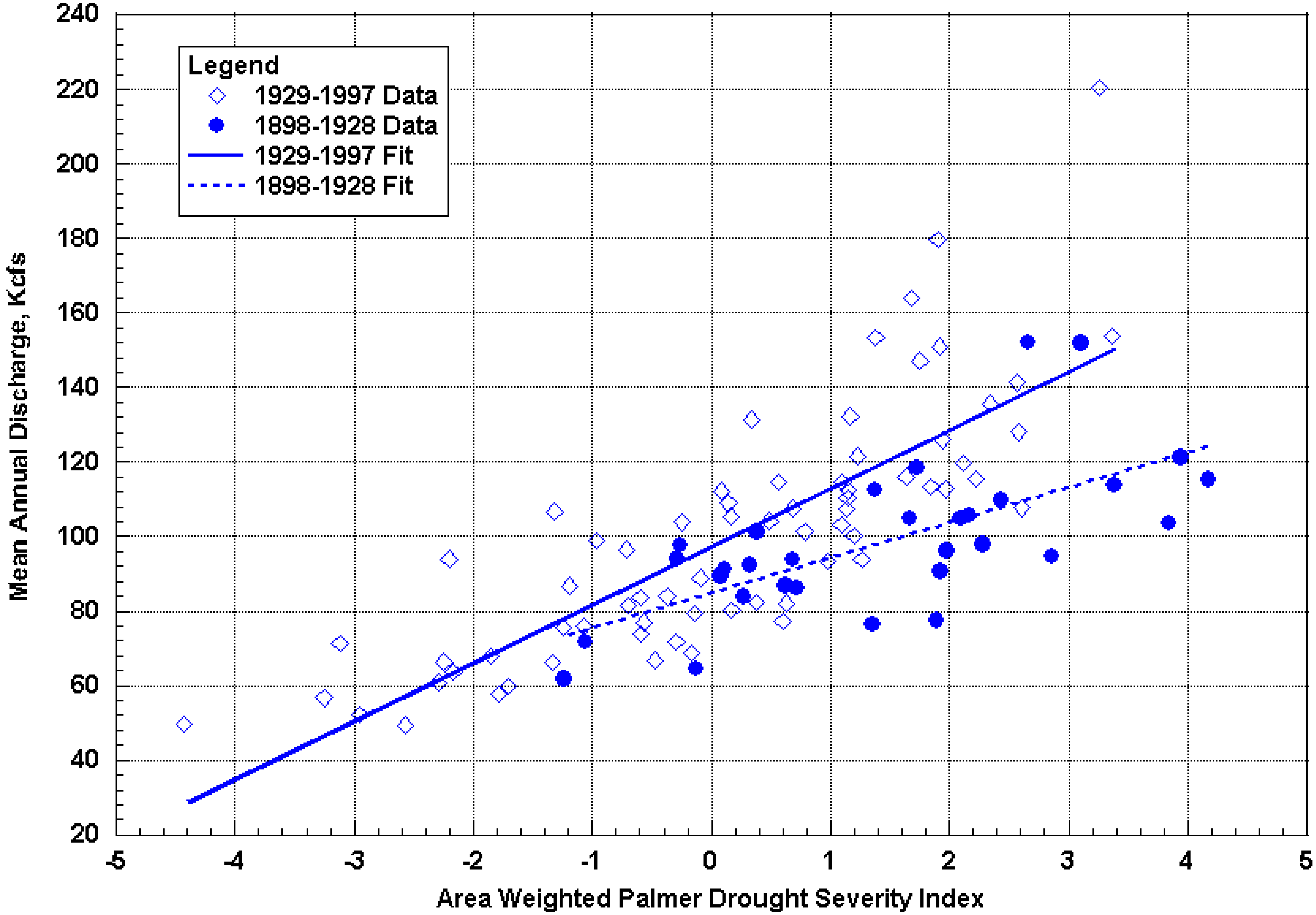
Mean Annual Unregulated Flow at Sioux City vs. Upper Missouri Palmer Drought Index



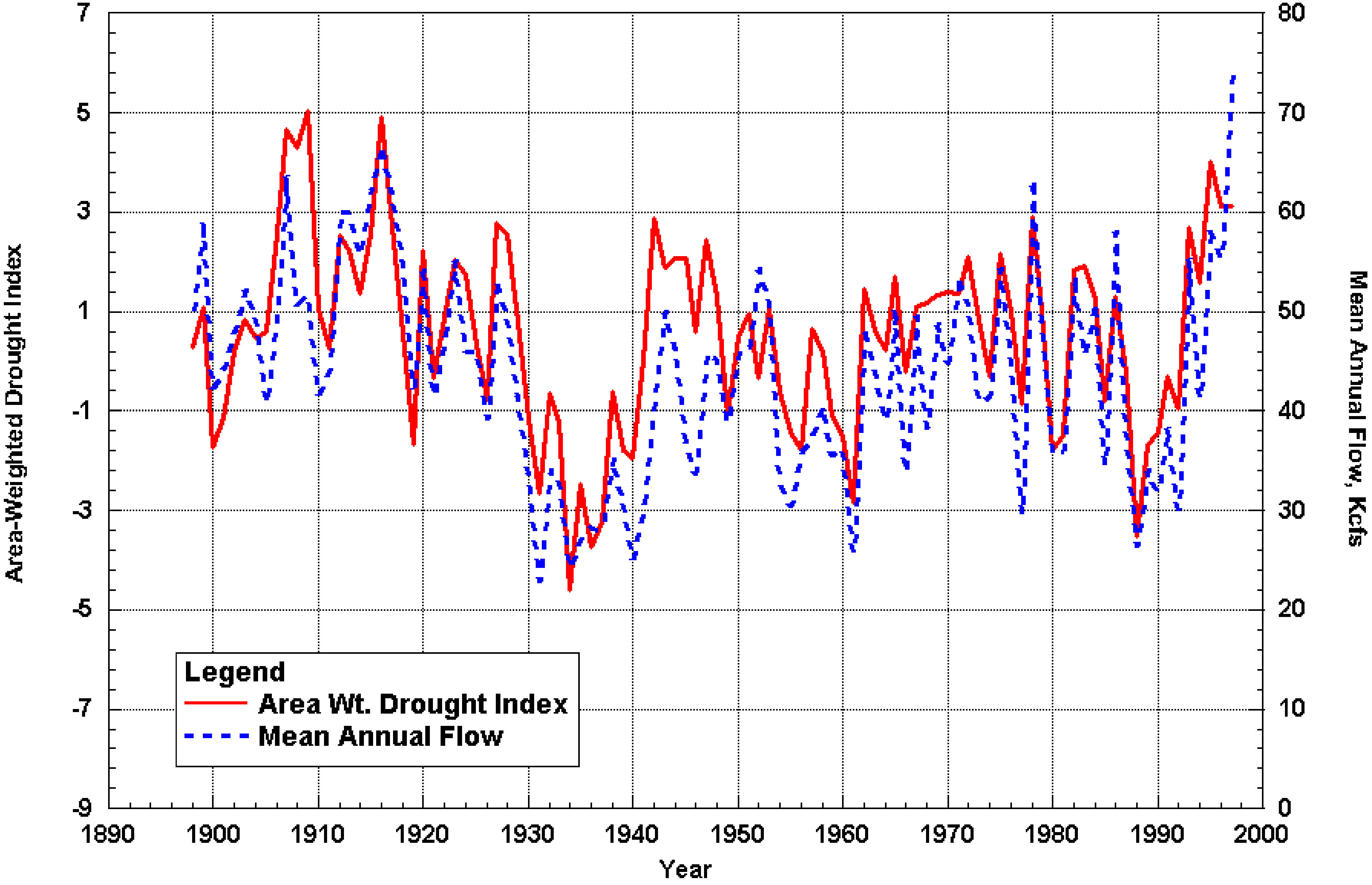

Mean Annual Unregulated Flow at Nebraska City vs. Upper Missouri Palmer Drought Index
Legend
◇ 1929-1997 Data
● 1898-1928 Data
1929-1997 Fit
1898-1928 Fit
Mean Annual Discharge, Kcfs
100
90
80
70
60
50
40
30
20
-5
-4
-3
-2
-1
0
1
2
3
4
5
Area Weighted Palmer Drought Severity Index


Mean Annual Unregulated Flow at Kansas City vs. Upper Missouri Palmer Drought Index
Legend
◇ 1929-1997 Data
● 1898-1928 Data
1929-1997 Fit
1898-1928 Fit
Mean Annual Discharge, Kcfs
160
140
120
100
80
60
40
20
-5
-4
-3
-2
-1
0
1
2
3
4
5
Area Weighted Palmer Drought Severity Index

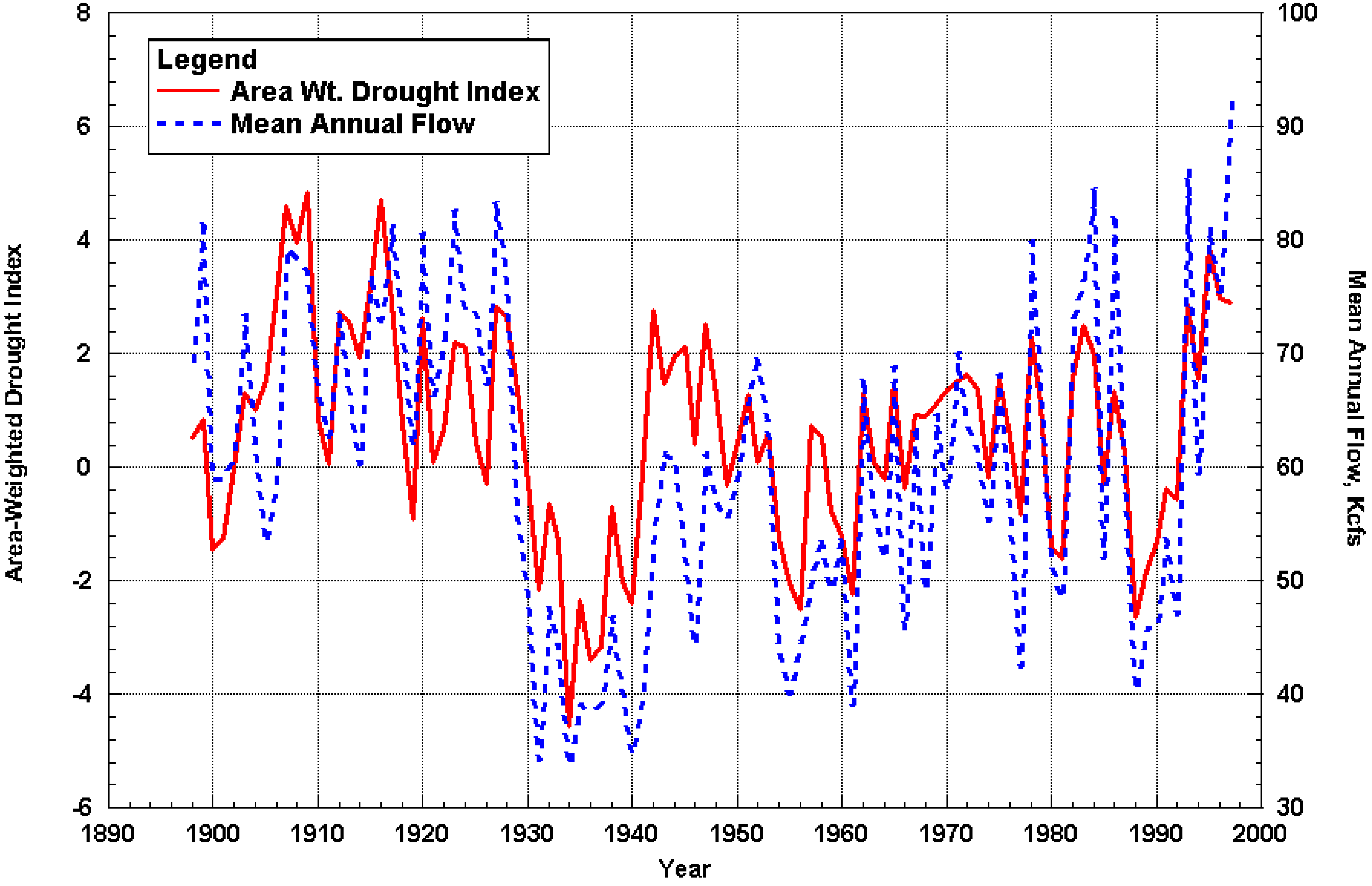
Mean Annual Unregulated Flow at Hermann vs. Upper Missouri Palmer Drought Index



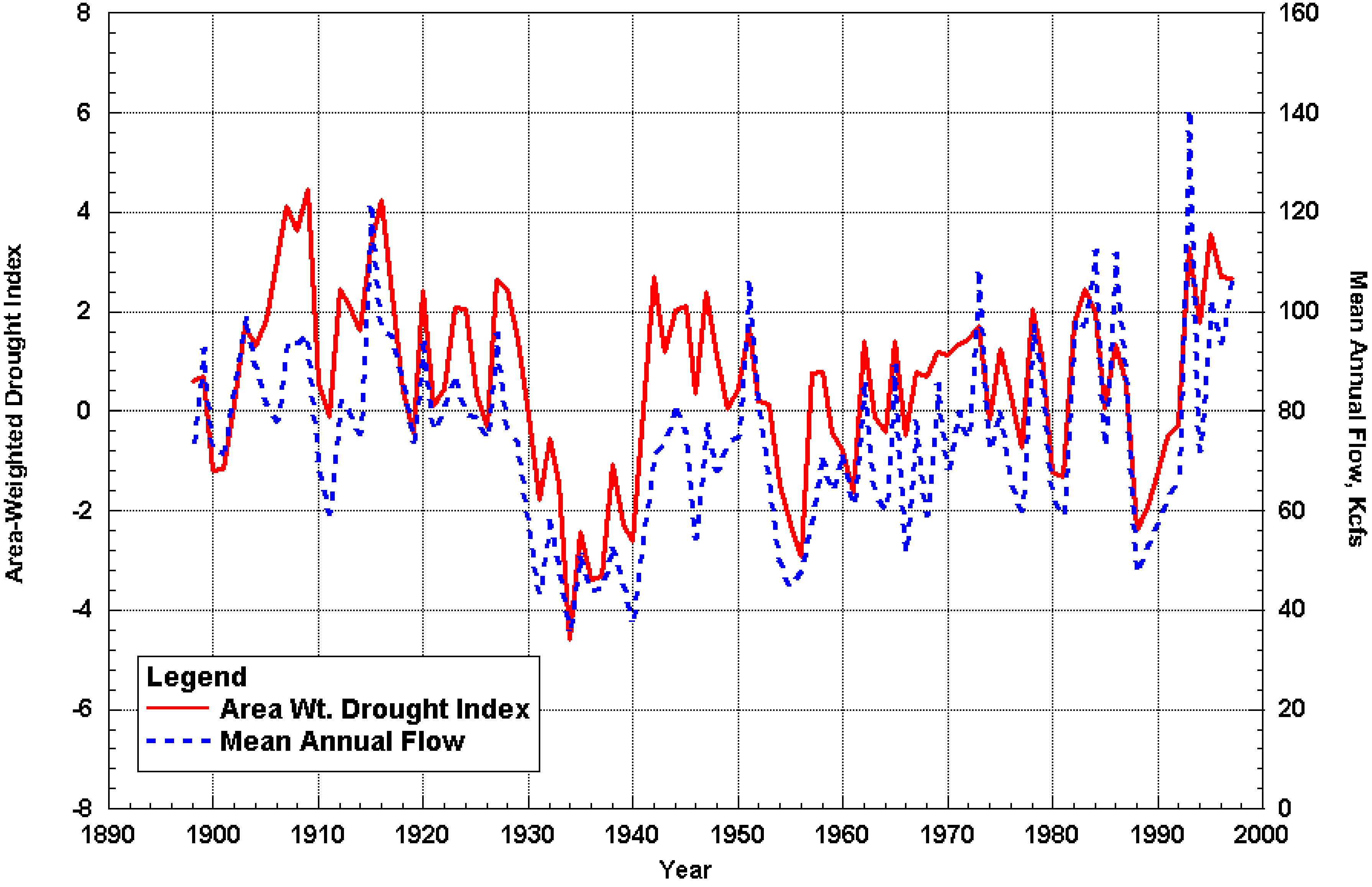
Comparison of Annual Mean Unregulated Flow and Area-Weighted Drought Index at Sioux City



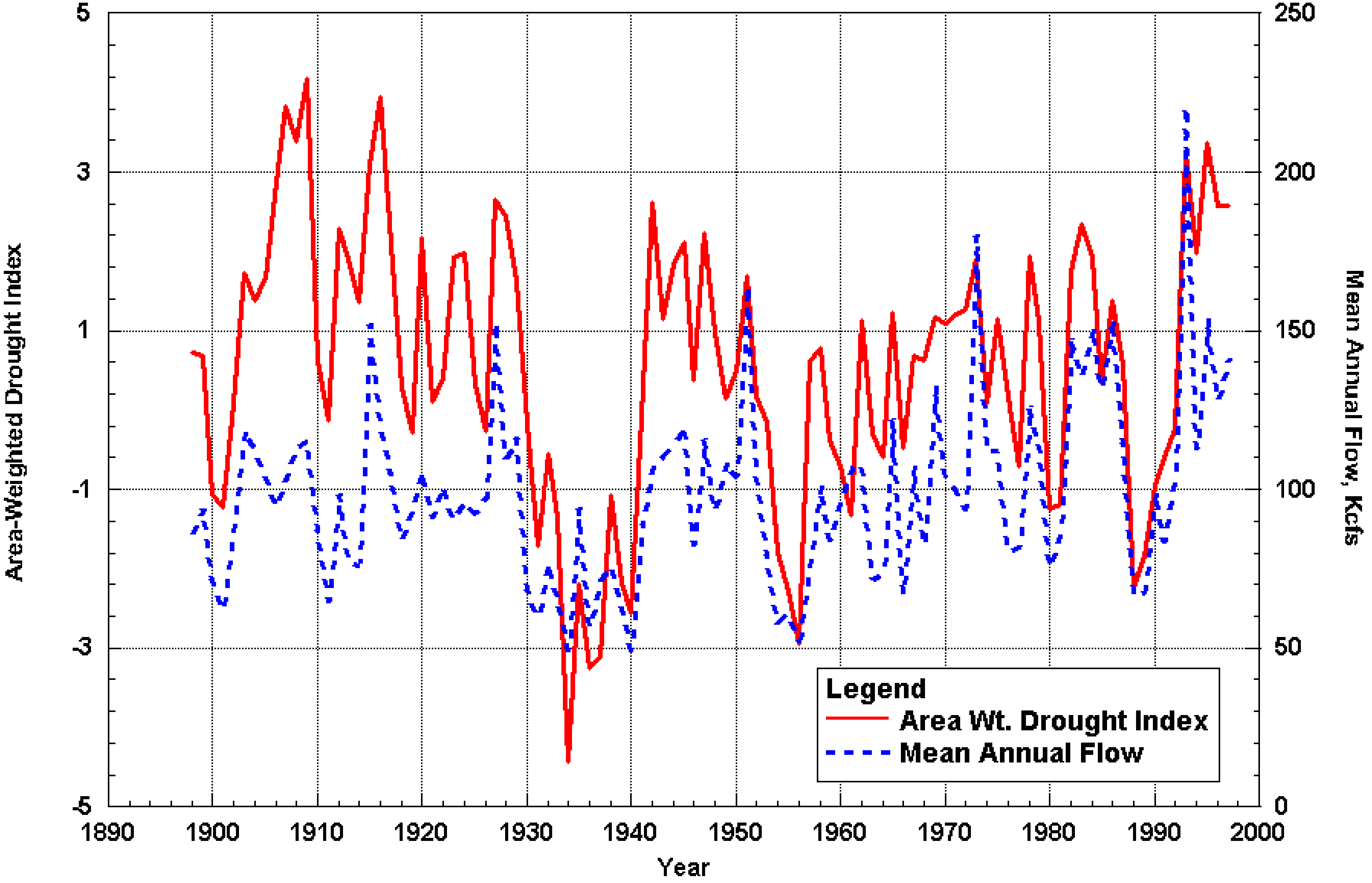
Comparison of Annual Mean Unregulated Flow and Area-Weighted Drought Index at Nebraska City



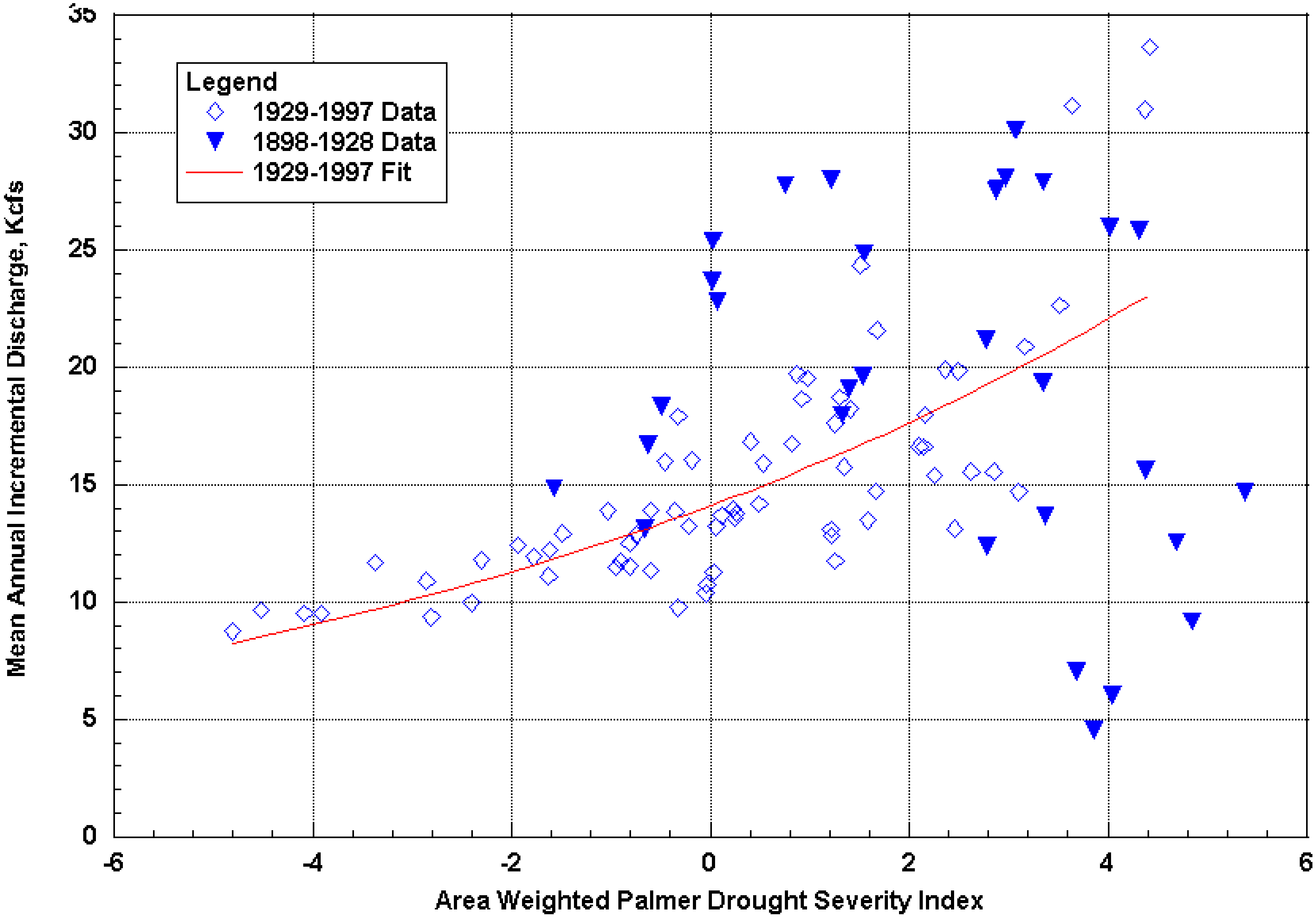
Comparison of Annual Mean Unregulated Flow and Area-Weighted Drought Index at Kansas City



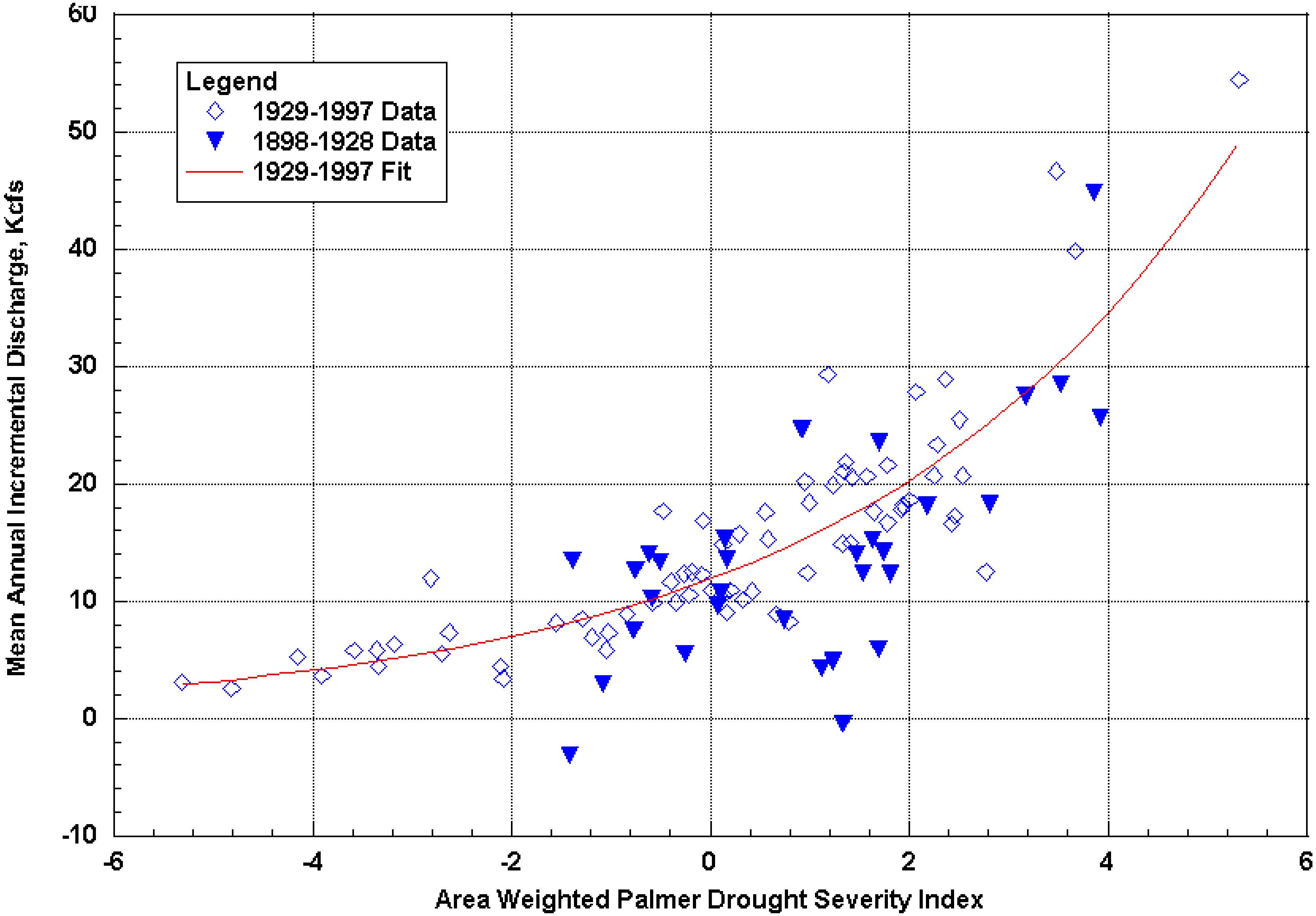
Comparison of Annual Mean Unregulated Flow and Area-Weighted Drought Index at Hermann

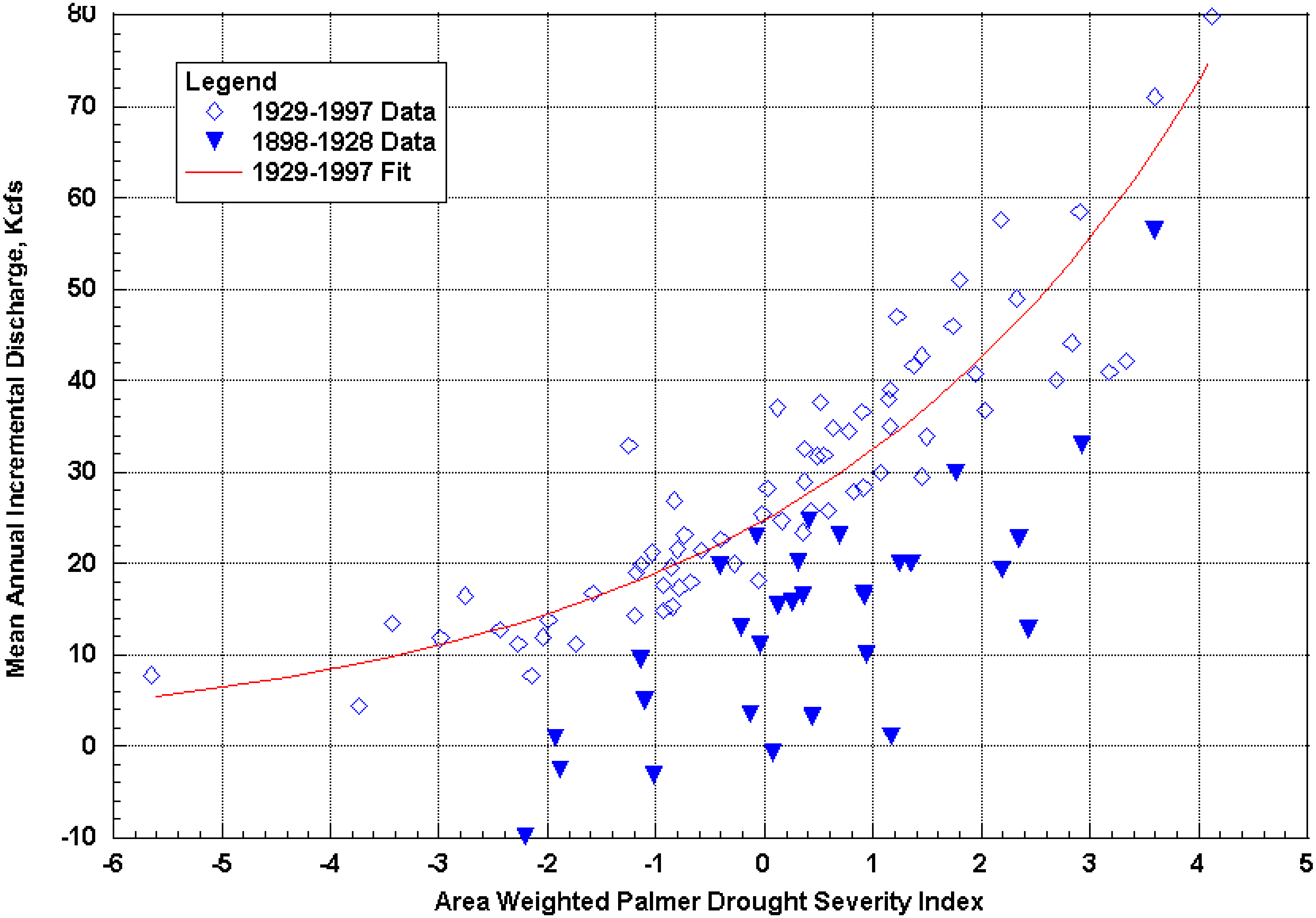


Mean Annual Incremental Unregulated Flow from Sioux City to Nebraska City vs. Area Weighted Palmer Drought Index

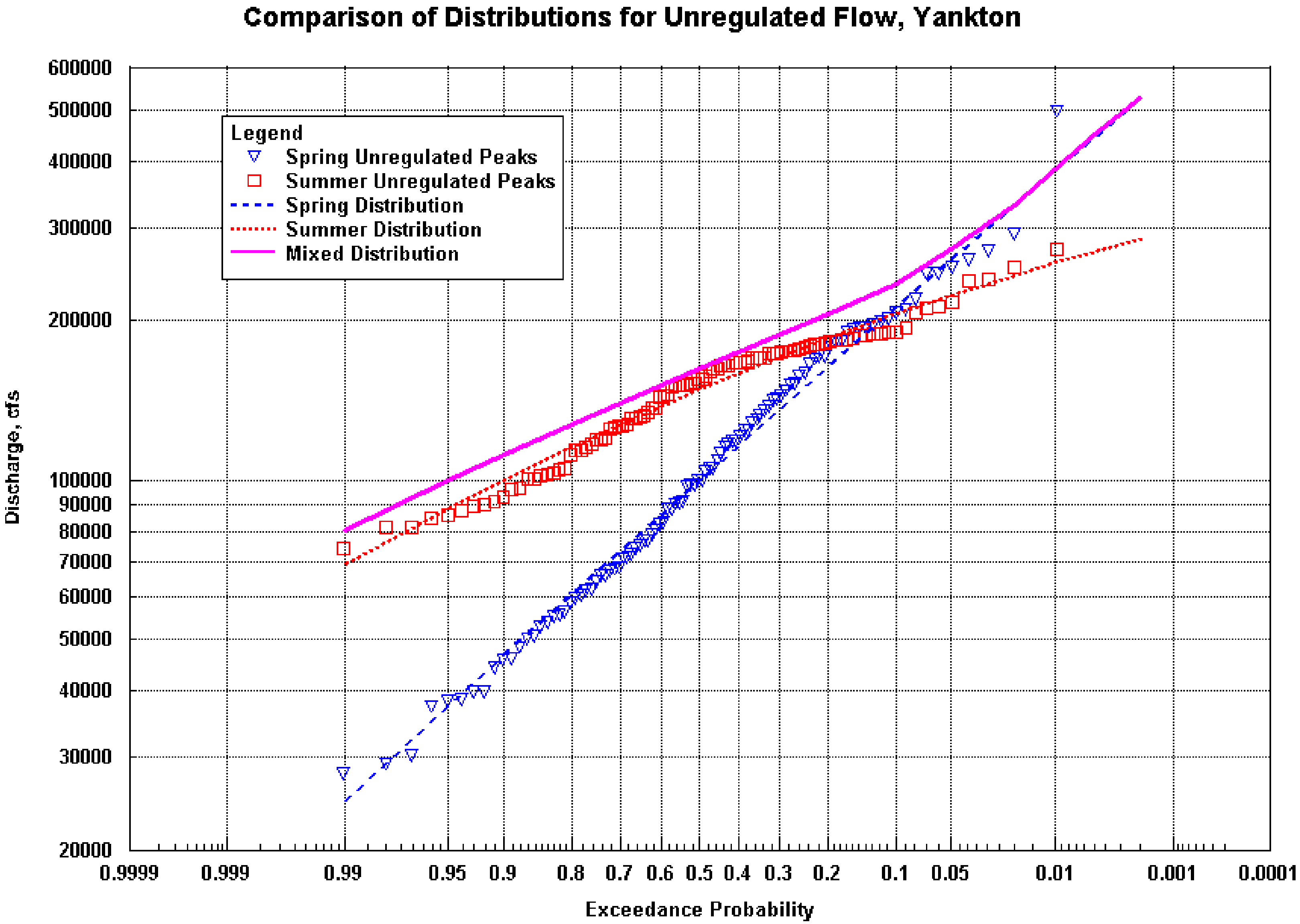


Mean Annual Incremental Unregulated Flow from Nebraska City to Kansas City vs. Area Weighted Palmer Drought Index

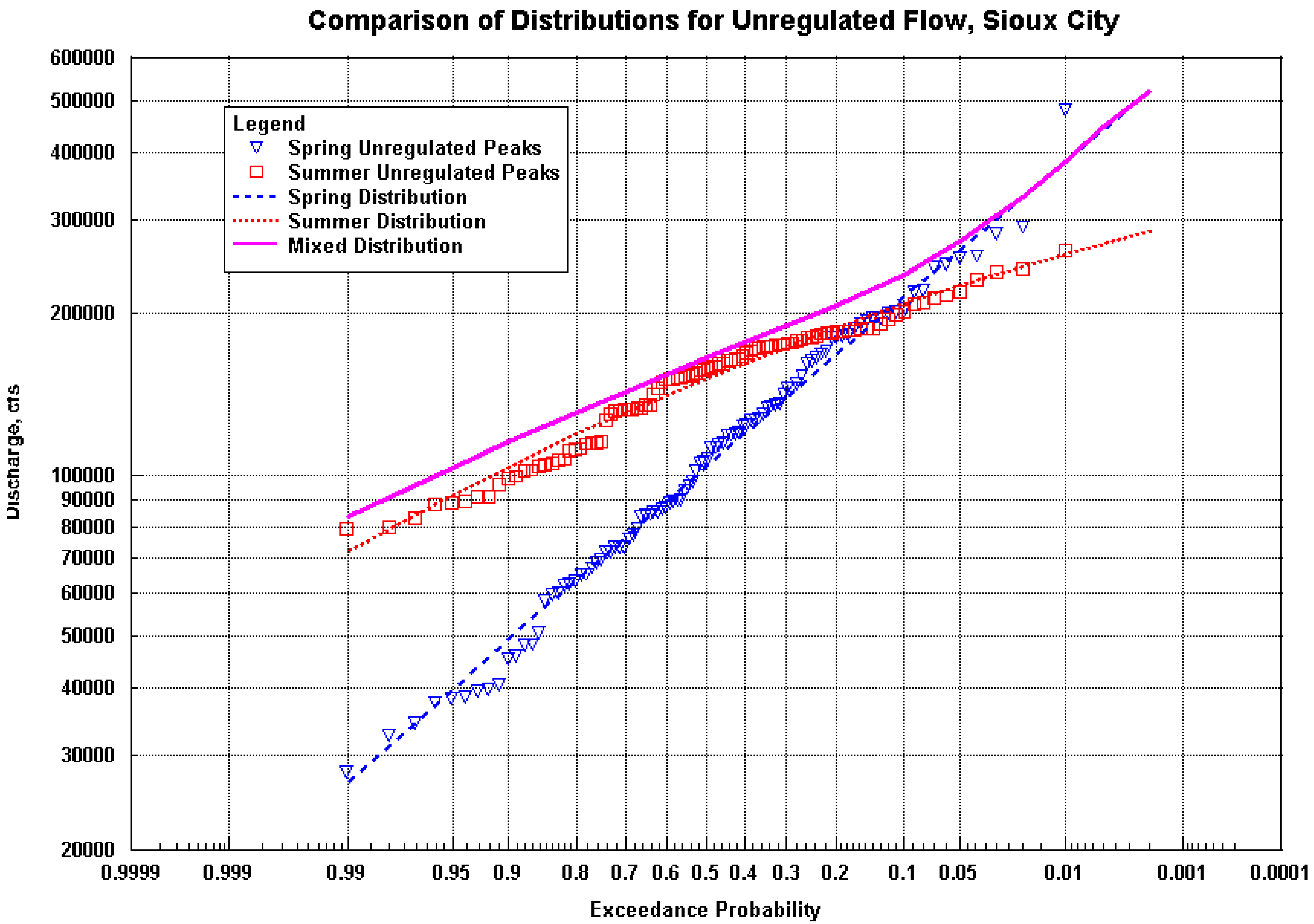


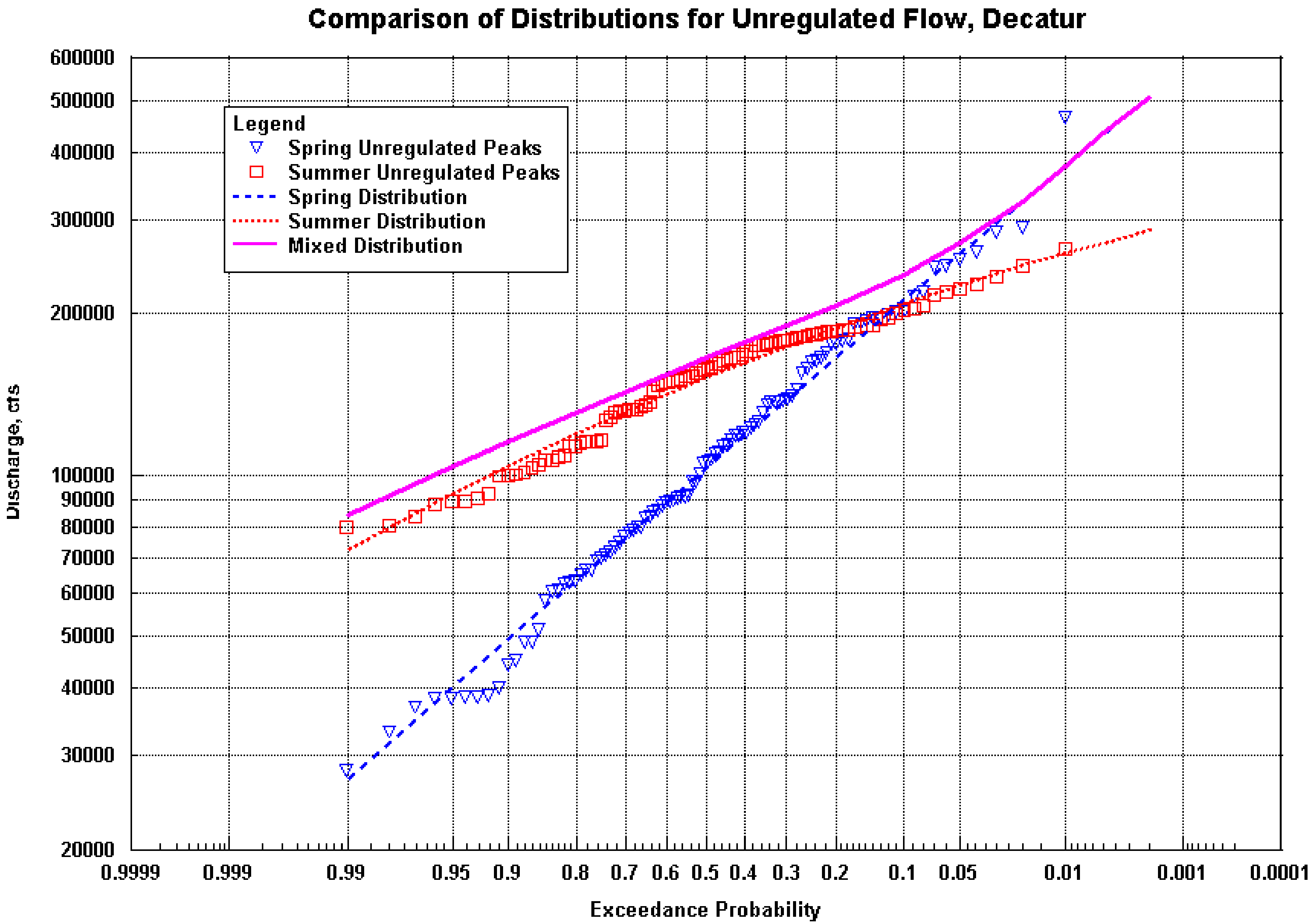


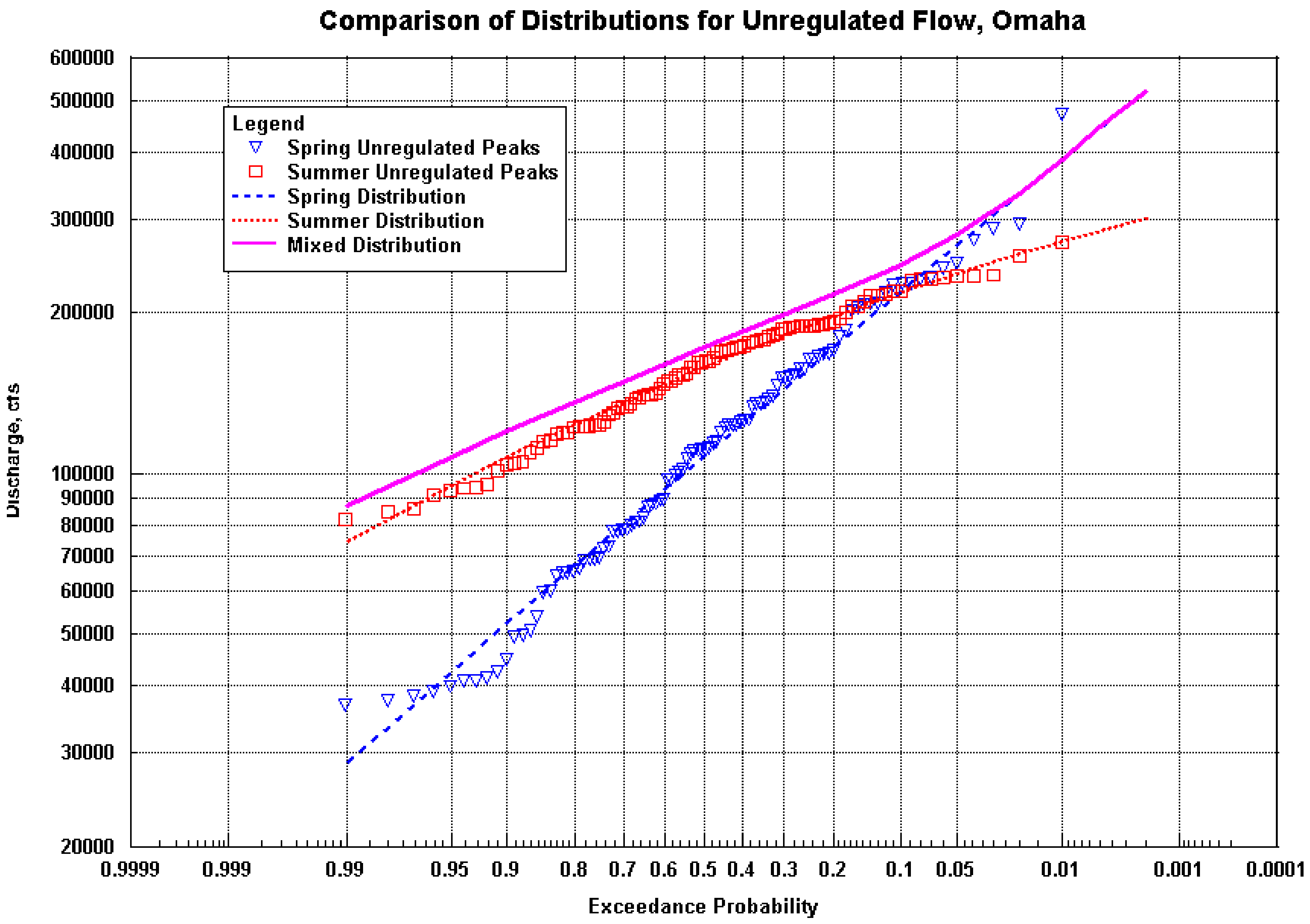
Mean Annual Incremental Unregulated Flow from Kansas City to Hermann vs. Area Weighted Palmer Drought Index



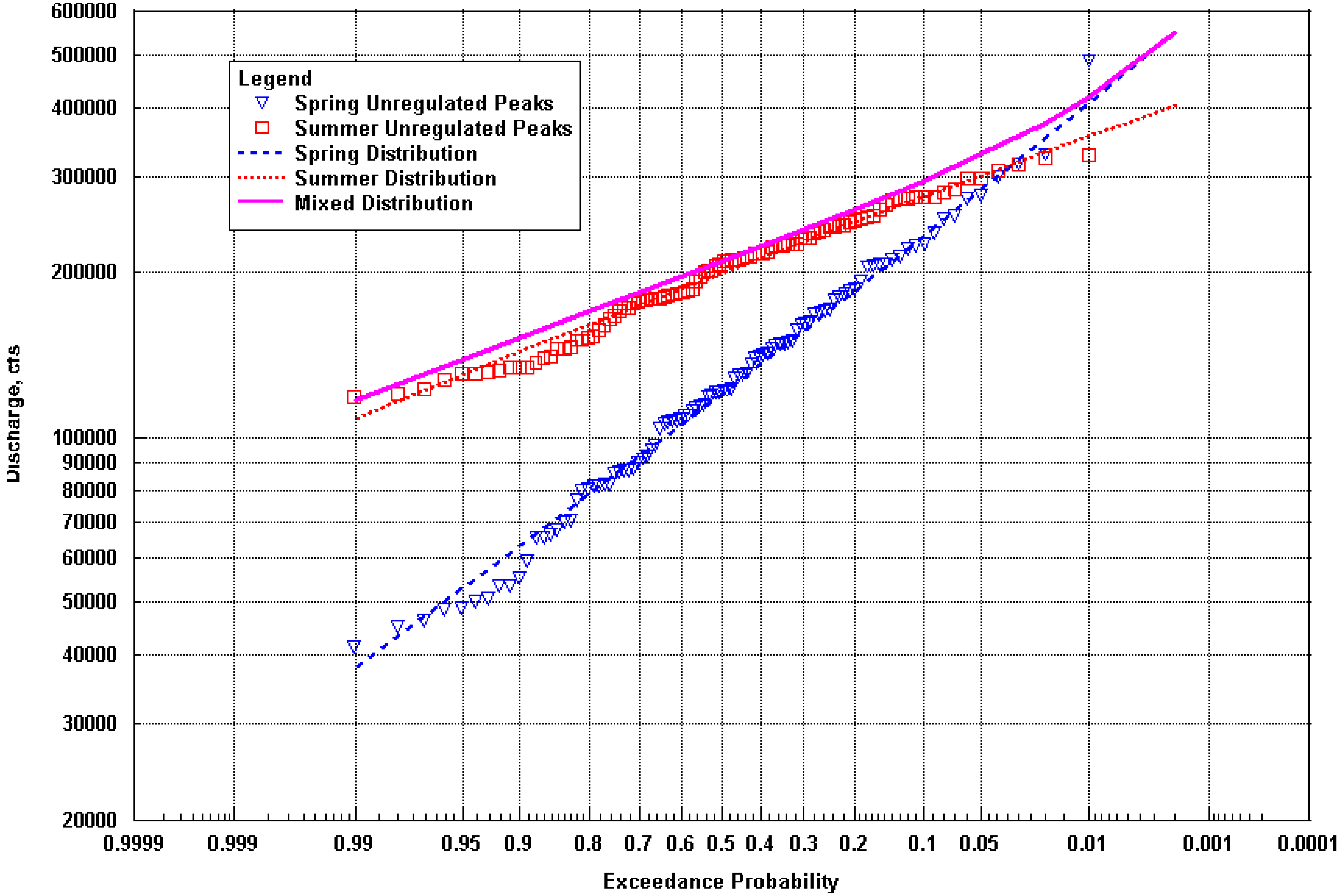
Comparison of Distributions for Unregulated Flow, Yankton
Legend
▽ Spring Unregulated Peaks
□ Summer Unregulated Peaks
Spring Distribution
Summer Distribution
Mixed Distribution
Discharge, cfs
600000
500000
400000
300000
200000
100000
90000
80000
70000
60000
50000
40000
30000
20000
0.9999
0.999
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.01
0.001
0.0001
Exceedance Probability


Comparison of Distributions for Unregulated Flow, Sioux City
Legend
Spring Unregulated Peaks
Summer Unregulated Peaks
Spring Distribution
Summer Distribution
Mixed Distribution
Discharge, cfs
600000
500000
400000
300000
200000
100000
90000
80000
70000
60000
50000
40000
30000
20000
0.9999
0.999
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.01
0.001
0.0001
Exceedance Probability

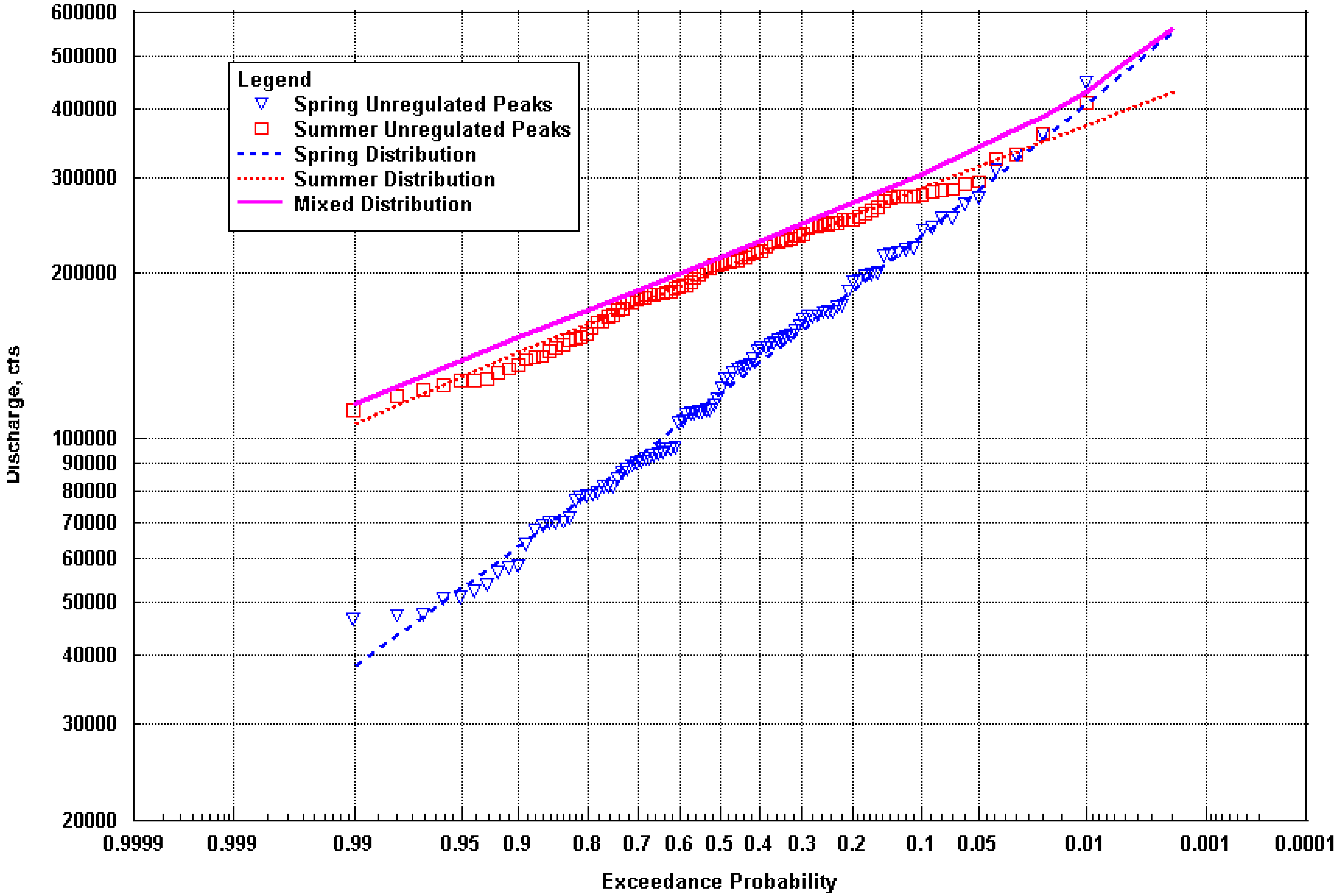

Comparison of Distributions for Unregulated Flow, Decatur


Comparison of Distributions for Unregulated Flow, Omaha
Legend
▽ Spring Unregulated Peaks
□ Summer Unregulated Peaks
Spring Distribution
Summer Distribution
Mixed Distribution
600000
500000
400000
300000
200000
100000
90000
80000
70000
60000
50000
40000
30000
20000
Discharge, cfs
0.9999
0.999
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.01
0.001
0.0001
Exceedance Probability

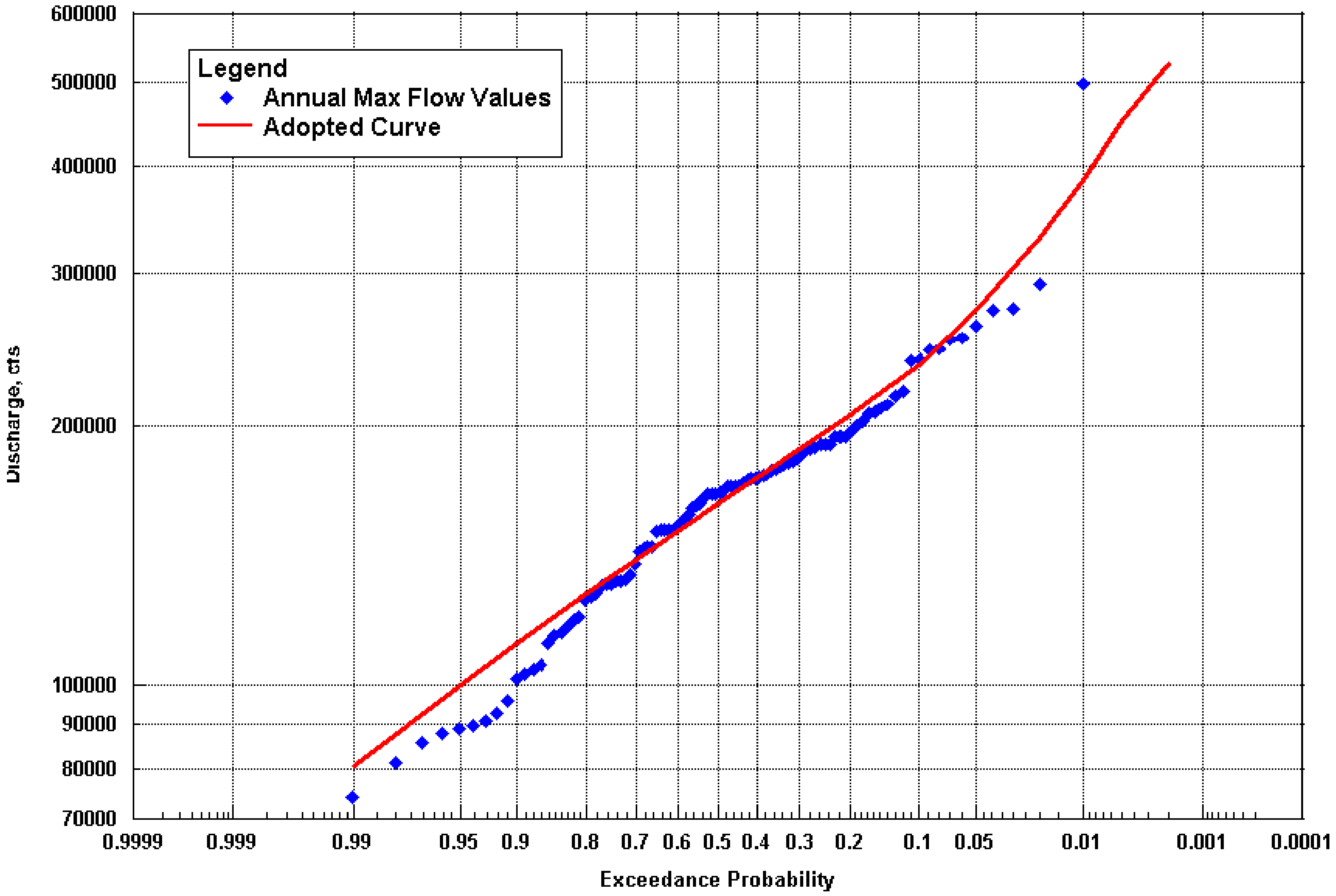
Comparison of Distributions for Unregulated Flow, Nebraska City



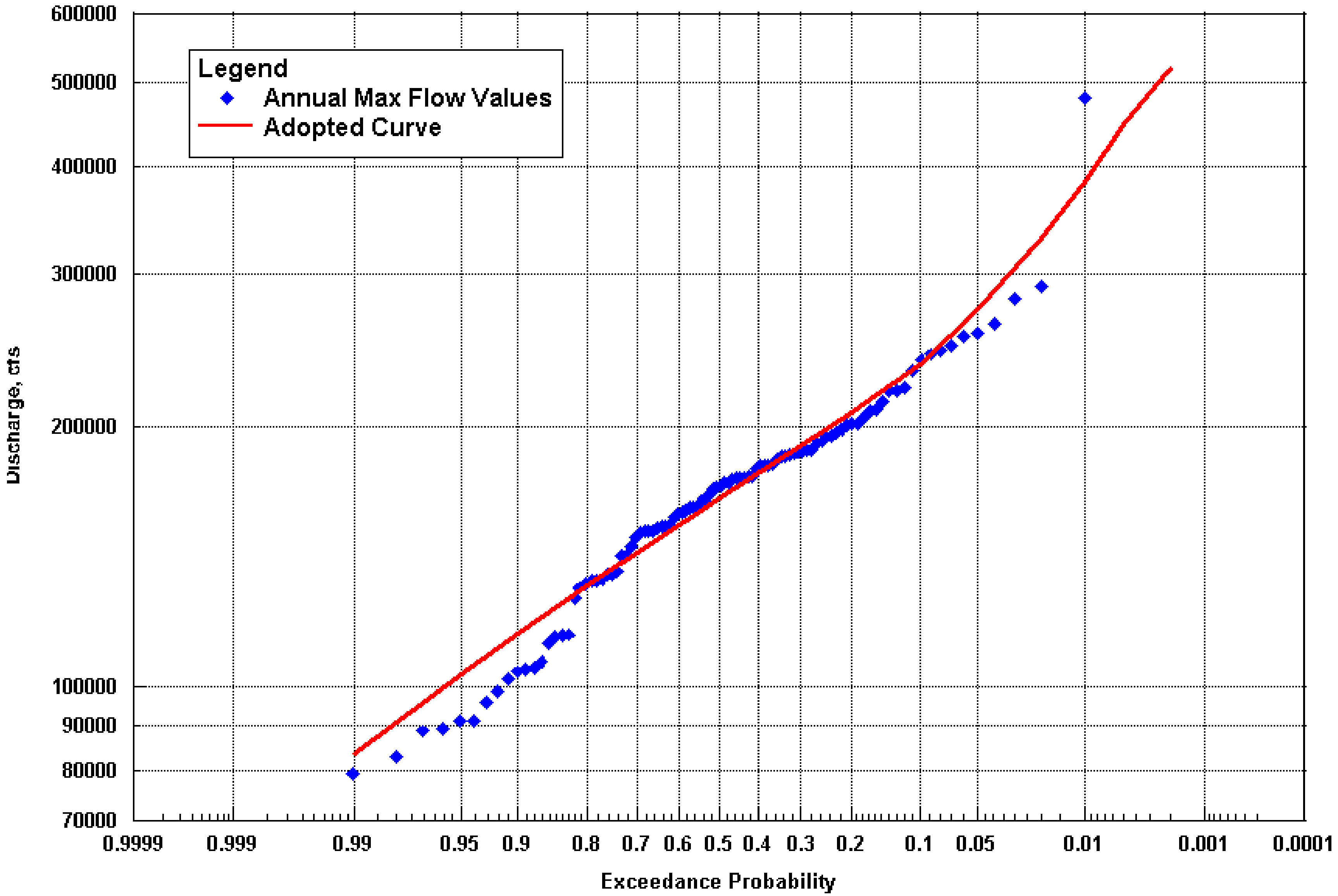
Comparison of Distributions for Unregulated Flow, Rulo

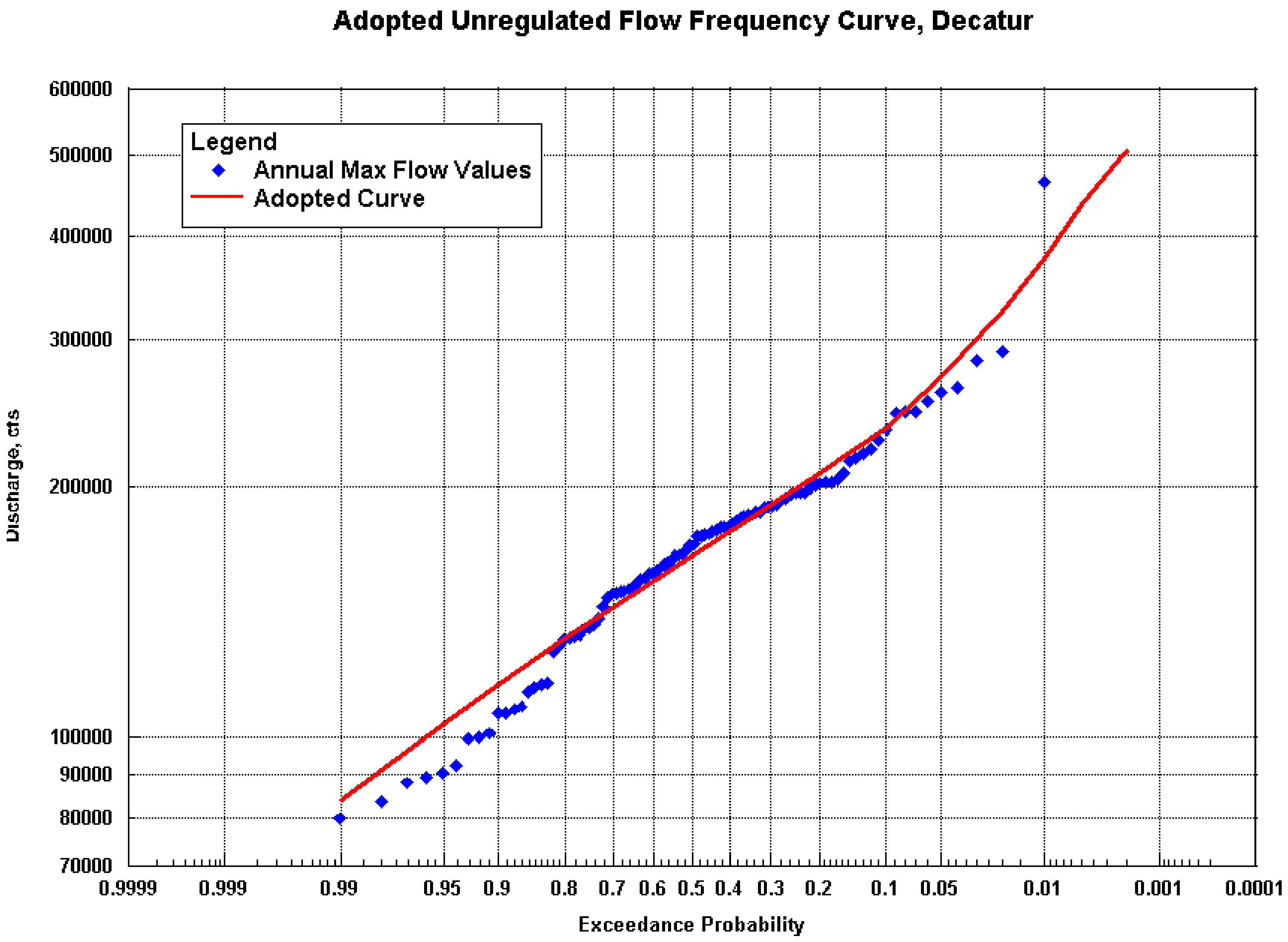


Adopted Unregulated Flow Frequency Curve, Yankton



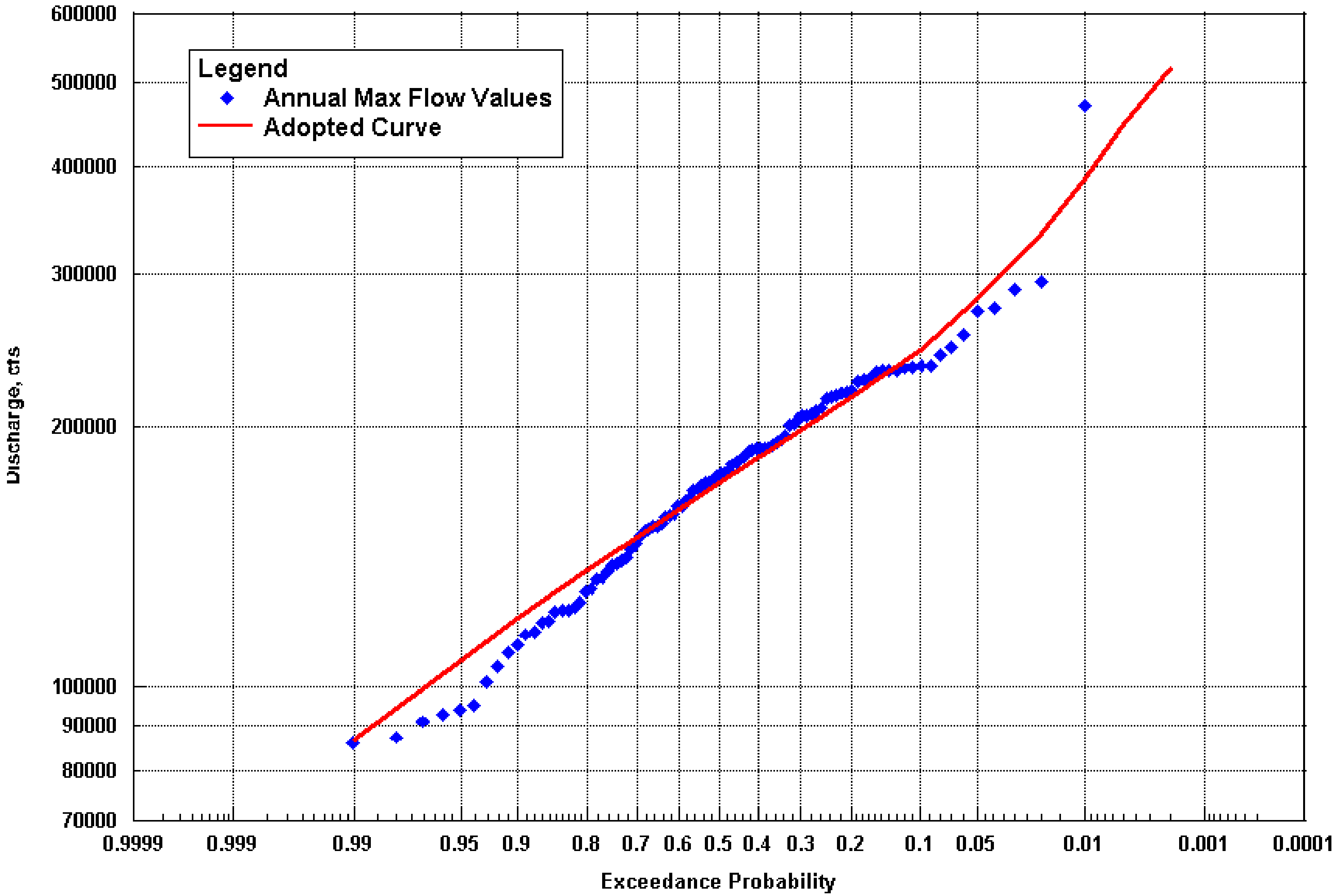
Adopted Unregulated Flow Frequency Curve, Sioux City



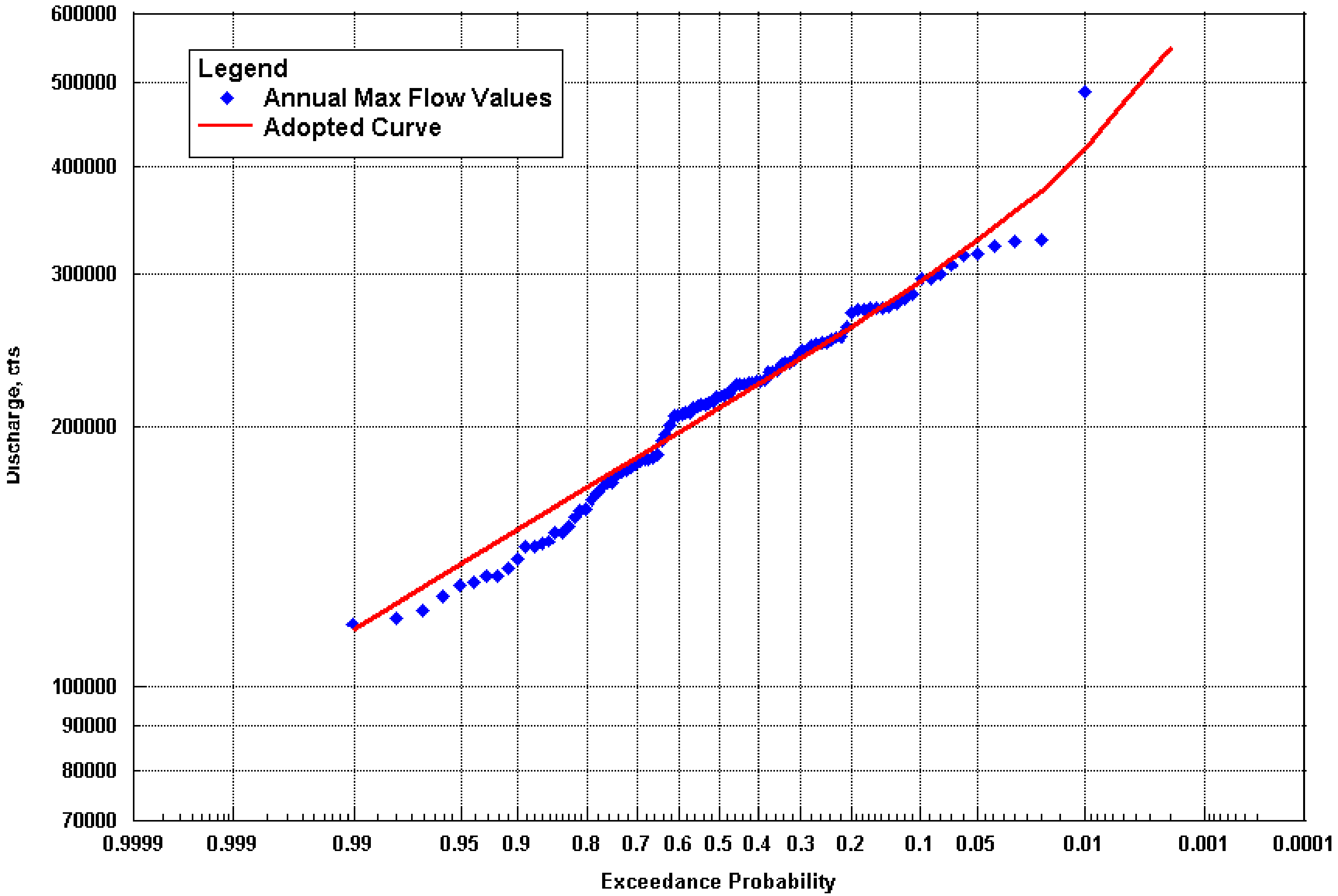


Adopted Unregulated Flow Frequency Curve, Decatur

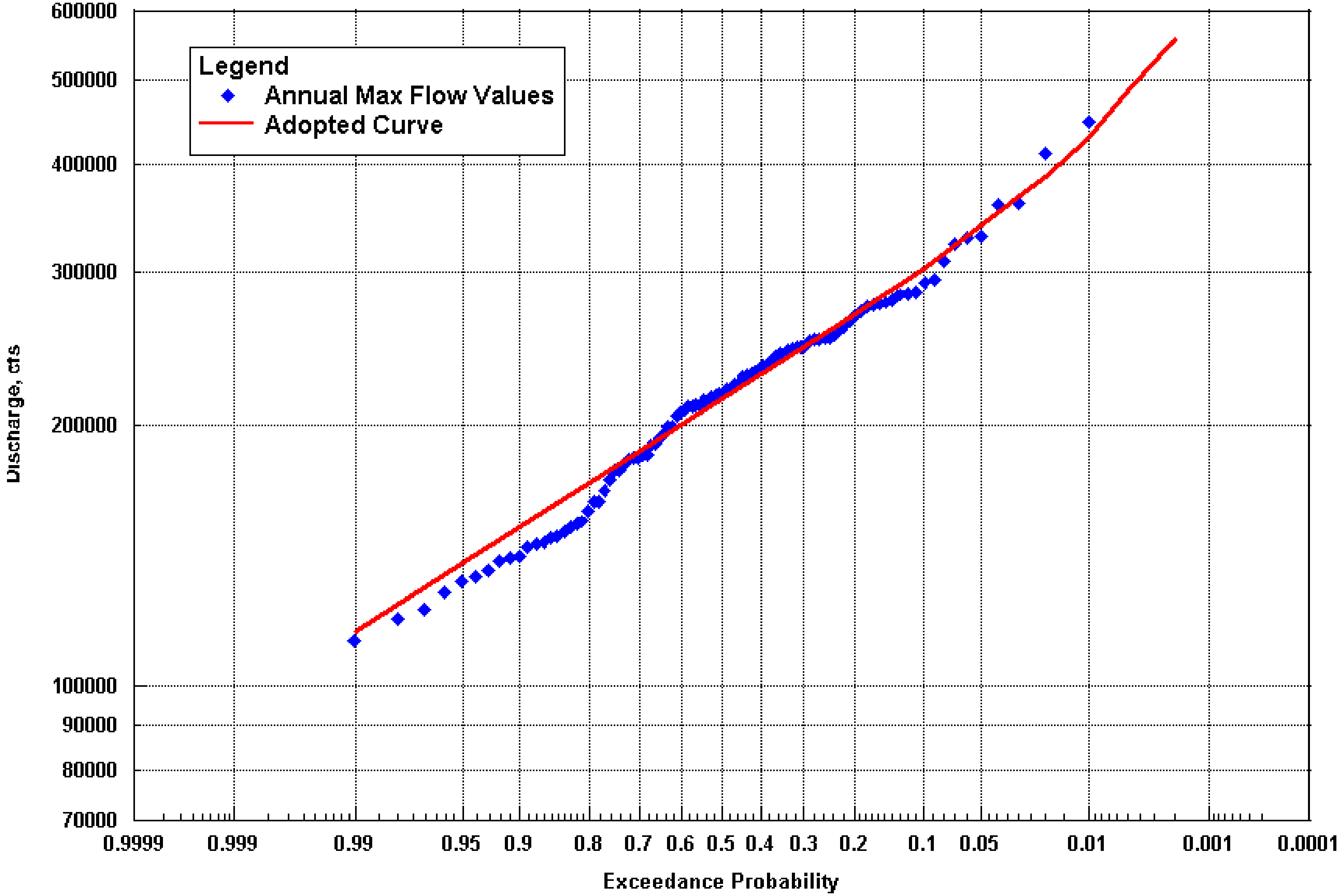
Adopted Unregulated Flow Frequency Curve, Omaha

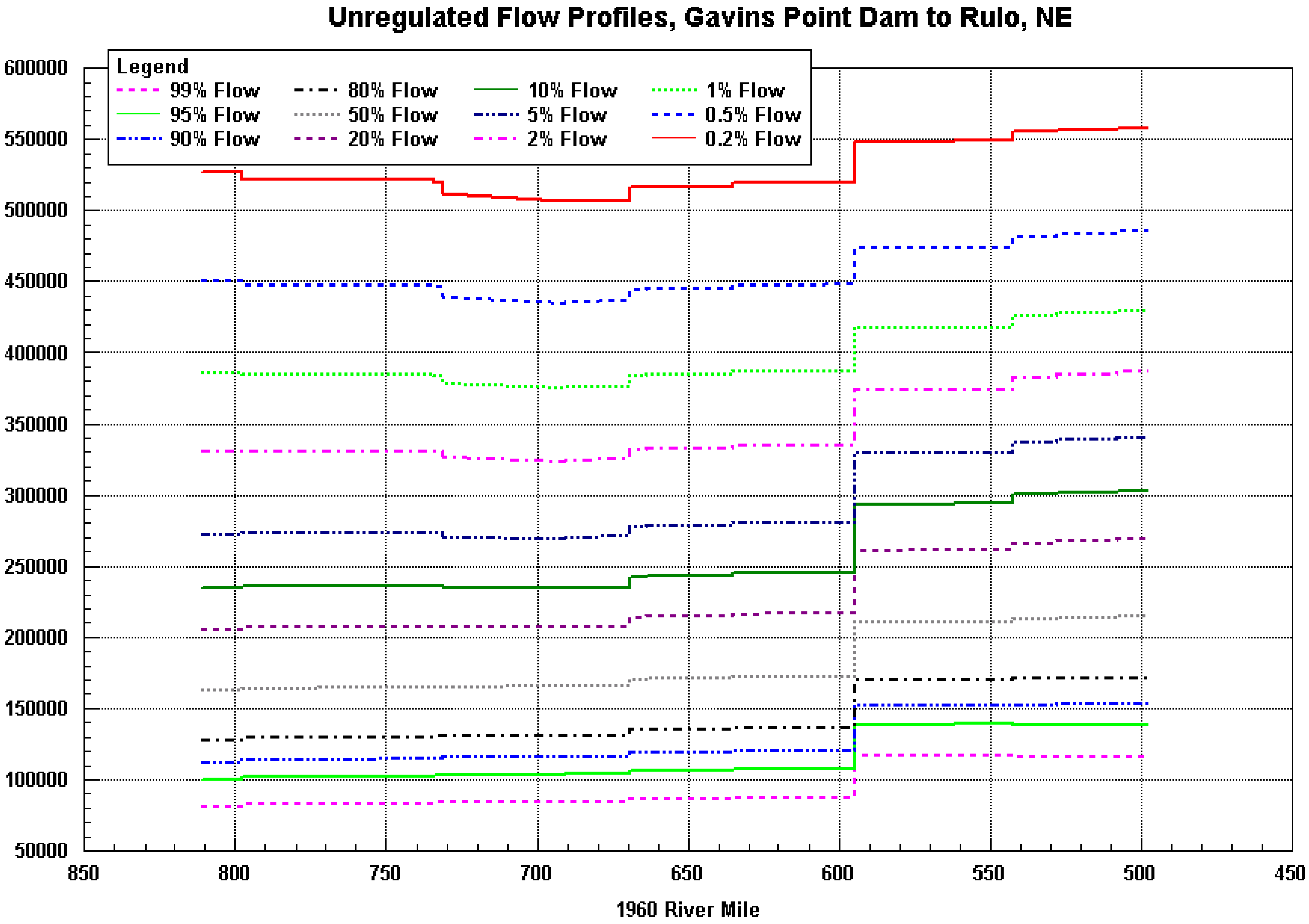


Adopted Unregulated Flow Frequency Curve, Nebraska City

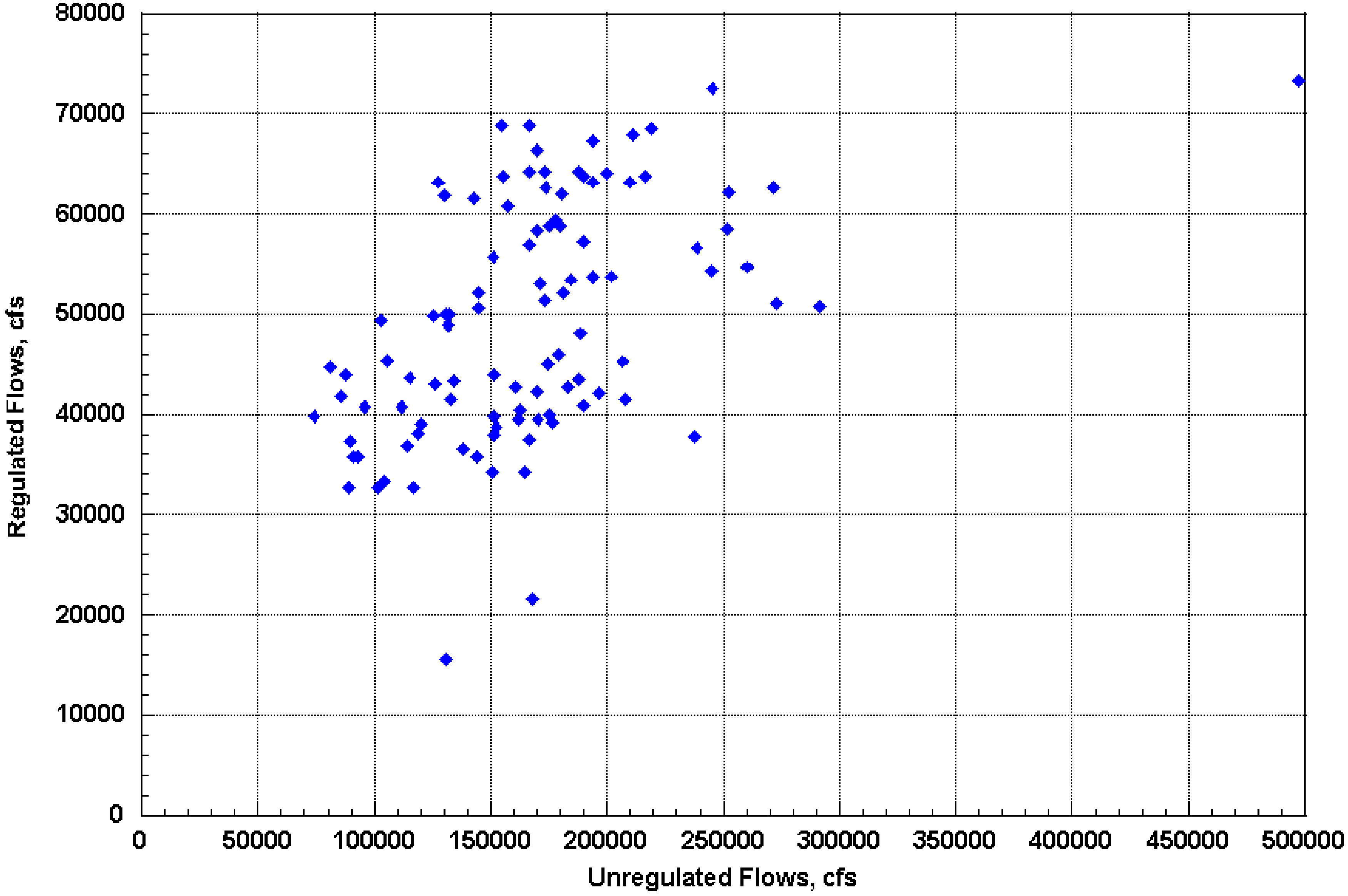


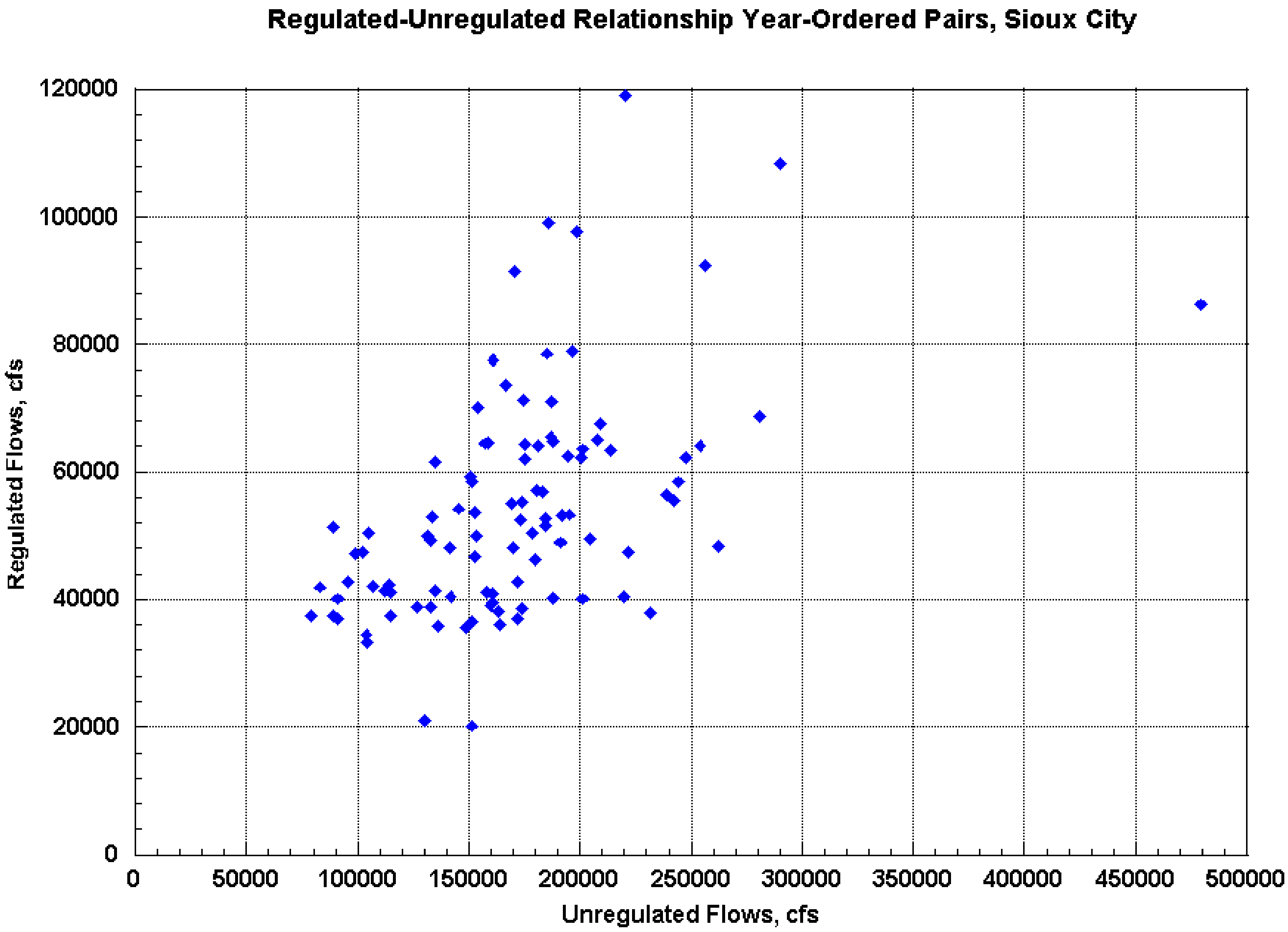
Adopted Unregulated Flow Frequency Curve, Rulo

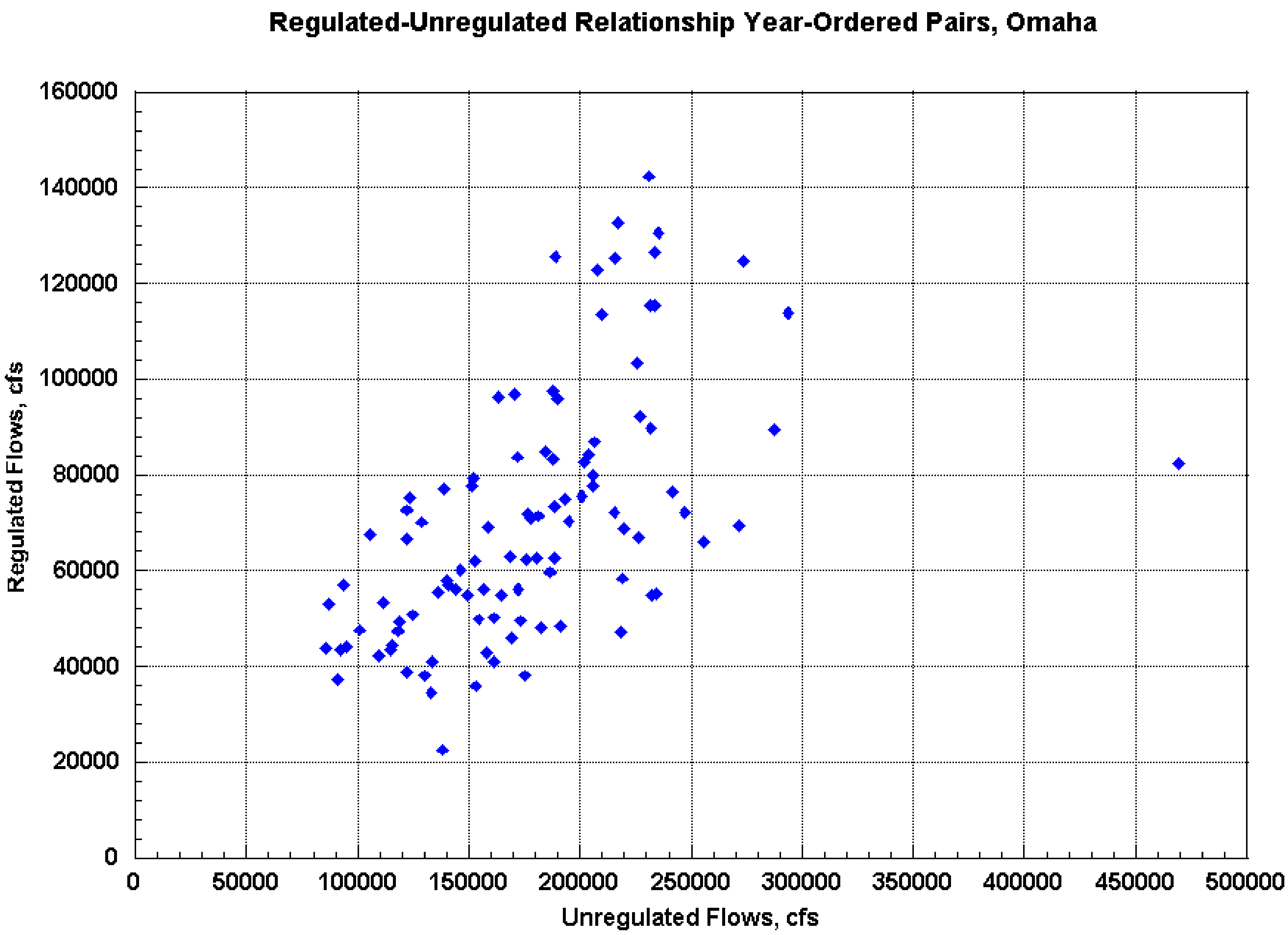


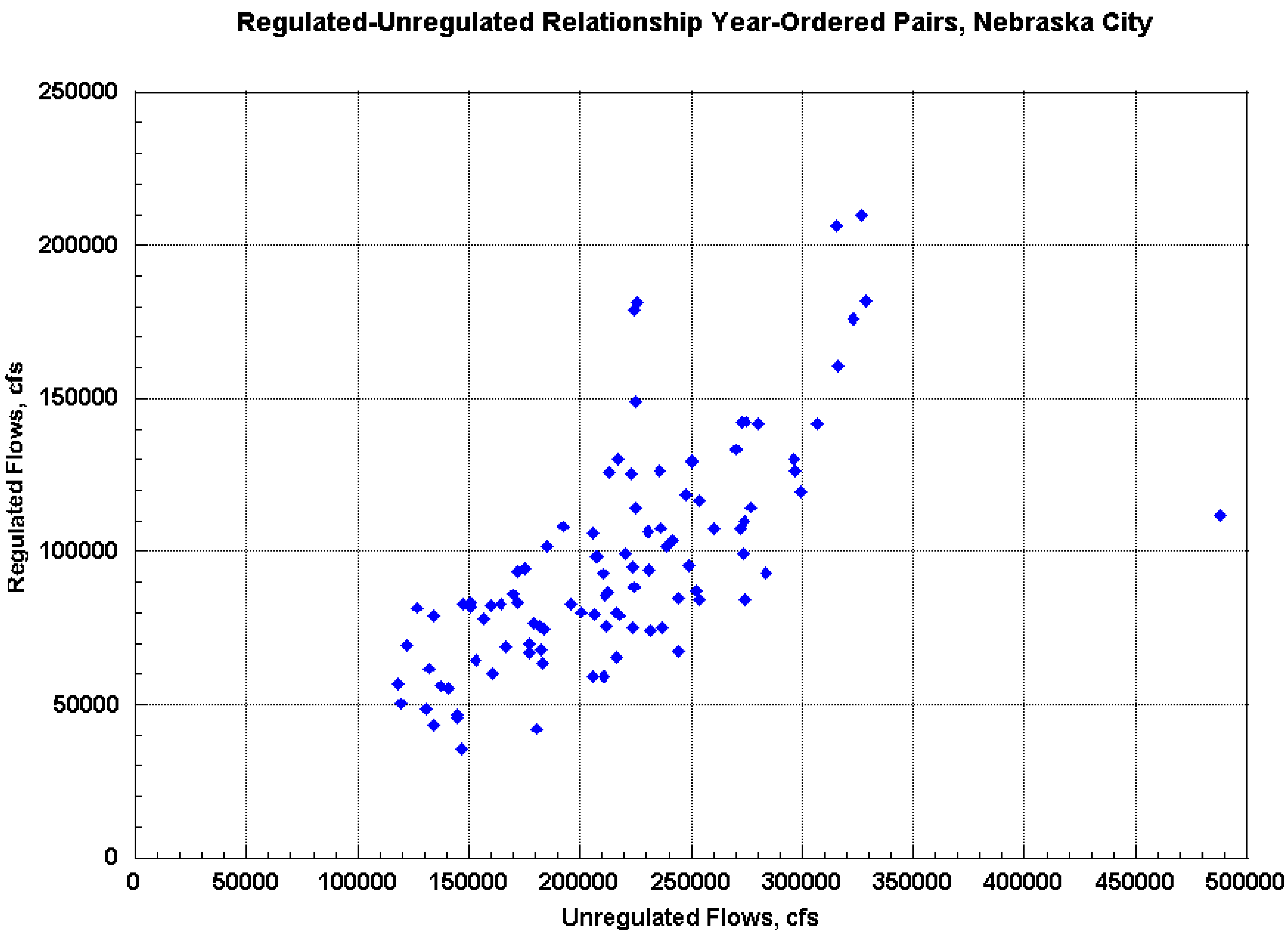

Unregulated Flow Profiles, Gavins Point Dam to Rulo, NE
Legend
99% Flow
95% Flow
90% Flow
80% Flow
50% Flow
20% Flow
10% Flow
5% Flow
2% Flow
1% Flow
0.5% Flow
0.2% Flow
600000
550000
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
850
800
750
700
650
600
550
500
450
1960 River Mile

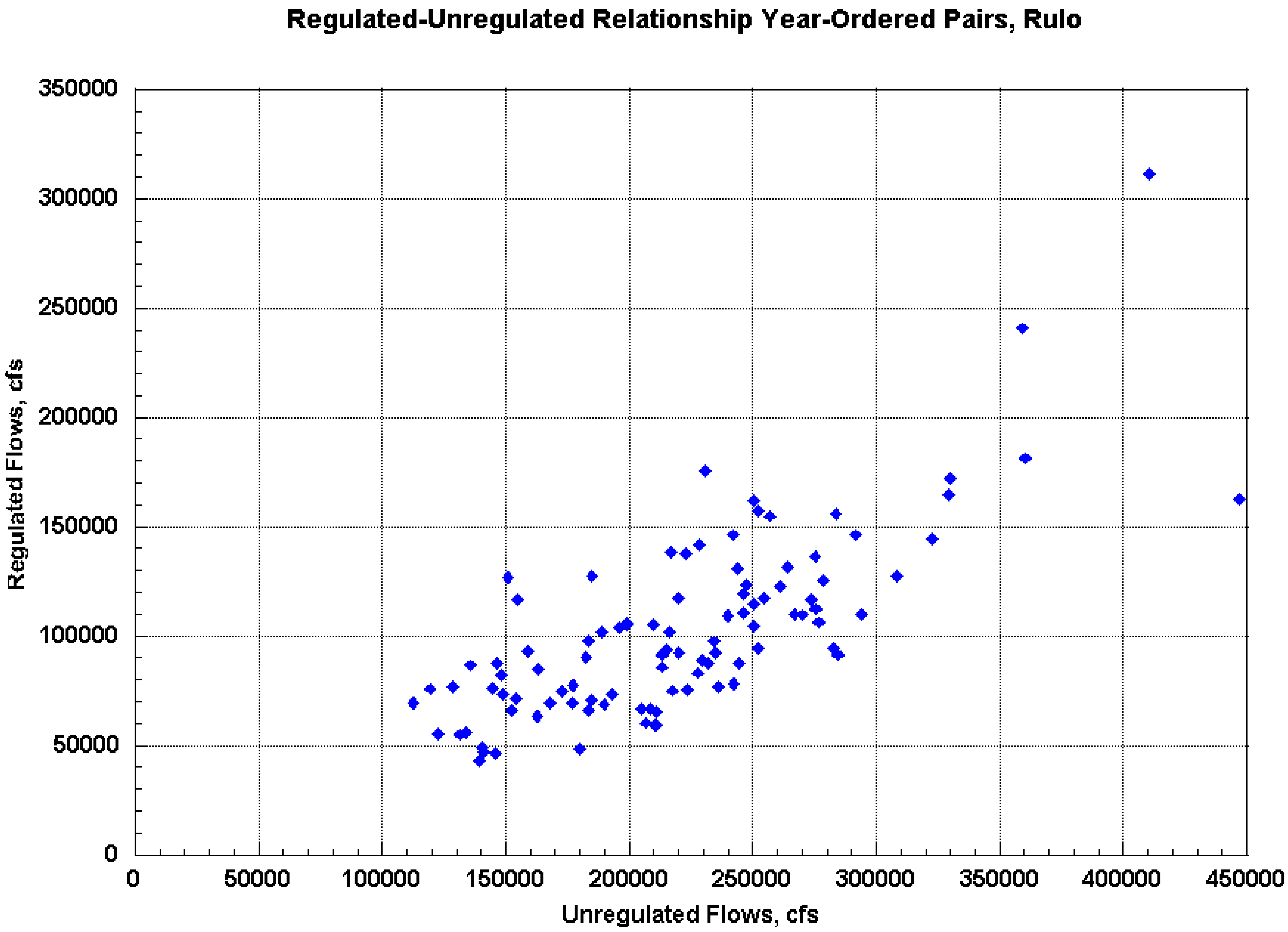
Regulated-Unregulated Relationship Year-Ordered Pairs, Yankton

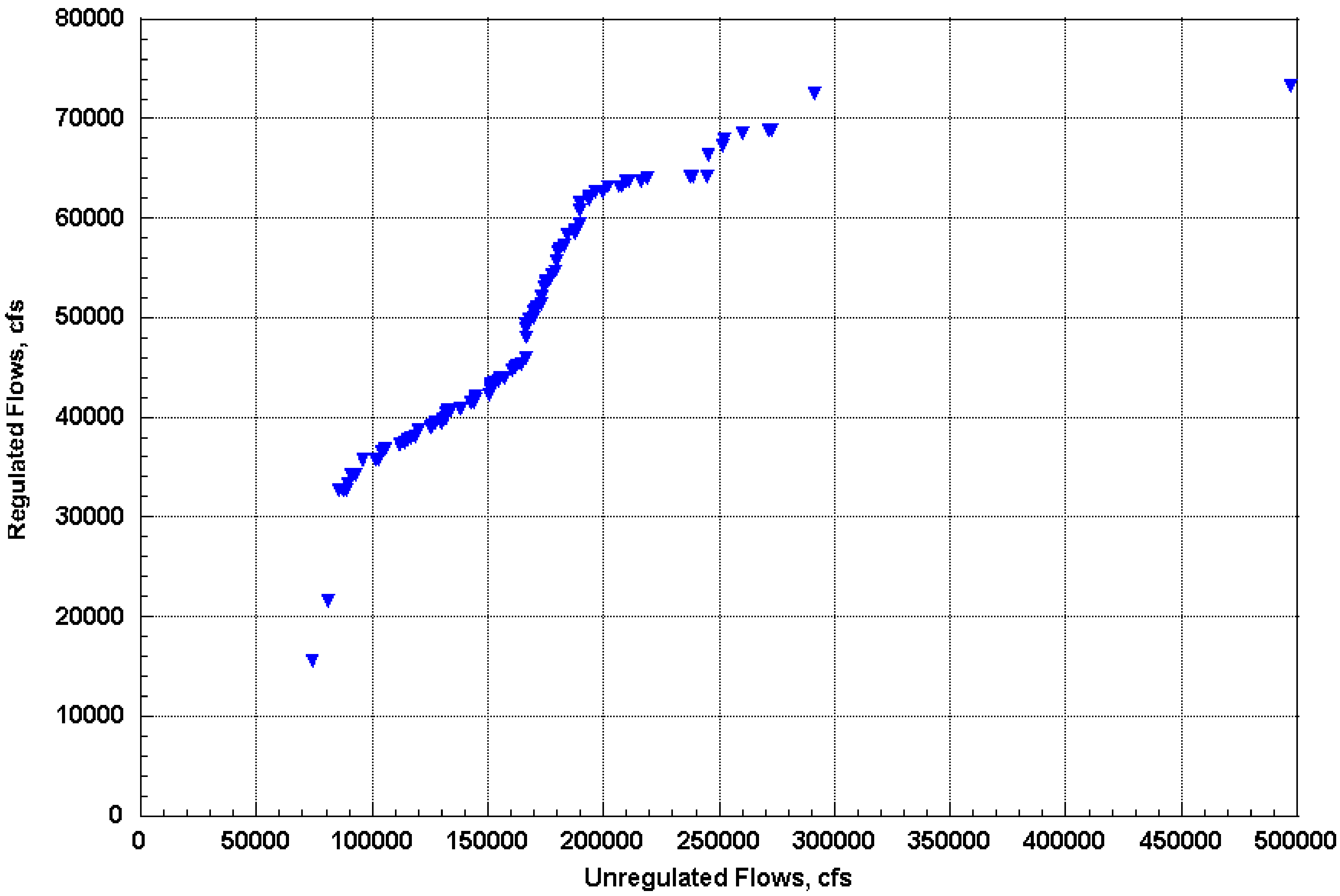



Regulated-Unregulated Relationship Year-Ordered Pairs, Sioux City
Regulated Flows, cfs
Unregulated Flows, cfs
0
20000
40000
60000
80000
100000
120000
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
500000

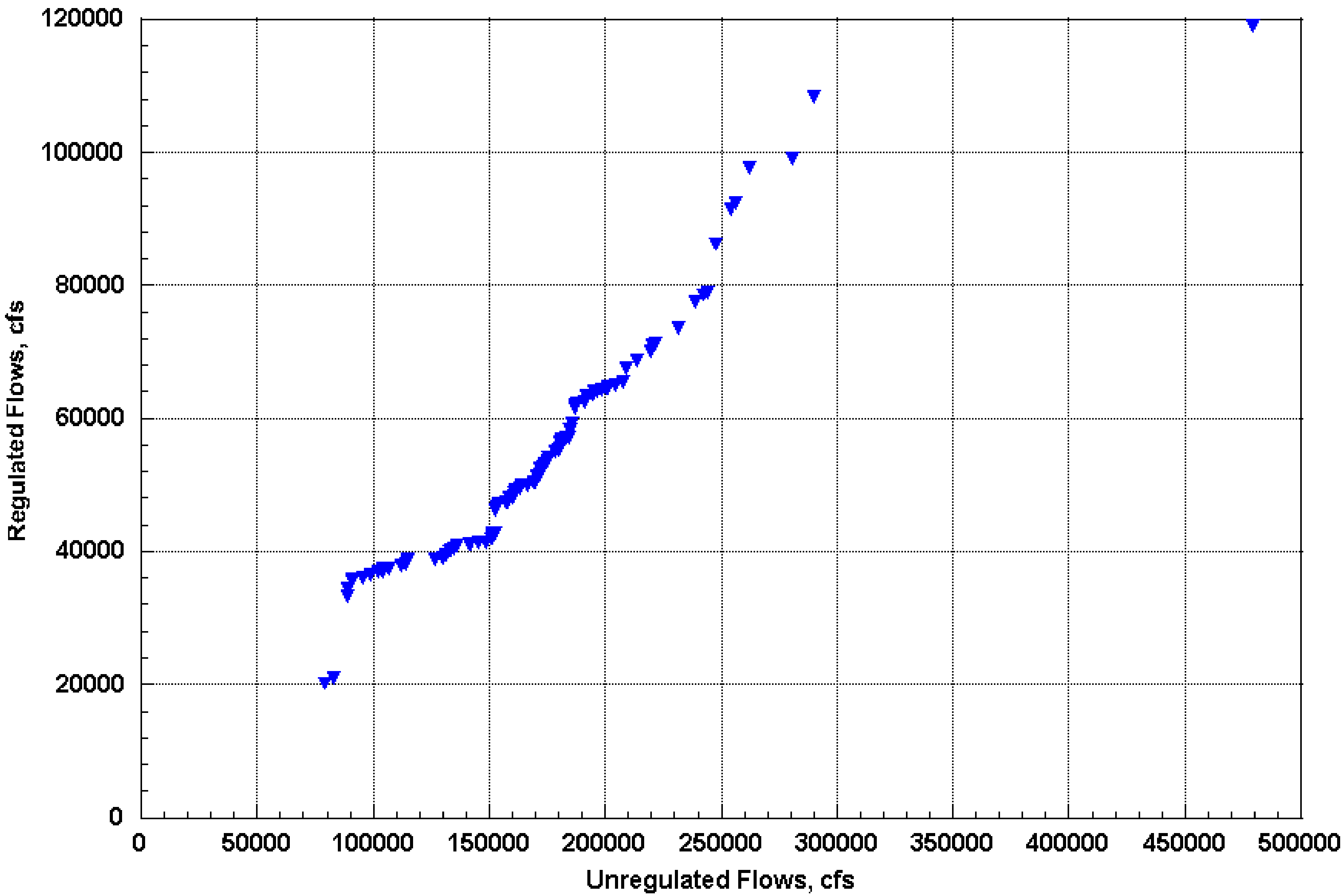

Regulated-Unregulated Relationship Year-Ordered Pairs, Omaha
160000
140000
120000
100000
80000
60000
40000
20000
0
Regulated Flows, cfs
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
500000
Unregulated Flows, cfs


Regulated-Unregulated Relationship Year-Ordered Pairs, Nebraska City
Regulated Flows, cfs
Unregulated Flows, cfs
0
50000
100000
150000
200000
250000
300000
350000
400000
450000
500000


Regulated-Unregulated Relationship Year-Ordered Pairs, Rulo
Regulated Flows, cfs
Unregulated Flows, cfs
350000
300000
250000
200000
150000
100000
50000
0
0
50000
100000
150000
200000
250000
300000
350000
400000
450000

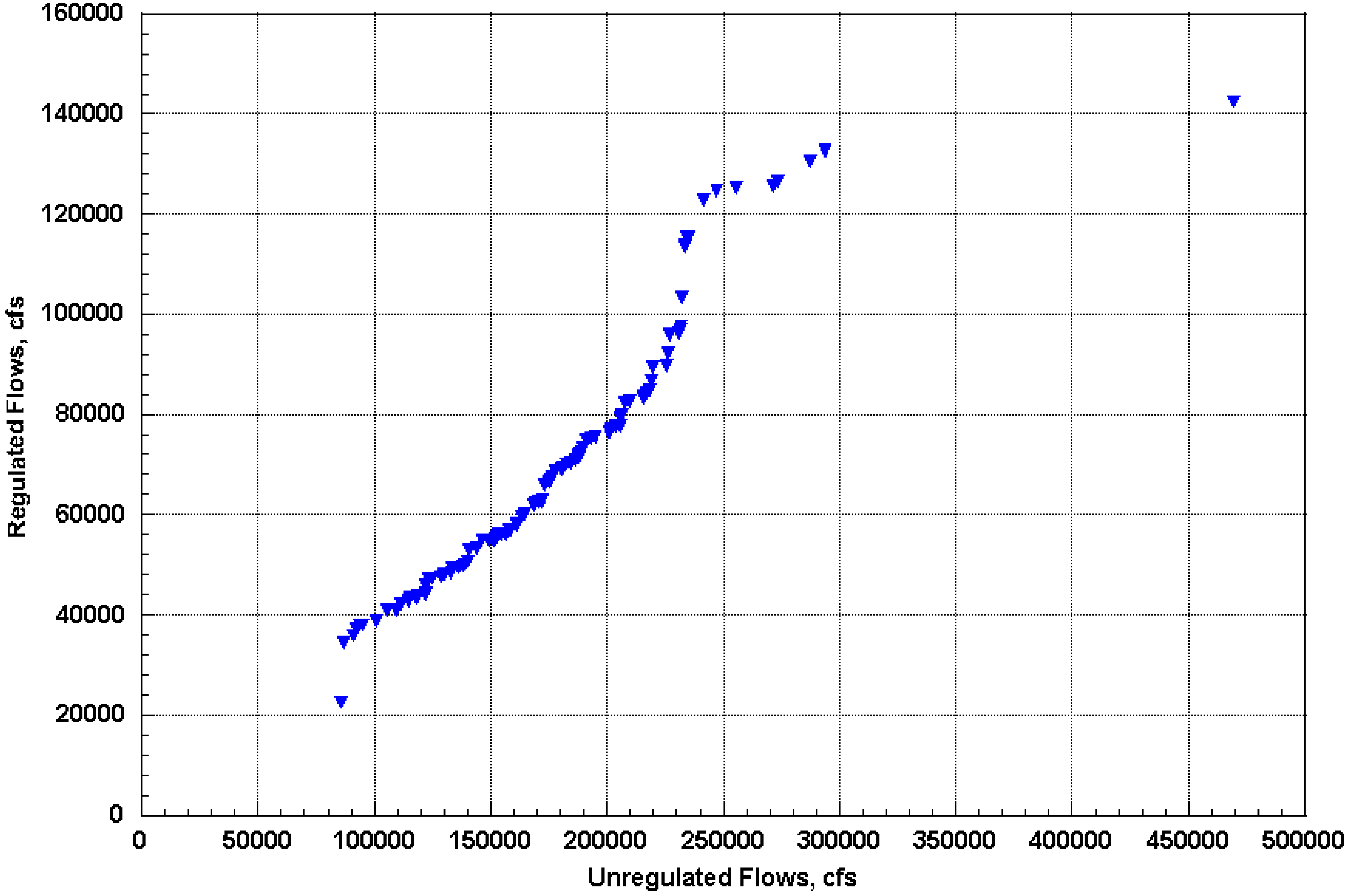


Regulated-Unregulated Relationship Rank-Ordered Pairs, Yankton

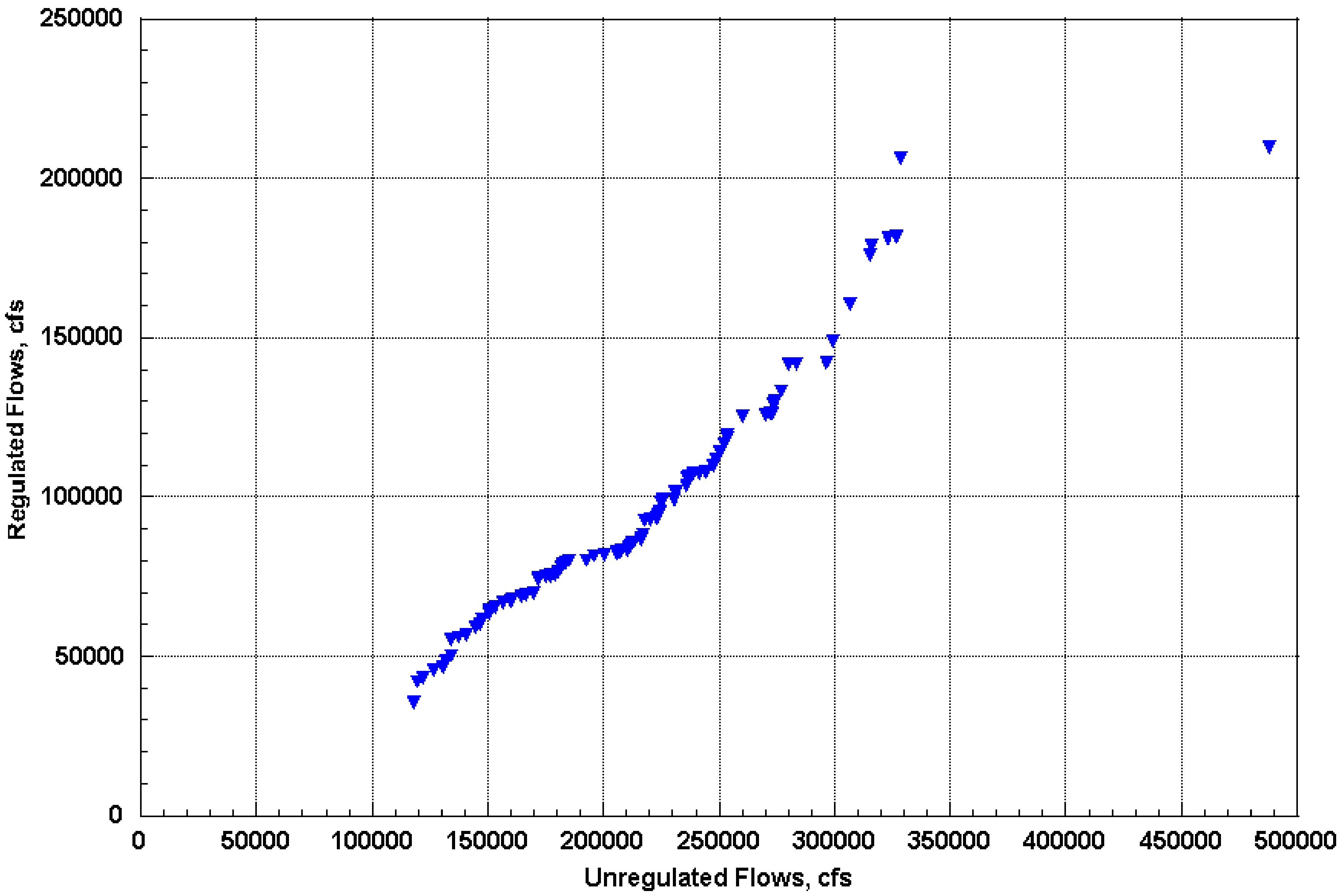


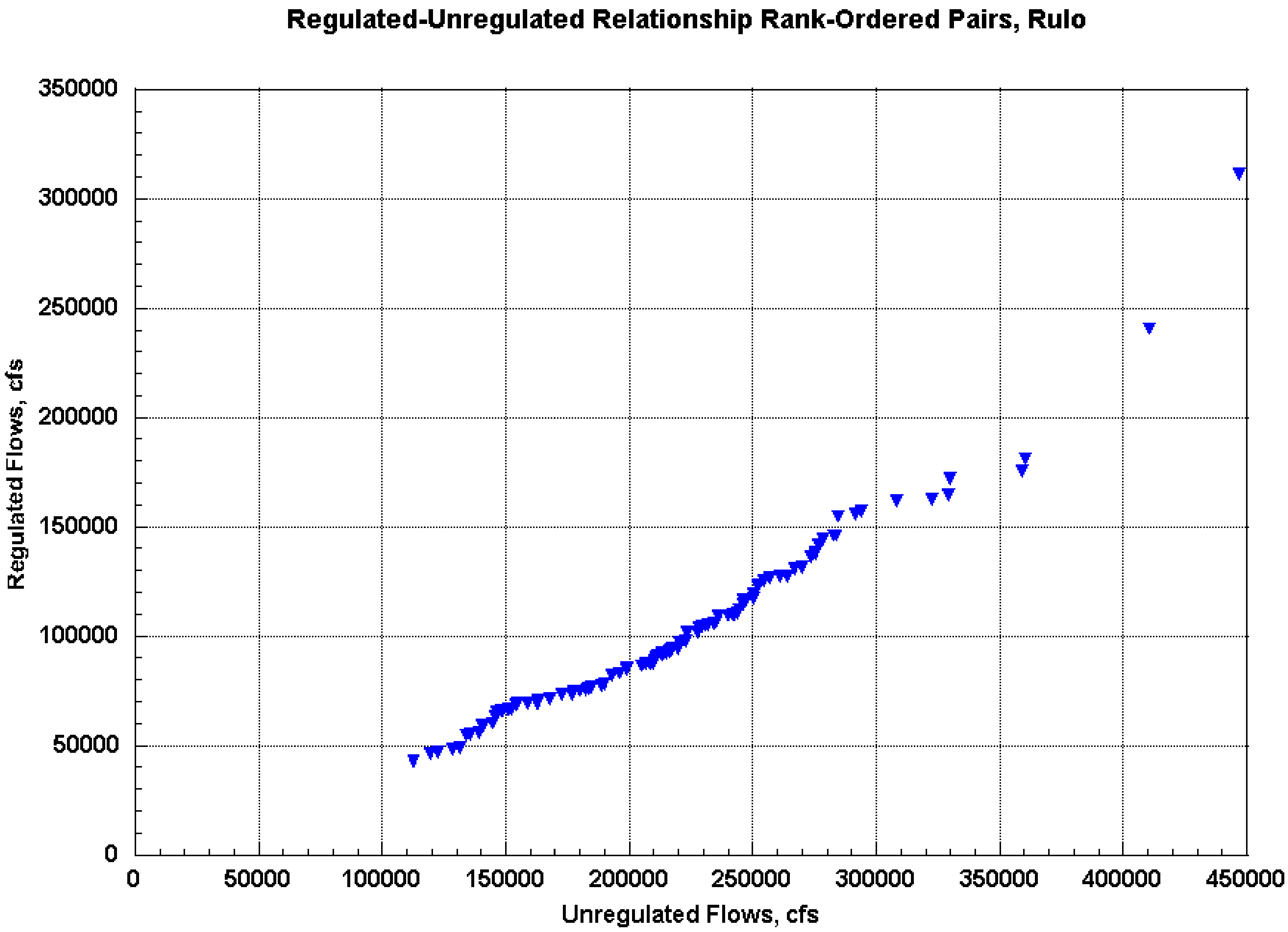
Regulated-Unregulated Relationship Rank-Ordered Pairs, Sioux City

Regulated-Unregulated Relationship Rank-Ordered Pairs, Omaha

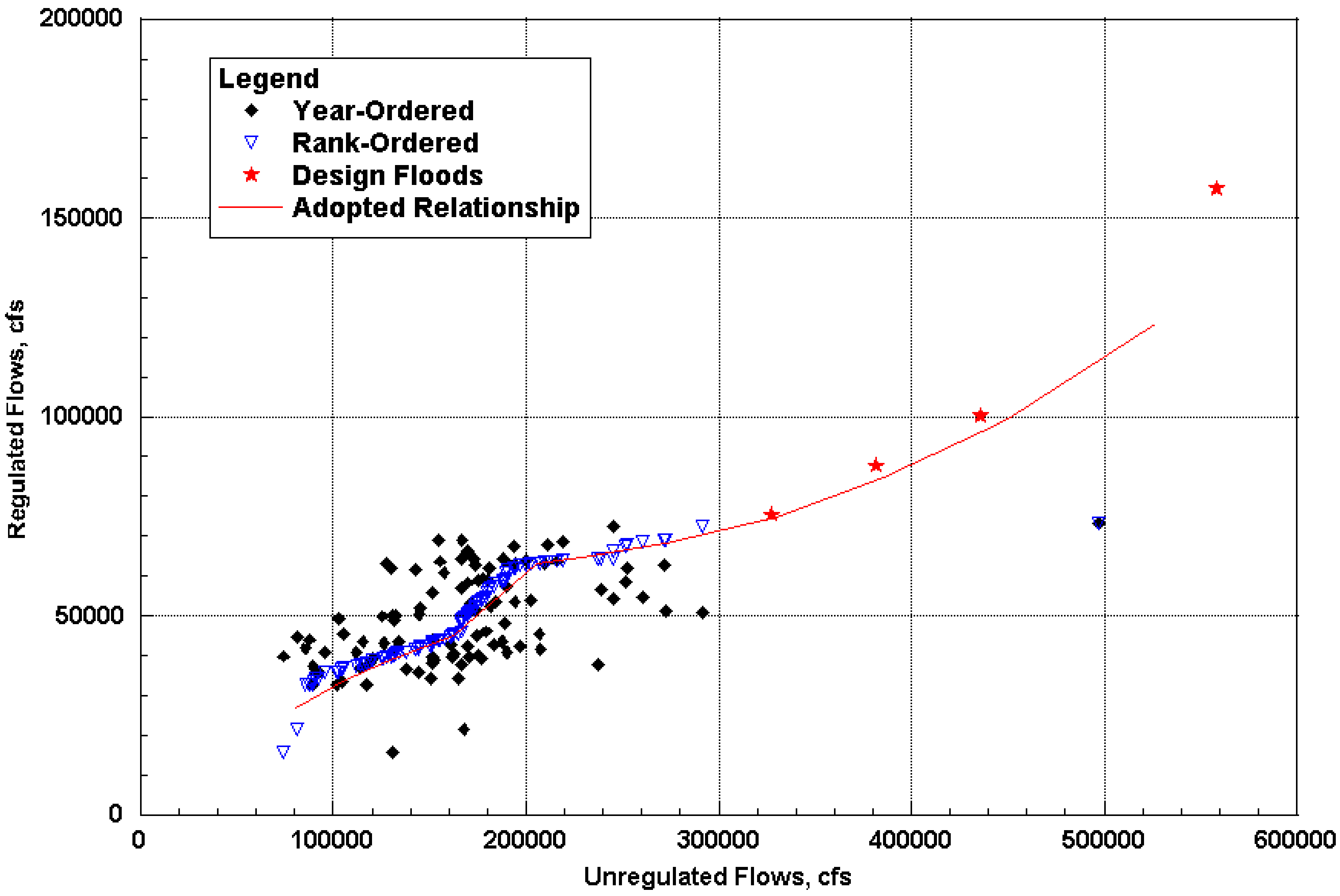


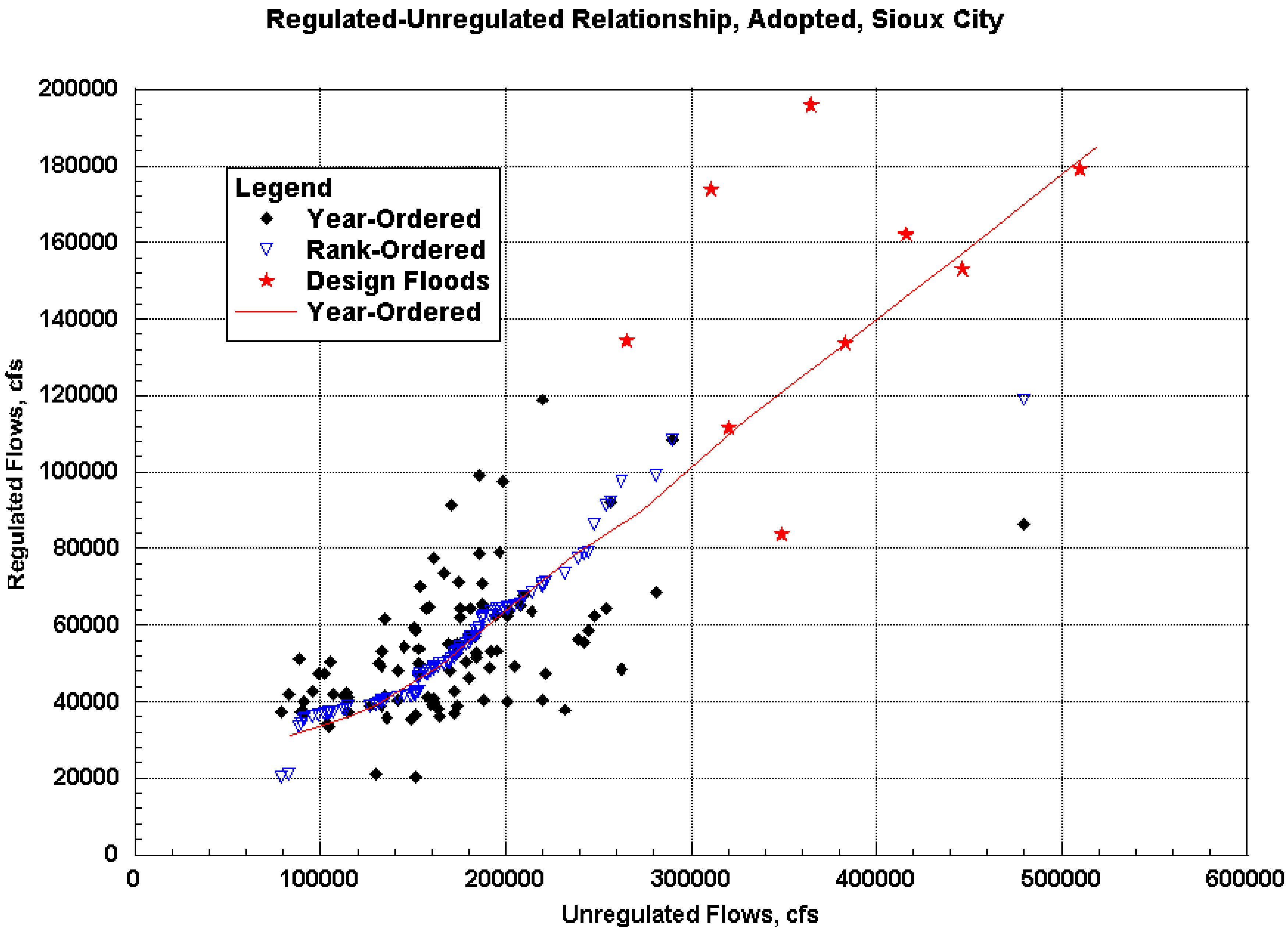
Regulated-Unregulated Relationship Rank-Ordered Pairs, Nebraska City

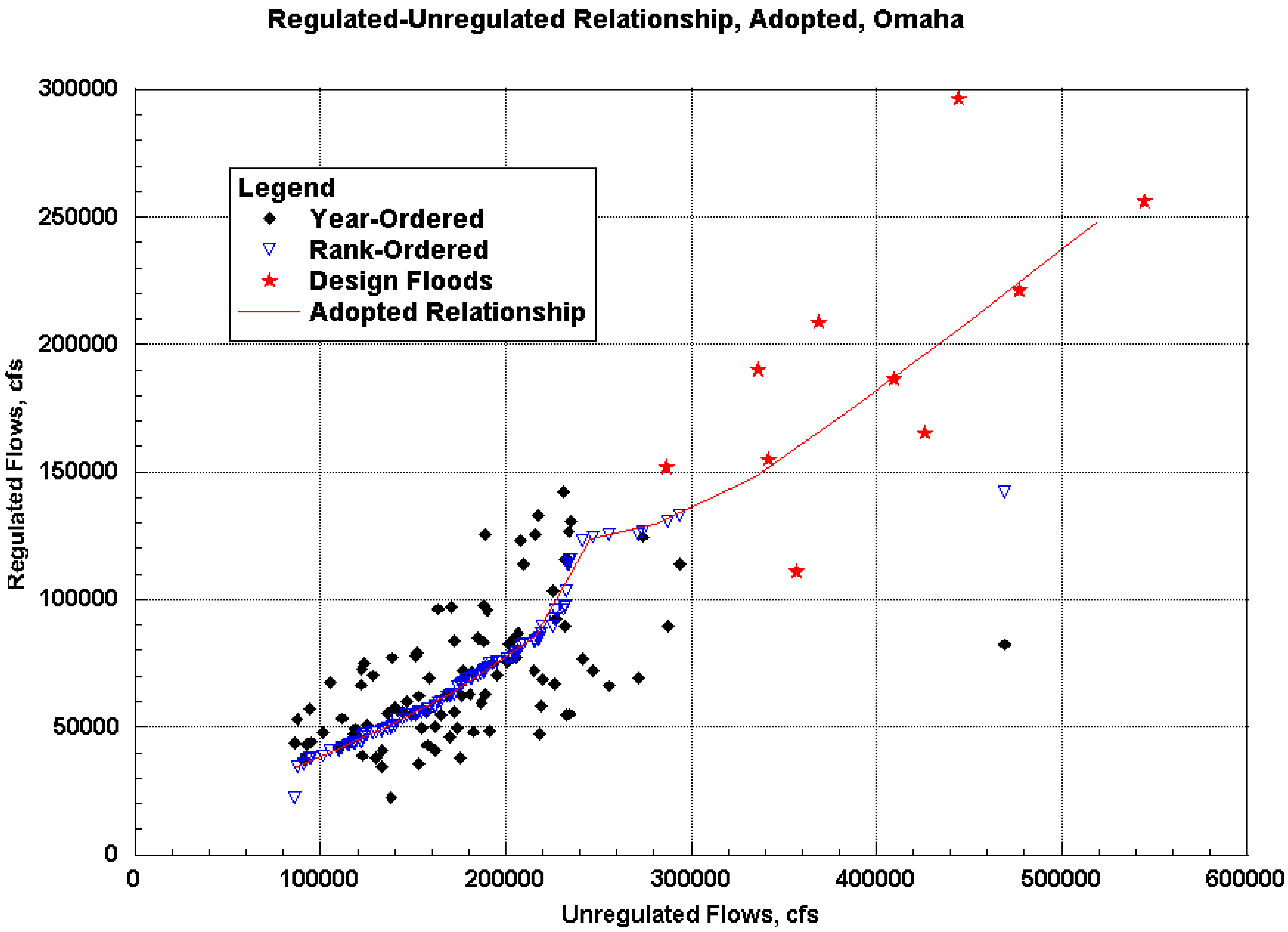



Regulated-Unregulated Relationship Rank-Ordered Pairs, Rulo
Regulated Flows, cfs
Unregulated Flows, cfs
0
50000
100000
150000
200000
250000
300000
350000
400000
450000

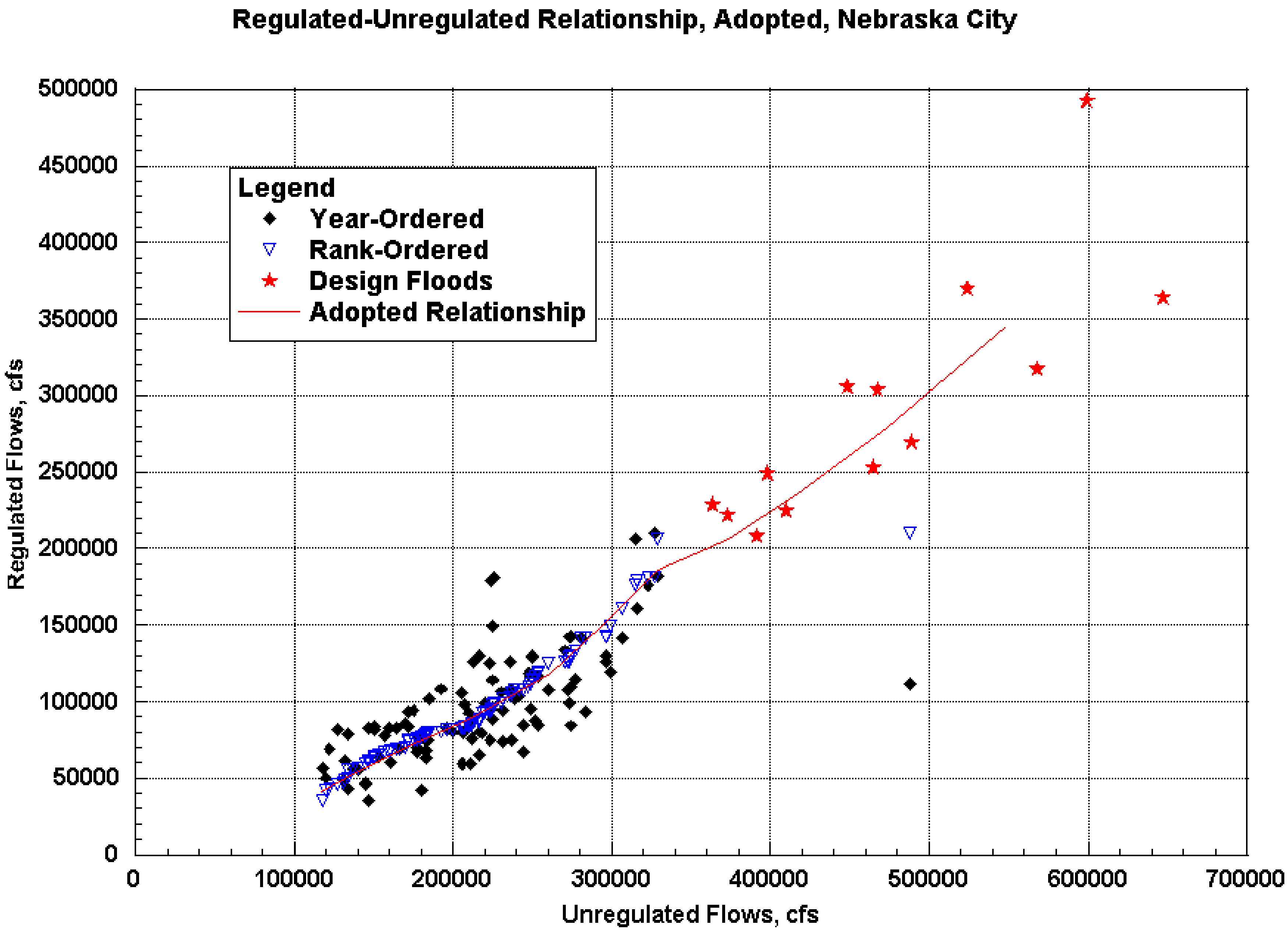
Regulated-Unregulated Relationship, Adopted, Yankton



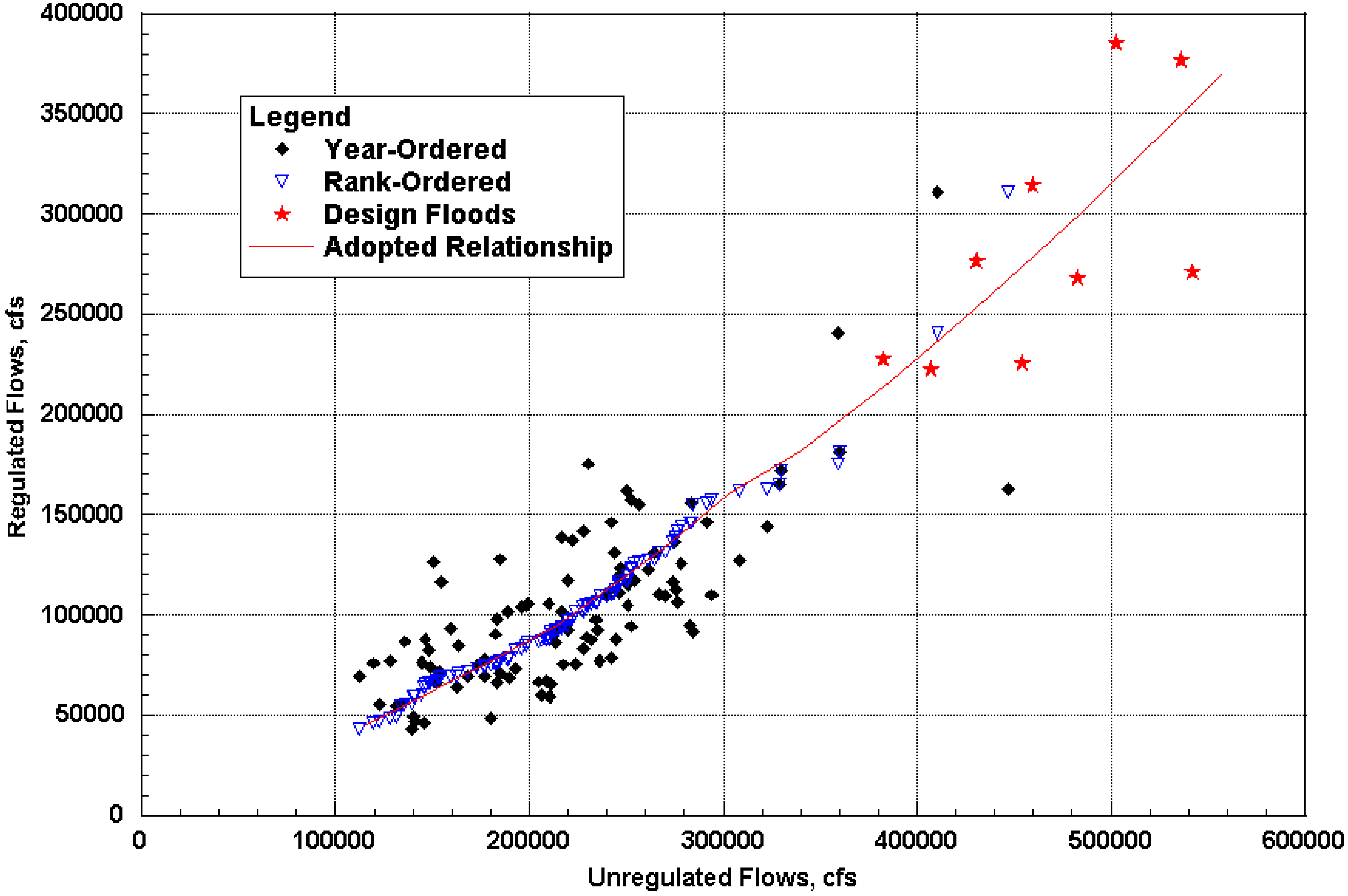

Regulated-Unregulated Relationship, Adopted, Sioux City
Legend
◆ Year-Ordered
▽ Rank-Ordered
★ Design Floods
Year-Ordered
Regulated Flows, cfs
Unregulated Flows, cfs
0
20000
40000
60000
80000
100000
120000
140000
160000
180000
200000
0
100000
200000
300000
400000
500000
600000



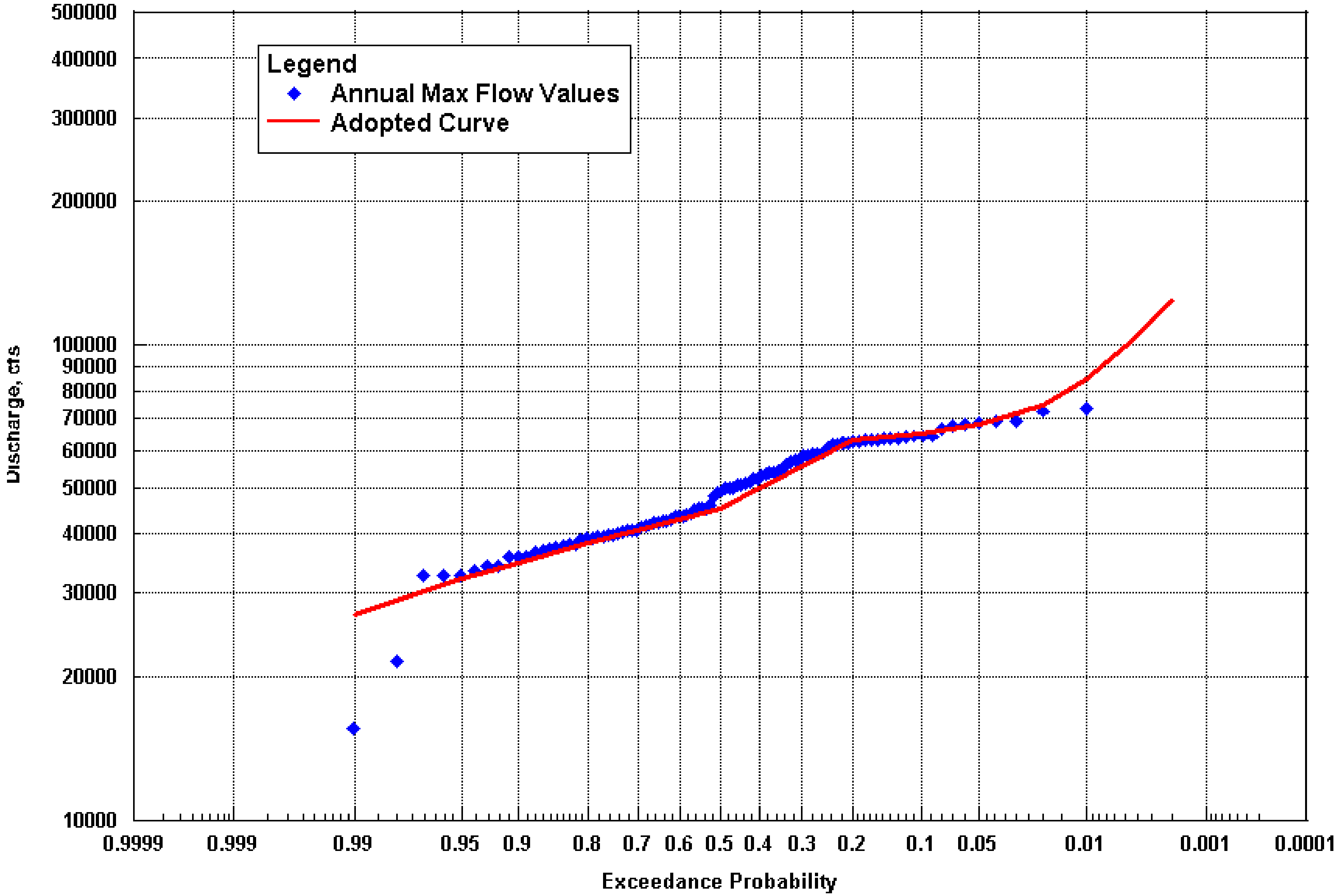
Regulated-Unregulated Relationship, Adopted, Omaha
Legend
Year-Ordered
Rank-Ordered
Design Floods
Adopted Relationship
Regulated Flows, cfs
Unregulated Flows, cfs
0
50000
100000
150000
200000
250000
300000
0
100000
200000
300000
400000
500000
600000

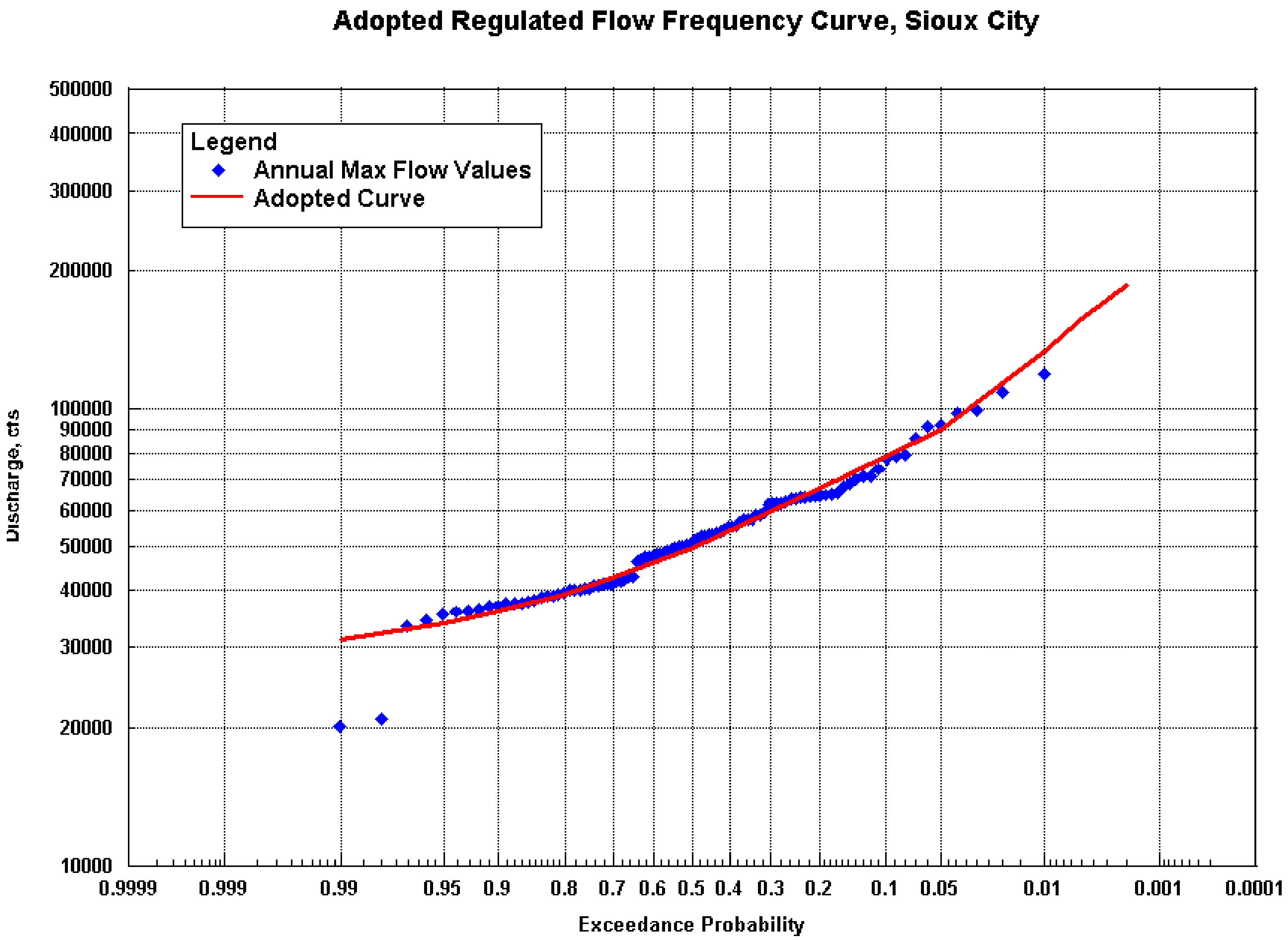

Regulated-Unregulated Relationship, Adopted, Nebraska City
Legend
◆ Year-Ordered
▽ Rank-Ordered
★ Design Floods
Adopted Relationship
Regulated Flows, cfs
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
0
100000
200000
300000
400000
500000
600000
700000
Unregulated Flows, cfs

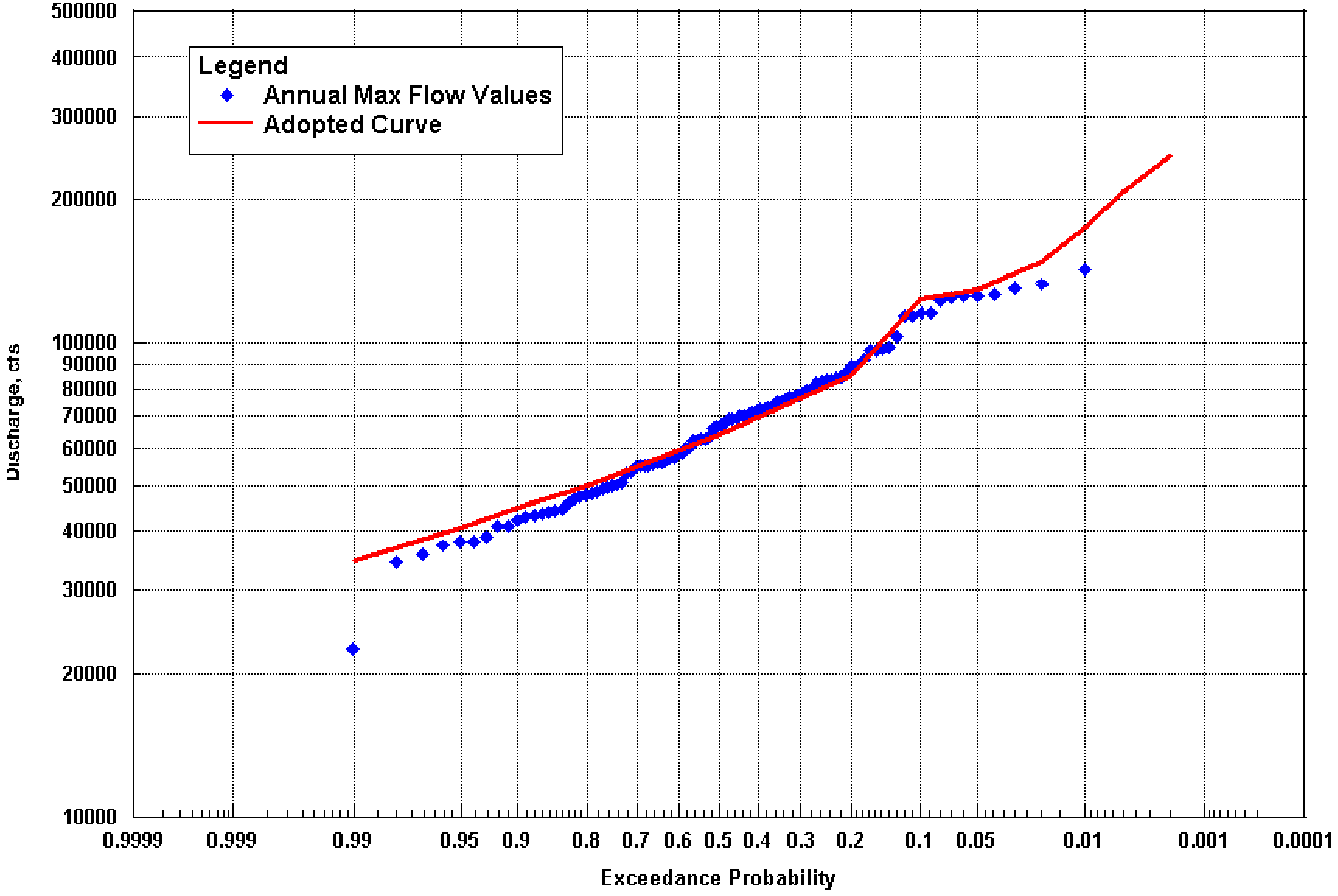
Regulated-Unregulated Relationship, Adopted, Rulo



Adopted Regulated Flow Frequency Curve, Yankton

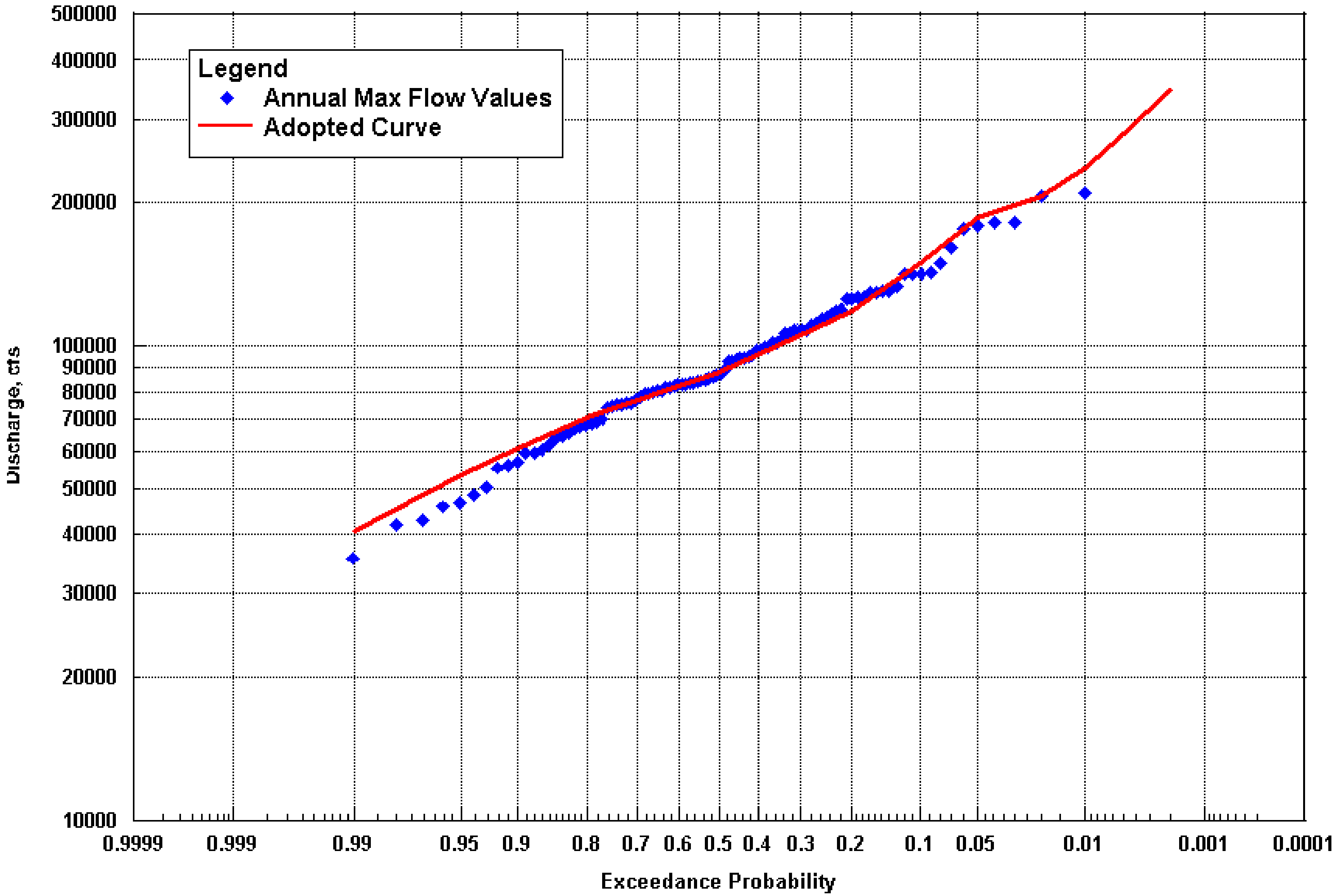



Adopted Regulated Flow Frequency Curve, Sioux City
Legend
◆ Annual Max Flow Values
Adopted Curve
500000
400000
300000
200000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
Discharge, cfs
0.9999
0.999
0.99
0.95
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.05
0.01
0.001
0.0001
Exceedance Probability

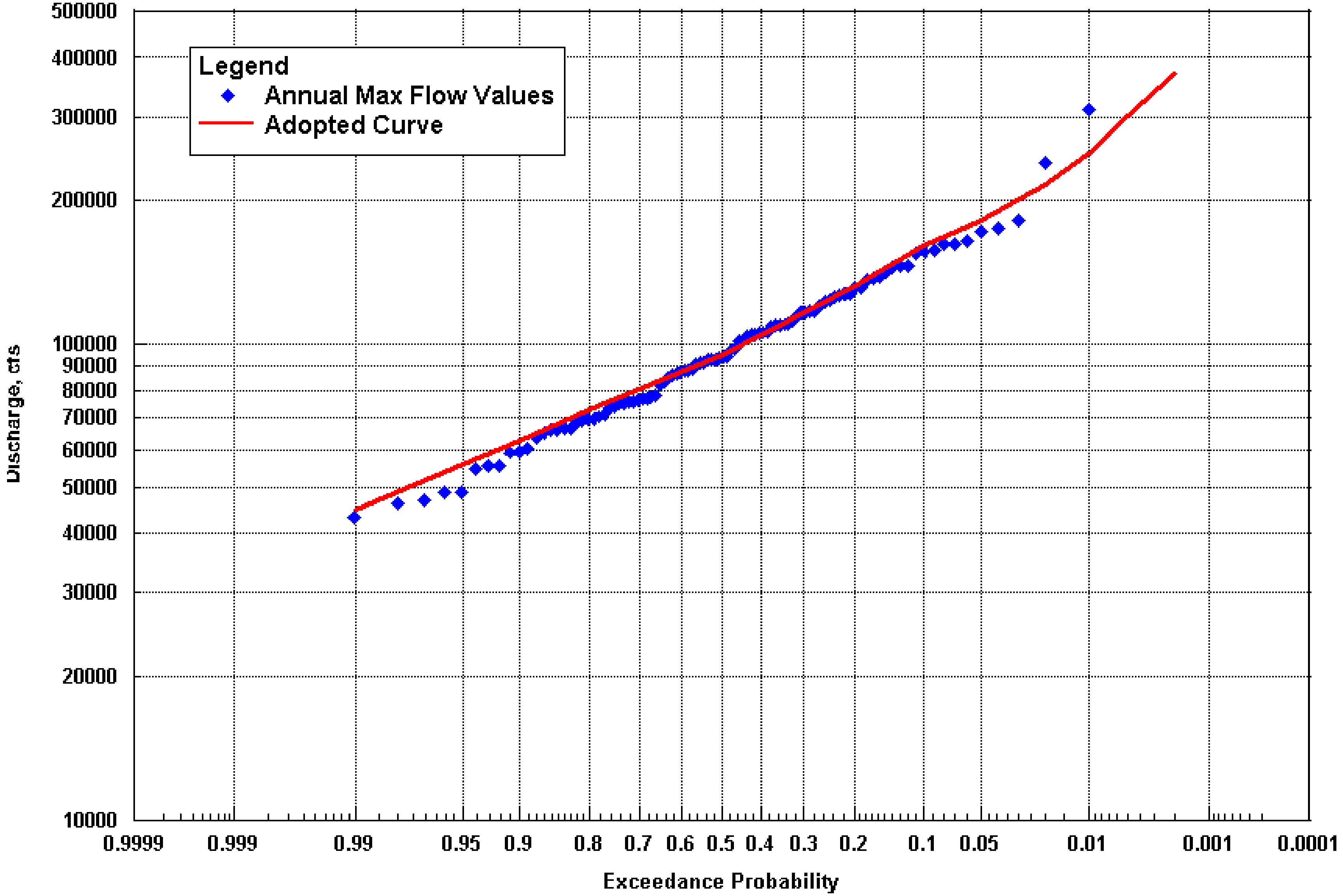


Adopted Regulated Flow Frequency Curve, Omaha

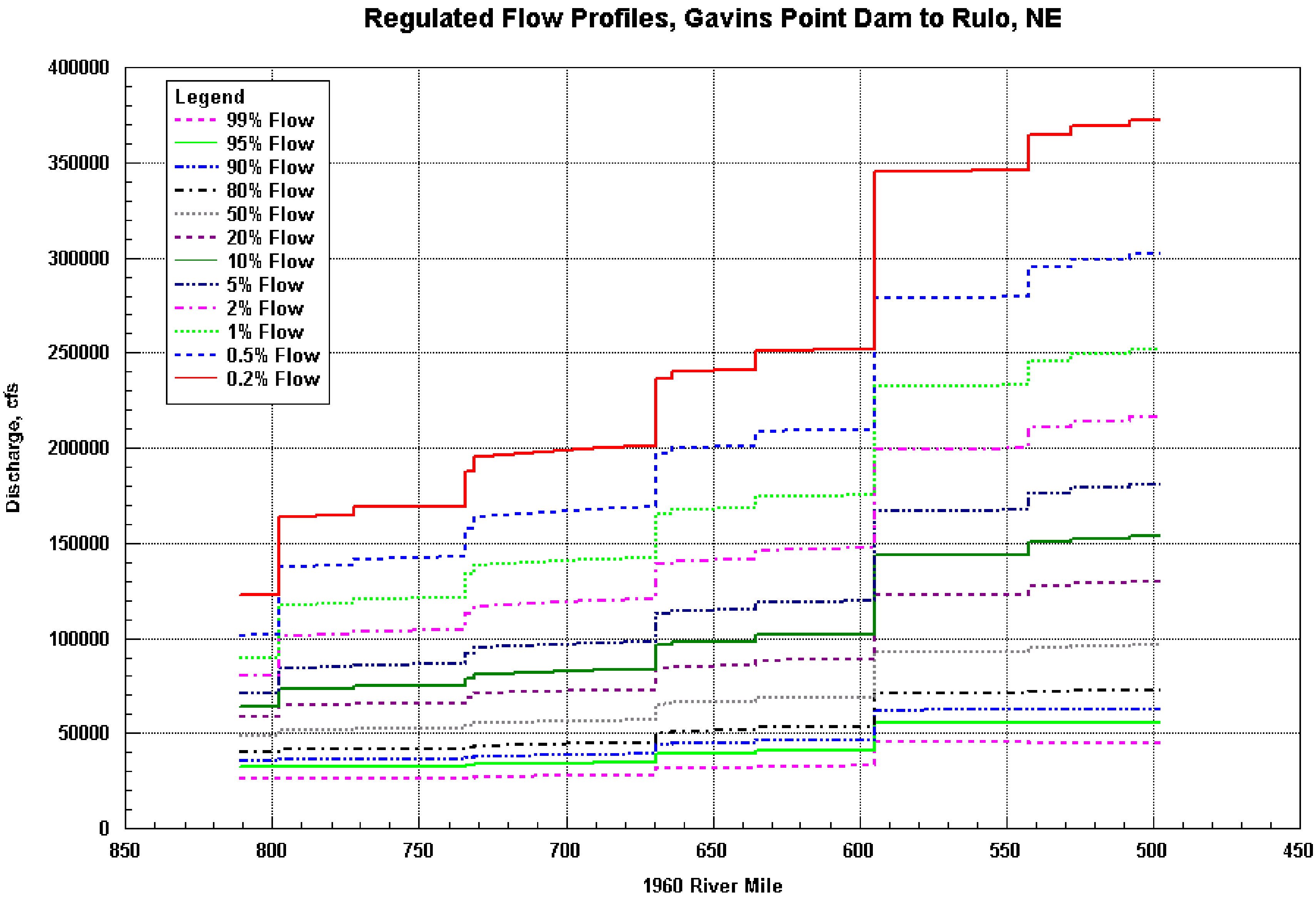
Adopted Regulated Flow Frequency Curve, Nebraska City



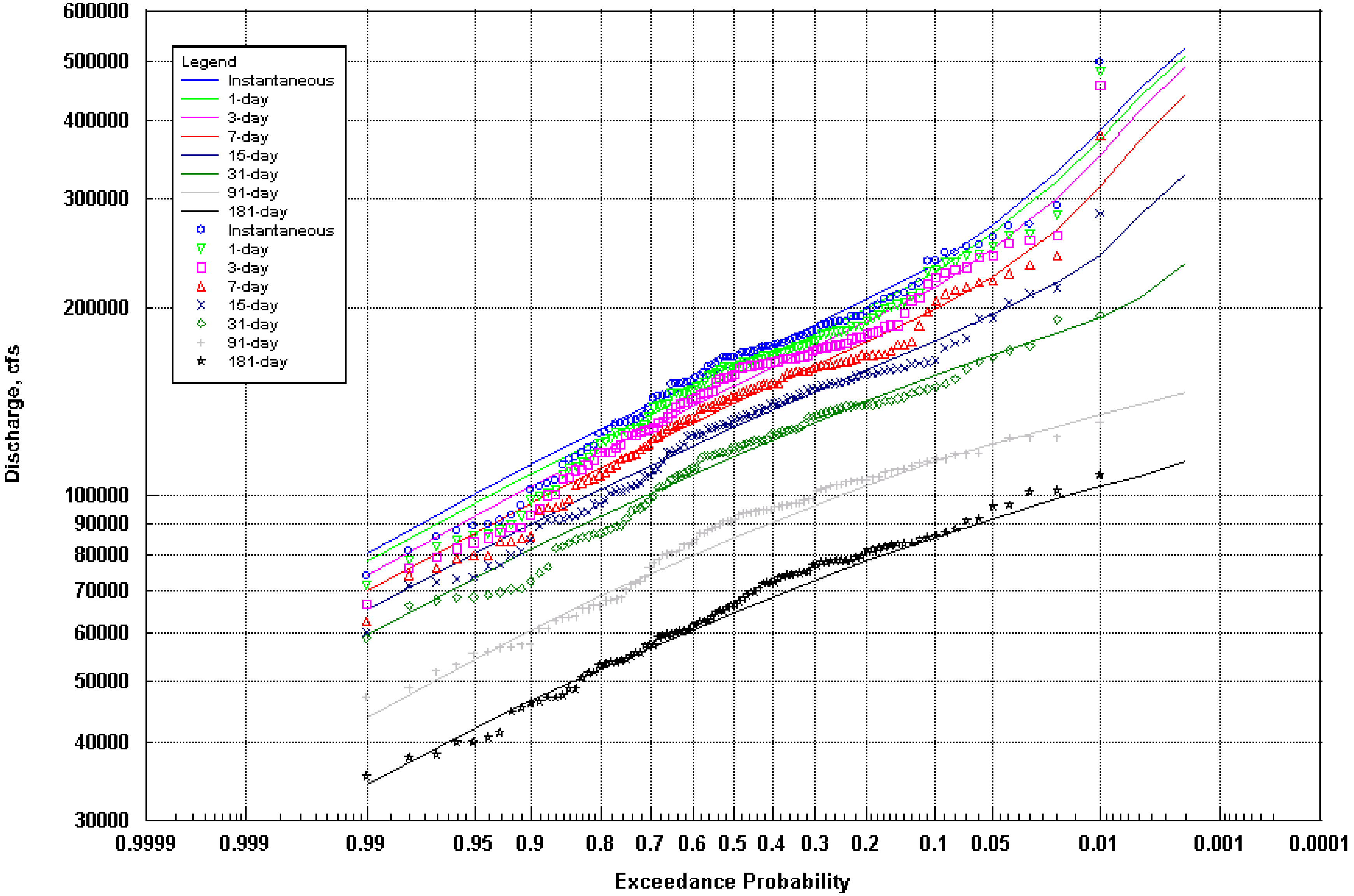
Adopted Regulated Flow Frequency Curve, Rulo



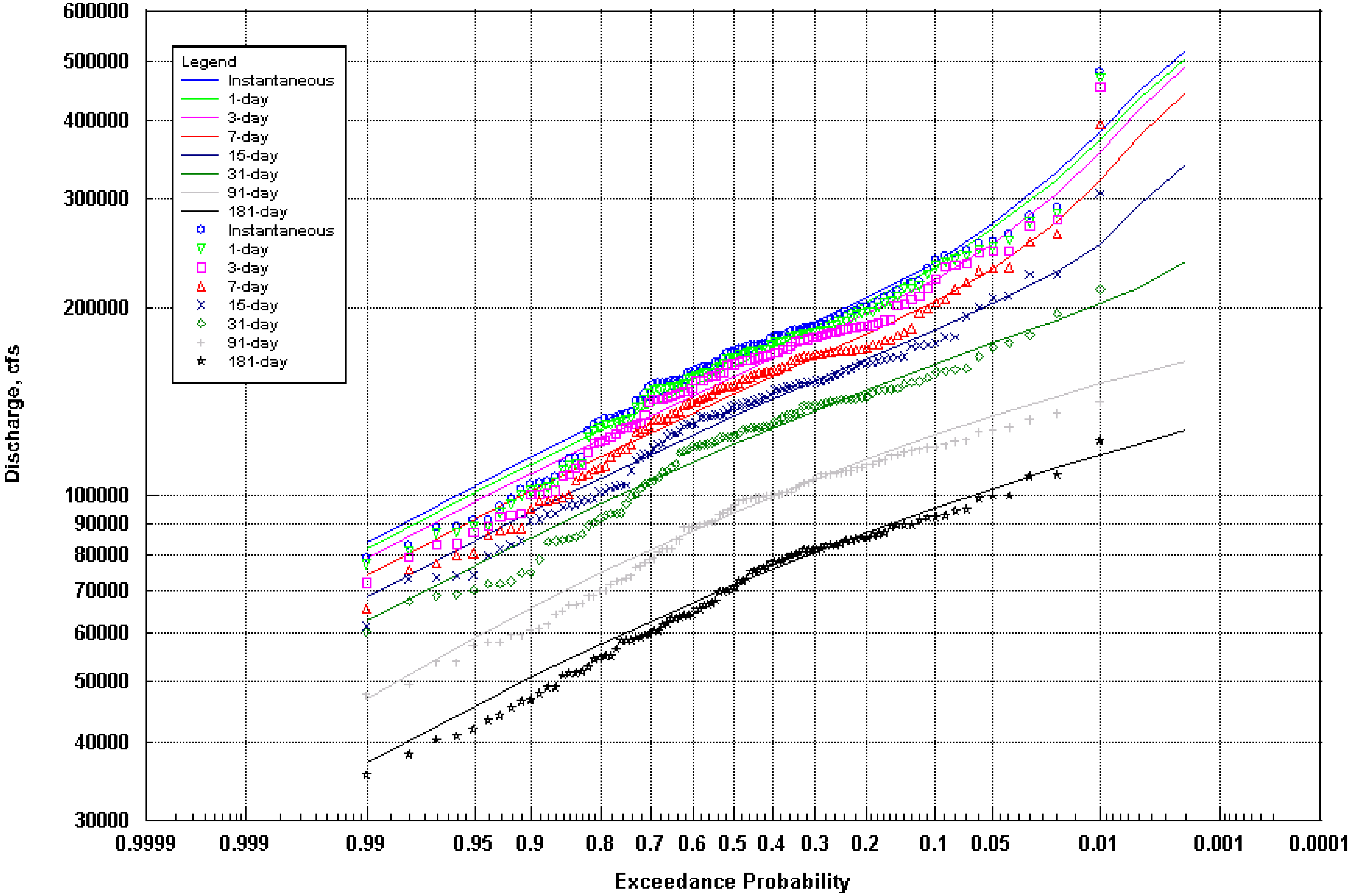
NOTE: Data revised during the Hydraulic Analysis.



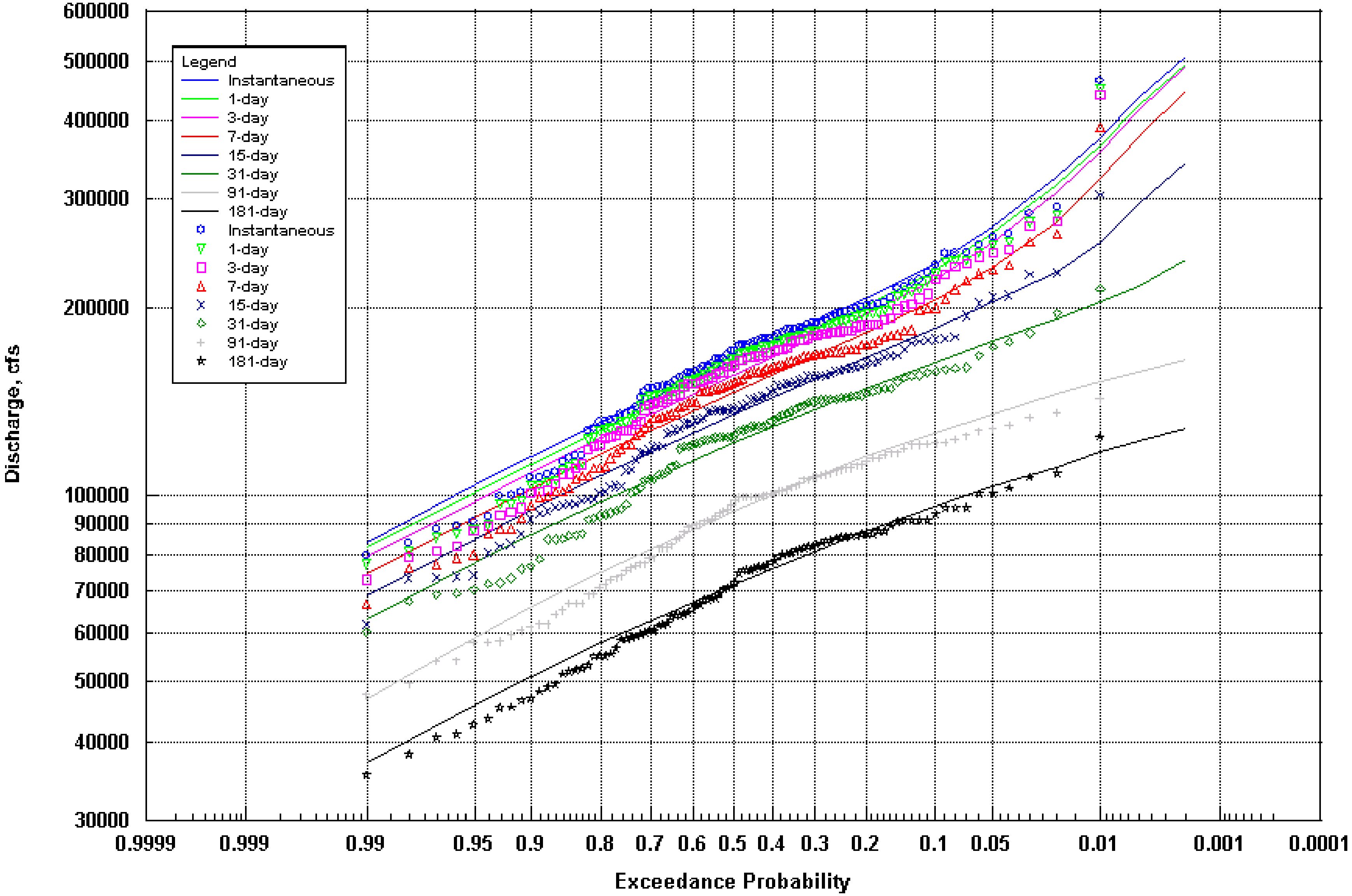
Volume-Duration Unregulated Frequency Curves, Yankton

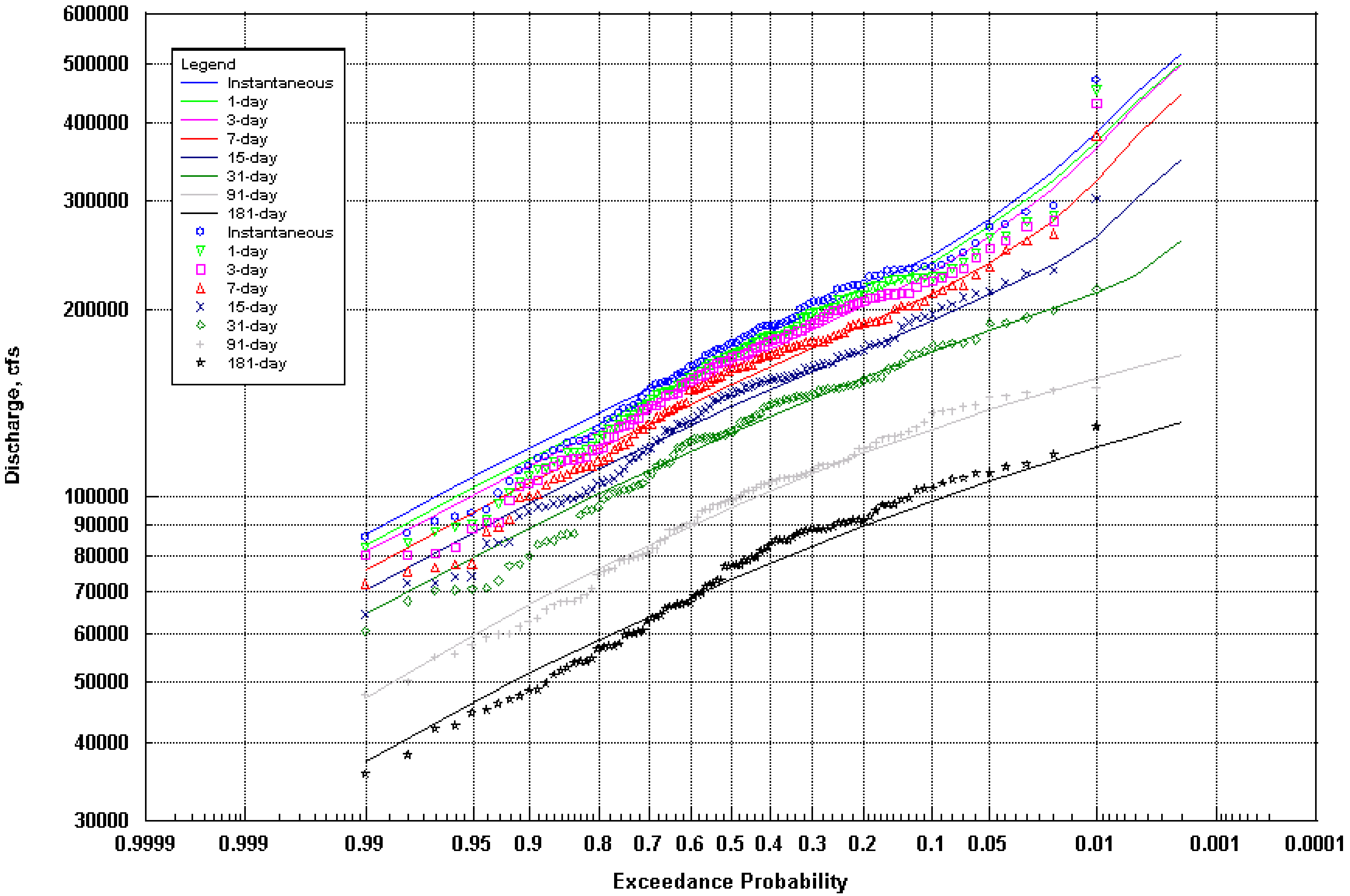


Volume-Duration Unregulated Frequency Curves, Sioux City

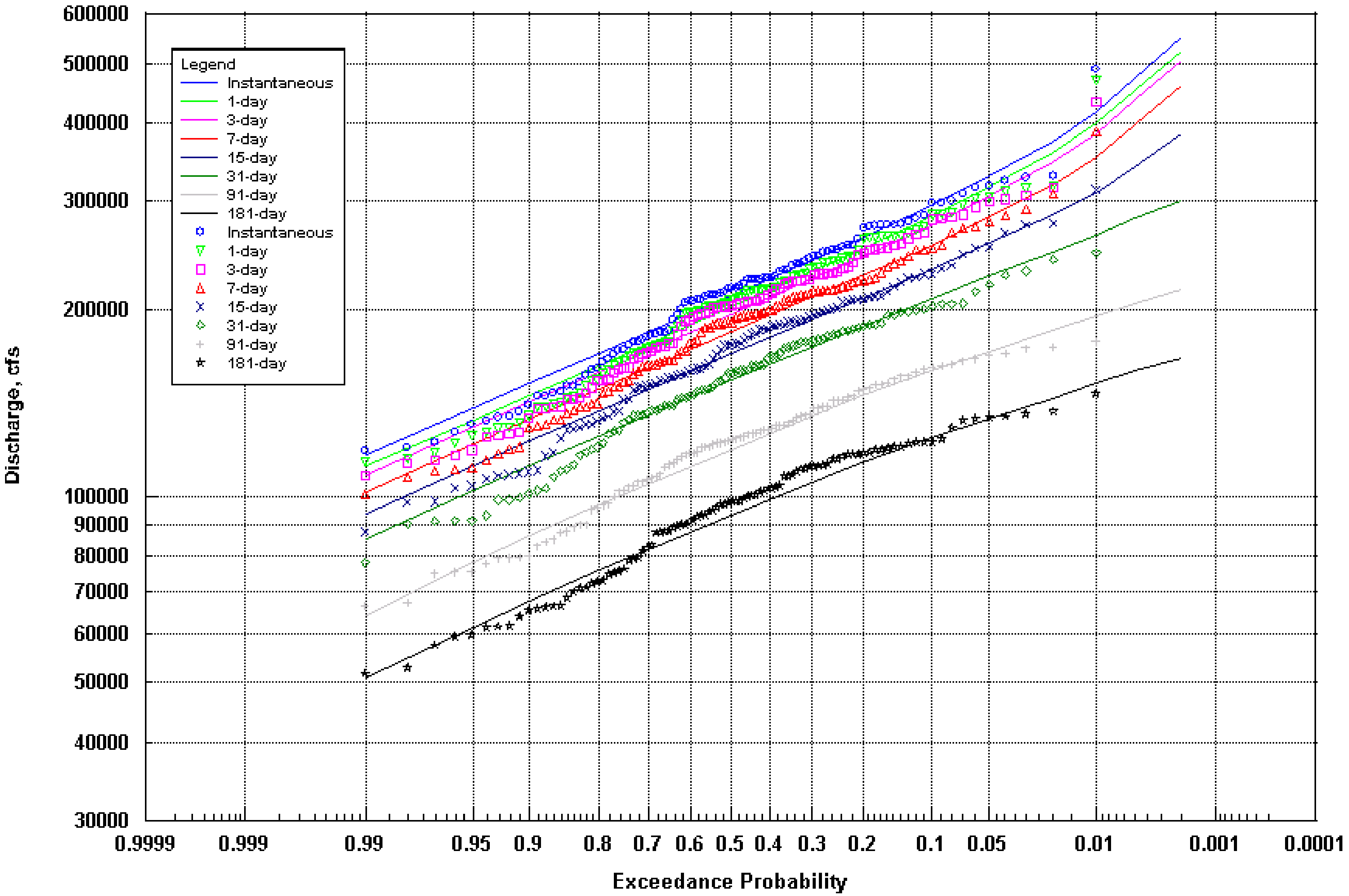


Volume-Duration Unregulated Frequency Curves, Decatur



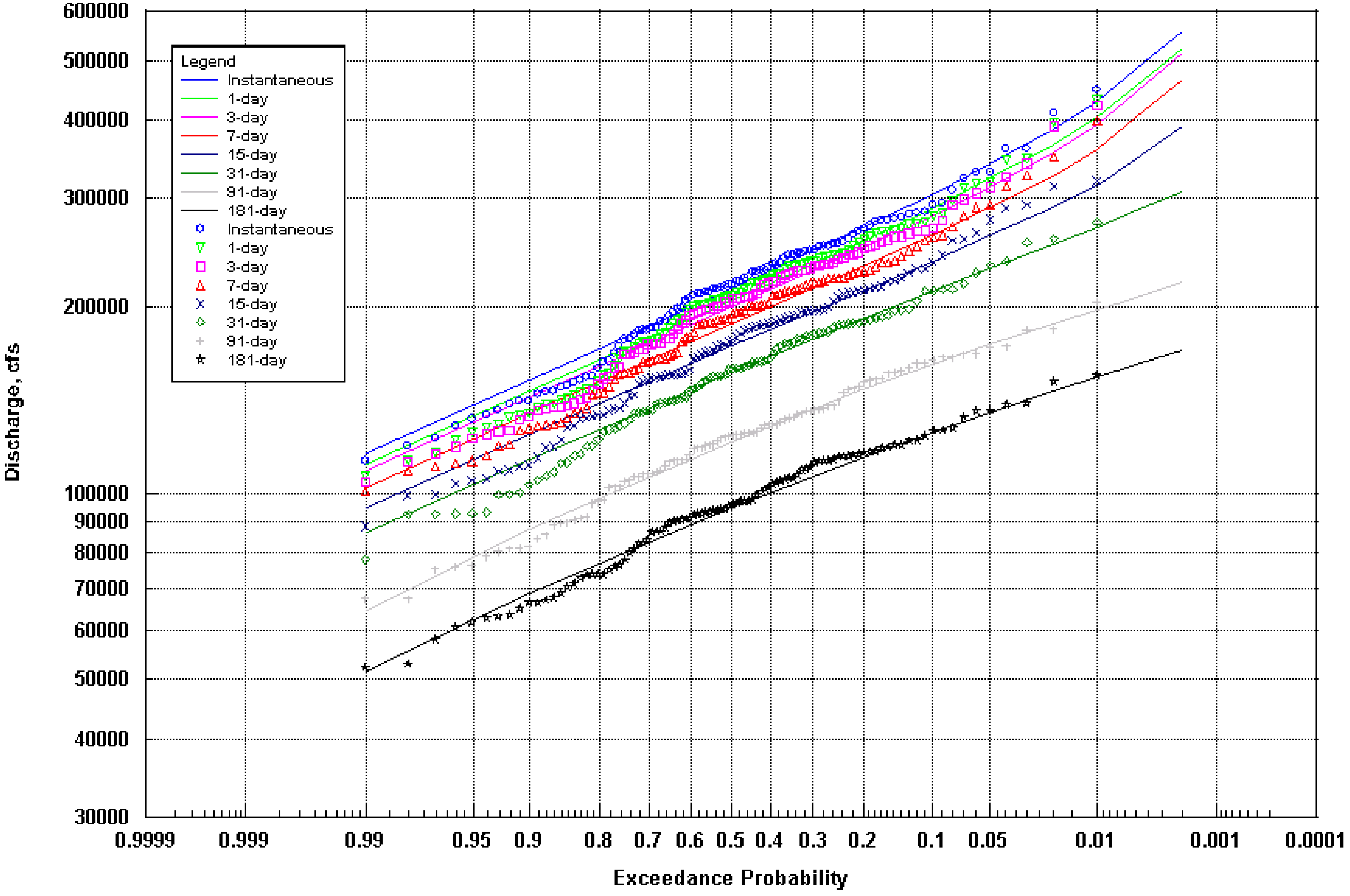


Volume-Duration Unregulated Frequency Curves, Omaha



Volume-Duration Unregulated Frequency Curves, Nebraska City

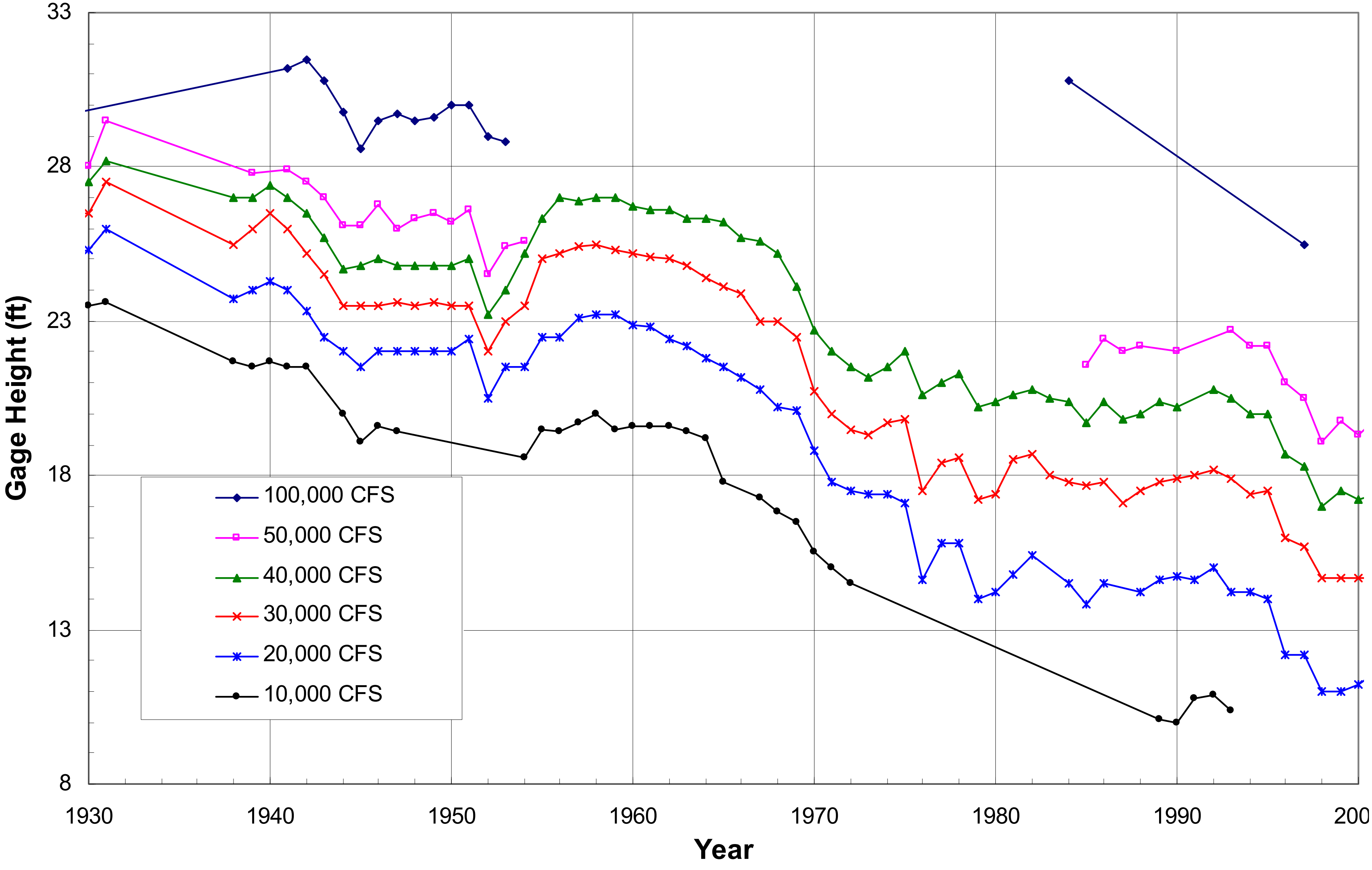
Volume-Duration Unregulated Frequency Curves, Rulo

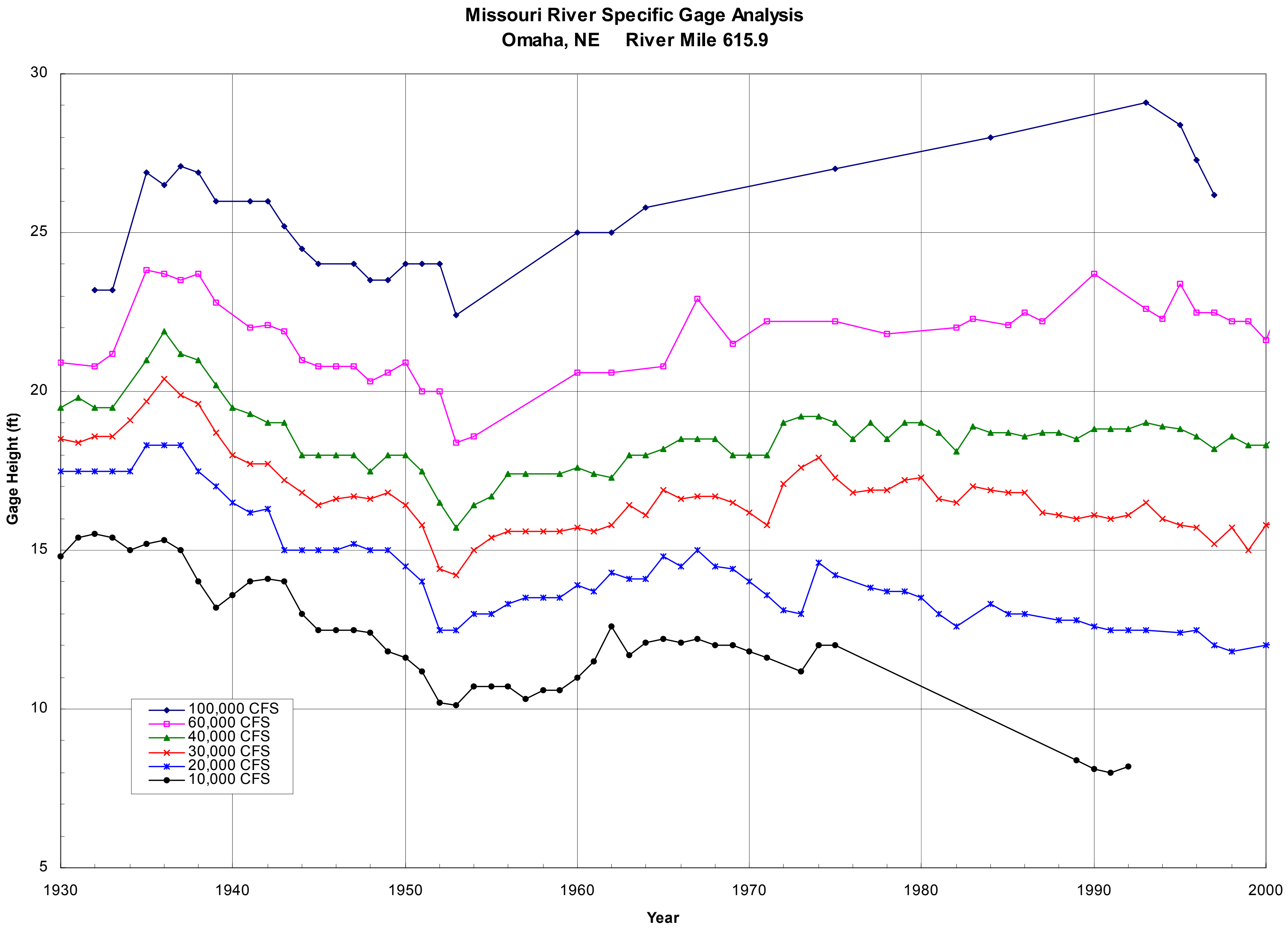


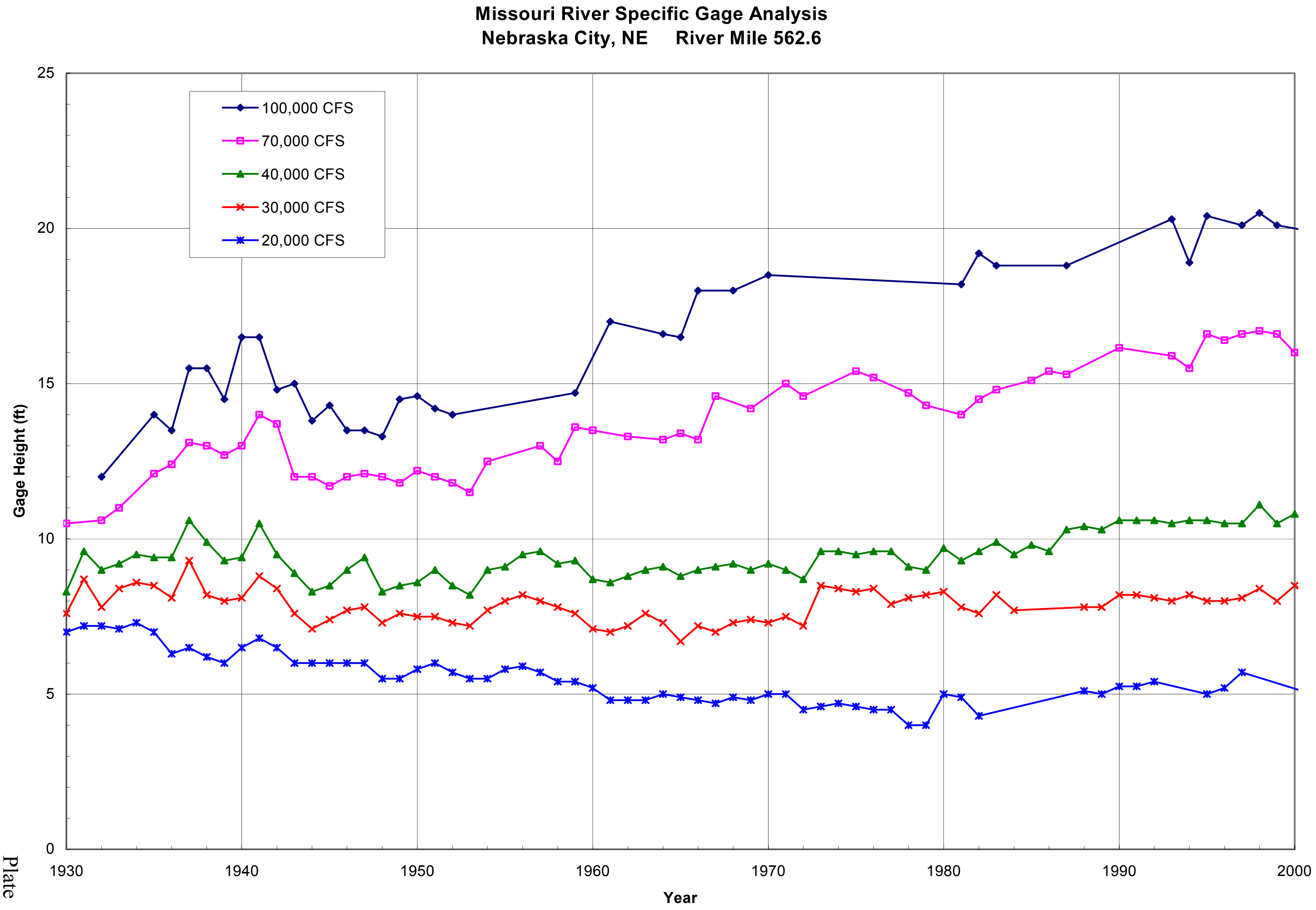
Missouri River from Gavins Point to St. Joseph
Drainage Area Accounting

Stream	Station	Mo. River Mile	Mo. River Drainage Area	USGS Flow Record	Tributary Drainage Area	Drainage Area Cumulative	RM Weighted Ungaged Area	Cumul. With Ungaged
Missouri River	**Yankton, SD**	805.8	279,500	10/1/30 -->		279,500		279,500
James River	Yankton-Scot.	797.7		9/1/28 -->	20,942	300,442	305.7	300,748
Bow Creek	St James, NE	787.6		10/1/78 -->	304	300,746	381.2	301,433
Vermillion River	Vermill-Wak.	771.9		10/1/45 -->	2,302	303,048	592.5	304,327
Aowa Creek	Ponca, NE	745.2		None	222	303,270	1007.7	305,557
Elk Creek		737.3		None	132	303,402	298.2	305,987
Big Sioux River	Akron, IA	734.0		10/1/28 -->	8,424	311,826	124.5	314,536
Unknown	Ungaged				2,774	314,600	64.2	
Missouri River	**Sioux City, IA**	732.3	314,600	10/1/28 - 7/30/31 10/1/38 -->		314,600		314,600
Perry Creek	Sioux City, IA	732.1		10/1/45 -->	65	314,665	1.8	314,667
Floyd River	James, IA	731.3		10/1/35 -->	886	315,551	7.1	315,560
Omaha Creek	Homer, NE	719.9		10/1/45 -->	174	315,725	101.8	315,836
Blackbird Creek		697.6		None	106	315,831	199.2	316,141
Unknown	Ungaged				369	316,200	59.0	
Missouri River	**Decatur, NE**	691.0	316,200	10/1/87 -->		316,200		316,200
Monona Har. Ditch	Turin, IA	670.0		10/1/39 -->	900	317,100	106.8	317,207
Little Sioux River	Turin, IA	669.2		5/7/42 -->	3,526	320,626	4.1	320,737
Tekamah Dv. Ditch		665.0		None	124	320,750	21.4	320,882
Soldier River	Pisgah, IA	664.0		3/5/40 -->	407	321,157	5.1	321,294
Old Soldier R.Ditch		649.3		None	100	321,257	74.8	321,469
Fish Creek		647.9		None	124	321,381	7.1	321,600
Boyer River	Logan, IA	635.2		5/24/18 -->	871	322,252	64.6	322,536
Pigeon Creek		622.0		None	166	322,418	67.1	322,769
Unknown	Ungaged				382	322,800	31.0	
Missouri River	**Omaha, NE**	615.9	322,800	9/1/28 -->		322,800		322,800
Mosquito Cr		605.8		None	238	323,038	148.2	323,186
Big Papillion Cr	Fort Crook	596.6		08/1/86 -->	384	323,422	135.0	323,705
Platte River	Ashland-Louis.	594.8		10/1/28 -->	85,370	408,792	26.4	409,102
Watkins Ditch		587.5		None	185	408,977	107.1	409,394
Weeping Water Cr	Union	568.7		3/1/50 -->	241	409,218	275.8	409,911
Unknown					782	410,000	89.5	
Missouri River	**Nebraska City**	562.6	410,000	8/11/29 -->		410,000		410,000
Nishnabotna River	Hamburg	542.1		3/1/22 -->	2,806	412,806	214.8	413,021
Little Nemaha River	Auburn	527.8		9/1/49 -->	793	413,599	149.9	413,964
Rock Creek		522.2		None	104	413,703	58.7	414,126
Tarkio River	Fairfax, MO	507.6		4/1/22 -->	520	414,223	153.0	414,799
Unknown					677	414,900	100.6	
Missouri River	**Rulo**	498.0	414,900	9/1/49 -->		414,900		414,900
Muddy Creek	Big Nem. Trib	495.0		None	258	415,158	109.8	415,268
Big Nemaha River	Falls City, NE	494.8		4/1/44 -->	1,340	416,498	7.3	416,615
Little Tarkio River		492.4		None	170	416,668	87.9	416,873
Squaw Creek		486.3		None	178	416,846	223.3	417,274
Wolf Creek		478.8		None	251	417,097	274.5	417,800
Nodaway River	Graham/Burling	463.0		4/1/22 -->	1,380	418,477	578.4	419,758
Unknown					1,823	420,300	541.8	420,300
Missouri River	**St. Joseph**	448.2	420,300	9/1/28 -->		420,300		

Missouri River Specific Gage Analysis
Sioux City, IA River Mile 732.3




Missouri River Specific Gage Analysis
Omaha, NE River Mile 615.9
Gage Height (ft)
Year
30
25
20
15
10
5
1930
1940
1950
1960
1970
1980
1990
2000
100,000 CFS
60,000 CFS
40,000 CFS
30,000 CFS
20,000 CFS
10,000 CFS


Missouri River Specific Gage Analysis
Nebraska City, NE River Mile 562.6
100,000 CFS
70,000 CFS
40,000 CFS
30,000 CFS
20,000 CFS
Gage Height (ft)
25
20
15
10
5
0
1930
1940
1950
1960
1970
1980
1990
2000
Year

Missouri River Survey Data Accuracy

The photogrammetric mapping products were designed and collected according to American Society of Photogrammetry and Remote Sensing (ASPRS) Standards. The accuracy and quality of the digital elevation data is suitable for 4' contour interval mapping. The mapping contractor included breaklines to define levee, road and railroad locations and elevations. No ground surveys to increase elevation data accuracy were included. As a result, well defined grided elevation points shown on the levee profile should be within 1.33 feet RMSE (95% of the time) of the actual elevation in areas that are clearly identified in the aerial photography. Areas that are hard surfaces (i.e. roads, parking areas, cleared fields) will provide elevations that are within 0.67 feet RMSE (67% of the time).

The survey coordinate system is:

Horizontal: UTM Zone 15 NAD 1983
Vertical: NGVD 1929
U.S. Feet

The following were requirements were furnished to the survey contractor for collection of survey data from 1999 aerial photography along the Missouri River corridor within the Omaha District.

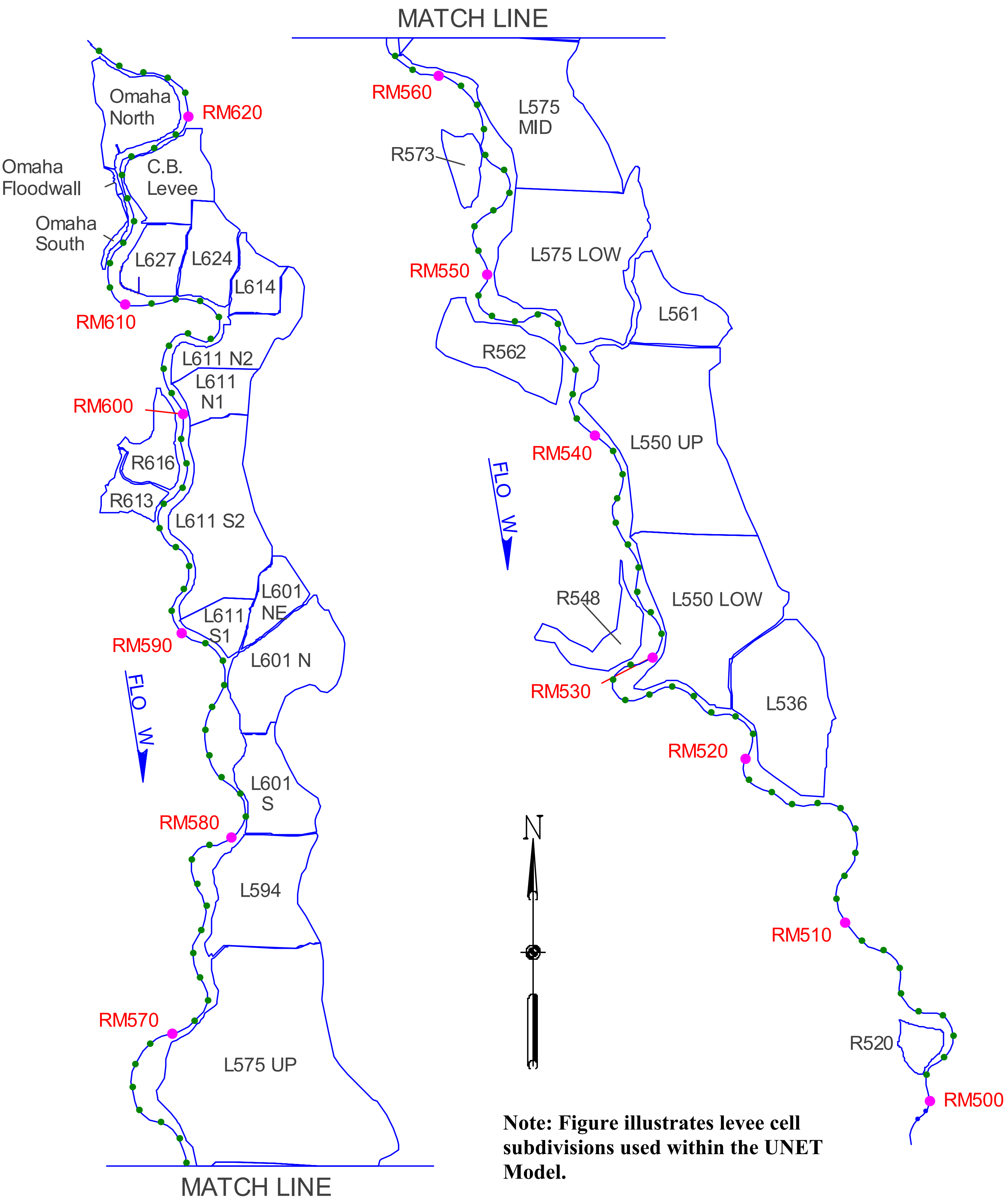
1. The Contractor shall collect DTM data (mass points and breaklines) to sufficiently depict the horizontal and vertical location of elevated roads, railroads, and levees. Additional (minimal) DTM points shall be collected to optimize the vertical accuracy of DEM data points. All DTM data shall be in ASCII X,Y,Z (Easting, Northing and Elevation respectively) format fully compatible with Intergraph InRoads software. All data shall be referenced to NAD 27 and NGVD 29 datum and use UTM projection. The DTM data (mass points and breaklines) shall have an RMSE of 0.67' with a one sigma (0.67%) confidence factor.

2. The Contractor shall also generate DEM data at the posting of 15 feet. The DEM data shall be referenced to NAD 27 and NGVD 29 datums and use UTM projection. All DEM data shall be in ASCII X,Y,Z (Easting, Northing and Elevation respectively) format fully compatible with Intergraph InRoads software. The X and Y coordinates for the DEM data will be evenly devisable by 15 and a 1/10 foot vertical resolution. The RMSE of well defined DEM elevations shall not exceed 1.33' and the DEM must be of sufficient accuracy to support generation of 4' contours that meet U.S. Army Corps of Engineers Standards for Class I mapping as per EM1110-1-1000, dated 31 March 1993.

NOTE:

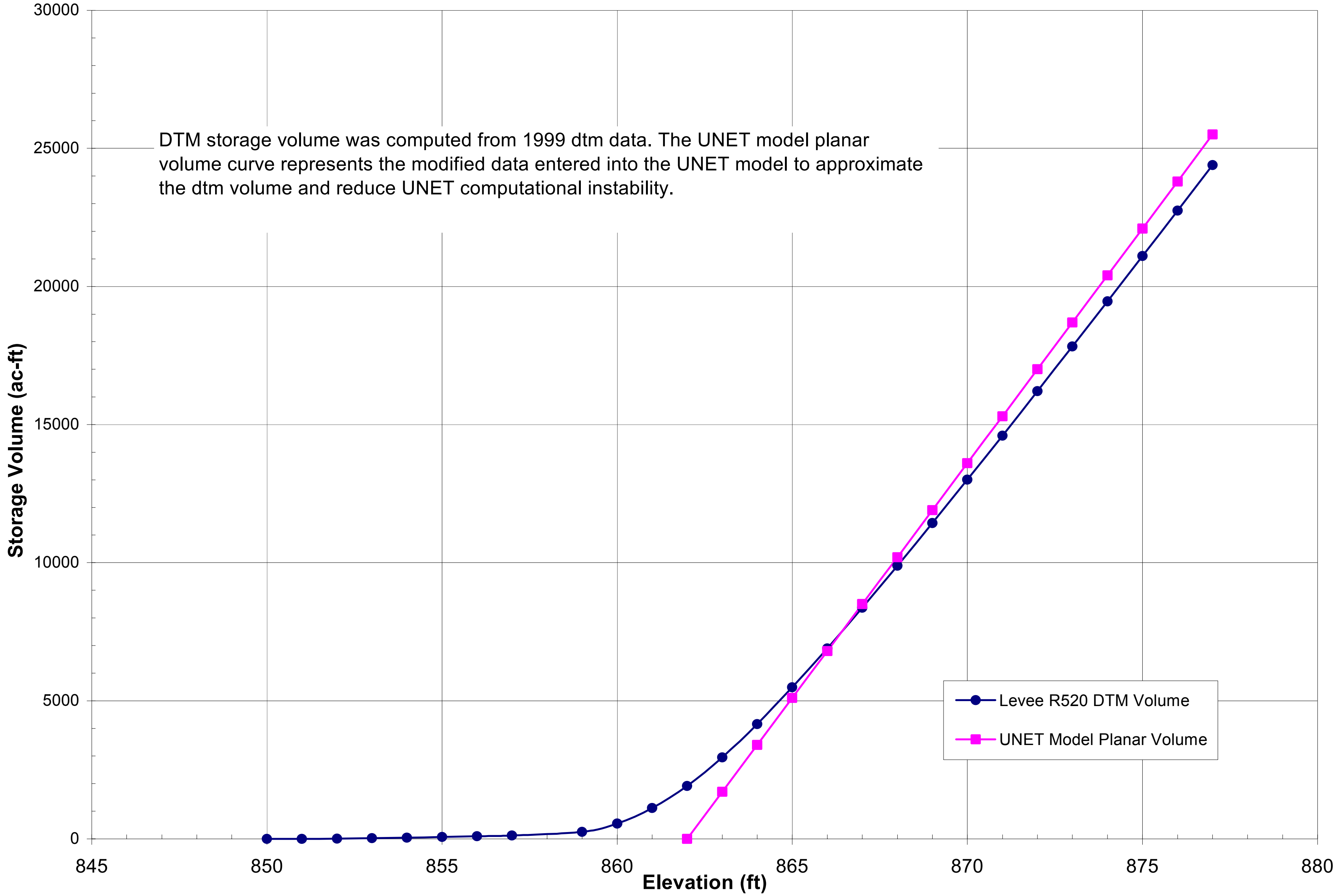
The map accuracy standards refer to the photogrammetric mapping products only. Below water survey information was previously collected in 1994 and 1995 and merged with the photogrammetric data to form the final dtm. The dtm files contain Missouri River hydrographic surveys in the form of random points along a cross section line at roughly 500 foot intervals. Since the hydrographic data are entered as random points and contain no breaklines, the cross section is only valid at the hydrographic data location. No hydrographic data is included for any tributaries or lakes other than the Missouri River.

Omaha District UNET Model Levee Cell Location

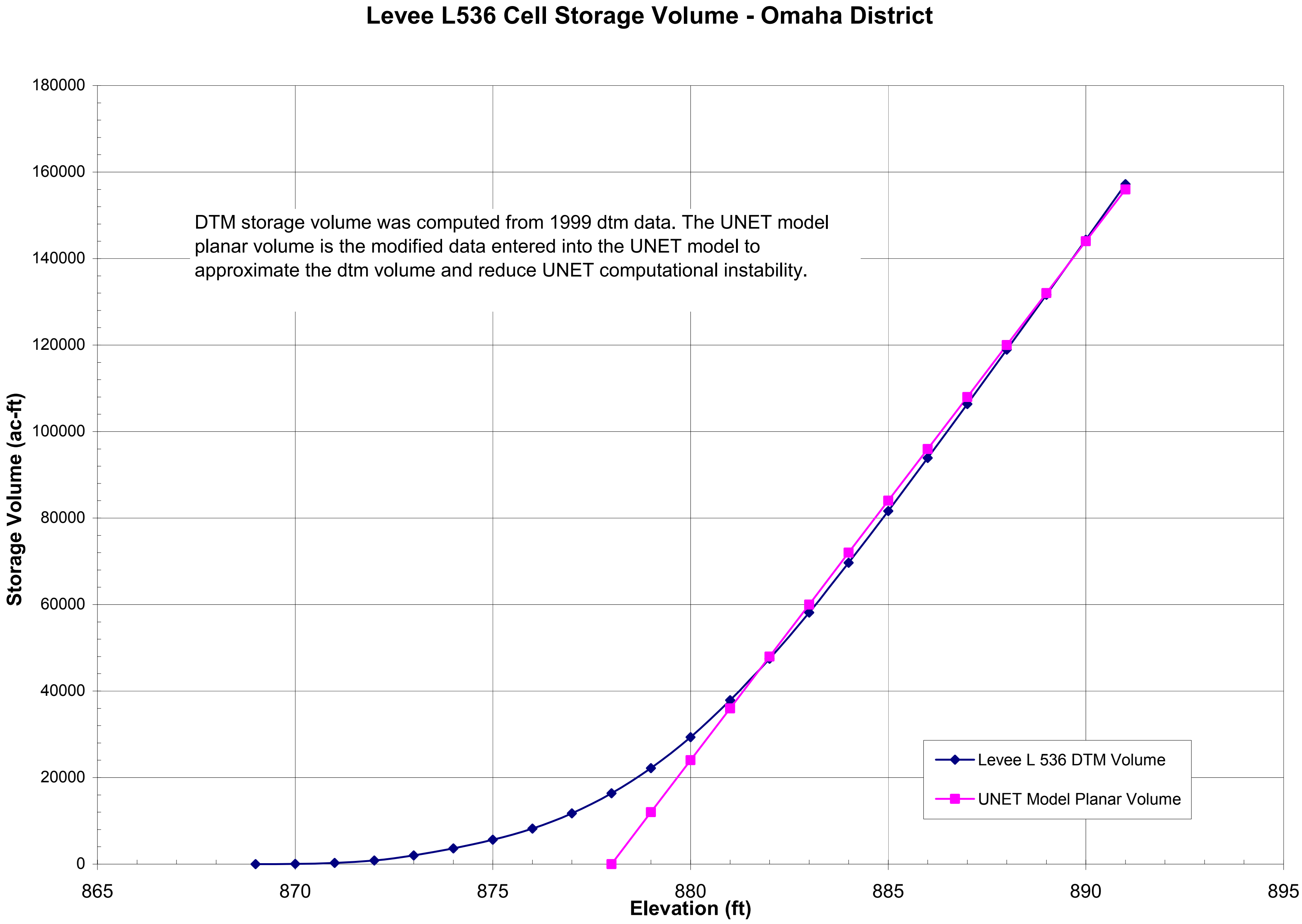


Note: Figure illustrates levee cell subdivisions used within the UNET Model.

Levee R520 Cell Storage Volume - Omaha District

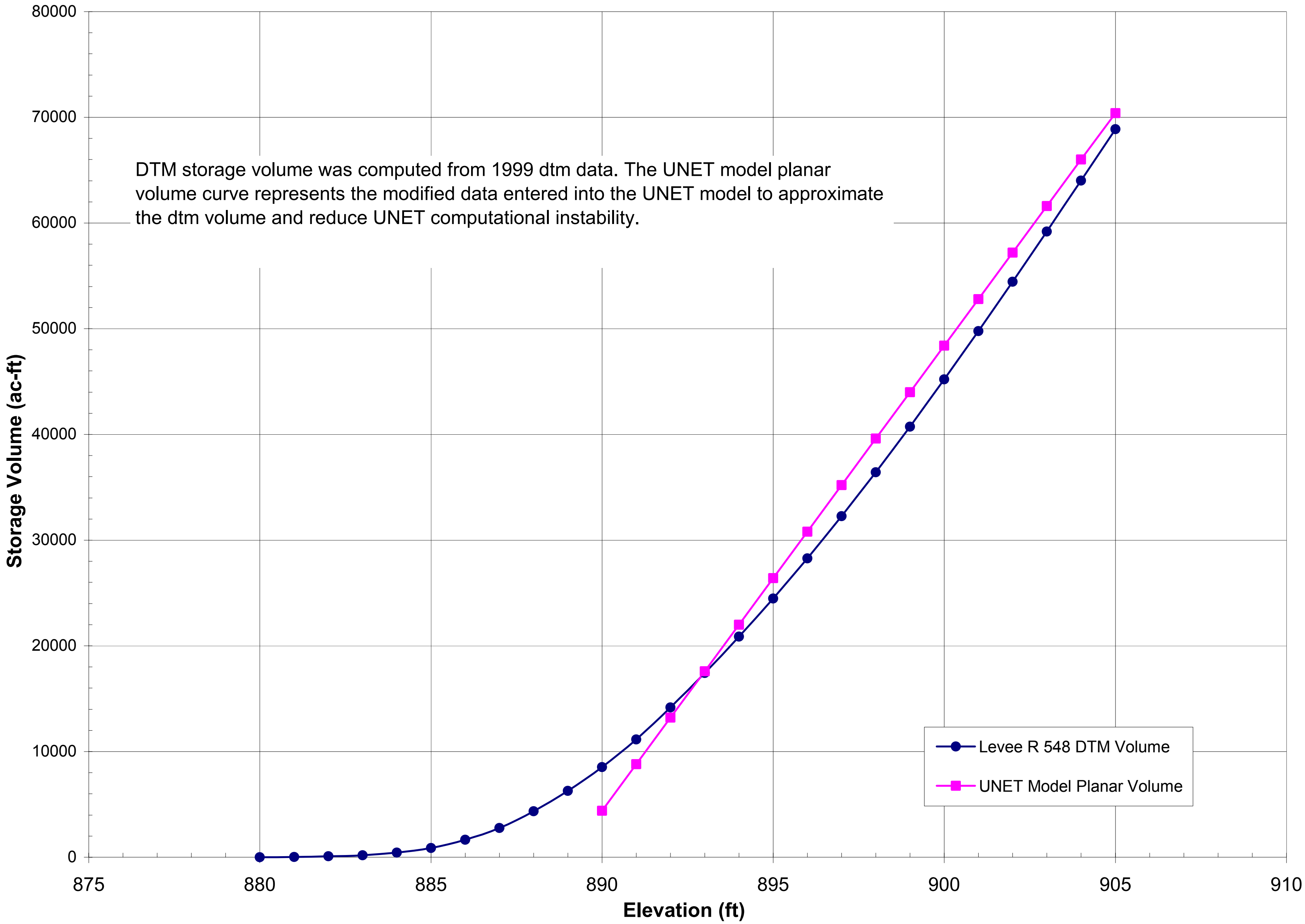


DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.



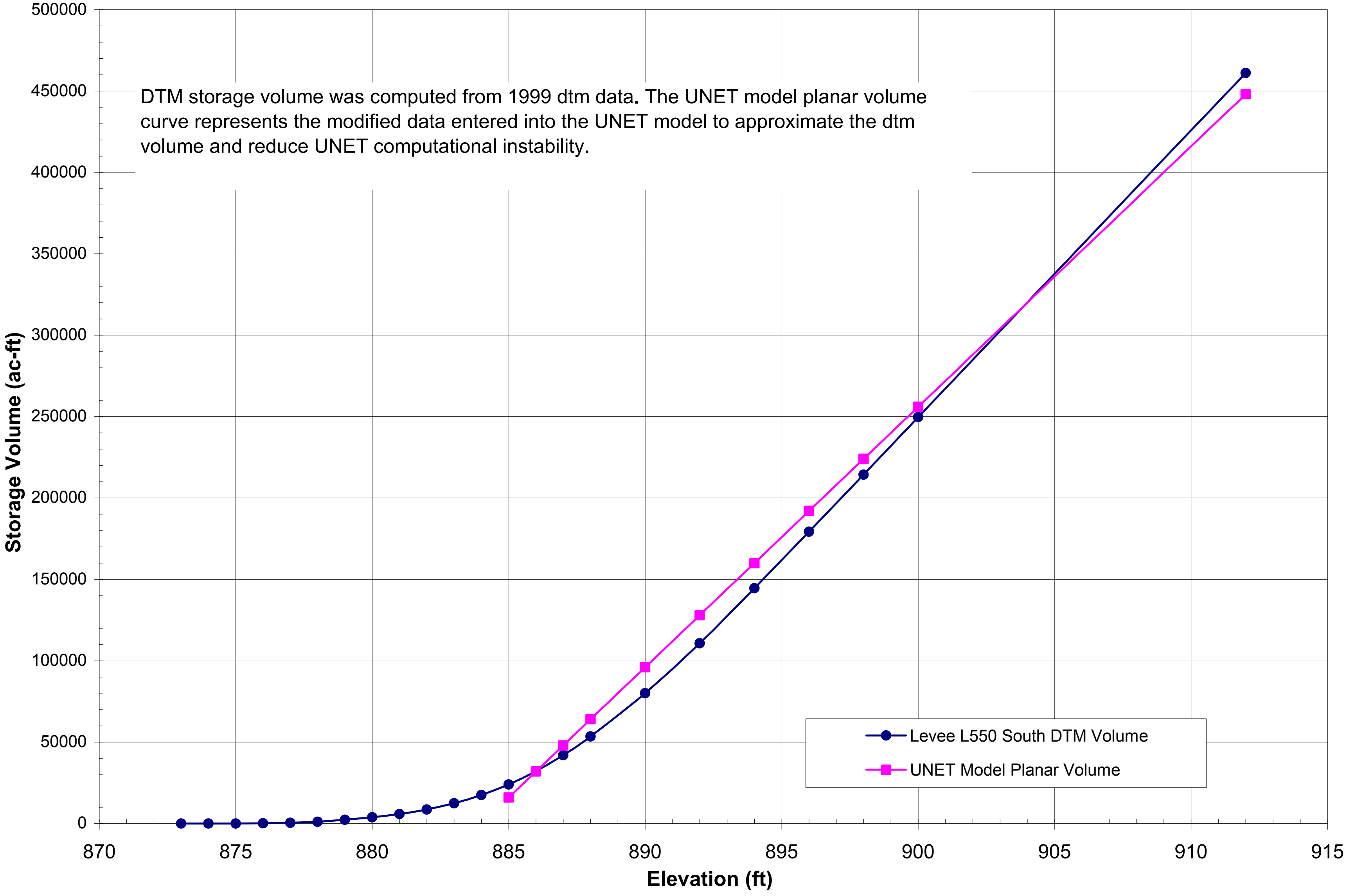
DTM storage volume was computed from 1999 dtm data. The UNET model planar volume is the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee R548 Cell Storage Volume - Omaha District

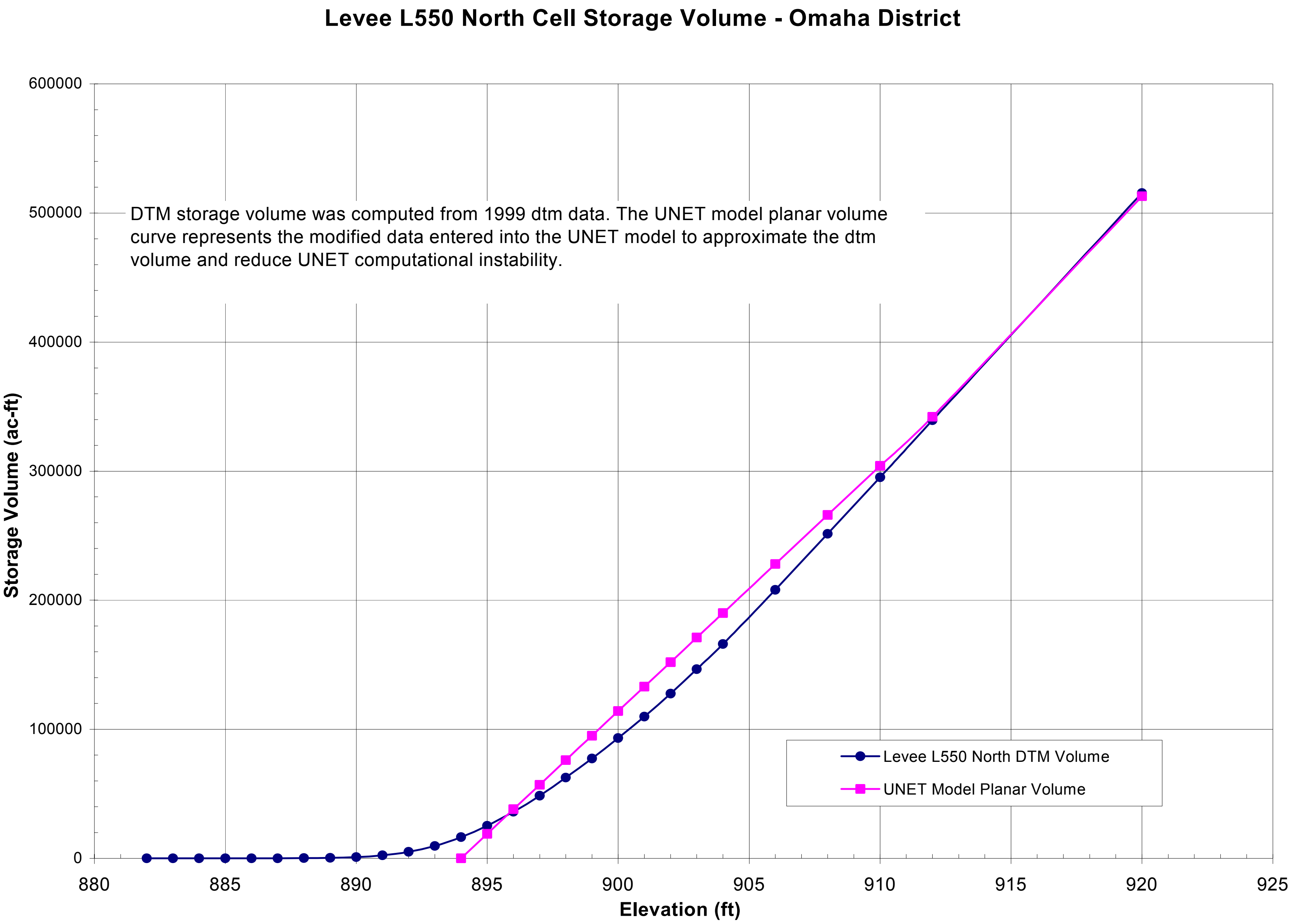


DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee L550 South Cell Storage Volume - Omaha District

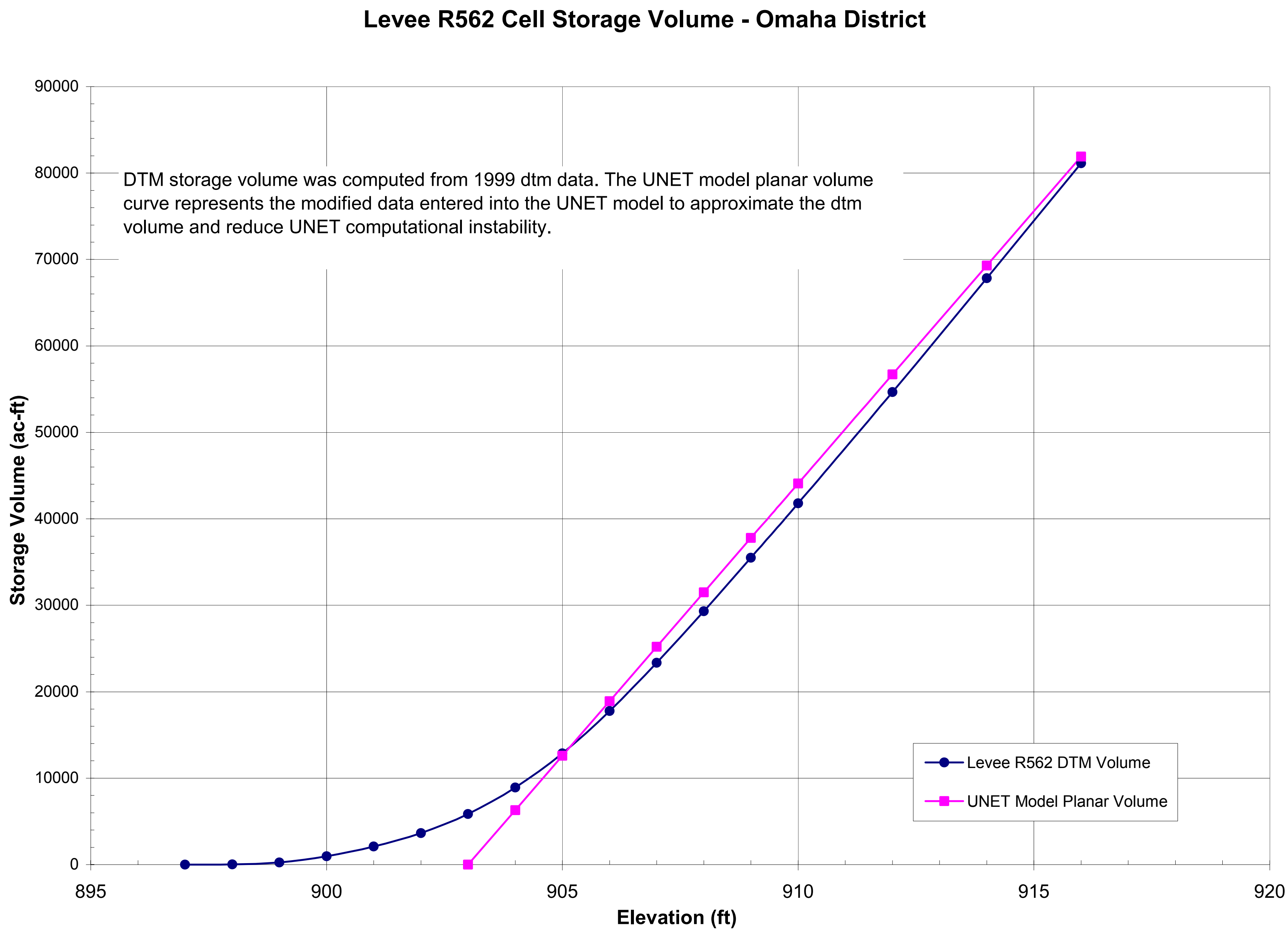


DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.



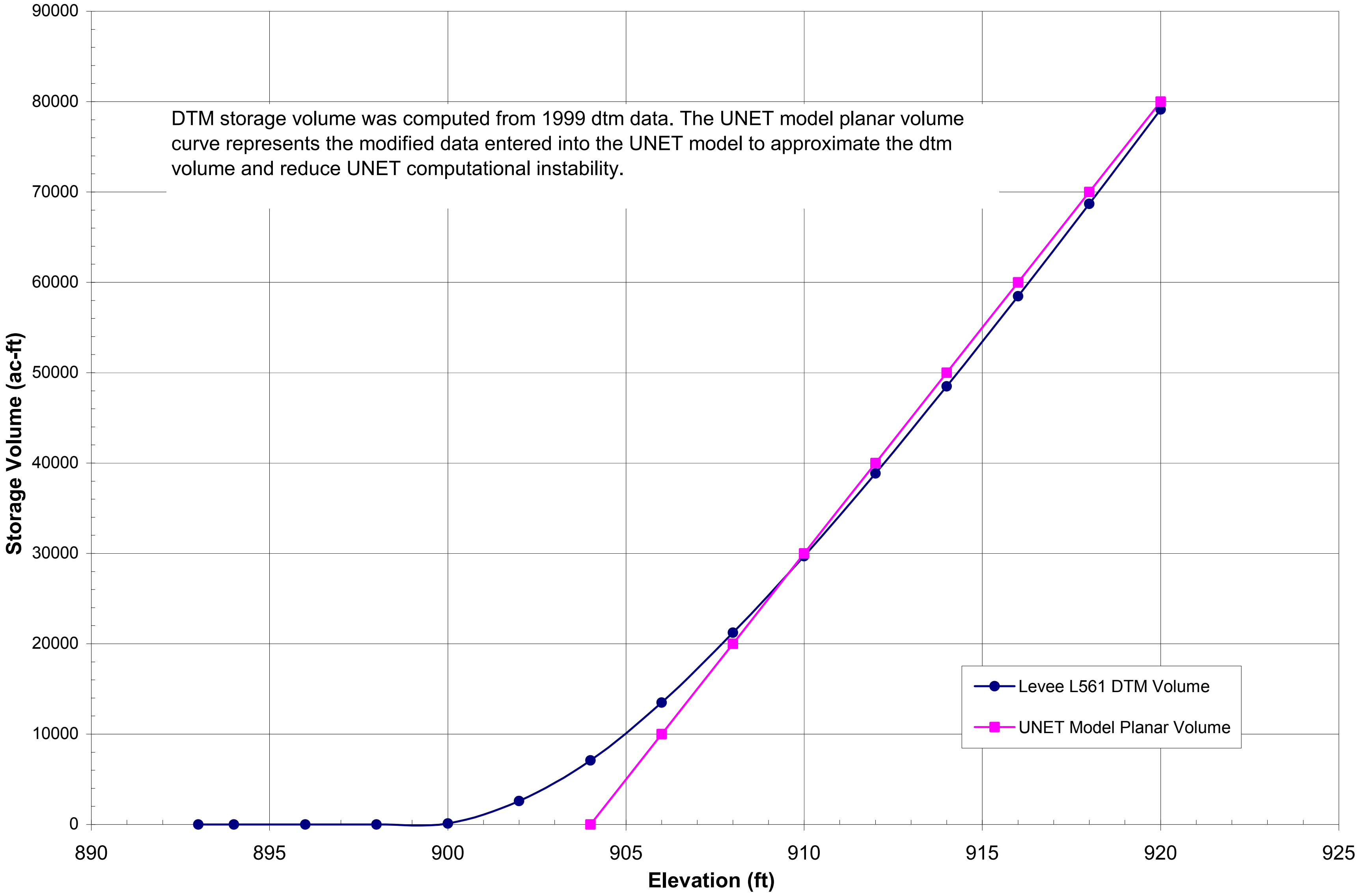
Levee L550 North Cell Storage Volume - Omaha District

DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.



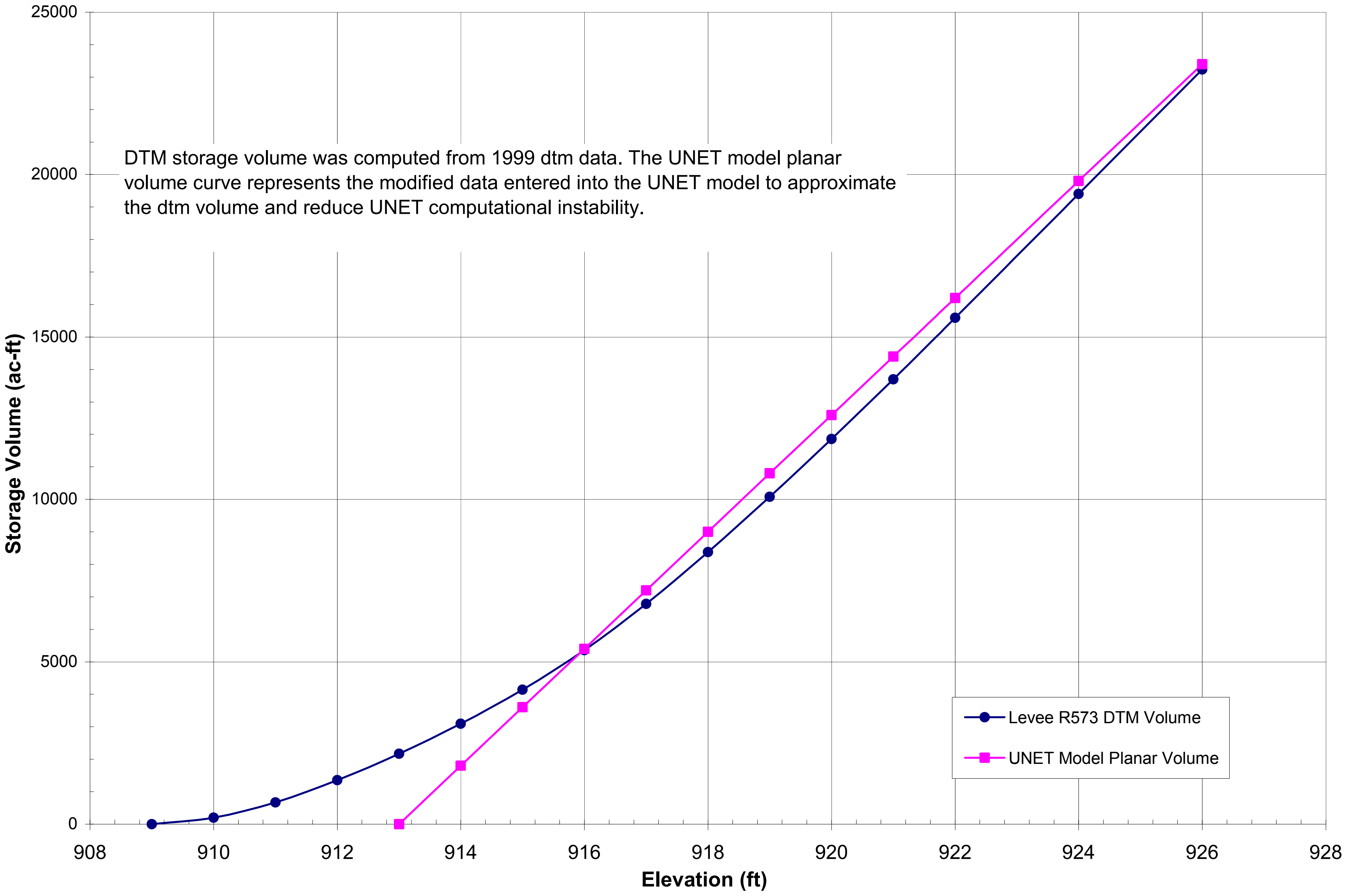
DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee L561 Cell Storage Volume - Omaha District



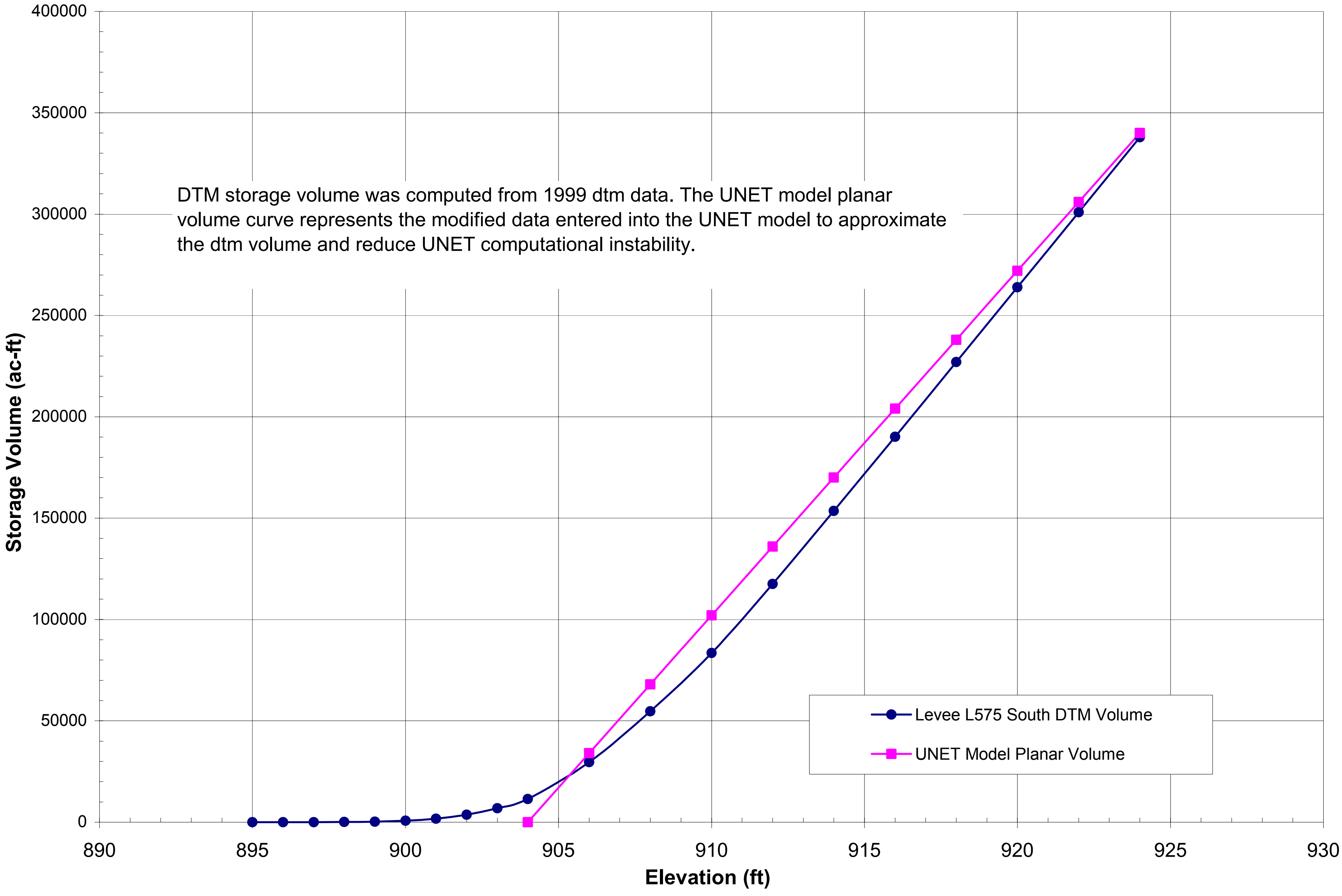
DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee R573 Cell Storage Volume - Omaha District

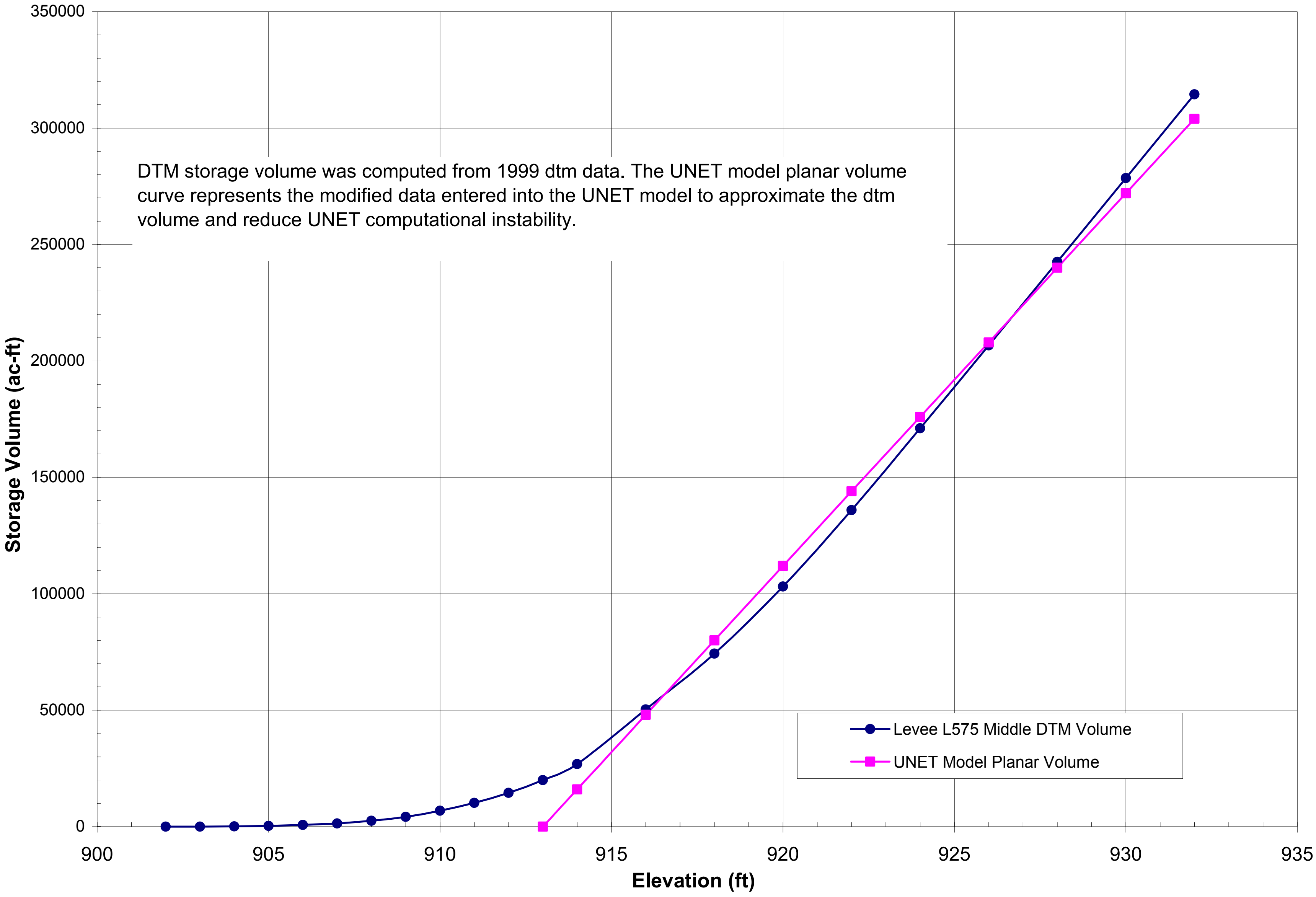


DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

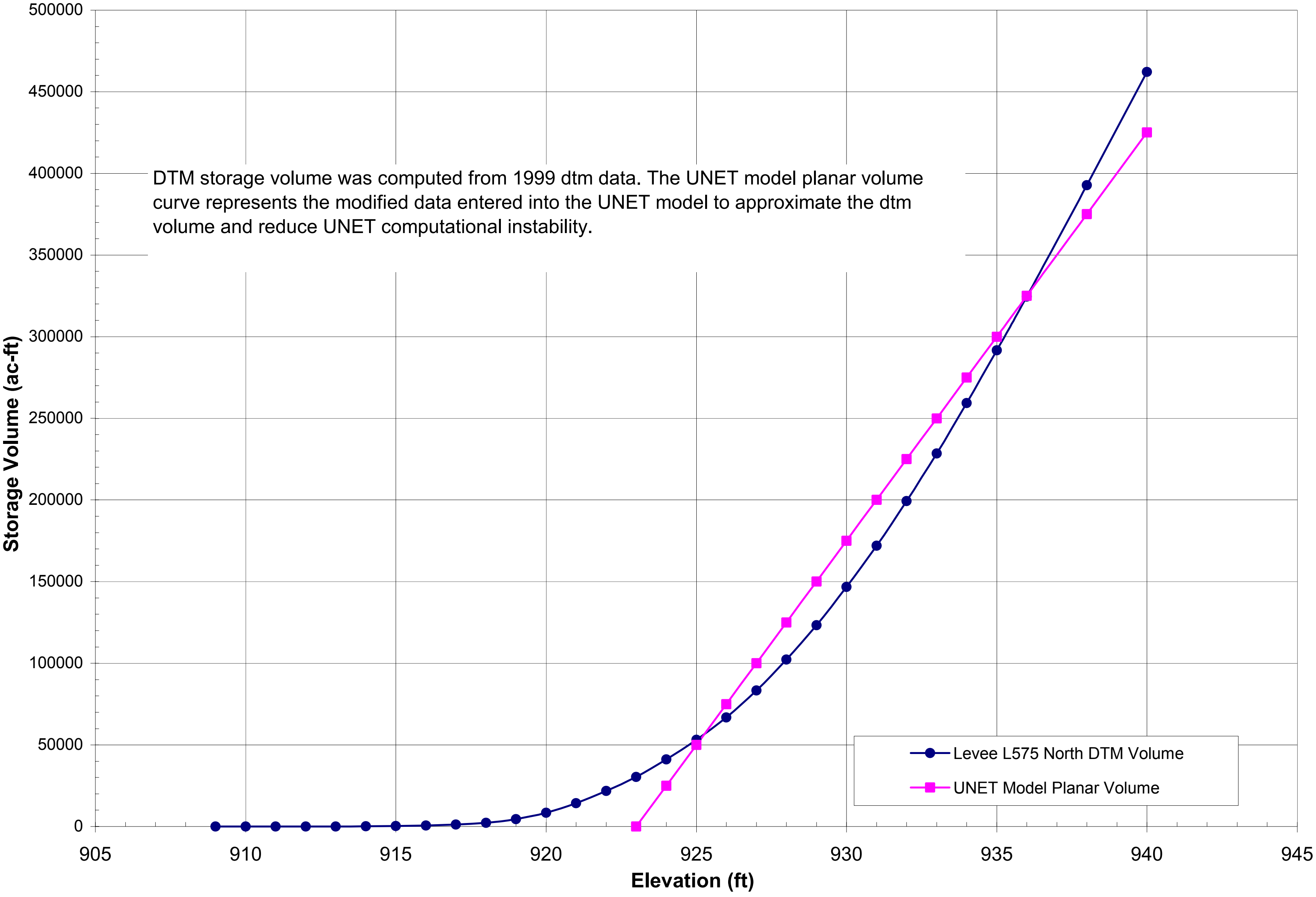
Levee L575 South Cell Storage Volume - Omaha District


DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee L575 Middle Cell Storage Volume - Omaha District

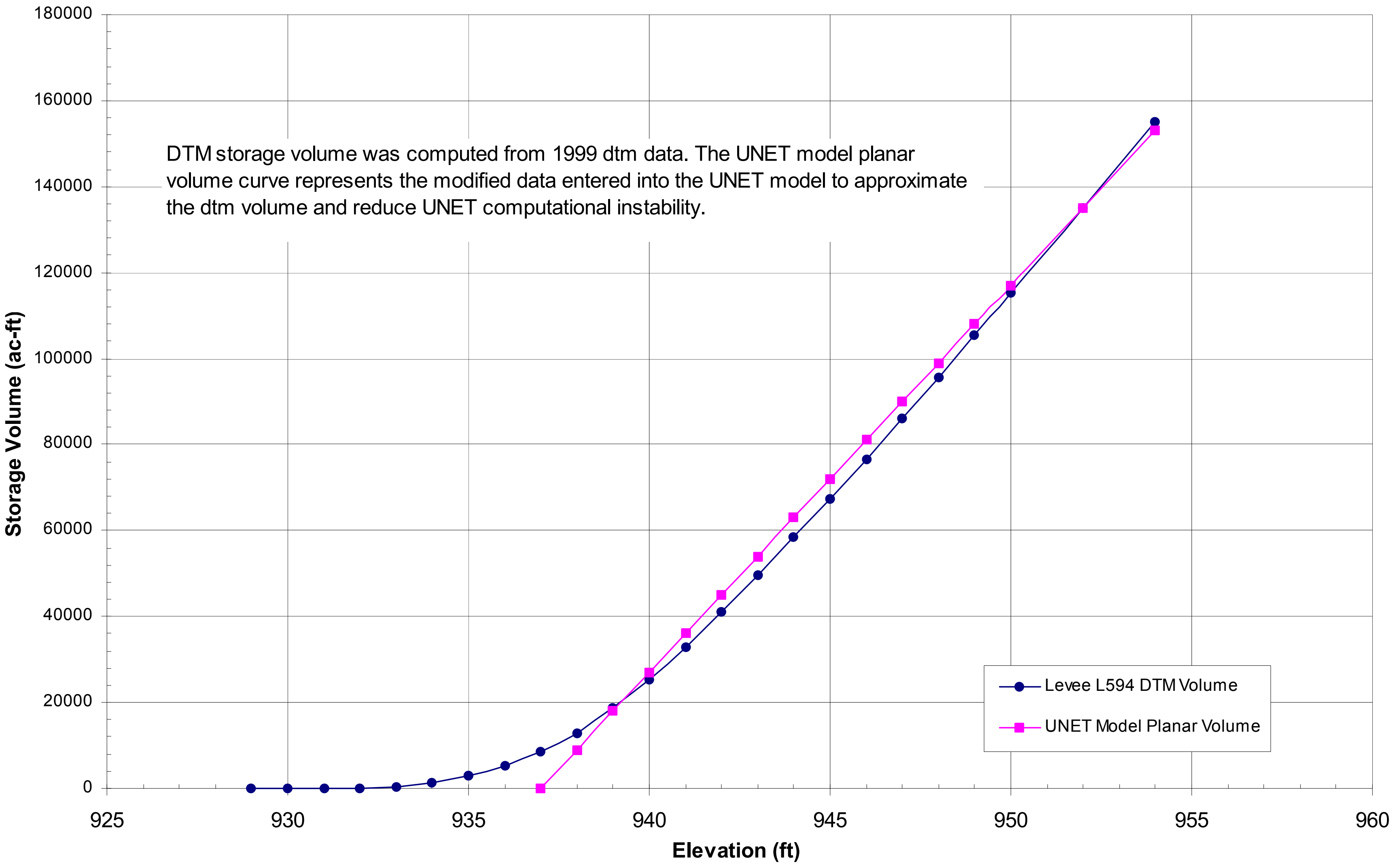

DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee L575 North Cell Storage Volume - Omaha District

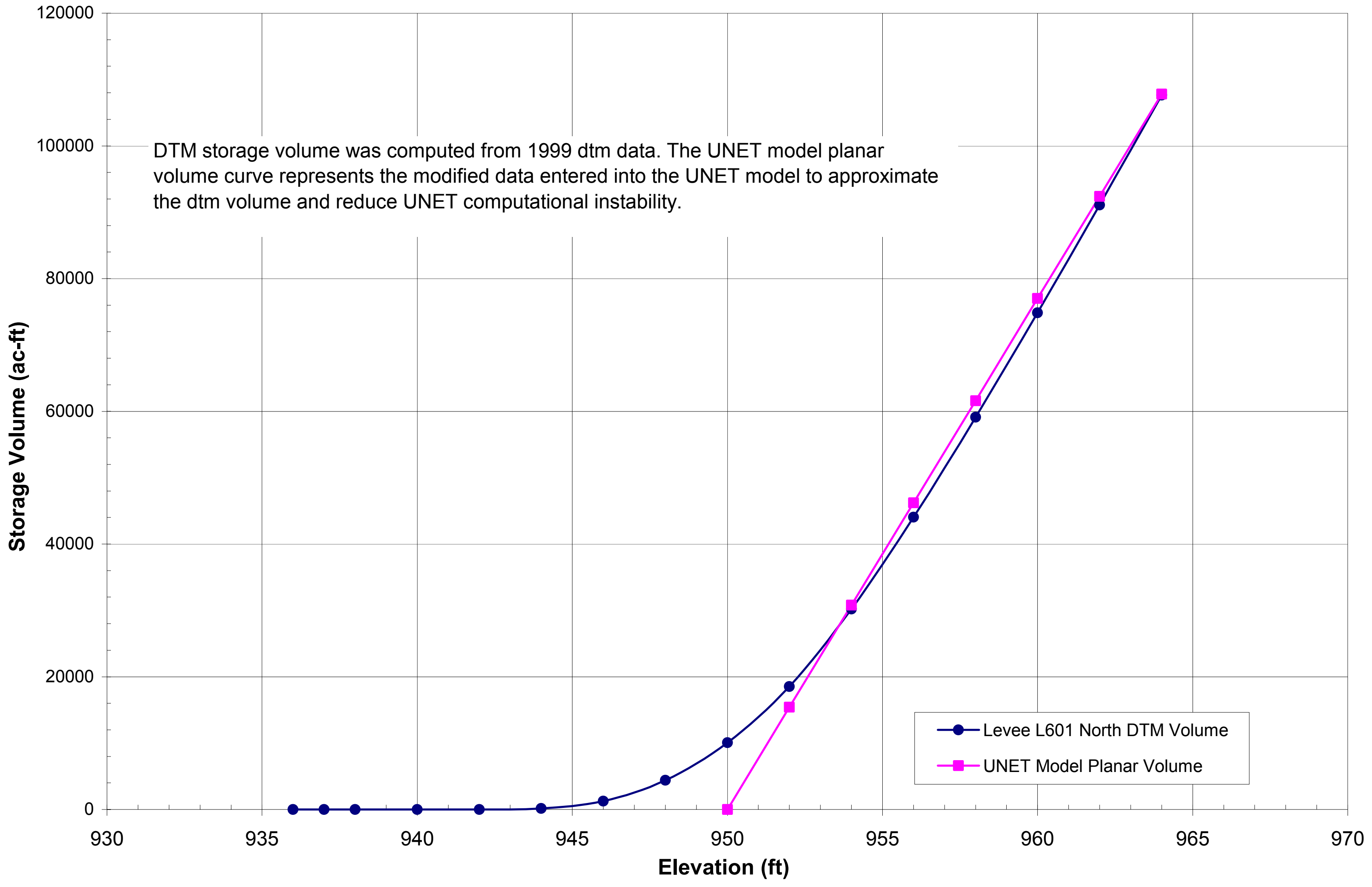


DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee L594 Cell Storage Volume - Omaha District



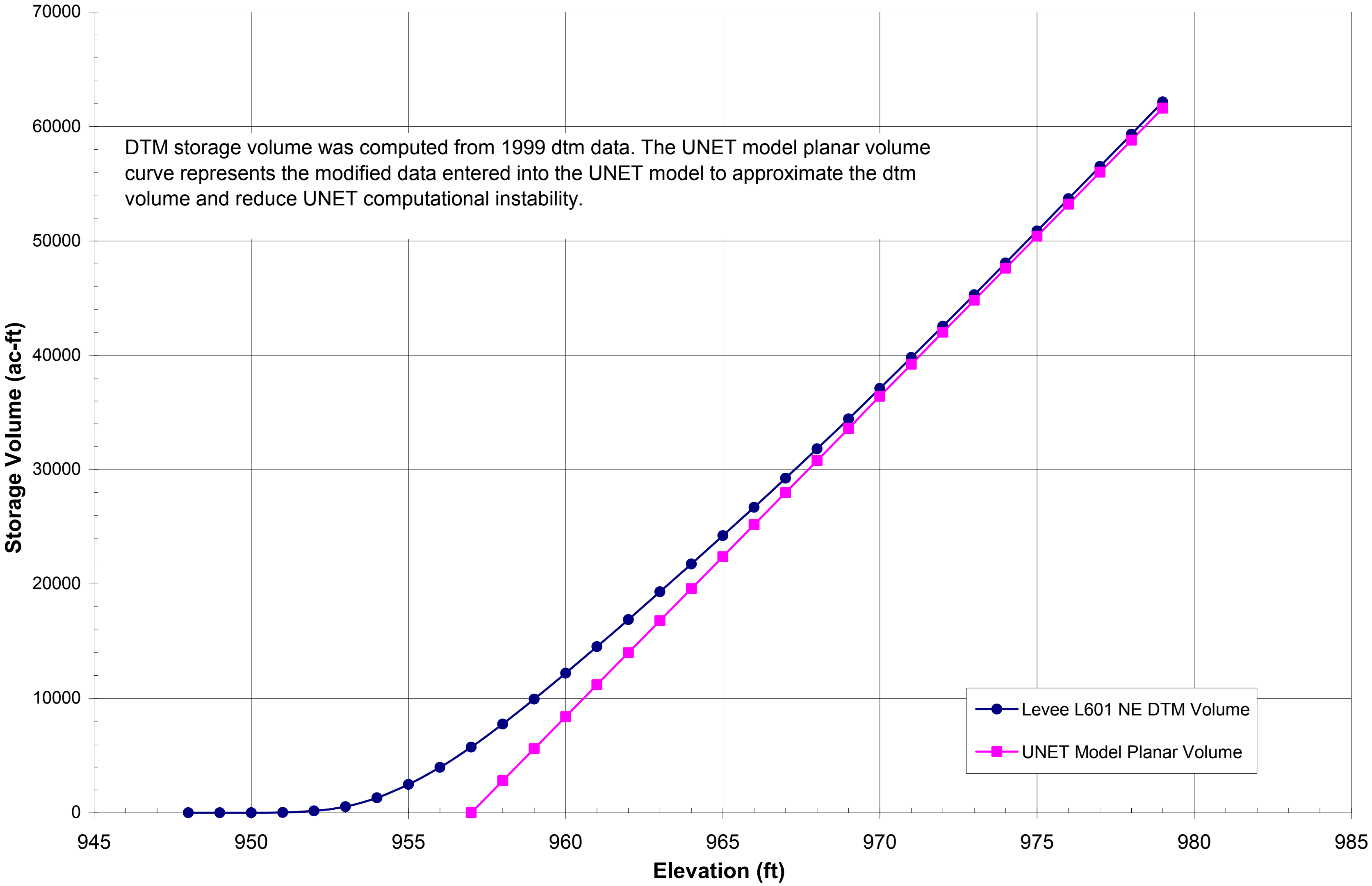
DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.



Levee L601 North Cell Storage Volume - Omaha District

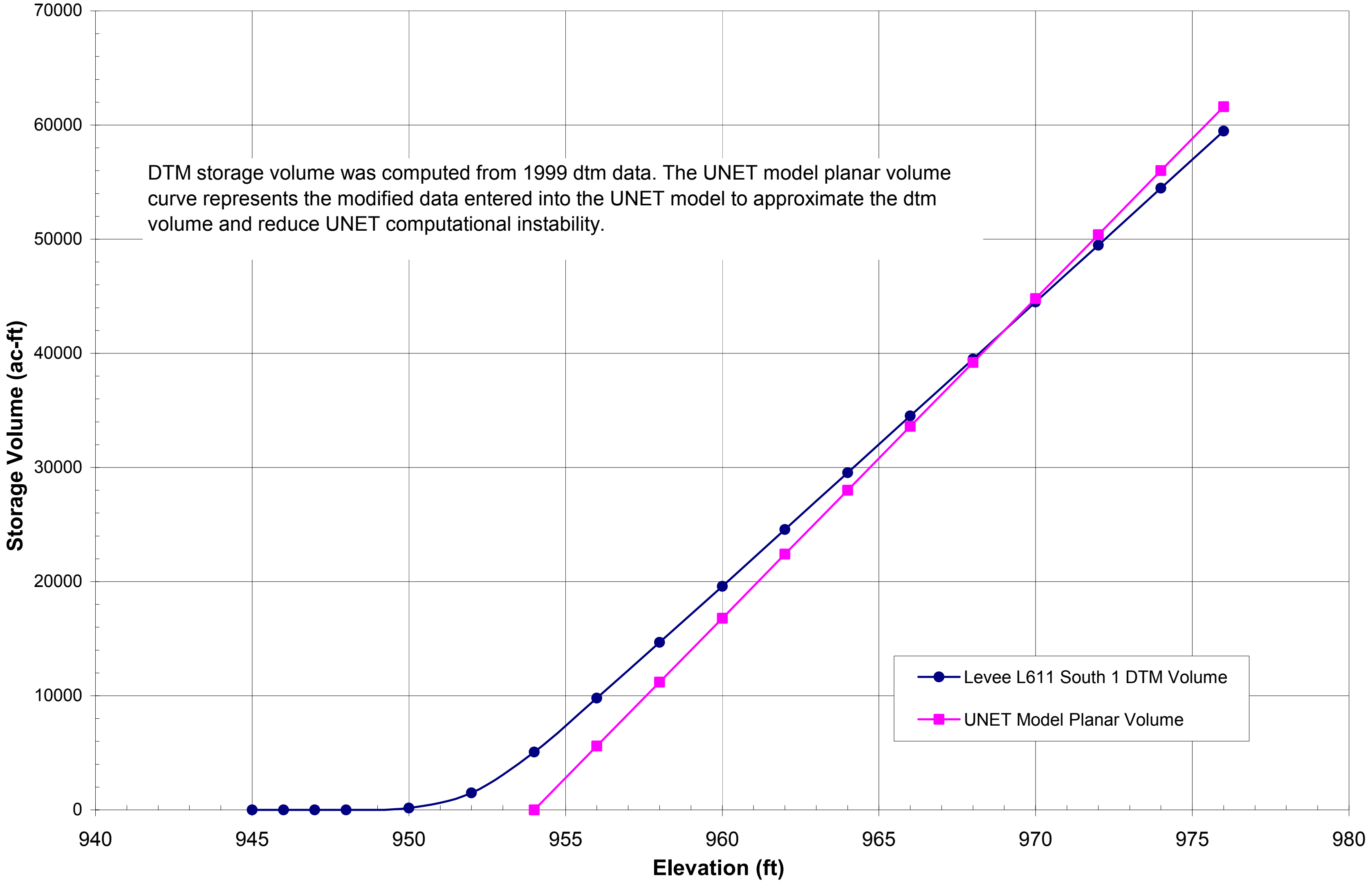
DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee L601 NE Cell Storage Volume - Omaha District



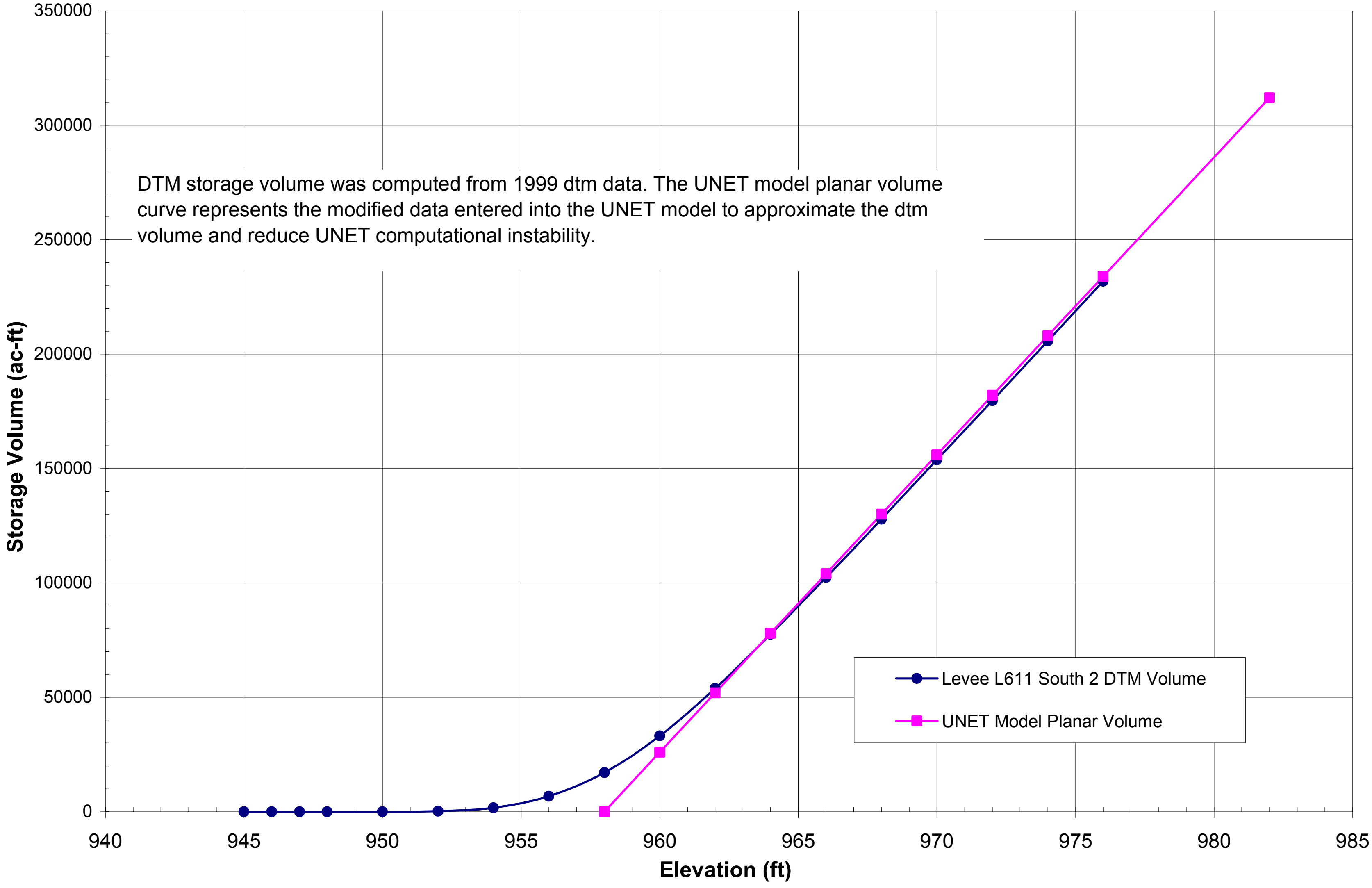
DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee L611 South 1 Cell Storage Volume - Omaha District

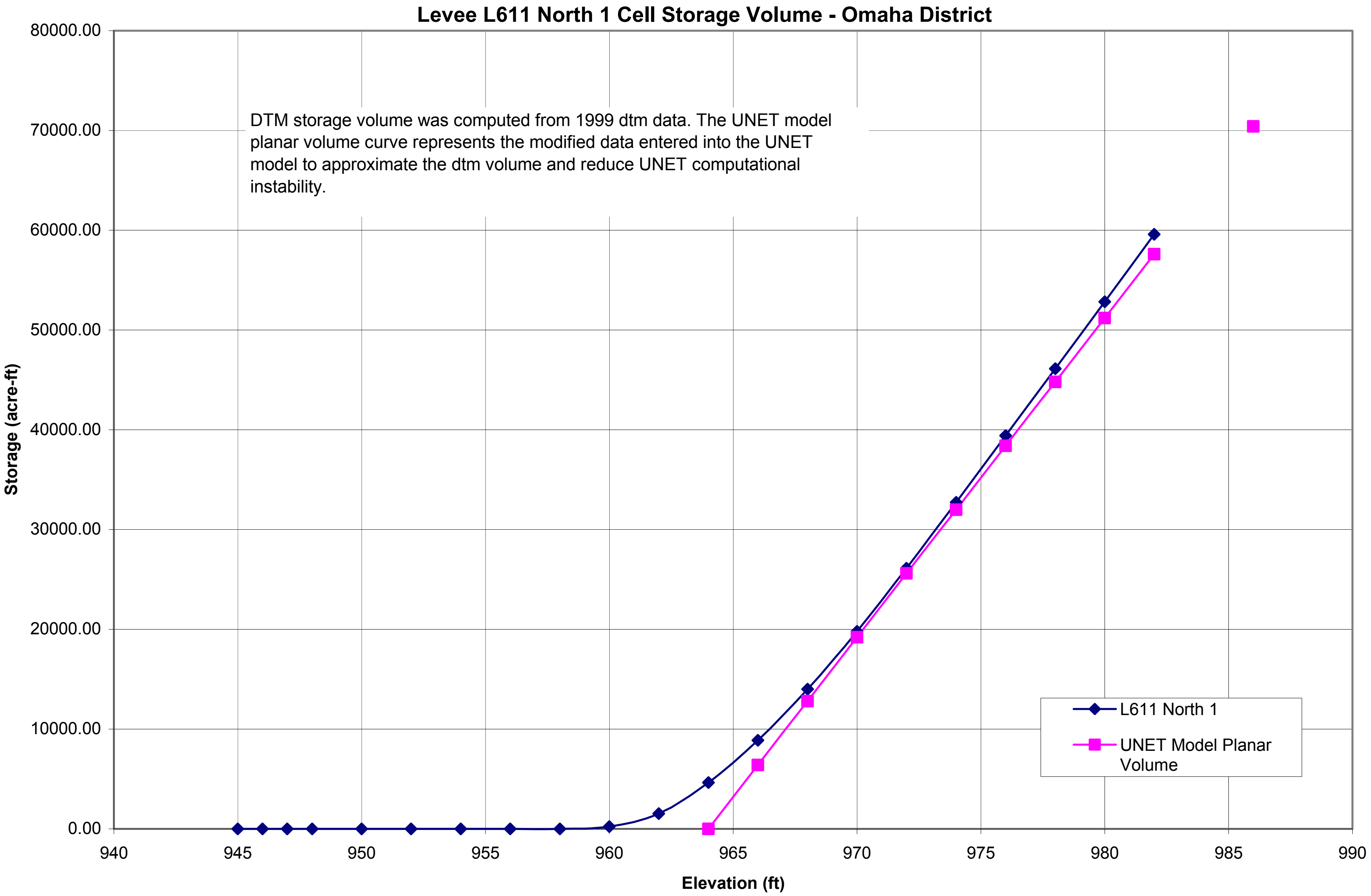


DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee L611 South 2 Cell Storage Volume - Omaha District

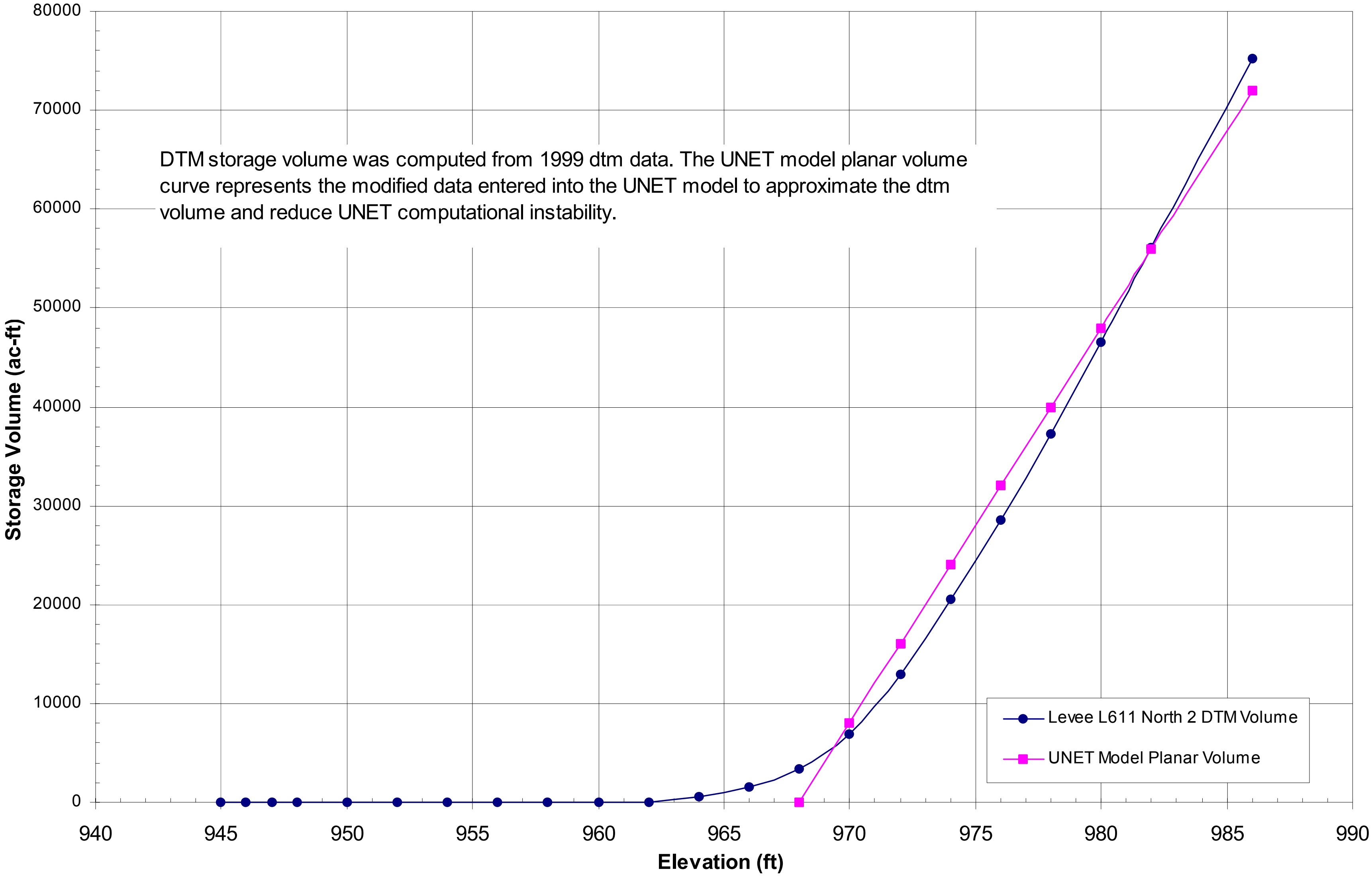


DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.



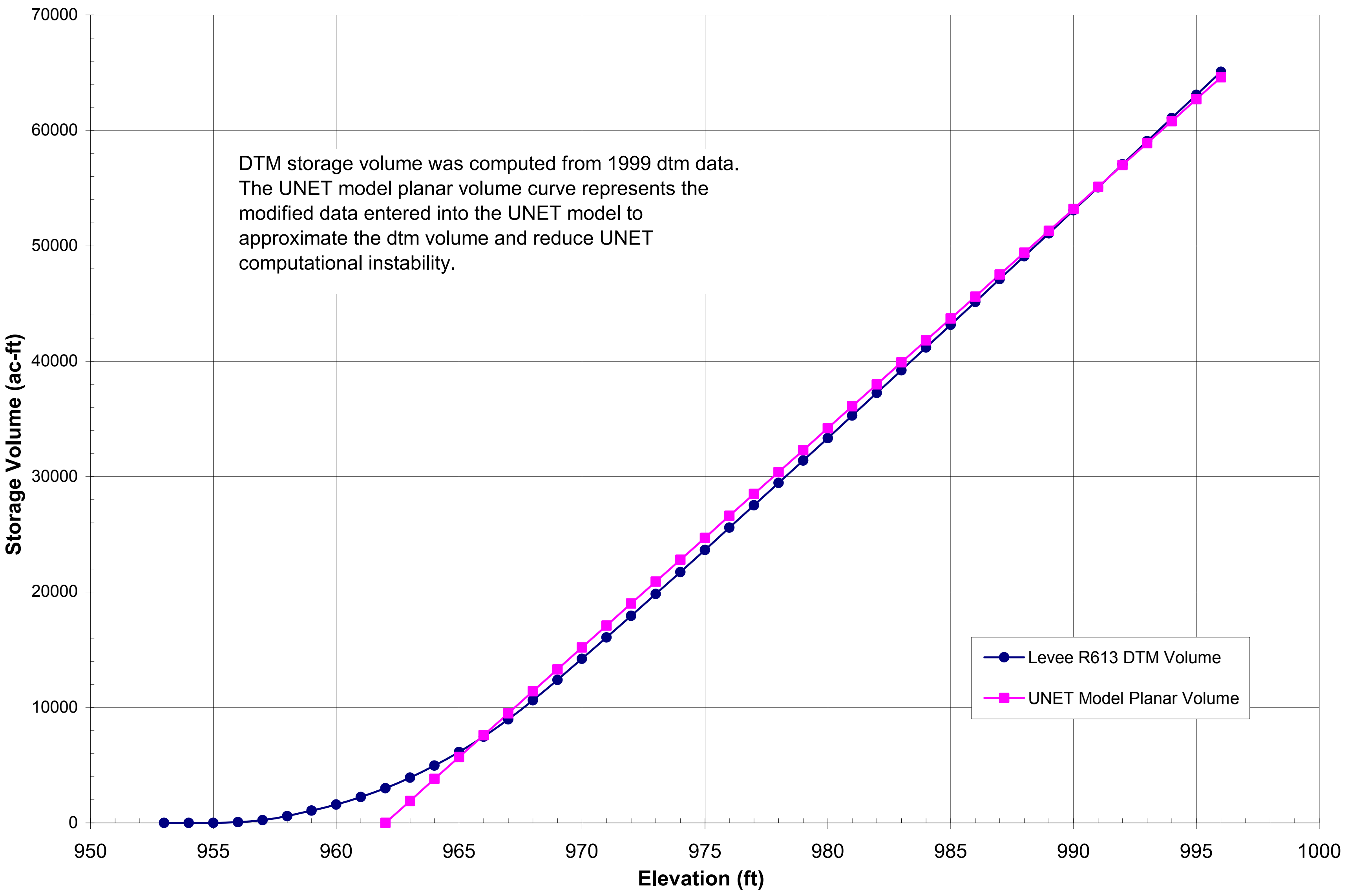
DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee L611 North 2 Cell Storage Volume - Omaha District

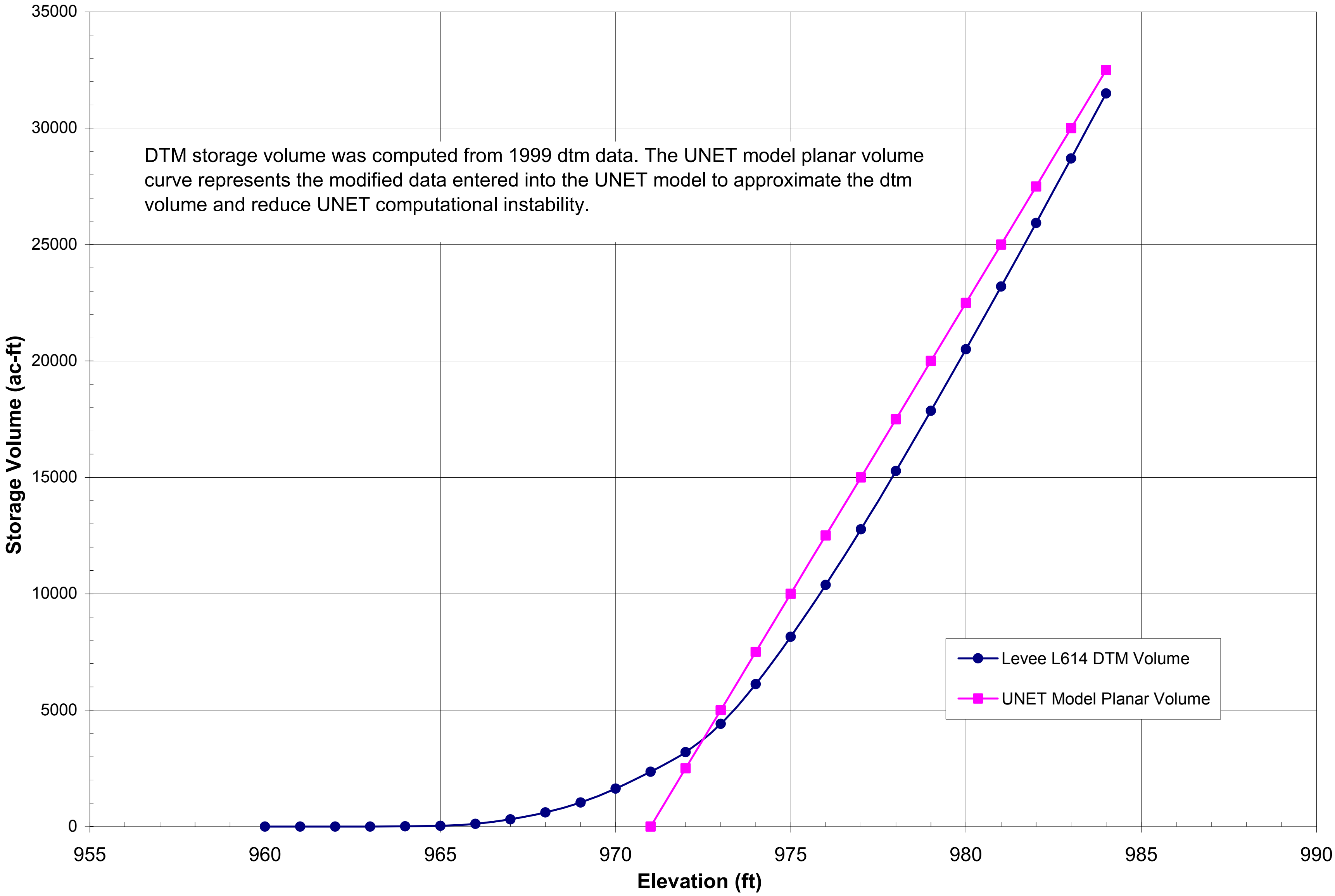


DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

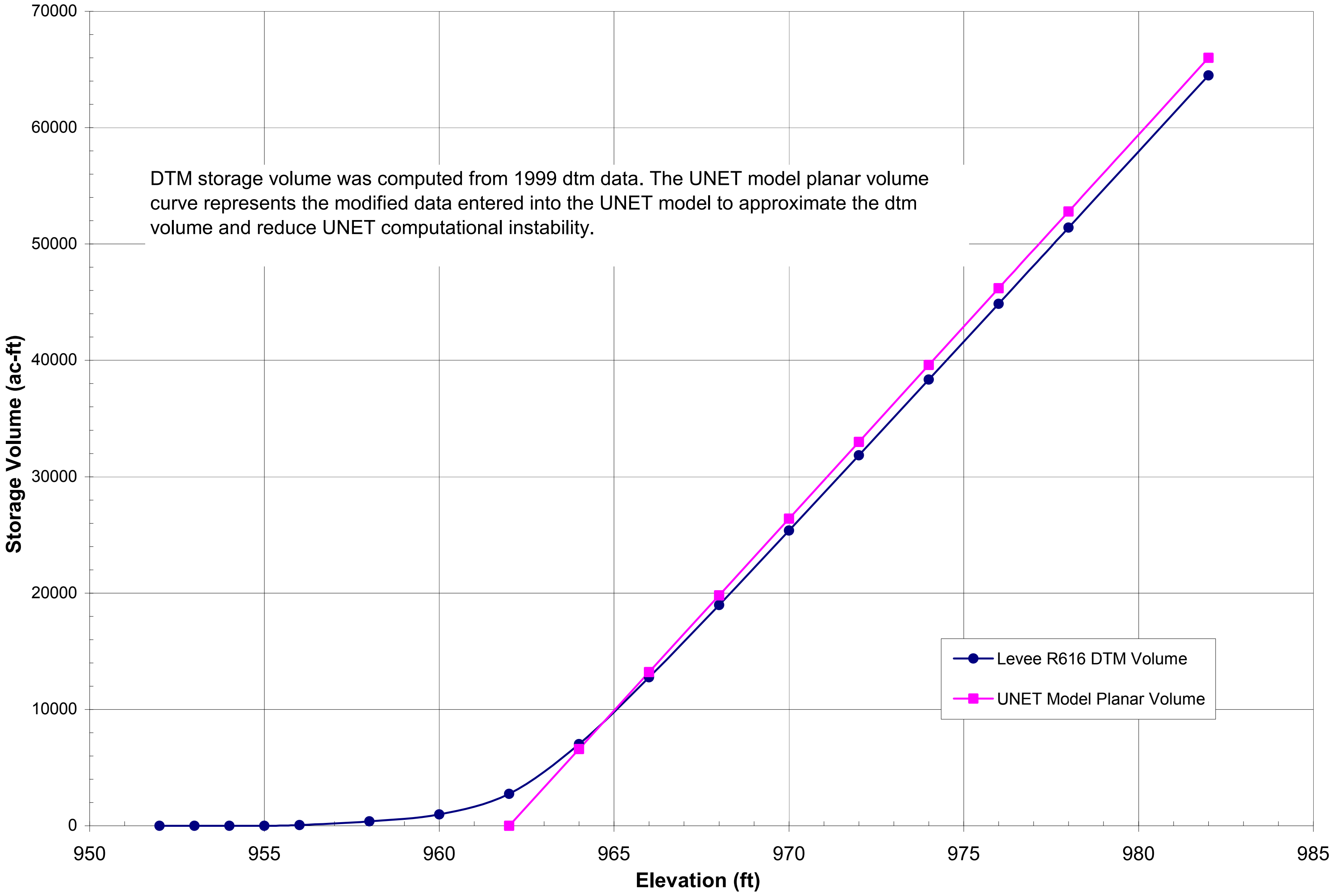
Levee R613 Cell Storage Volume - Omaha District


DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee L614 Cell Storage Volume - Omaha District

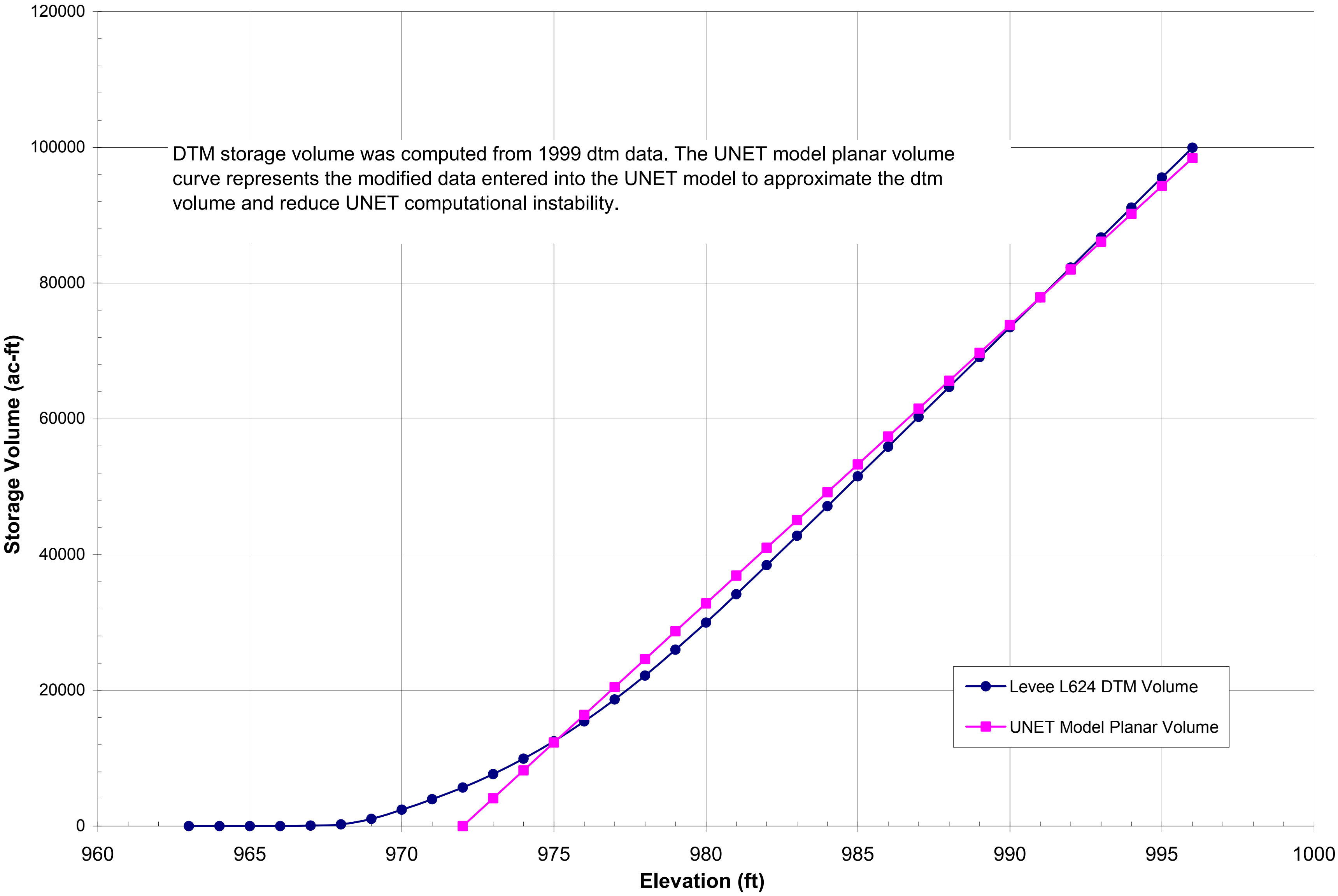

DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Levee R616 Cell Storage Volume - Omaha District



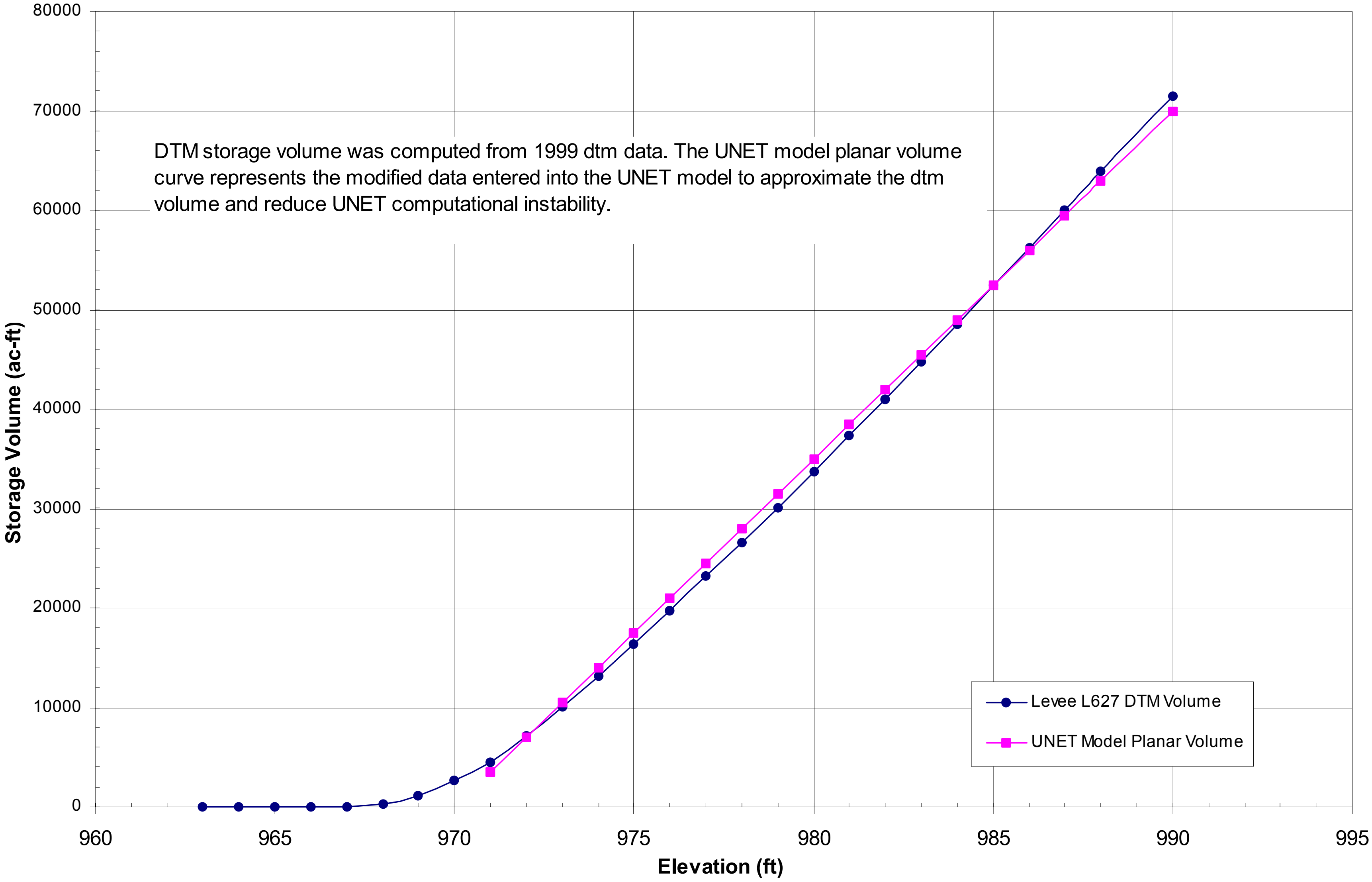
DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

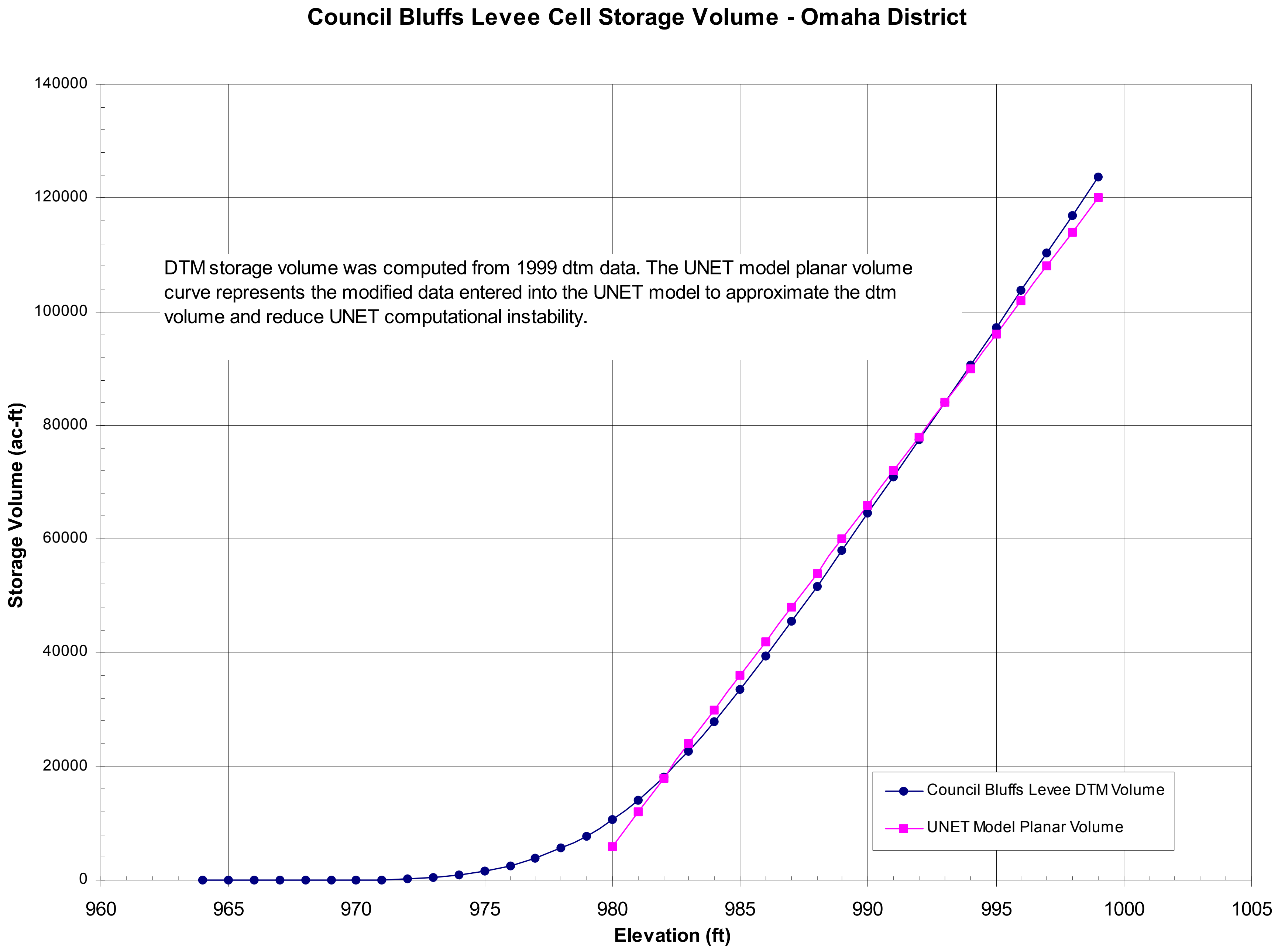
Levee L624 Cell Storage Volume - Omaha District



DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

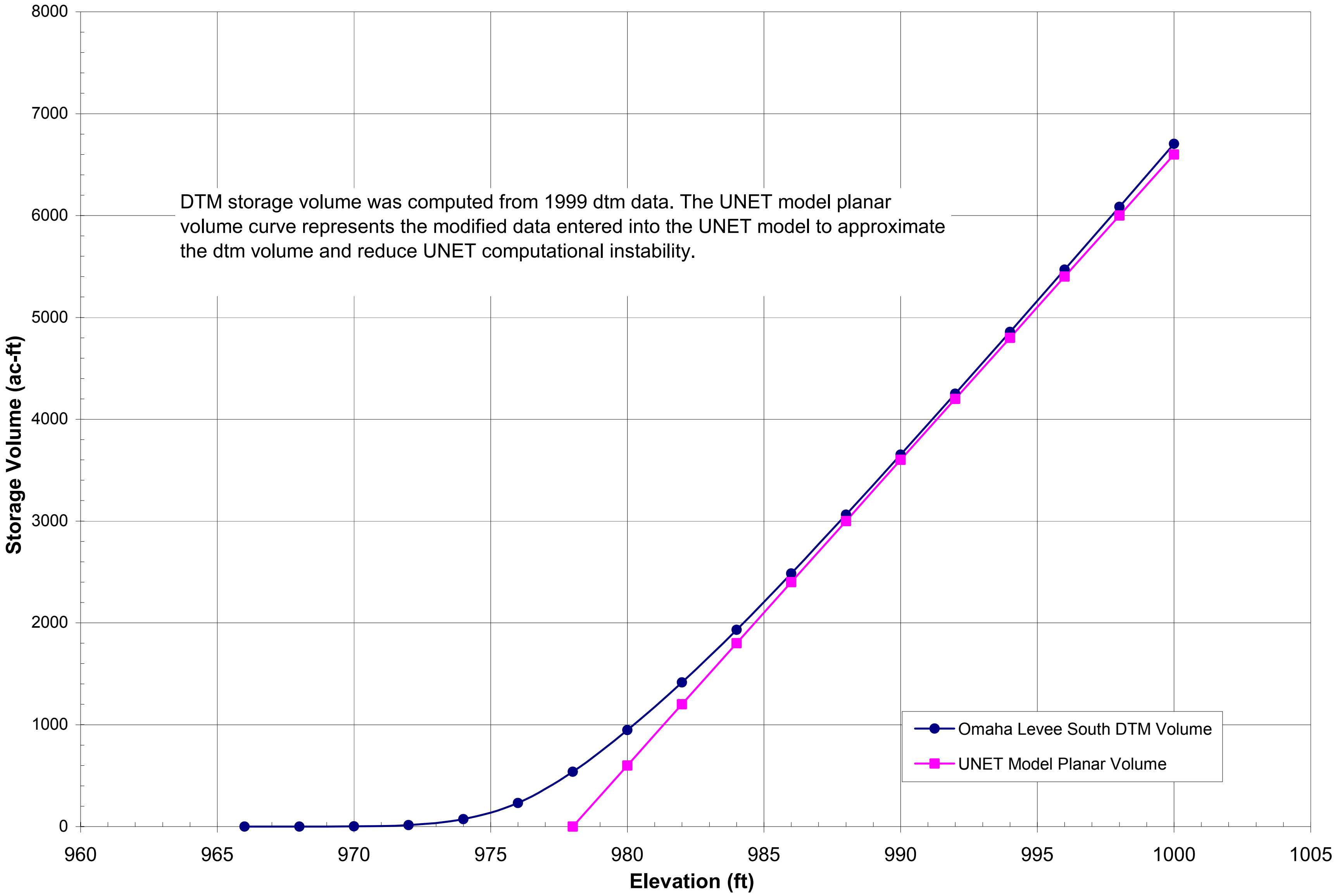
Levee L627 Cell Storage Volume - Omaha District


DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.



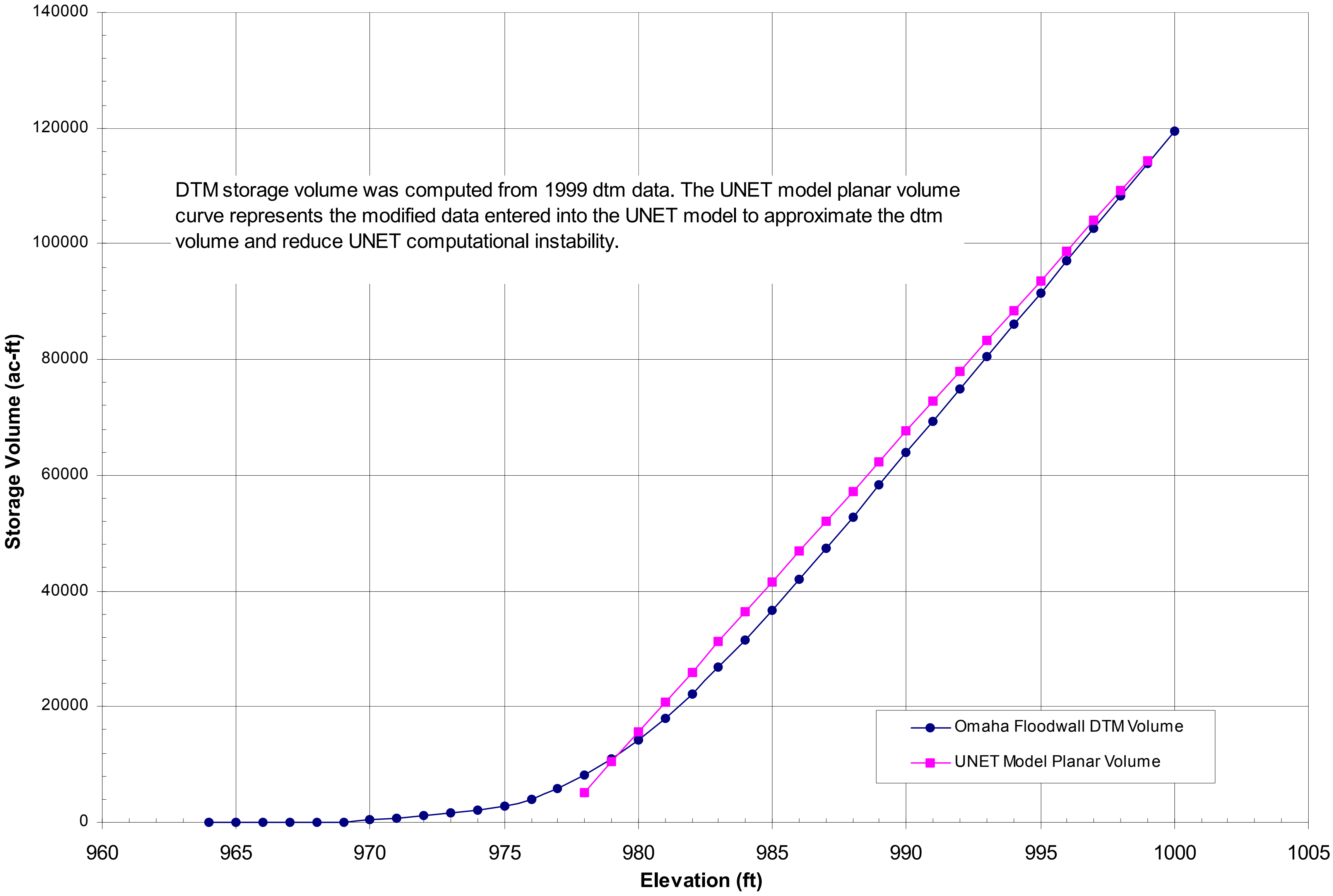
DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Omaha Levee South Cell Storage Volume - Omaha District



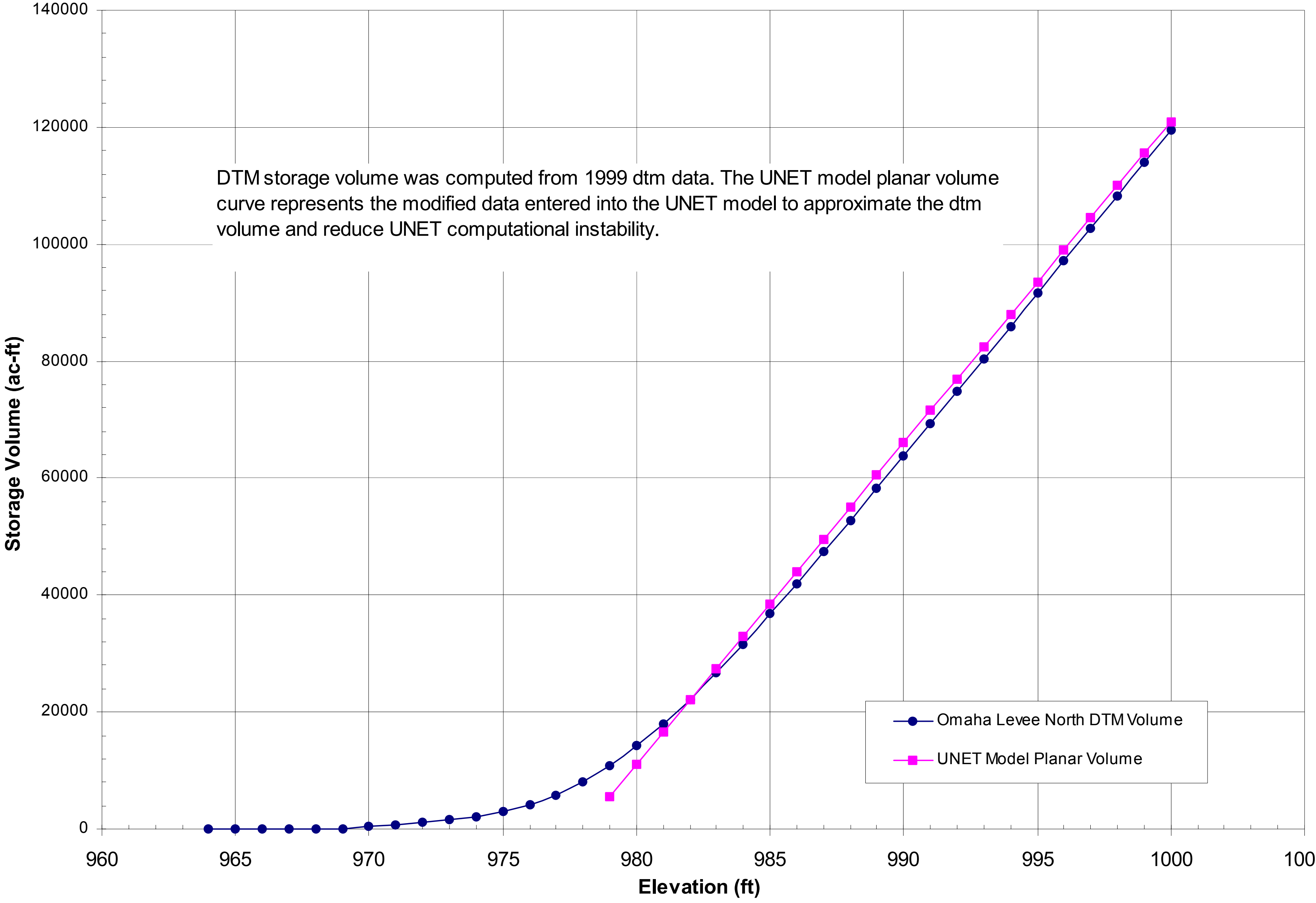
DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

Omaha Floodwall Levee Cell Storage Volume - Omaha District



DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

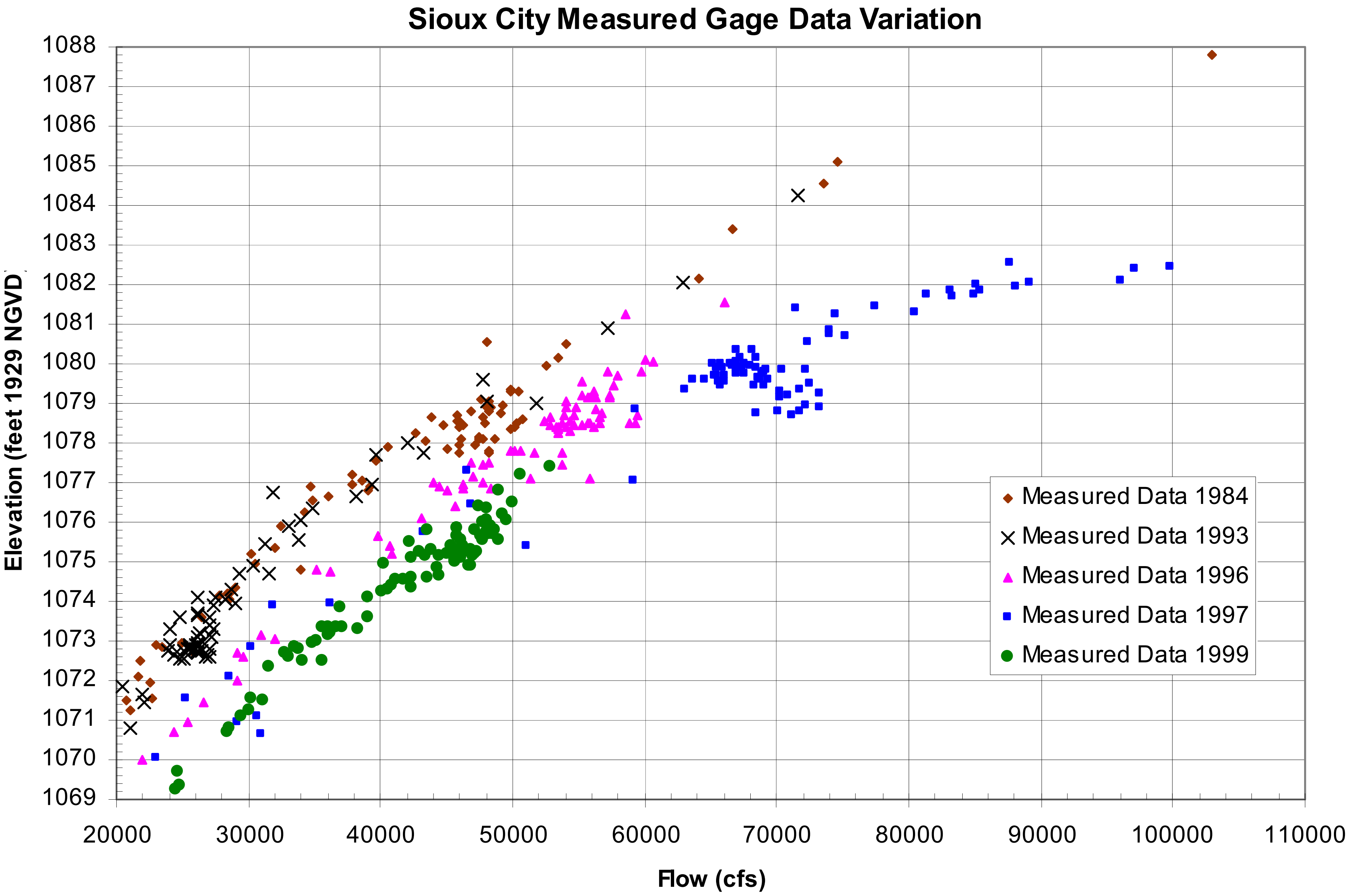
Omaha Levee North Cell Storage Volume - Omaha District

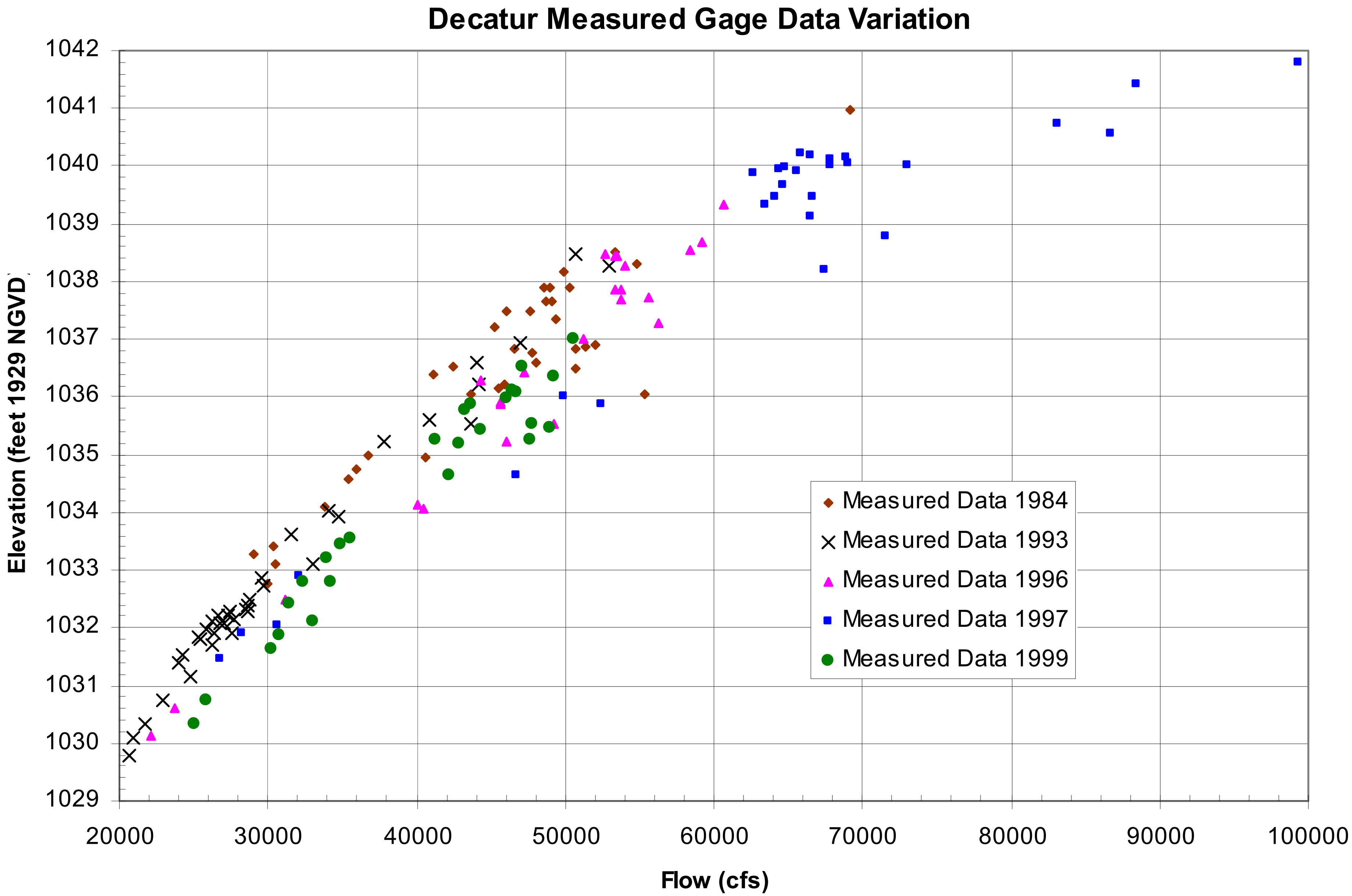

DTM storage volume was computed from 1999 dtm data. The UNET model planar volume curve represents the modified data entered into the UNET model to approximate the dtm volume and reduce UNET computational instability.

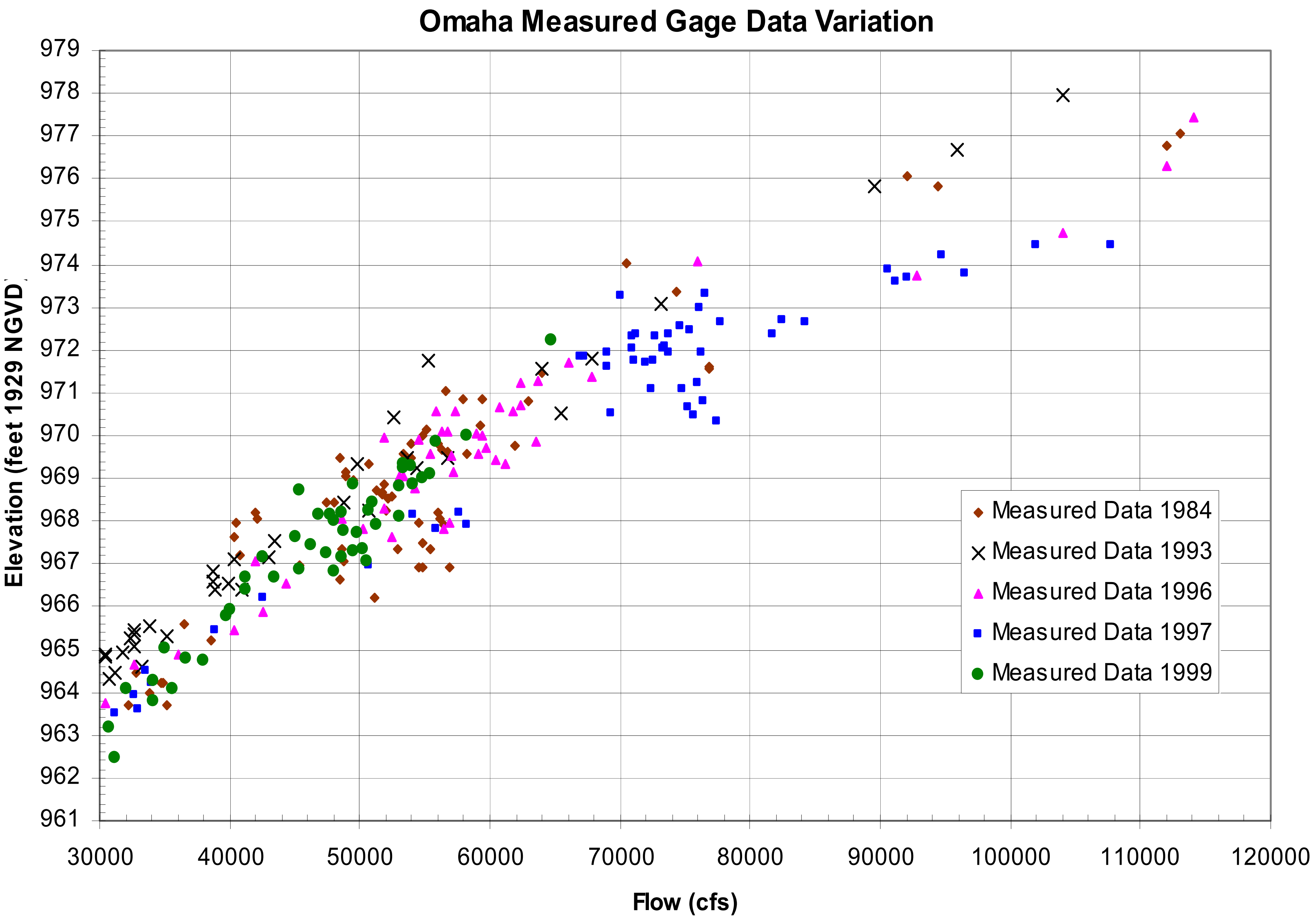
Missouri River Flow Frequency Study
Omaha District Hydraulic Modeling Levee Data

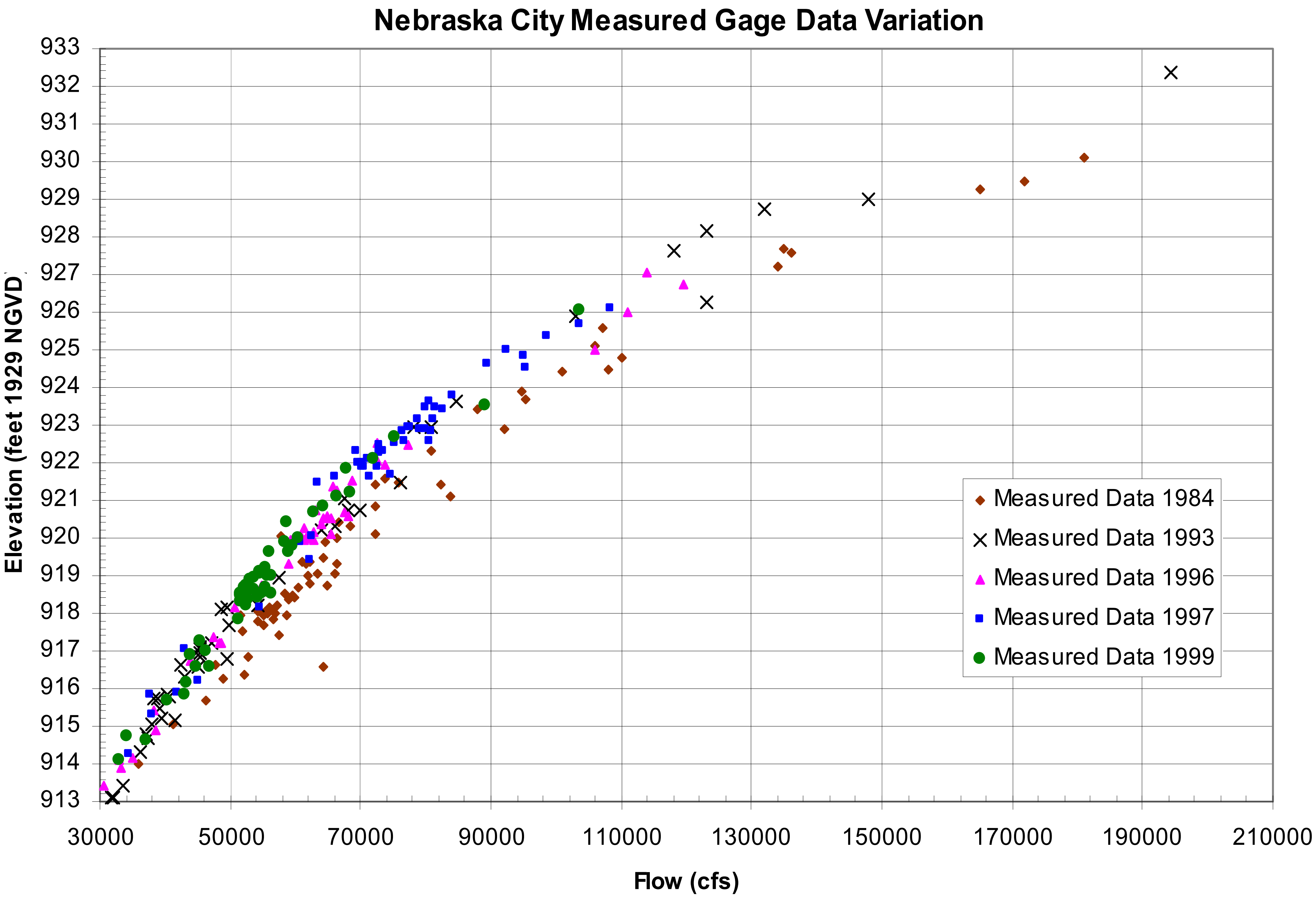
Levee Cell	Levee Upstream River Mile	Levee Downstream River Mile	Bank	Area of Protection (acres)	Upstream X-Section (River Mile)	Levee Crown Elevation at X-Section (ft)	Midpoint X-Section (River Mile)	Levee Crown Elevation at X-Section (ft)	Downstream X-Section (River Mile)	Levee Crown Elevation at X-Section (ft)
R-520	505.5	501	R	1,650	503.86	874	N.A.	N.A.	501.3	871.9
L-536	522.2	515.7	L	13,030	521.87	888.9	519.42	886.9	516	883.7
R-548	534.4	528.3	R	3,420	533.68	903.2	531.29	901.9	528.36	898
L-550 South	535.3	522.2	L	17,950	534.90	903.4	527.95	896.8	522.67	891.8
L-550 North	543.6	535.3	L	22,310	542.92	911.7	538.50	906.9	535.3	907
L-561	543.6	N.A.	L	5,680	543.71	915.5	N.A.	N.A.	N.A.	N.A.
R-562	549	541.7	R	6,770	547.80	918.2	544.13	915.1	542.51	910.3
R-573	557.2	552.7	R	2,080	556.75	924.4	N.A.	N.A.	553.07	923
L-575 South	554.2	543.5	L	18,610	553.89	925	548.22	918.6	544.53	913.1
L-575 Middle	561.9	554.2	L	18,200	561.13	933.1	557.56	929.5	554.3	926.2
L-575 North	573.7	561.9	L	36,510	572.87	945.8	567.18	941.8	562.35	933.7
L-594	580.3	573.8	L	10,370	580.16	952.7	576.88	949.7	574.47	949.5
L-601 South	584.9	580.3	L	14,150	584.60	954.8	582.19	954	580.98	951.6
L-601 North	588	584.9	L	10,580	587.83	963.6	586.63	960.5	585.01	957.5
L-601 NE	588	N.A.	L	3,040	588.24	963.5	N.A.	N.A.	N.A.	N.A.
L-611 South 1	590.5	588	L	2,520	590.27	965	N.A.	N.A.	588.65	964.7
L-611 South 2	599.5	590.5	L	13,200	599.26	973.2	595.33	972.4	590.7	966.4
L-611 North 1	601.4	599.5	L	3,390	600.92	976	N.A.	N.A.	599.67	973
L-611 North 2	606	601.4	L	5,590	605.45	979.5	N.A.	N.A.	601.71	977.5
R-613	596.7	595.2	R	2,030	596.47	971.1	N.A.	N.A.	595.66	971.7
R-616	601.4	596.7	R	3320	600.92	975.6	N.A.	N.A.	596.87	973.1
L-614	606.2	606	L	2,980	606.28	978.9	N.A.	N.A.	N.A.	N.A.
L-624	607.9	606.3	L	4,740	607.80	983.4	N.A.	N.A.	606.69	979.8
L-627	613.9	607.9	L	3,830	613.17	985.7	612.37	985.1	608.69	982.9
Council Bluffs	619.7	613.9	L	5,970	618.74	993.7	616.83	990.5	614.86	990.5
Omaha Levee So.	615.3	611.7	R	350	614.41	988	N.A.	N.A.	611.97	986.1
Omaha Floodwall	616.2	615.3	R	110	616.07	990	N.A.	N.A.	615.57	989.5
Omaha Levee No.	624.9	616.2	R	5,960	624.04	997.4	620.87	995.7	617.59	991.7

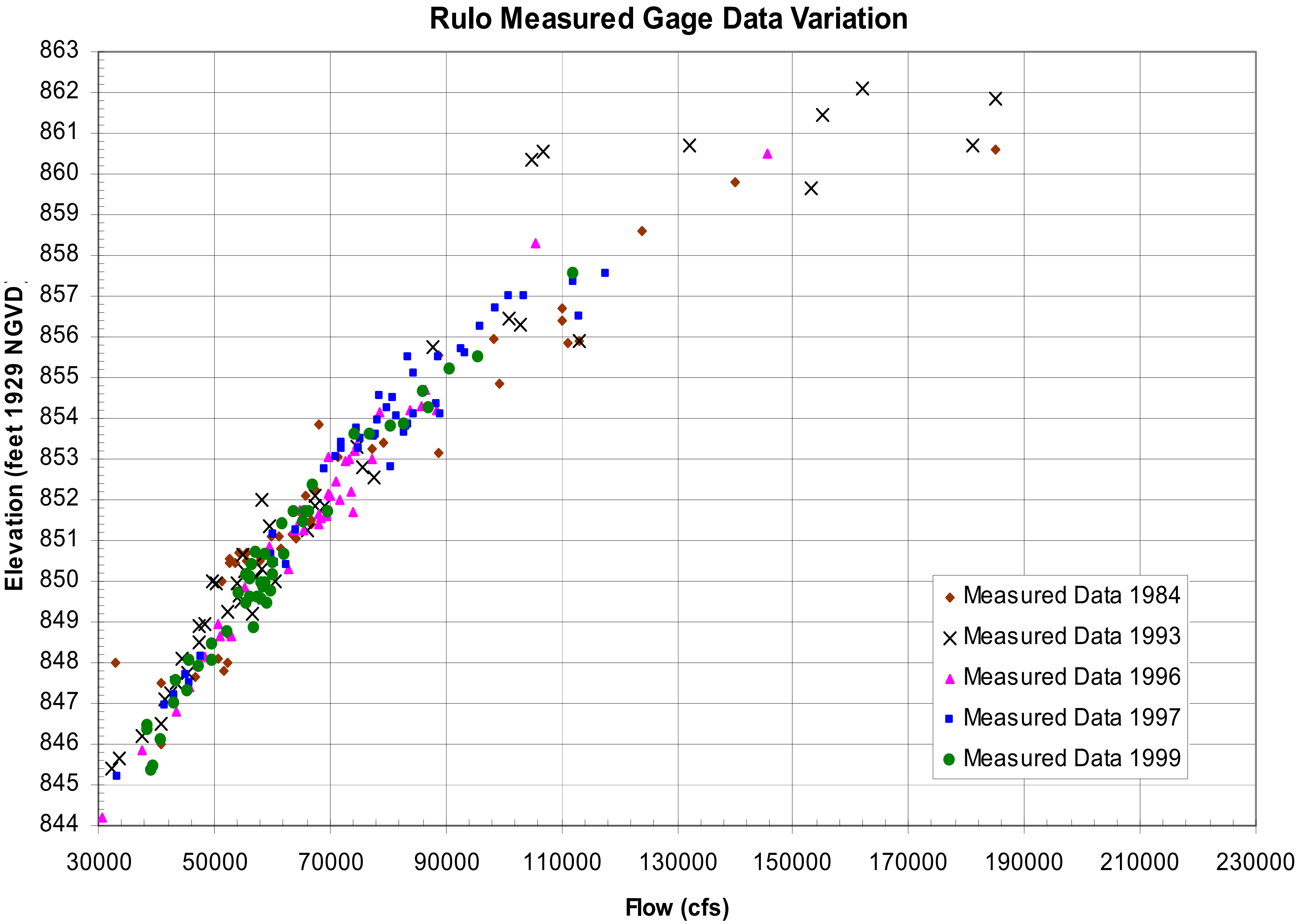
Notes: The levee cell name refers to the Federal Levee unit. Some units were subdivided to reduce levee cell size. Subdivision of levee cells follows roads or other interior elevated features. X-Section specifies the location of the cross section (river mile) and elevation (ft) for the connection within the hydraulic model. Midpoint hydraulic connections are not required for the smaller levee cells and is listed as N.A. within the table.

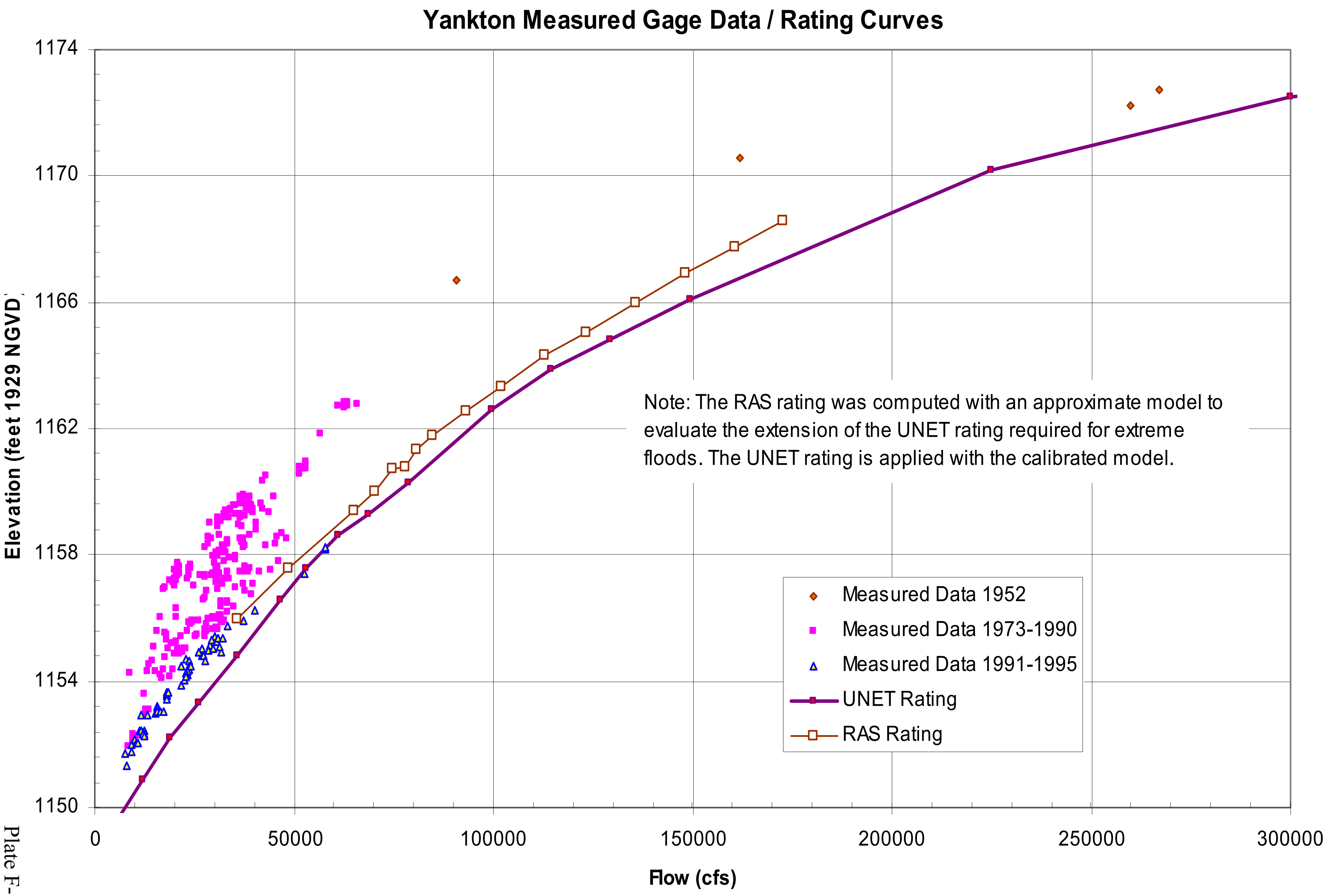

Sioux City Measured Gage Data Variation
Elevation (feet 1929 NGVD)
Flow (cfs)
1088
1087
1086
1085
1084
1083
1082
1081
1080
1079
1078
1077
1076
1075
1074
1073
1072
1071
1070
1069
20000
30000
40000
50000
60000
70000
80000
90000
100000
110000
Measured Data 1984
Measured Data 1993
Measured Data 1996
Measured Data 1997
Measured Data 1999


Decatur Measured Gage Data Variation
Elevation (feet 1929 NGVD)
Flow (cfs)
1042
1041
1040
1039
1038
1037
1036
1035
1034
1033
1032
1031
1030
1029
20000
30000
40000
50000
60000
70000
80000
90000
100000
Measured Data 1984
Measured Data 1993
Measured Data 1996
Measured Data 1997
Measured Data 1999


Omaha Measured Gage Data Variation
Elevation (feet 1929 NGVD)
979
978
977
976
975
974
973
972
971
970
969
968
967
966
965
964
963
962
961
30000
40000
50000
60000
70000
80000
90000
100000
110000
120000
Flow (cfs)
◆ Measured Data 1984
× Measured Data 1993
▲ Measured Data 1996
■ Measured Data 1997
● Measured Data 1999

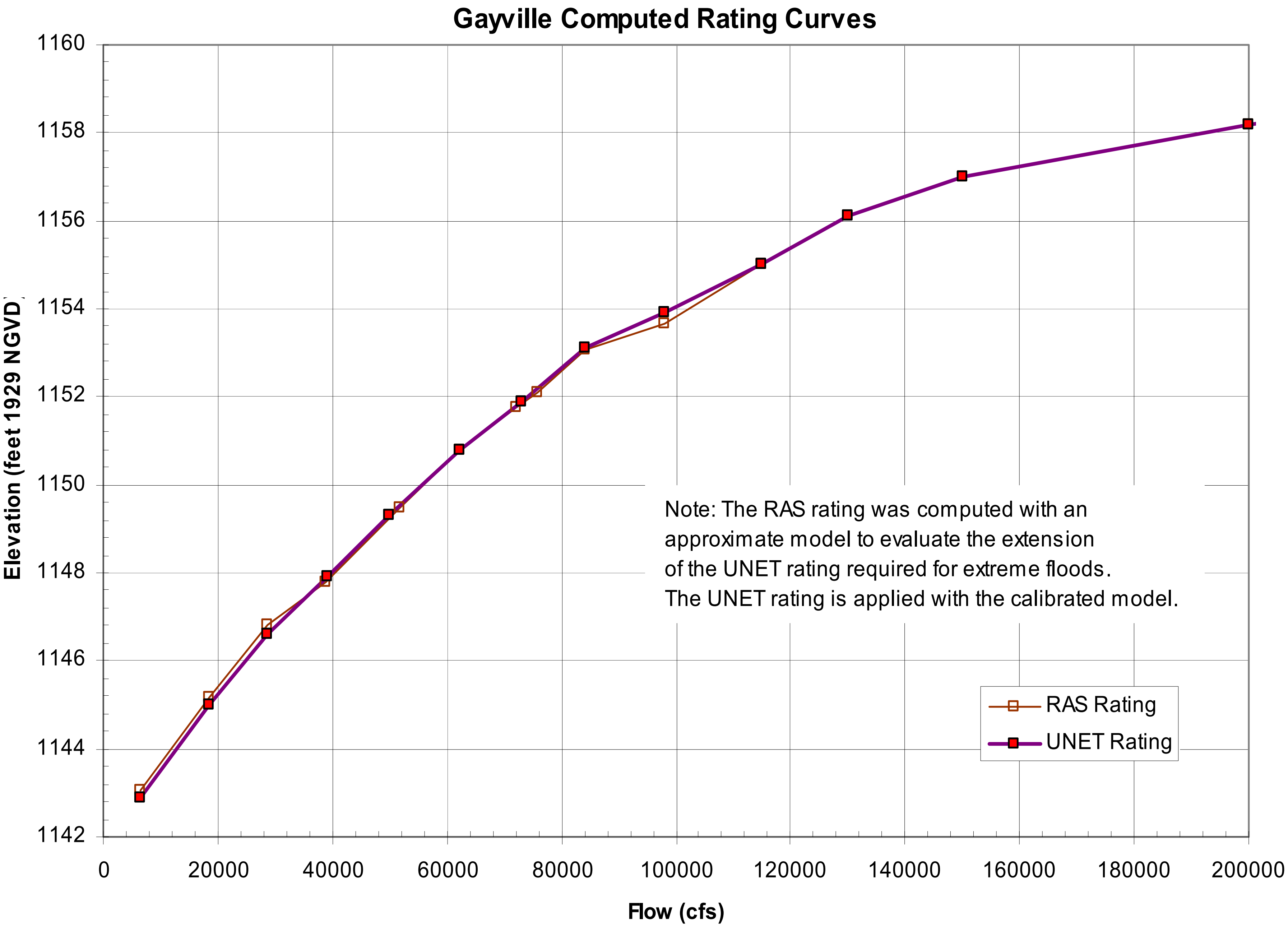

Nebraska City Measured Gage Data Variation
Elevation (feet 1929 NGVD)
933
932
931
930
929
928
927
926
925
924
923
922
921
920
919
918
917
916
915
914
913
30000
50000
70000
90000
110000
130000
150000
170000
190000
210000
Flow (cfs)
◆ Measured Data 1984
× Measured Data 1993
▲ Measured Data 1996
■ Measured Data 1997
● Measured Data 1999


Rulo Measured Gage Data Variation
Elevation (feet 1929 NGVD)
Flow (cfs)
863
862
861
860
859
858
857
856
855
854
853
852
851
850
849
848
847
846
845
844
30000
50000
70000
90000
110000
130000
150000
170000
190000
210000
230000
◆ Measured Data 1984
× Measured Data 1993
▲ Measured Data 1996
■ Measured Data 1997
● Measured Data 1999



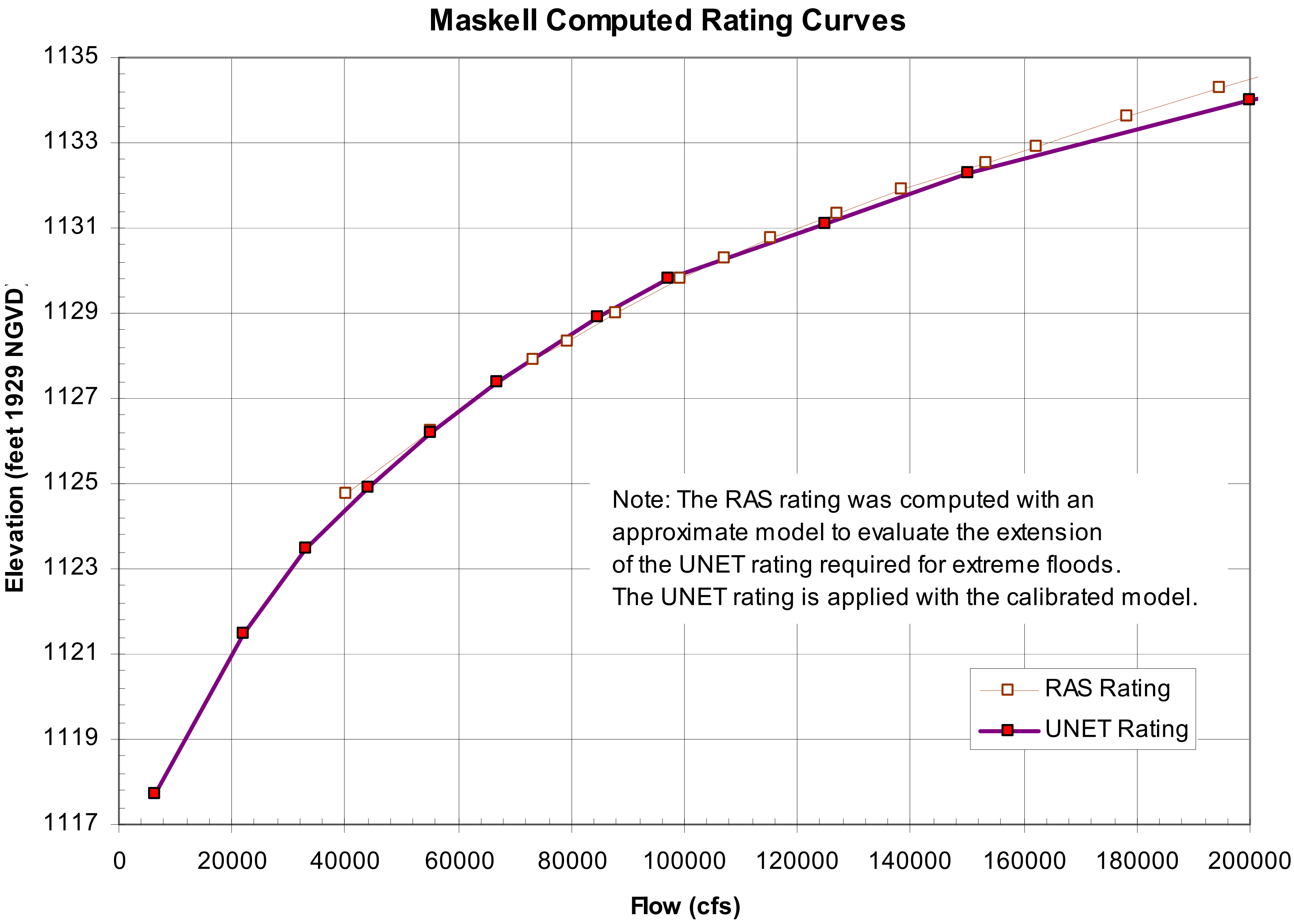
Yankton Measured Gage Data / Rating Curves

Note: The RAS rating was computed with an approximate model to evaluate the extension of the UNET rating required for extreme floods. The UNET rating is applied with the calibrated model.

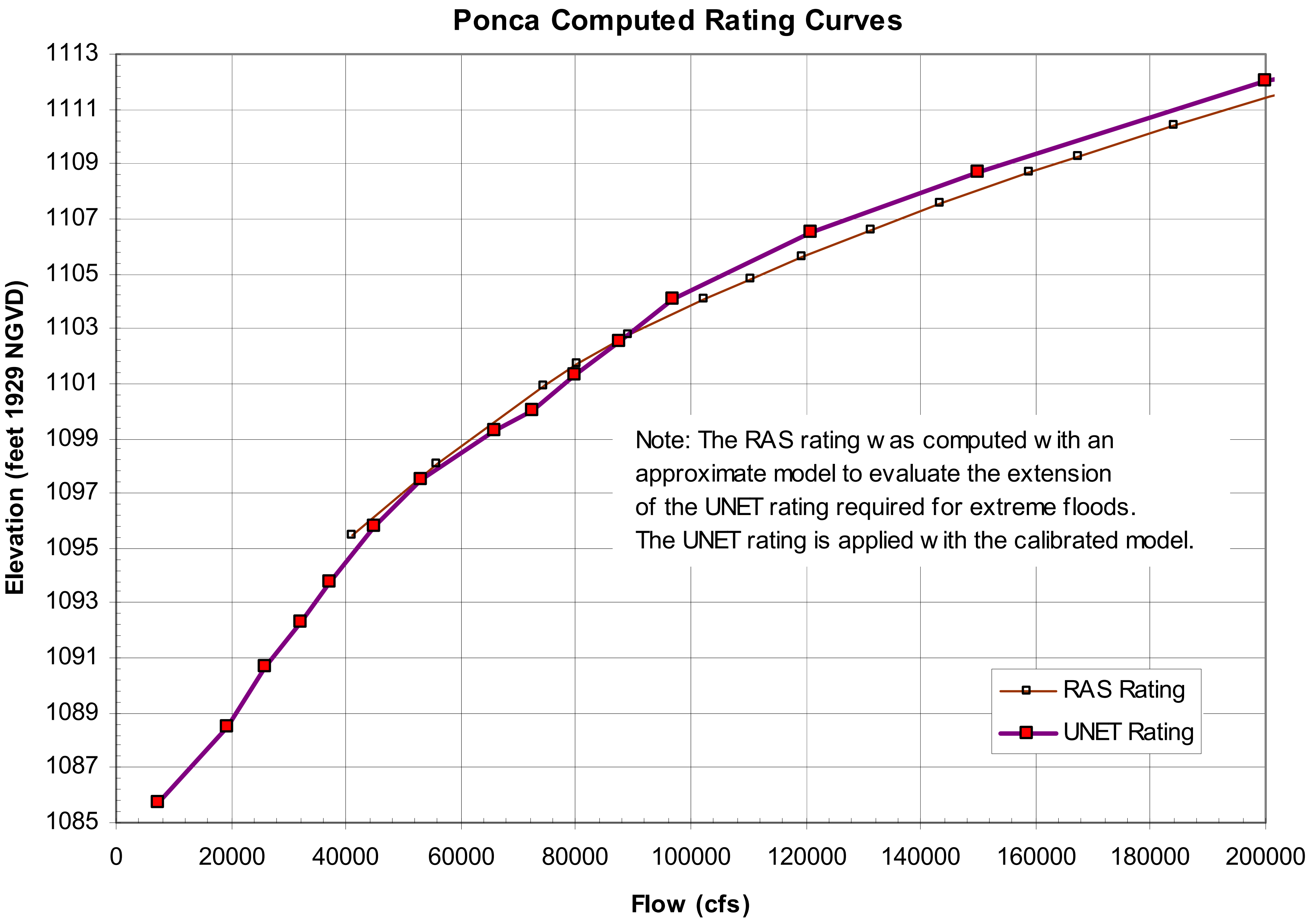


Gayville Computed Rating Curves

Note: The RAS rating was computed with an approximate model to evaluate the extension of the UNET rating required for extreme floods. The UNET rating is applied with the calibrated model.

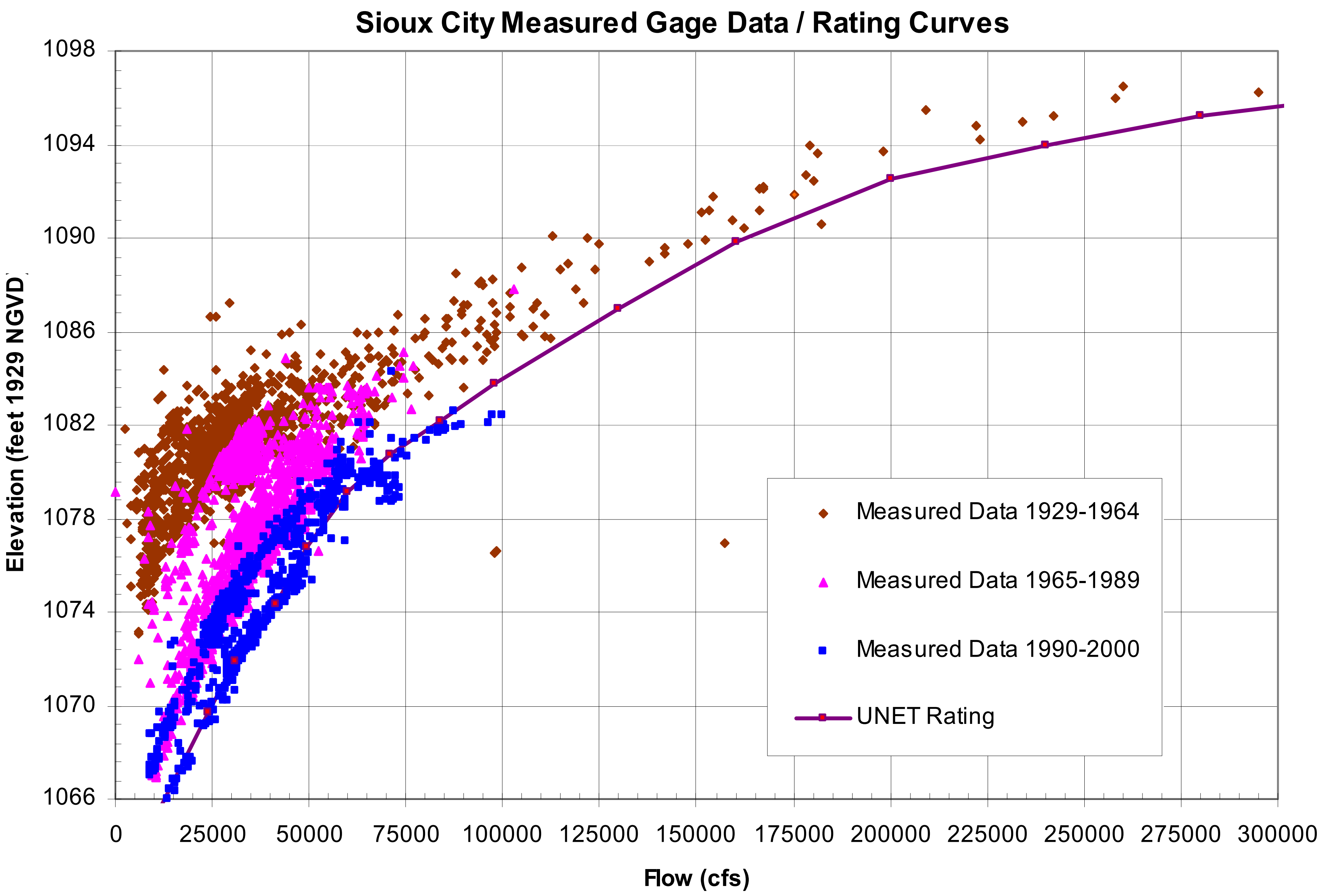


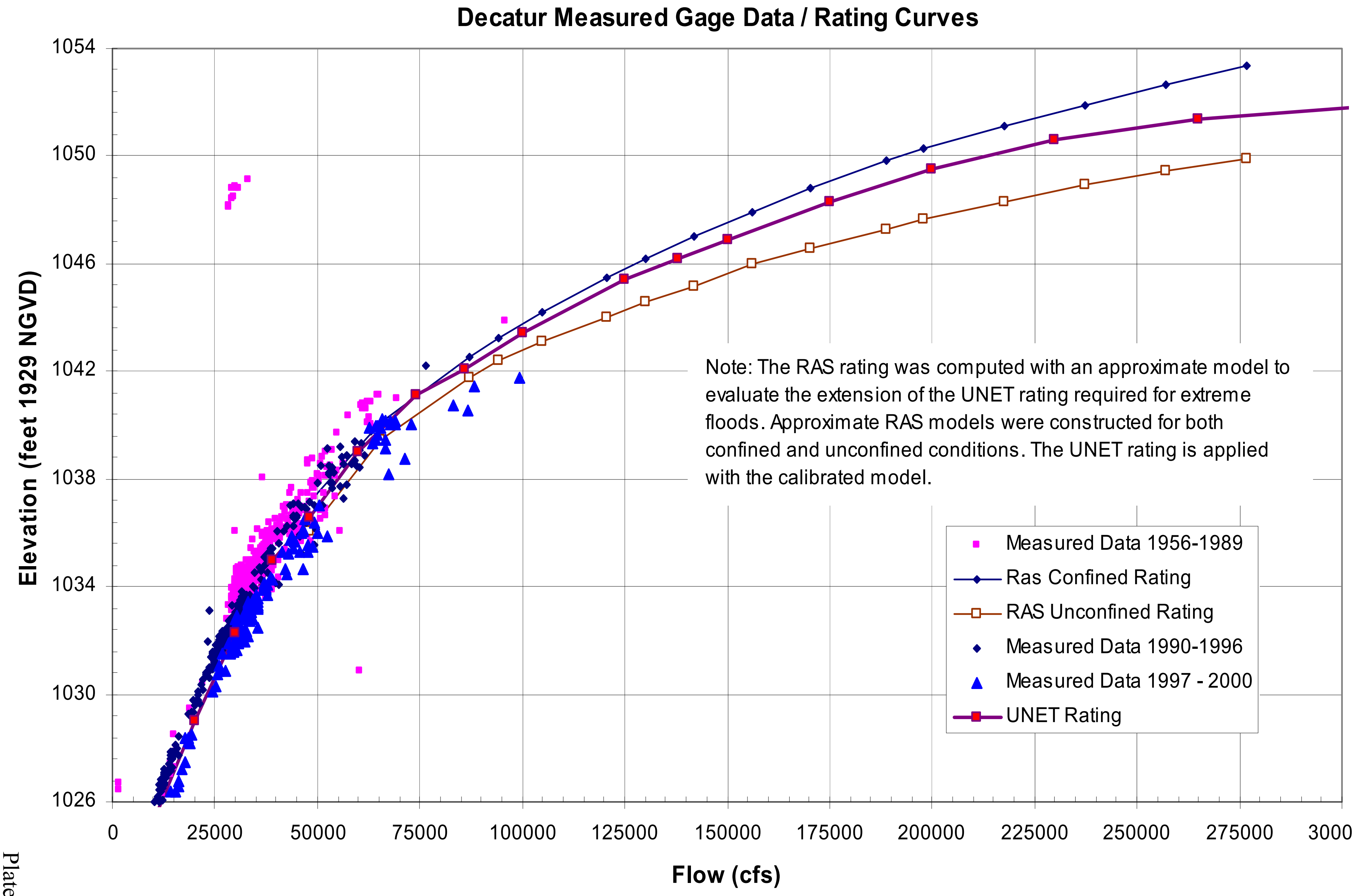
Note: The RAS rating was computed with an approximate model to evaluate the extension of the UNET rating required for extreme floods. The UNET rating is applied with the calibrated model.



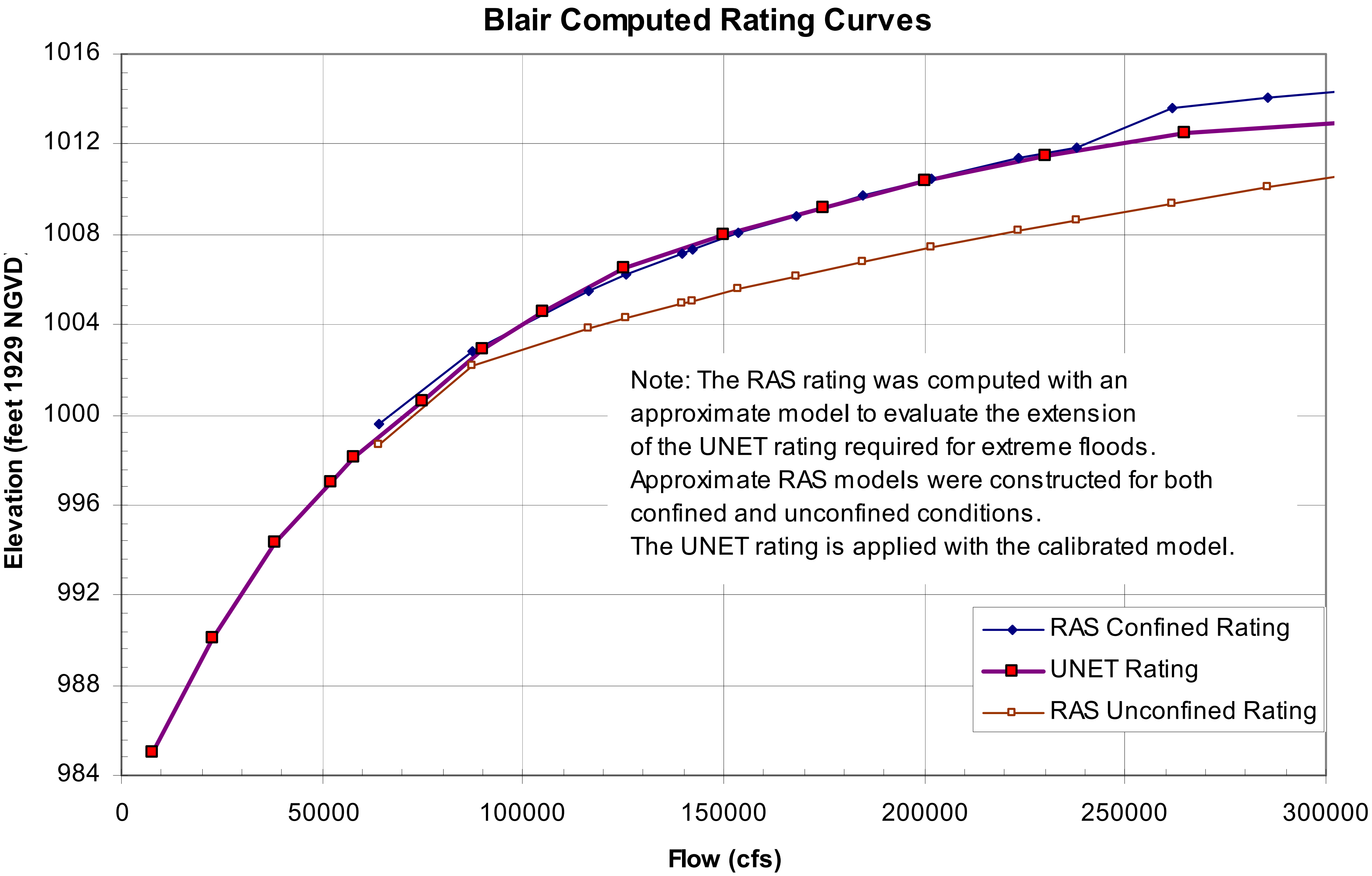
Ponca Computed Rating Curves

Note: The RAS rating was computed with an approximate model to evaluate the extension of the UNET rating required for extreme floods. The UNET rating is applied with the calibrated model.

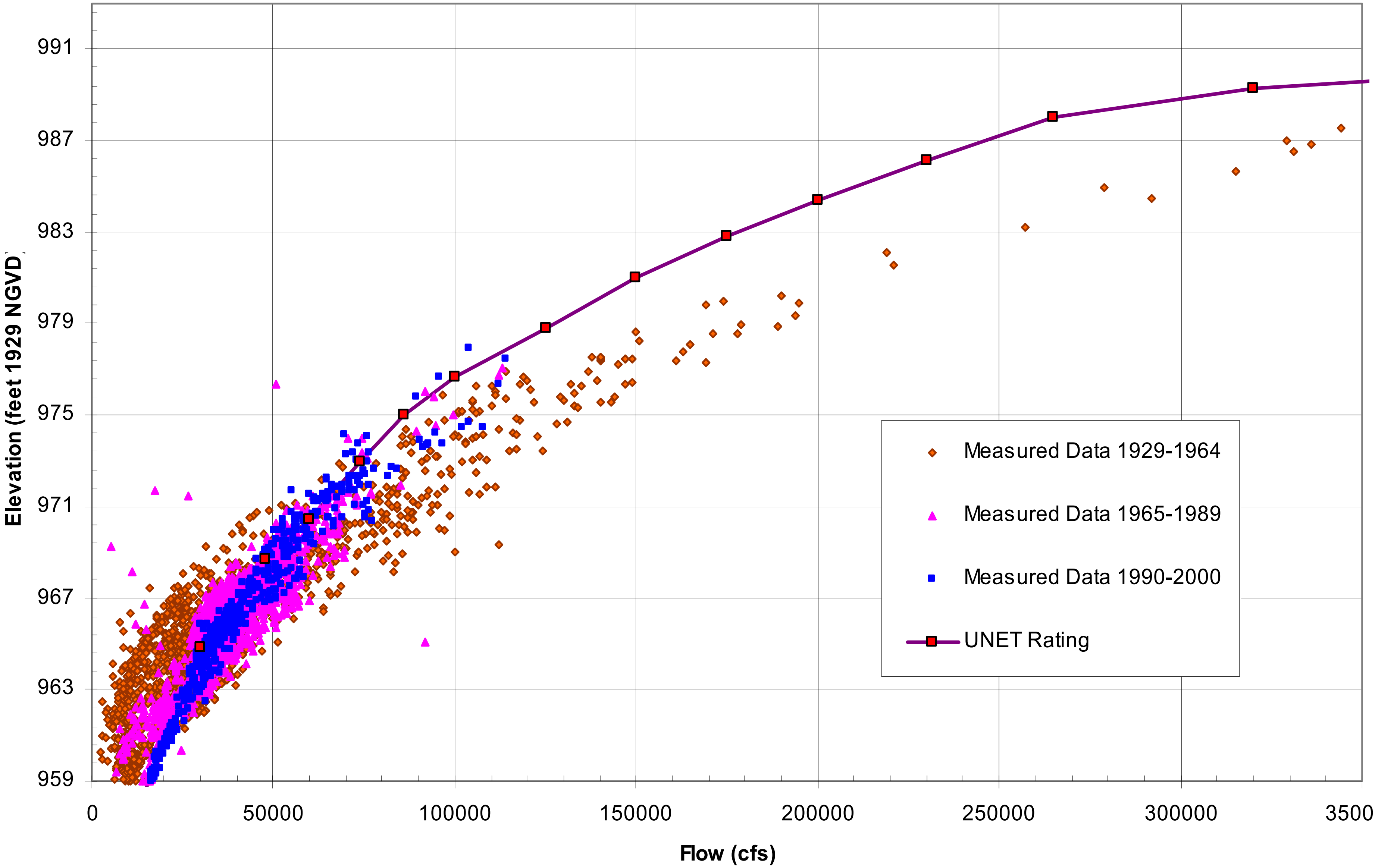

Sioux City Measured Gage Data / Rating Curves
Elevation (feet 1929 NGVD)
1098
1094
1090
1086
1082
1078
1074
1070
1066
0
25000
50000
75000
100000
125000
150000
175000
200000
225000
250000
275000
300000
Flow (cfs)
◆ Measured Data 1929-1964
▲ Measured Data 1965-1989
■ Measured Data 1990-2000
UNET Rating



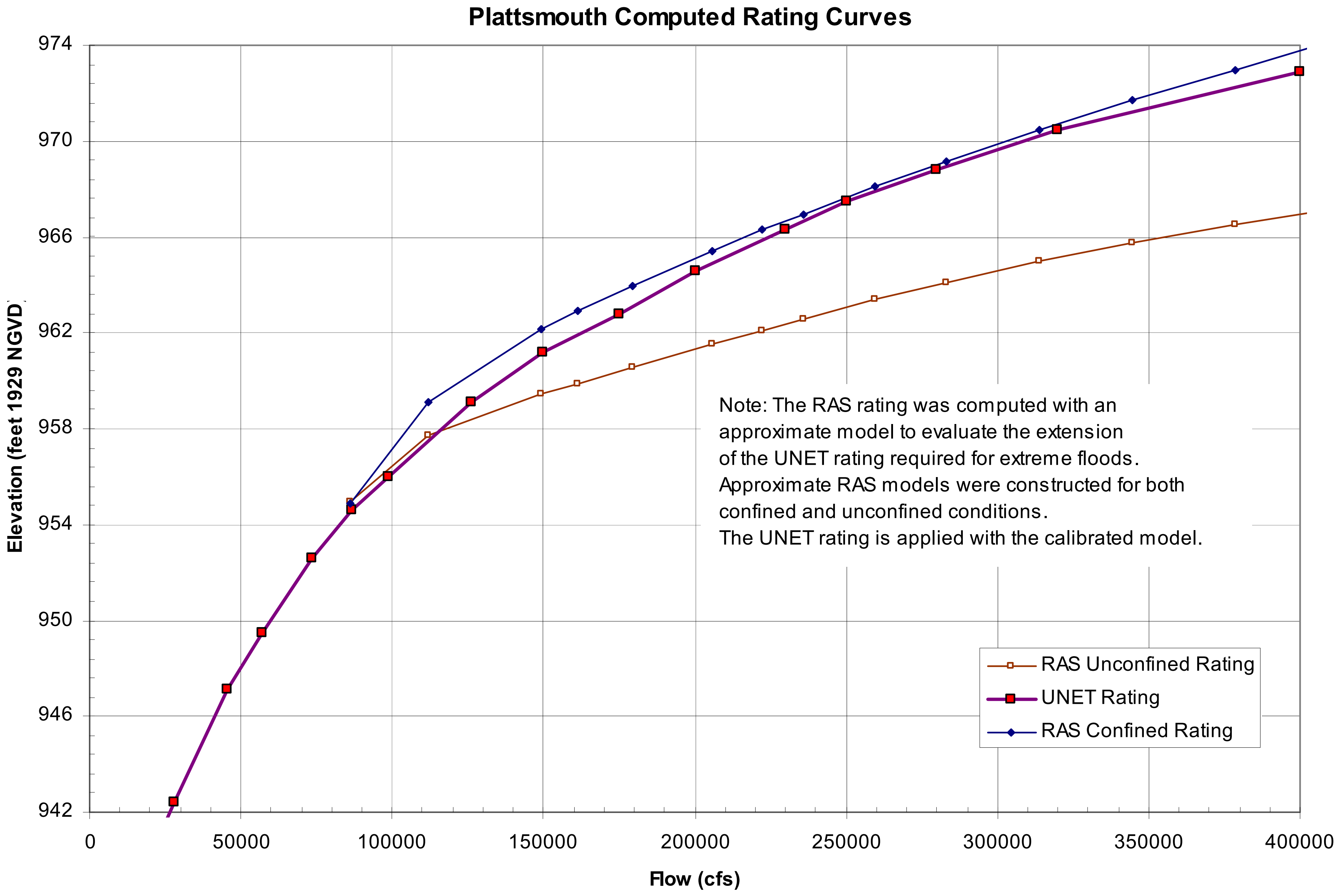
Note: The RAS rating was computed with an approximate model to evaluate the extension of the UNET rating required for extreme floods. Approximate RAS models were constructed for both confined and unconfined conditions. The UNET rating is applied with the calibrated model.



Note: The RAS rating was computed with an approximate model to evaluate the extension of the UNET rating required for extreme floods.
Approximate RAS models were constructed for both confined and unconfined conditions.
The UNET rating is applied with the calibrated model.

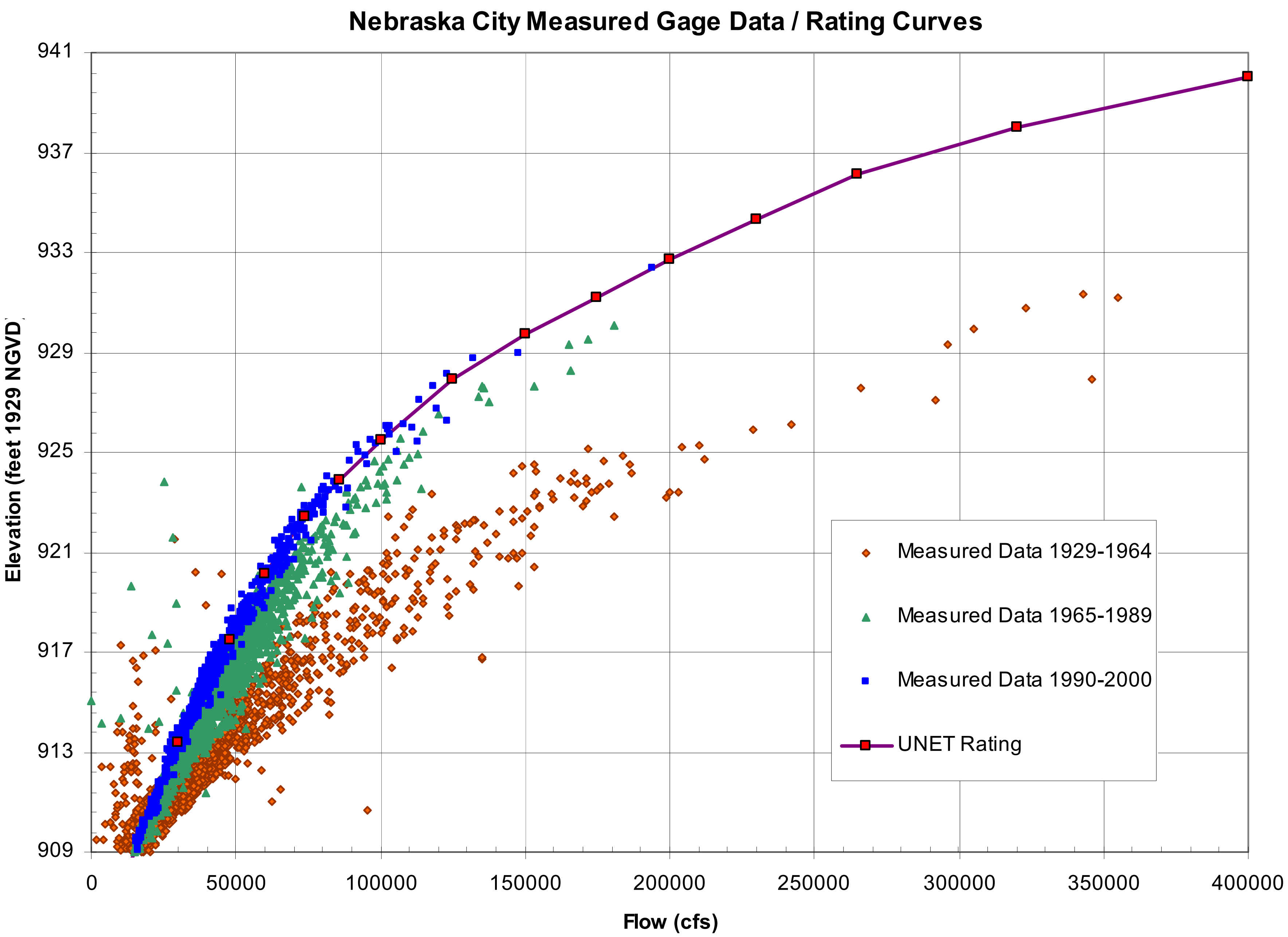


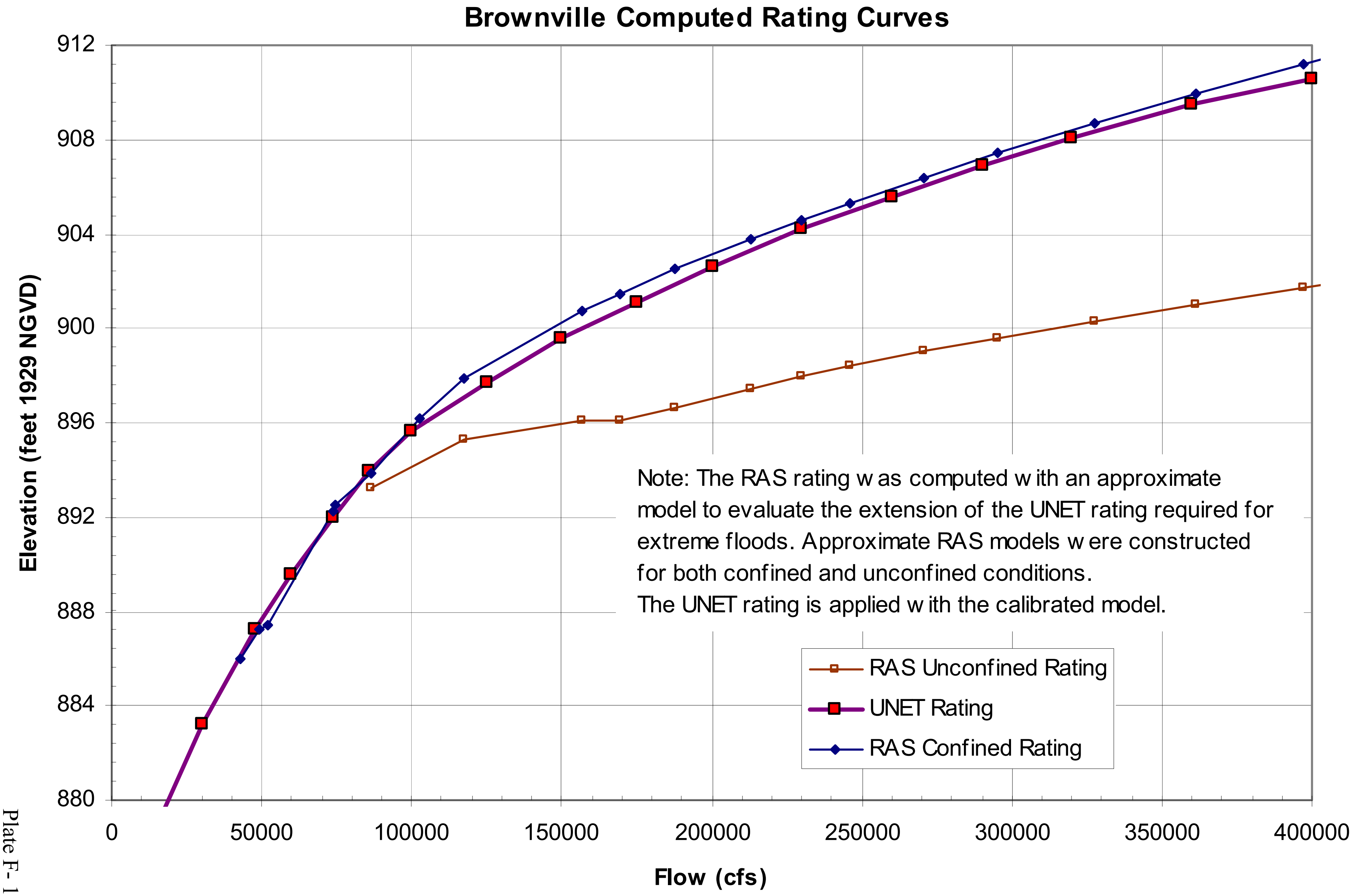
Omaha Measured Gage Data / Rating Curves



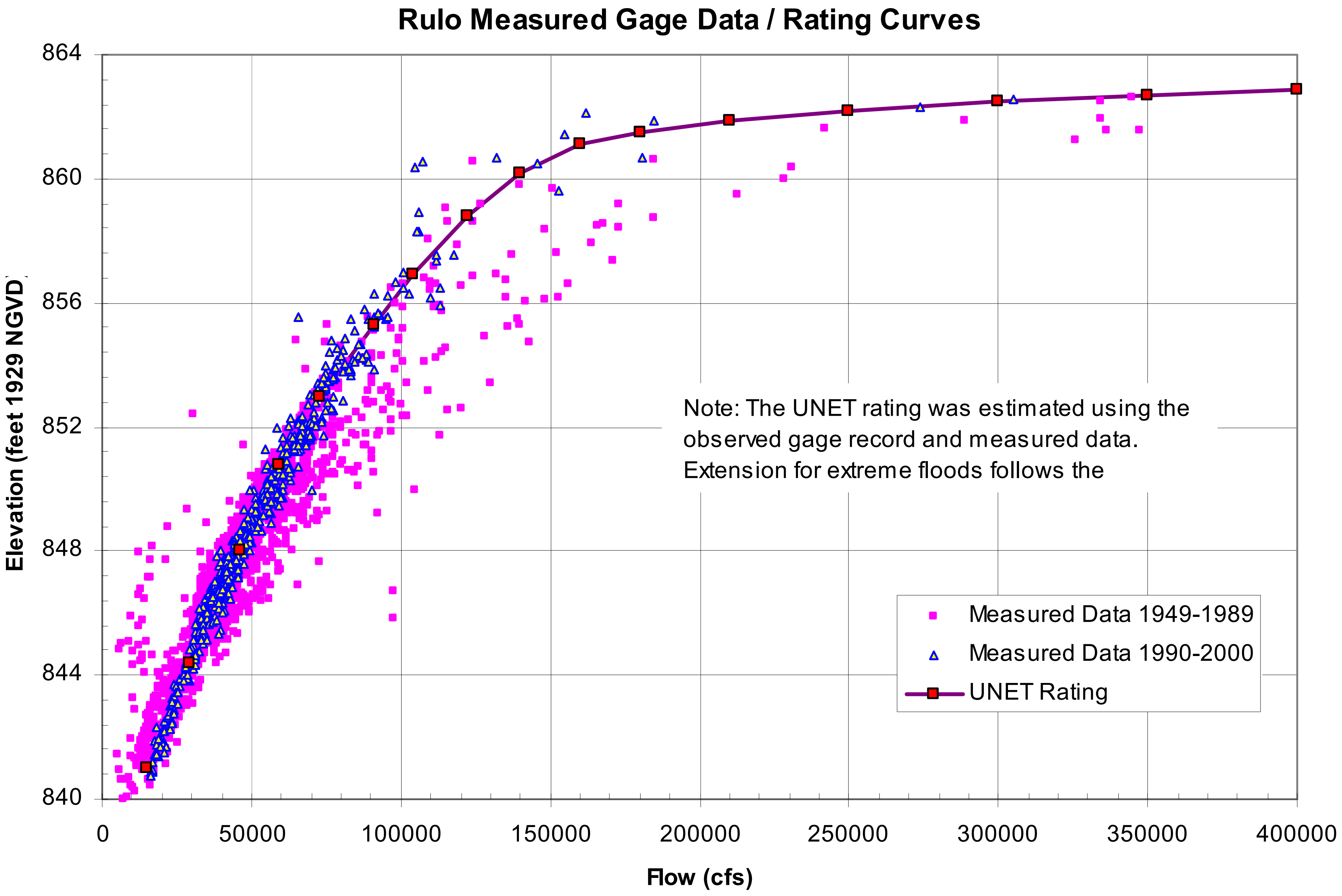
Plattsmouth Computed Rating Curves

Note: The RAS rating was computed with an approximate model to evaluate the extension of the UNET rating required for extreme floods. Approximate RAS models were constructed for both confined and unconfined conditions. The UNET rating is applied with the calibrated model.


Nebraska City Measured Gage Data / Rating Curves
Elevation (feet 1929 NGVD)
941
937
933
929
925
921
917
913
909
Flow (cfs)
0
50000
100000
150000
200000
250000
300000
350000
400000
Measured Data 1929-1964
Measured Data 1965-1989
Measured Data 1990-2000
UNET Rating

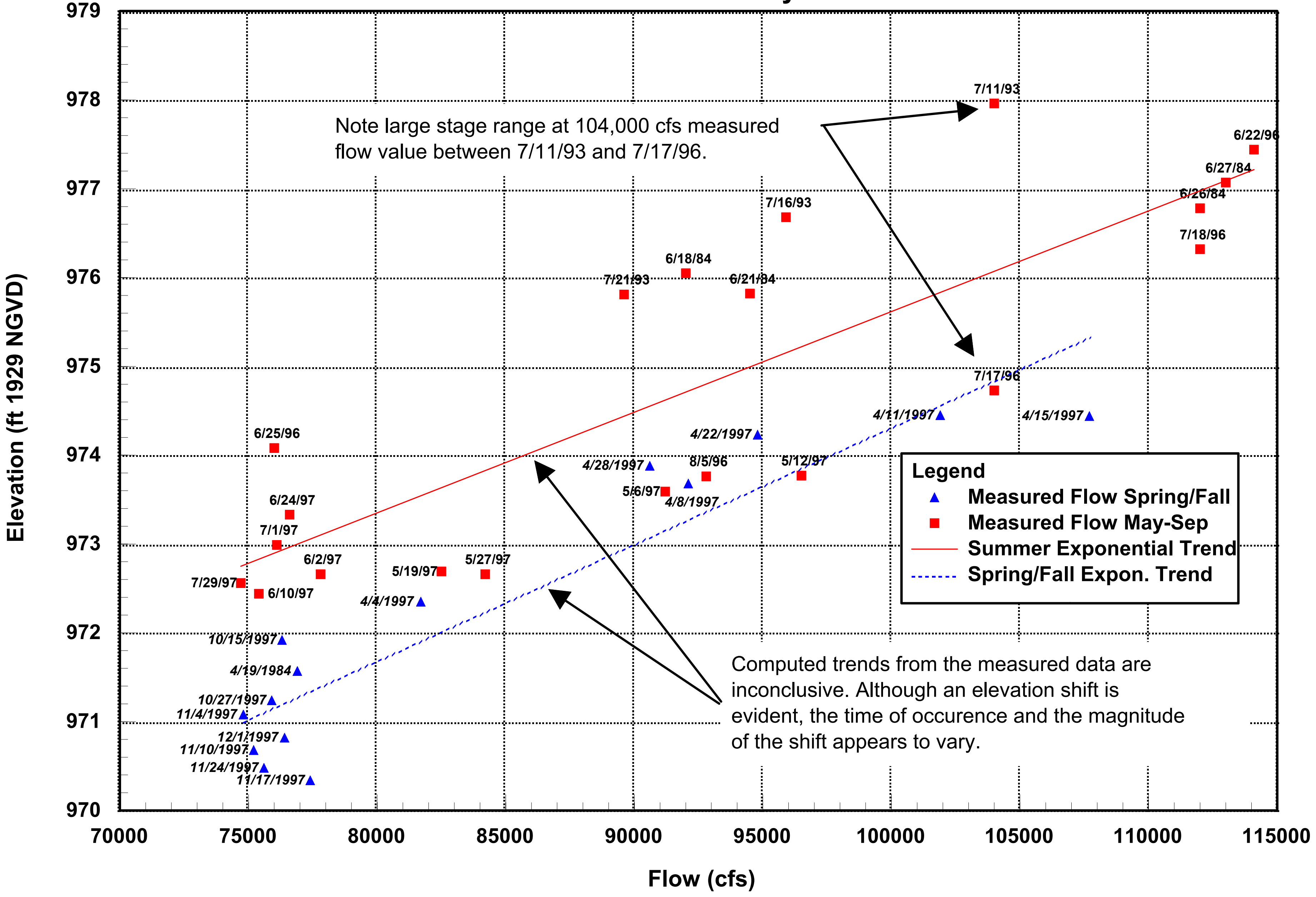

Brownville Computed Rating Curves

Note: The RAS rating was computed with an approximate model to evaluate the extension of the UNET rating required for extreme floods. Approximate RAS models were constructed for both confined and unconfined conditions.
The UNET rating is applied with the calibrated model.



Note: The UNET rating was estimated using the observed gage record and measured data. Extension for extreme floods follows the

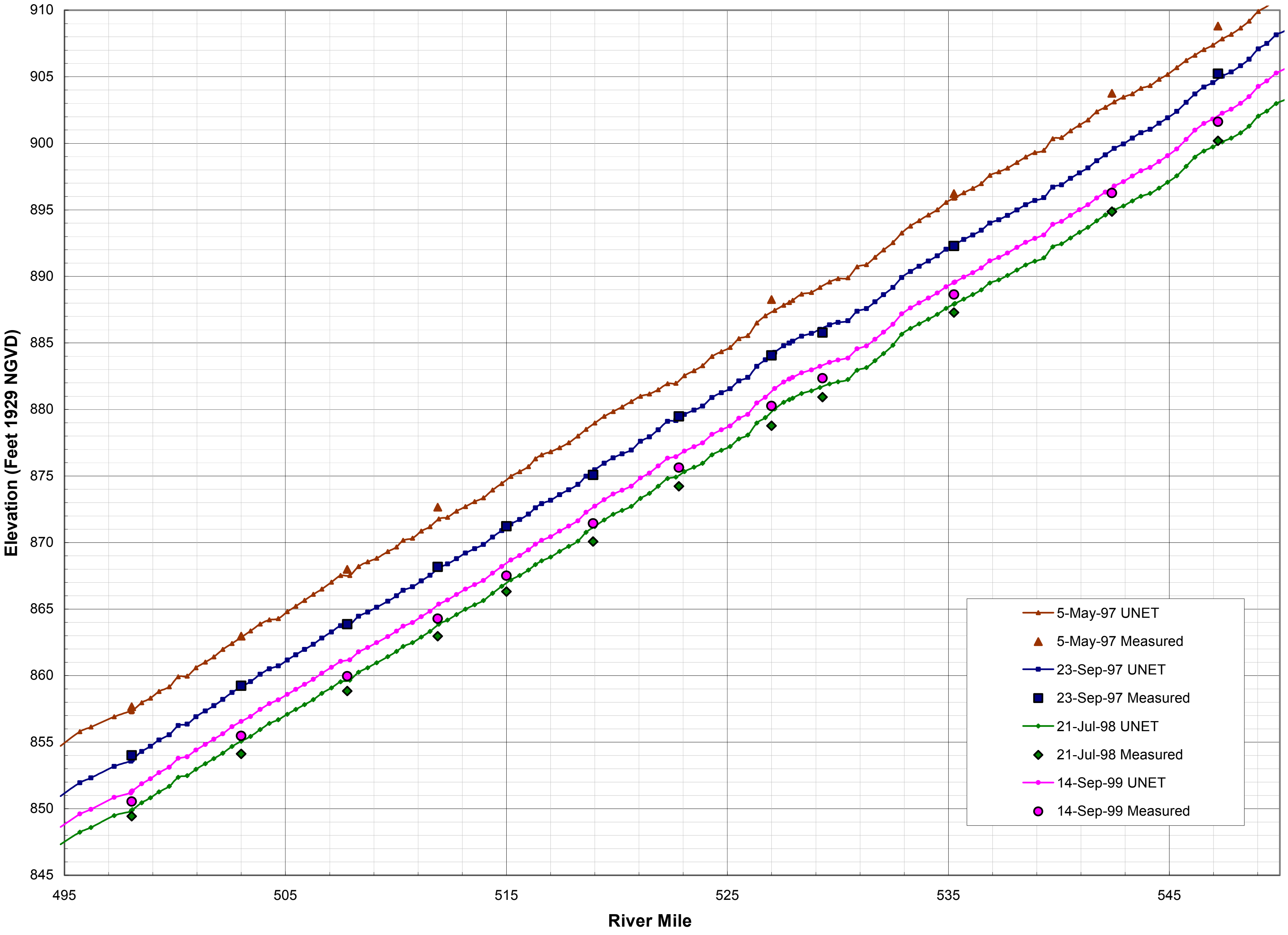
Missouri River at Omaha, NE
Measured Data Plotted By Season

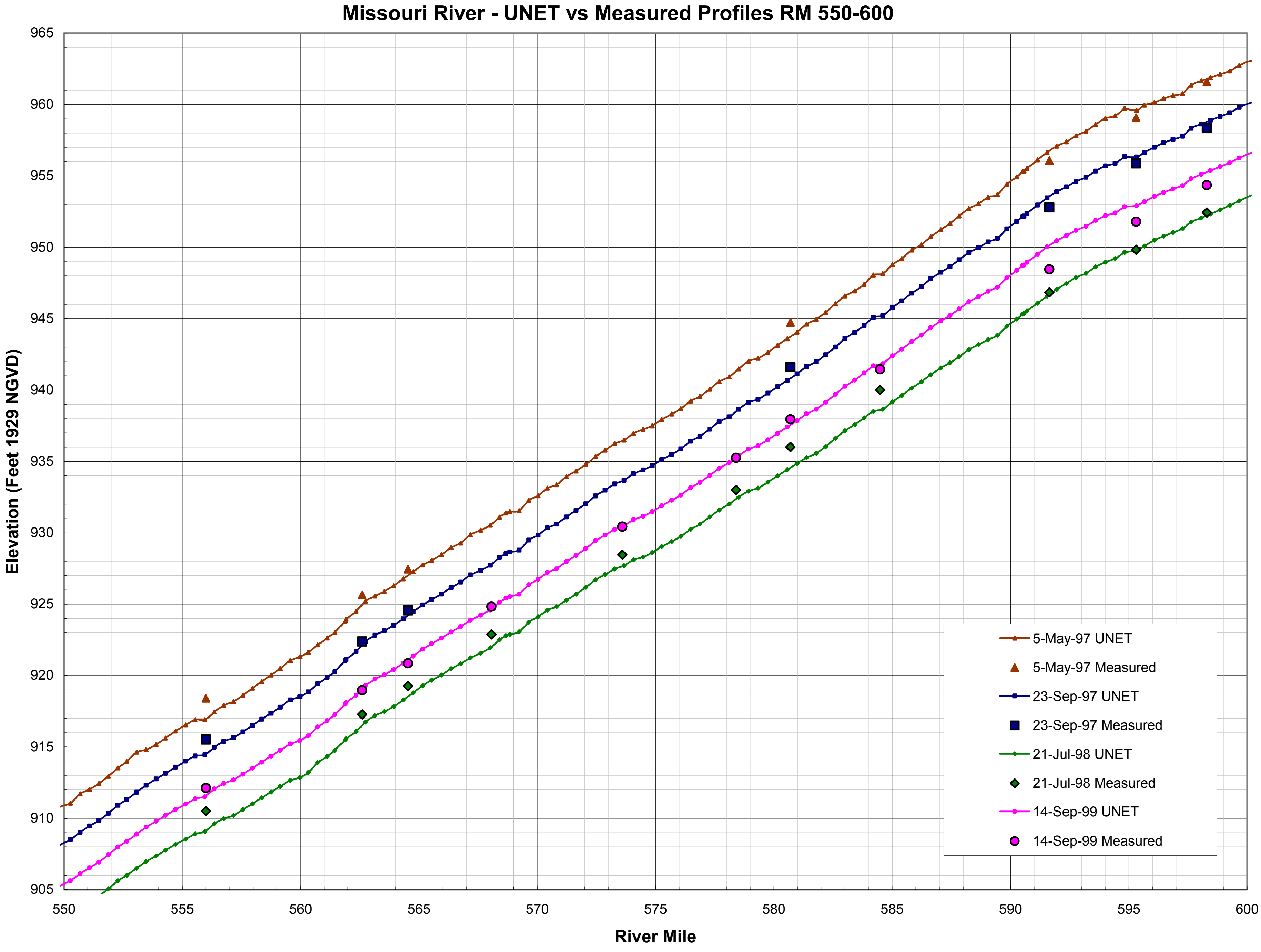


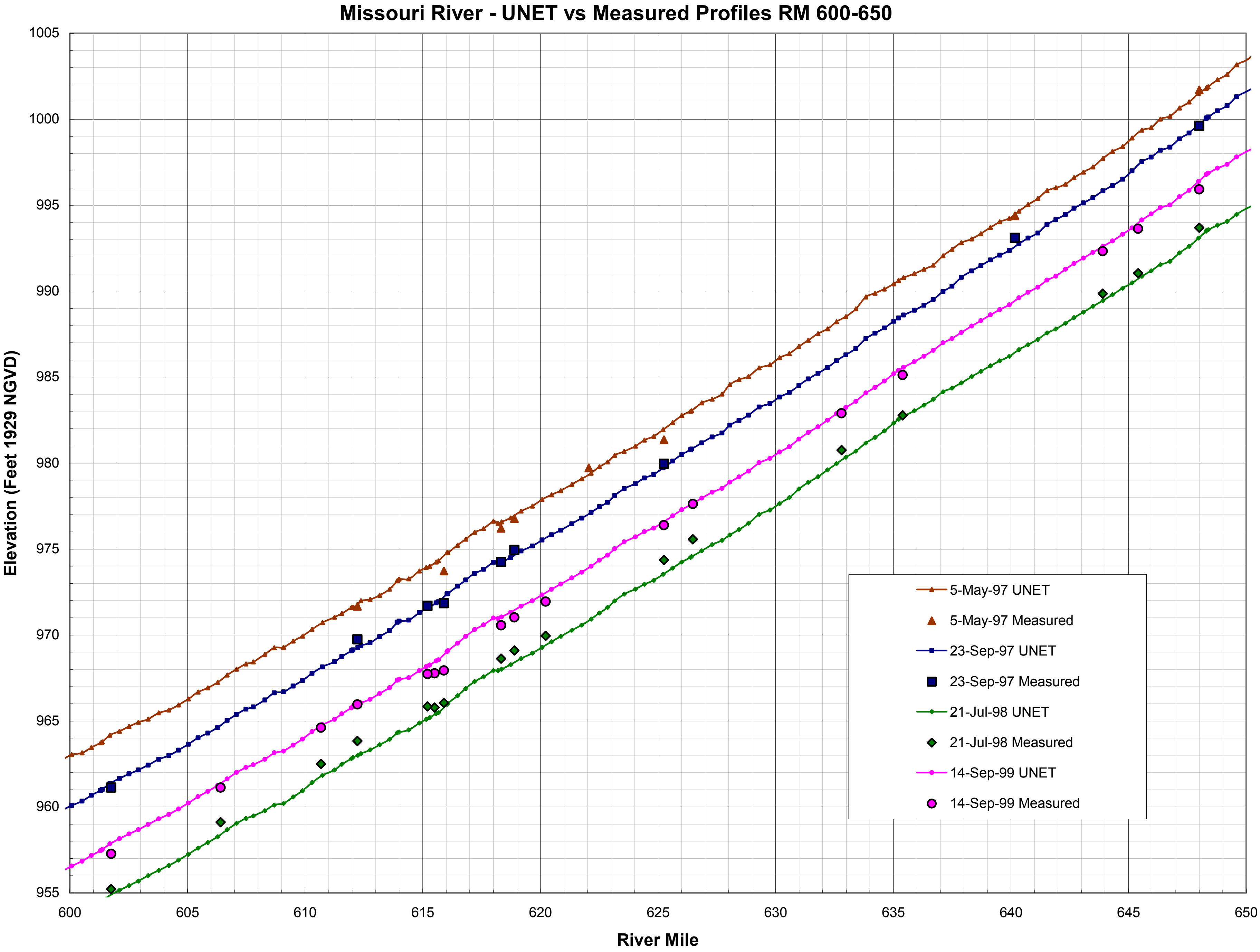
Note large stage range at 104,000 cfs measured flow value between 7/11/93 and 7/17/96.

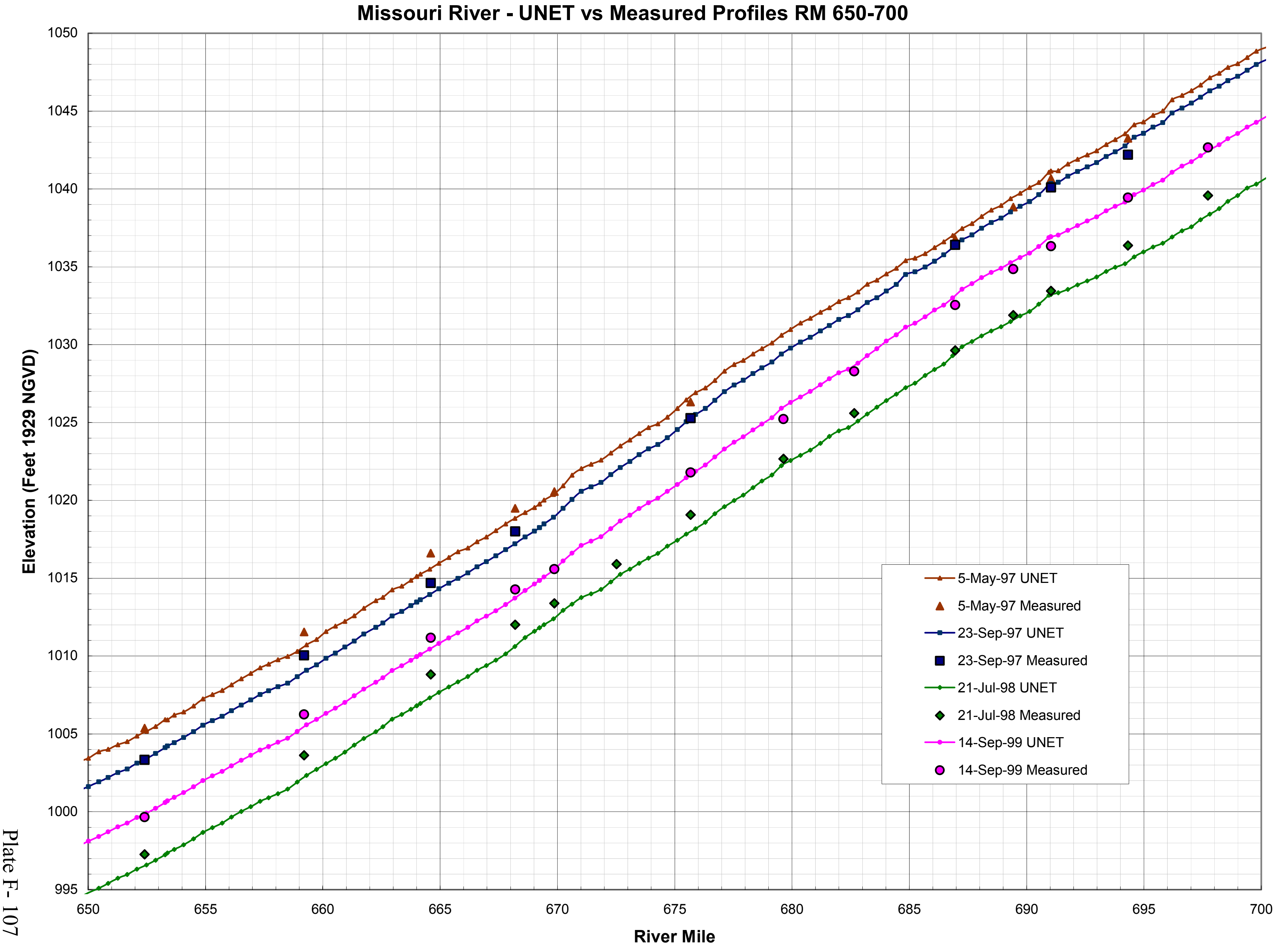
Computed trends from the measured data are inconclusive. Although an elevation shift is evident, the time of occurence and the magnitude of the shift appears to vary.

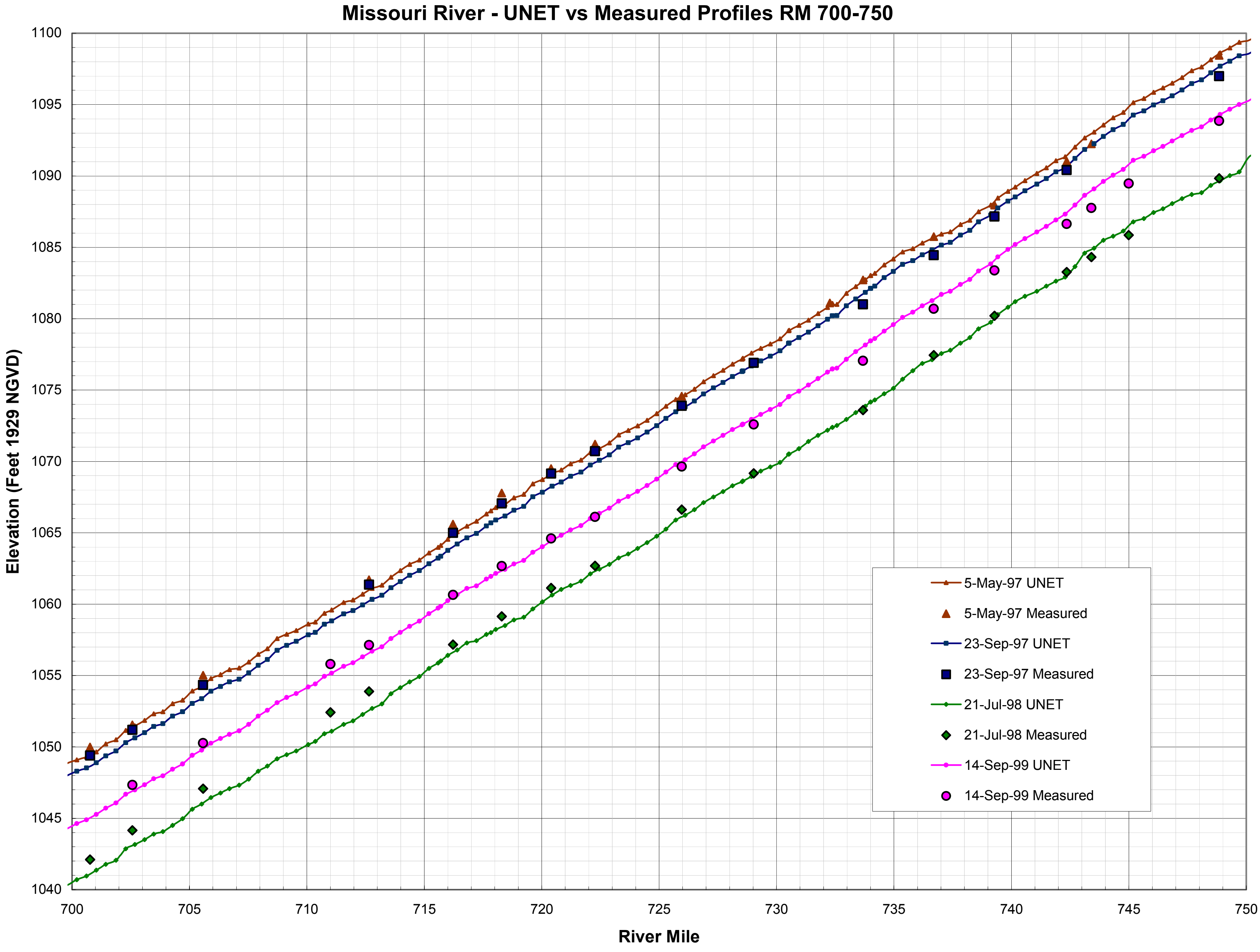
Missouri River - UNET vs Measured Profiles RM 495-550



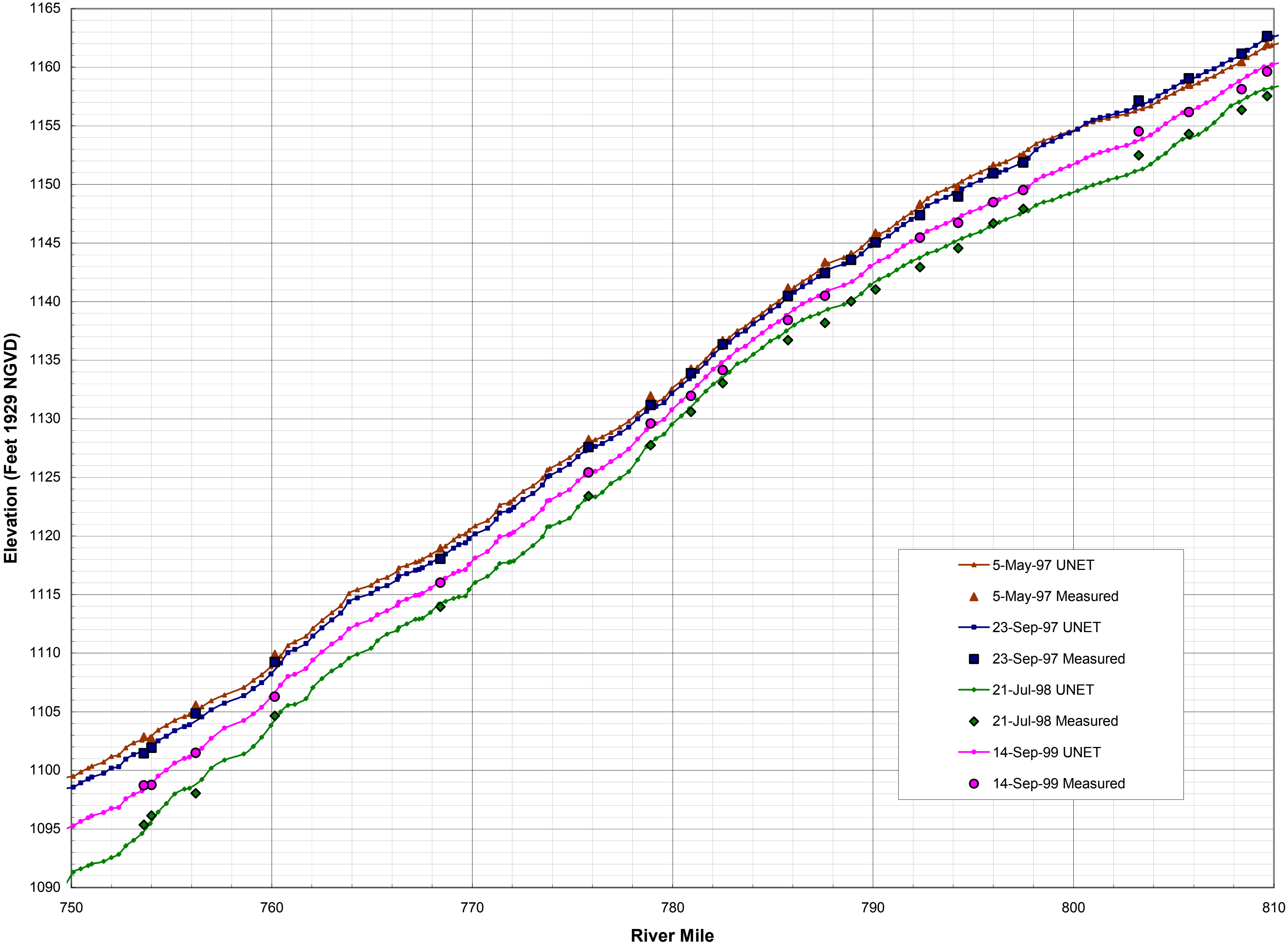

Missouri River - UNET vs Measured Profiles RM 550-600
Elevation (Feet 1929 NGVD)
965
960
955
950
945
940
935
930
925
920
915
910
905
River Mile
550
555
560
565
570
575
580
585
590
595
600
5-May-97 UNET
5-May-97 Measured
23-Sep-97 UNET
23-Sep-97 Measured
21-Jul-98 UNET
21-Jul-98 Measured
14-Sep-99 UNET
14-Sep-99 Measured


Missouri River - UNET vs Measured Profiles RM 600-650
Elevation (Feet 1929 NGVD)
1005
1000
995
990
985
980
975
970
965
960
955
River Mile
600
605
610
615
620
625
630
635
640
645
650
5-May-97 UNET
5-May-97 Measured
23-Sep-97 UNET
23-Sep-97 Measured
21-Jul-98 UNET
21-Jul-98 Measured
14-Sep-99 UNET
14-Sep-99 Measured

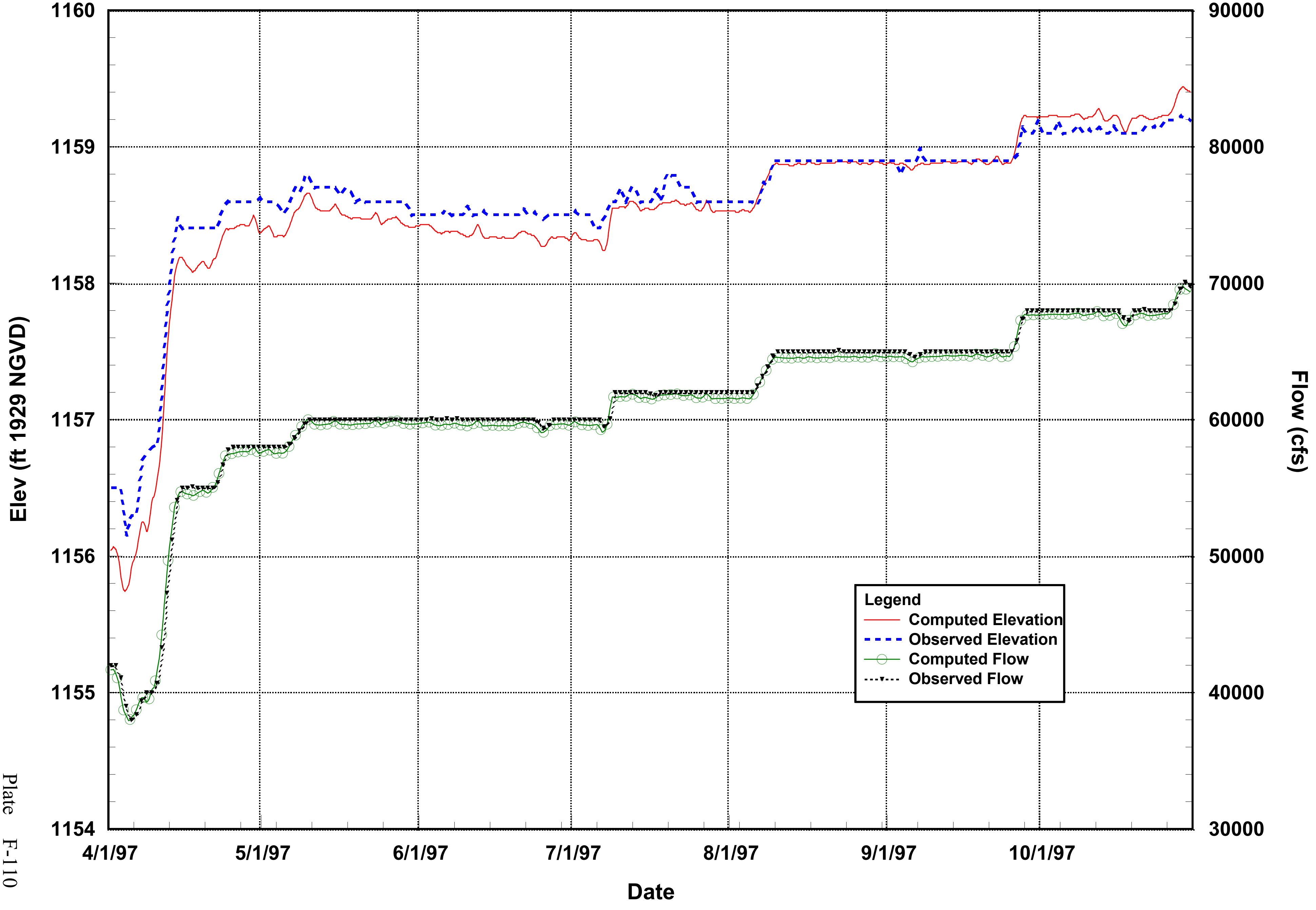

Missouri River - UNET vs Measured Profiles RM 650-700
Elevation (Feet 1929 NGVD)
1050
1045
1040
1035
1030
1025
1020
1015
1010
1005
1000
995
650
655
660
665
670
675
680
685
690
695
700
River Mile
5-May-97 UNET
5-May-97 Measured
23-Sep-97 UNET
23-Sep-97 Measured
21-Jul-98 UNET
21-Jul-98 Measured
14-Sep-99 UNET
14-Sep-99 Measured


Missouri River - UNET vs Measured Profiles RM 700-750
Elevation (Feet 1929 NGVD)
1100
1095
1090
1085
1080
1075
1070
1065
1060
1055
1050
1045
1040
River Mile
700
705
710
715
720
725
730
735
740
745
750
5-May-97 UNET
5-May-97 Measured
23-Sep-97 UNET
23-Sep-97 Measured
21-Jul-98 UNET
21-Jul-98 Measured
14-Sep-99 UNET
14-Sep-99 Measured

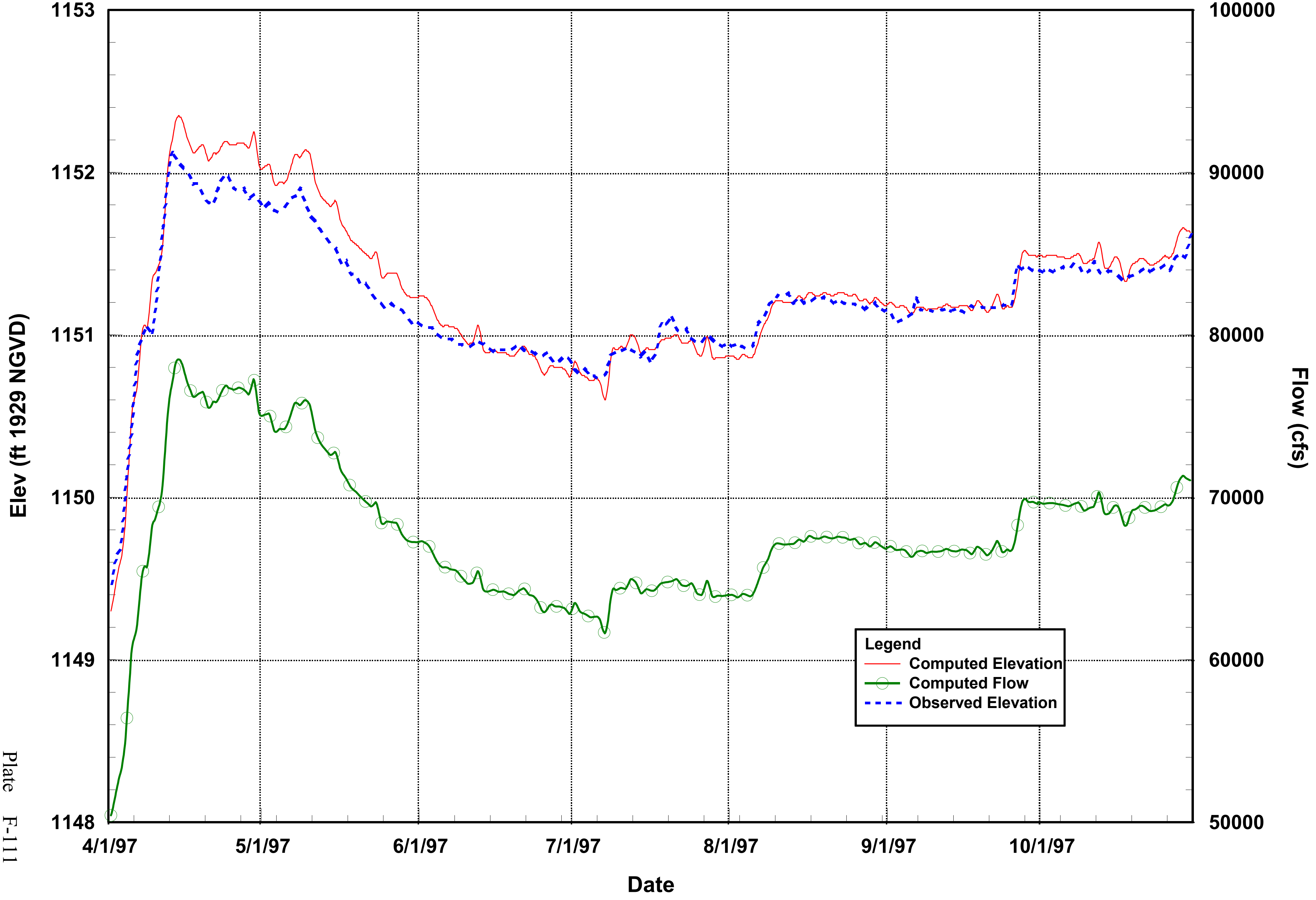
Missouri River - UNET vs Measured Profiles RM 750-810

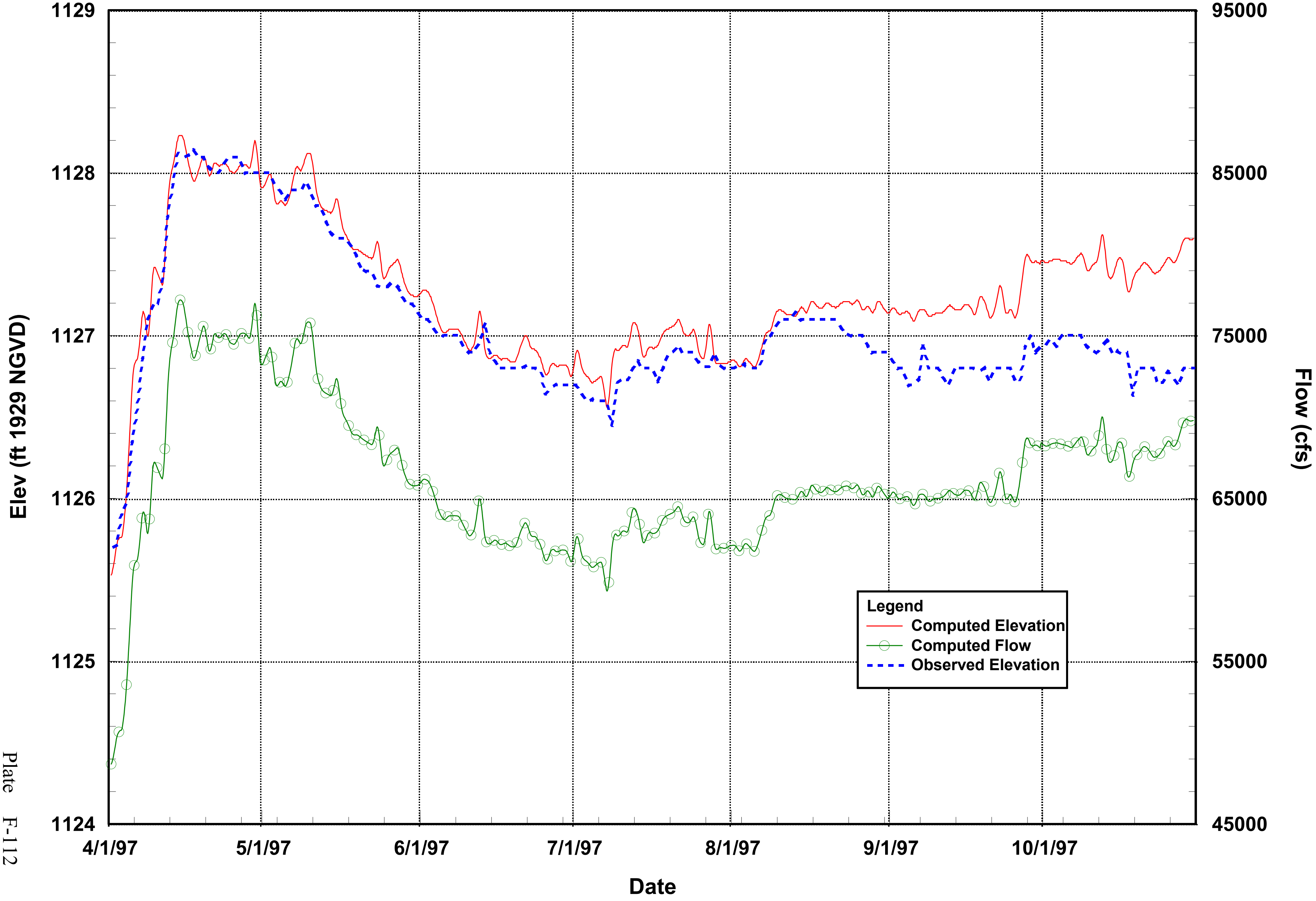


Missouri River at Yankton, SD
1997 Computed vs. Observed Data

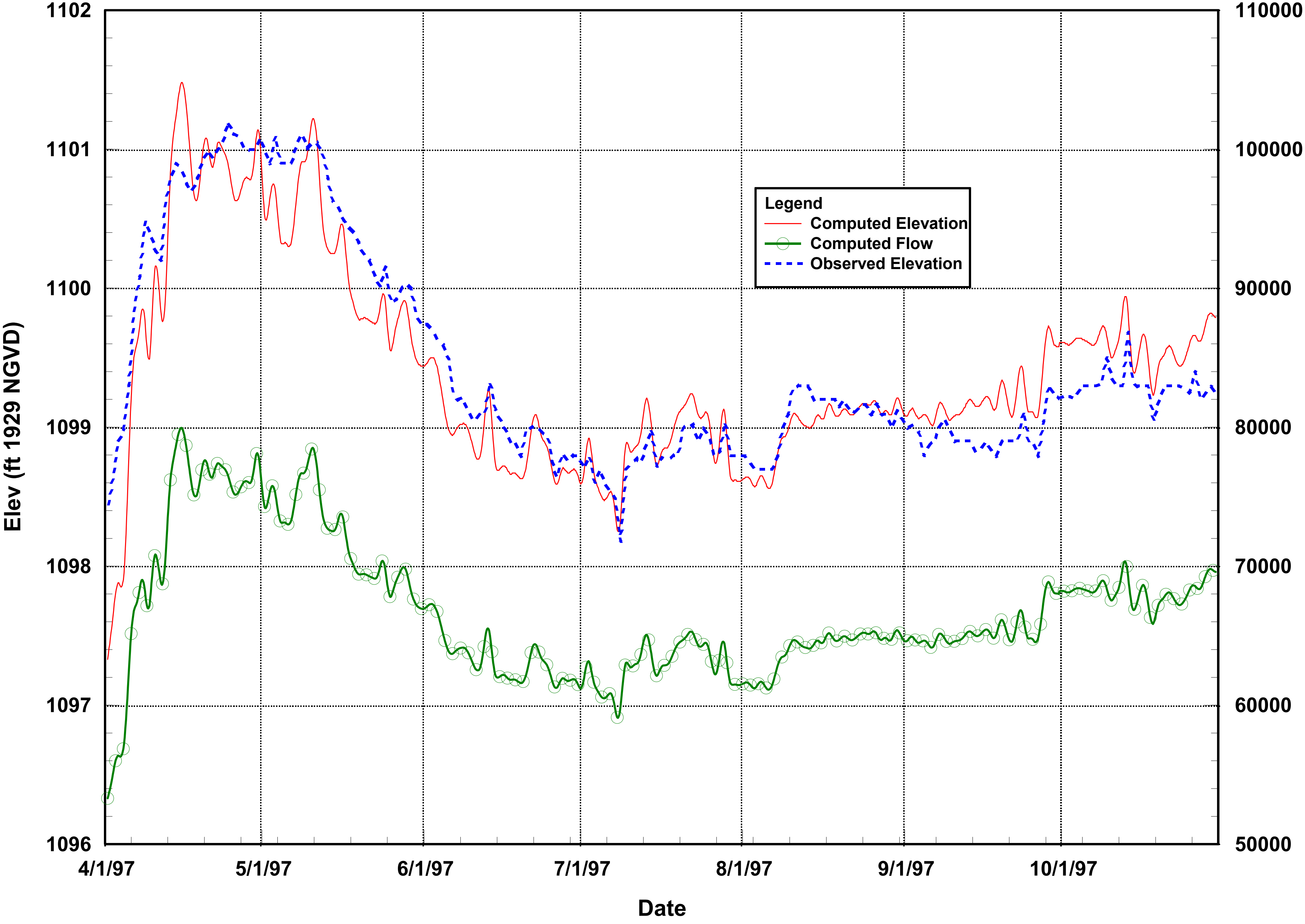


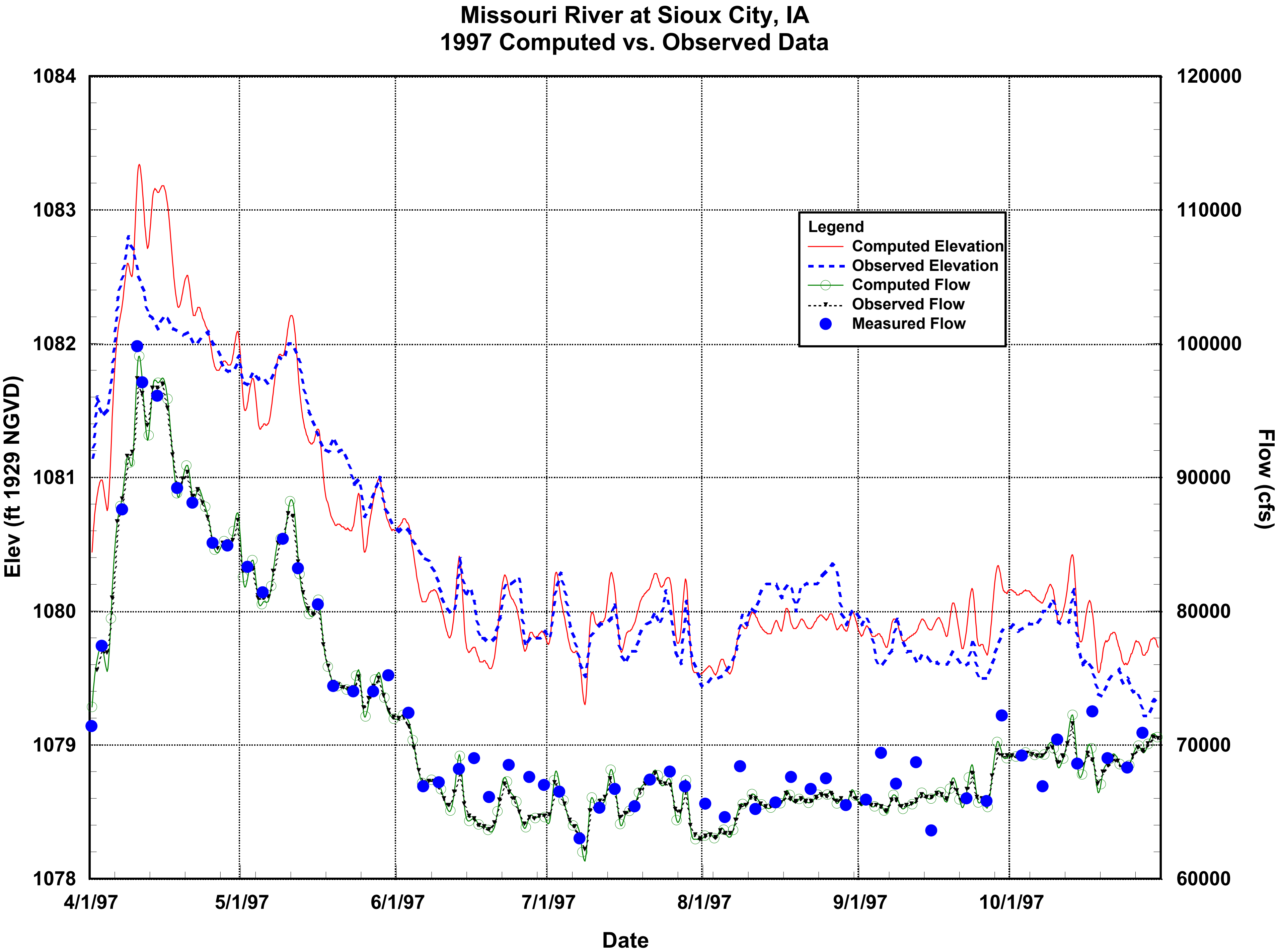
Missouri River at Gayville, SD
1997 Computed vs. Observed Data




Missouri River at Maskell, SD
1997 Computed vs. Observed Data

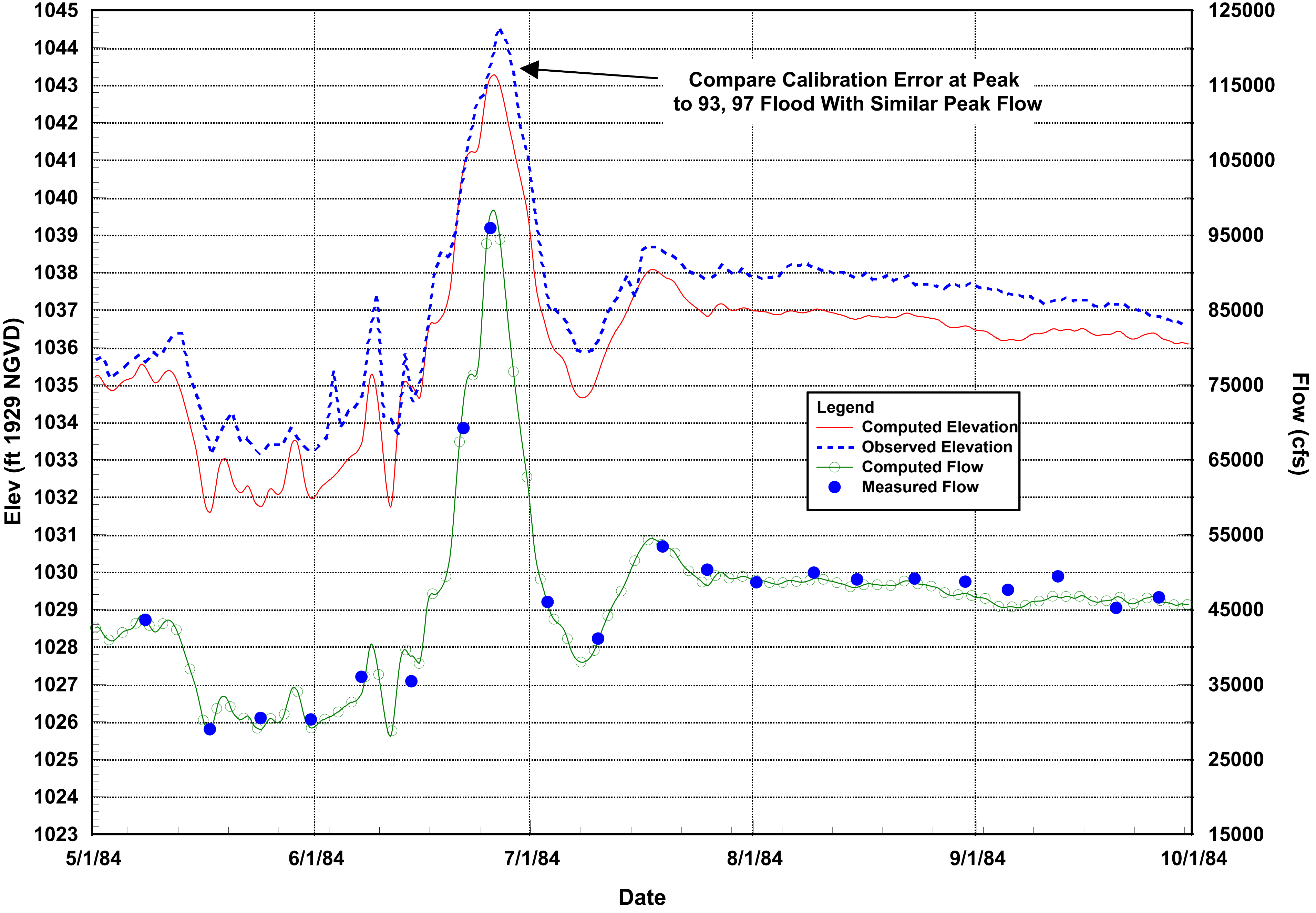
Missouri River at Ponca, NE
1997 Computed vs. Observed Data



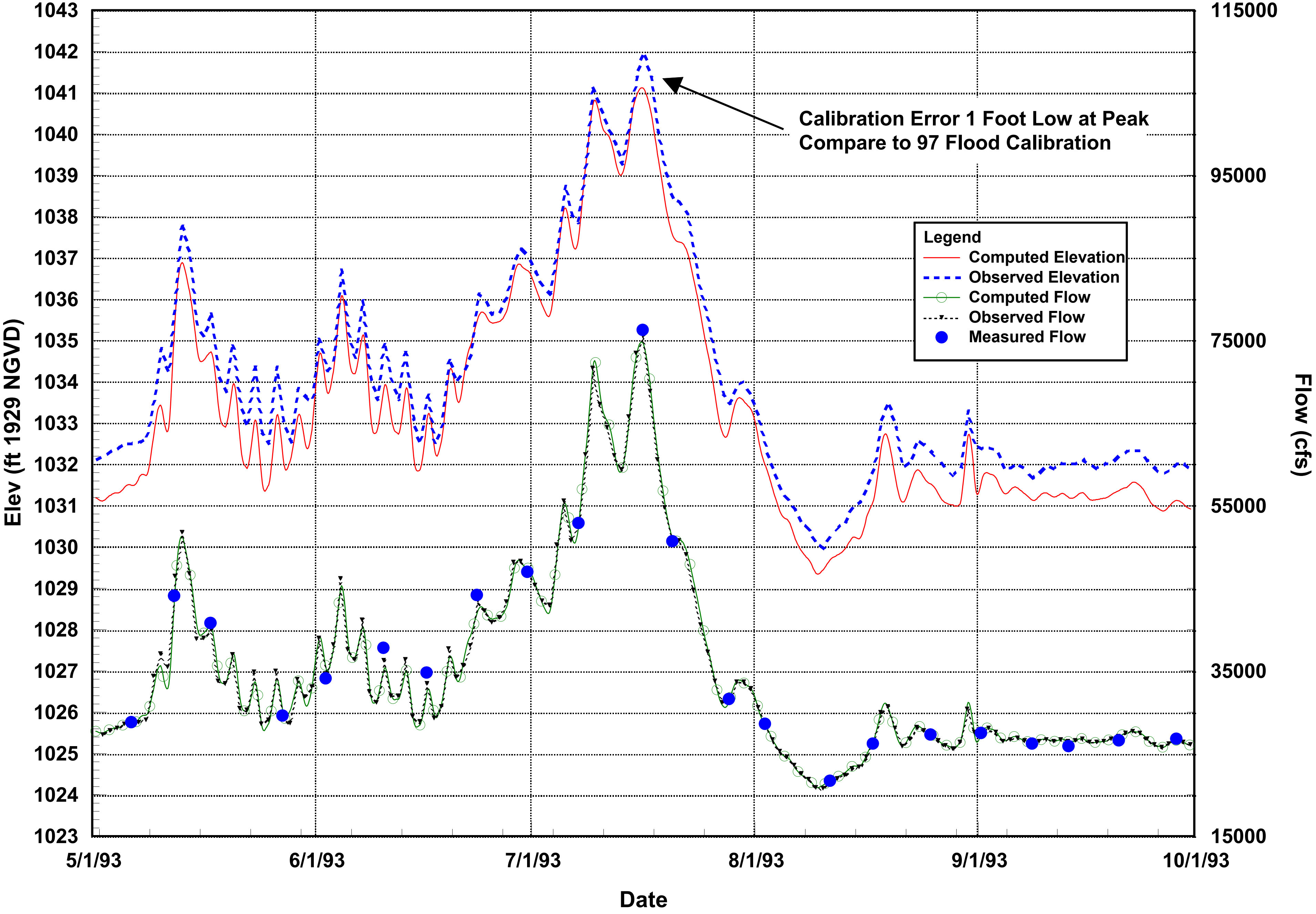


Missouri River at Sioux City, IA
1997 Computed vs. Observed Data

Missouri River at Decatur, NE
1984 Computed vs. Observed Data

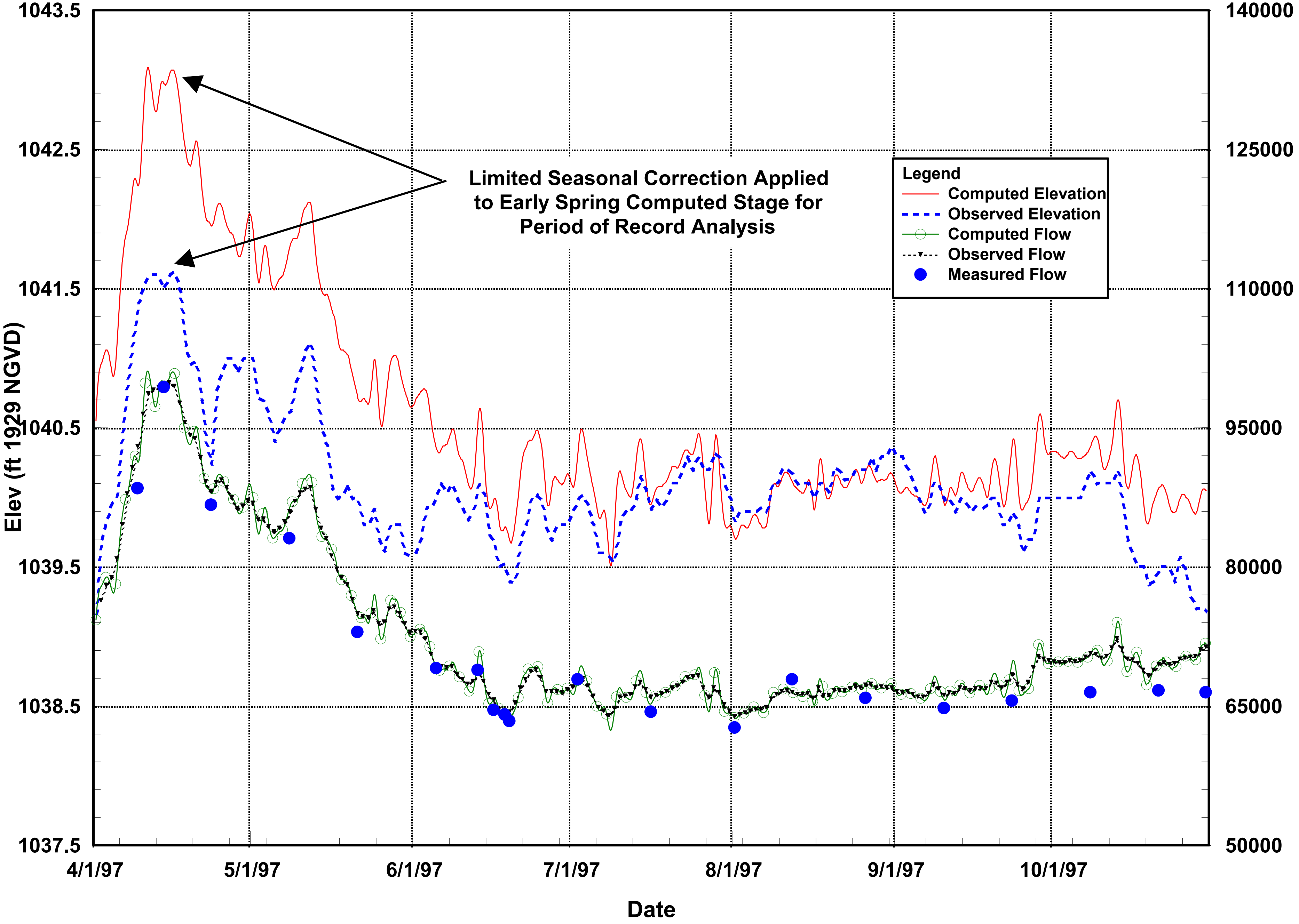


Missouri River at Decatur, NE
1993 Computed vs. Observed Data

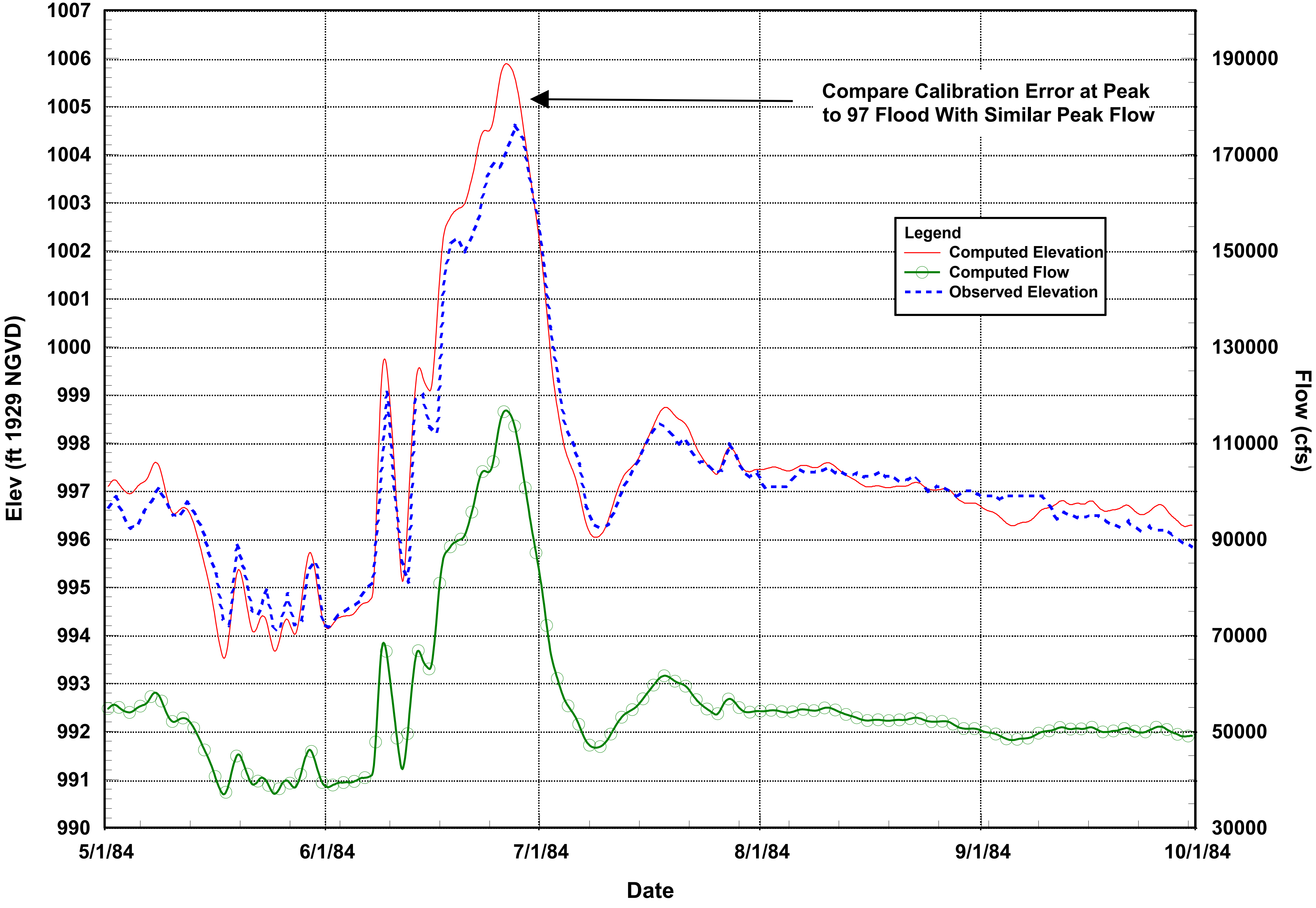


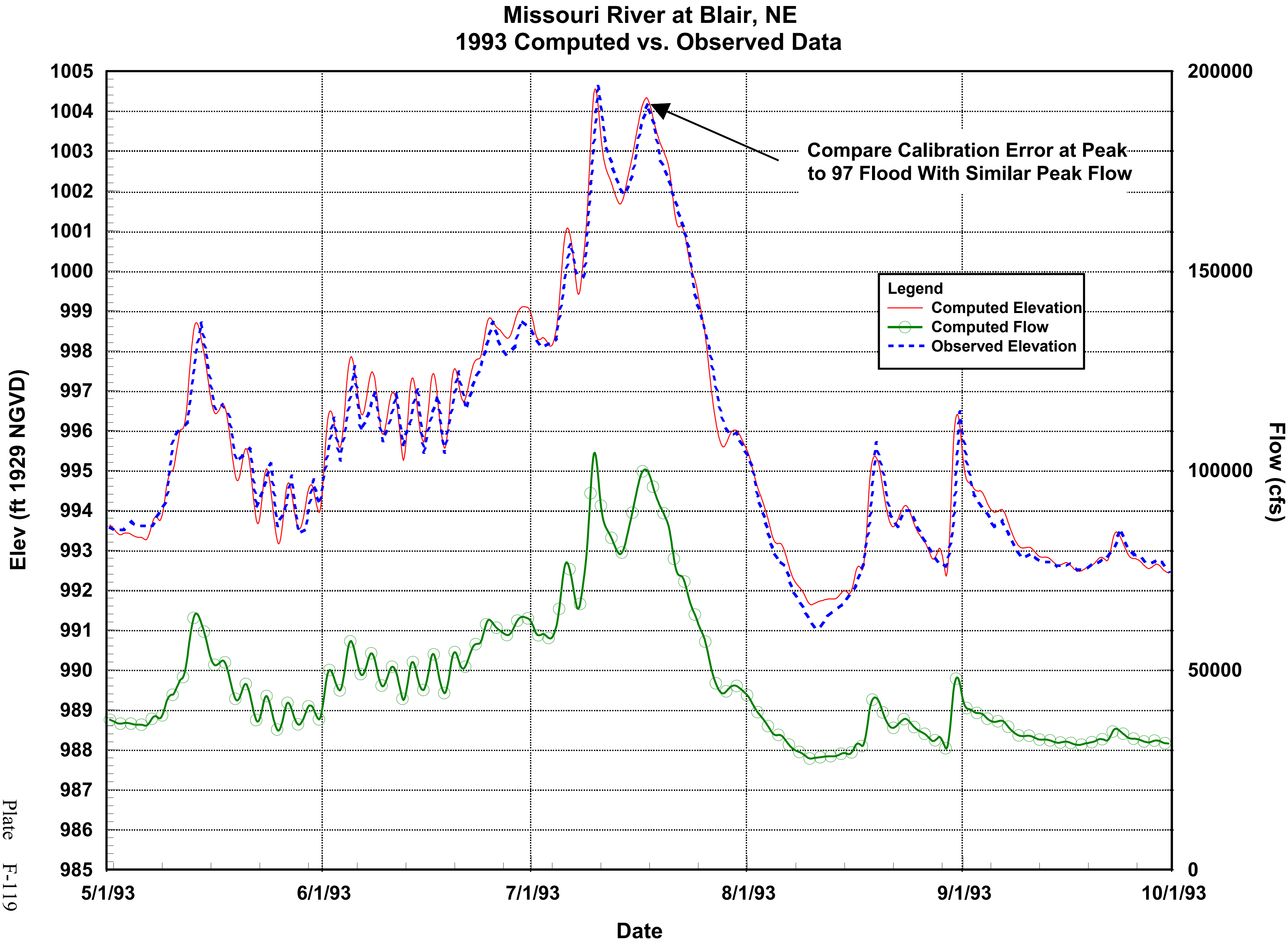
Calibration Error 1 Foot Low at Peak
Compare to 97 Flood Calibration

Missouri River at Decatur, NE
1997 Computed vs. Observed Data



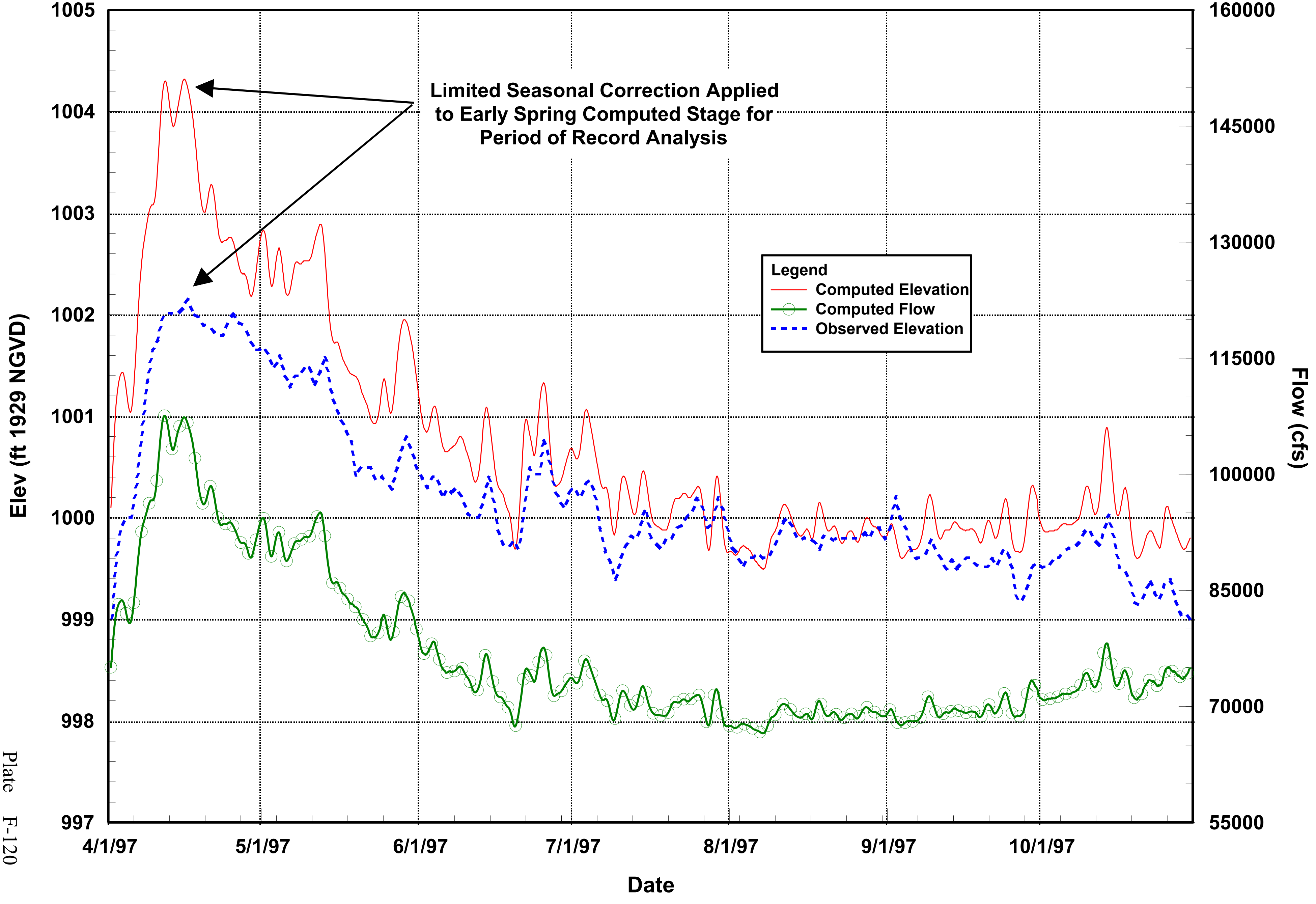
Missouri River at Blair, NE
1984 Computed vs. Observed Data


Compare Calibration Error at Peak to 97 Flood With Similar Peak Flow

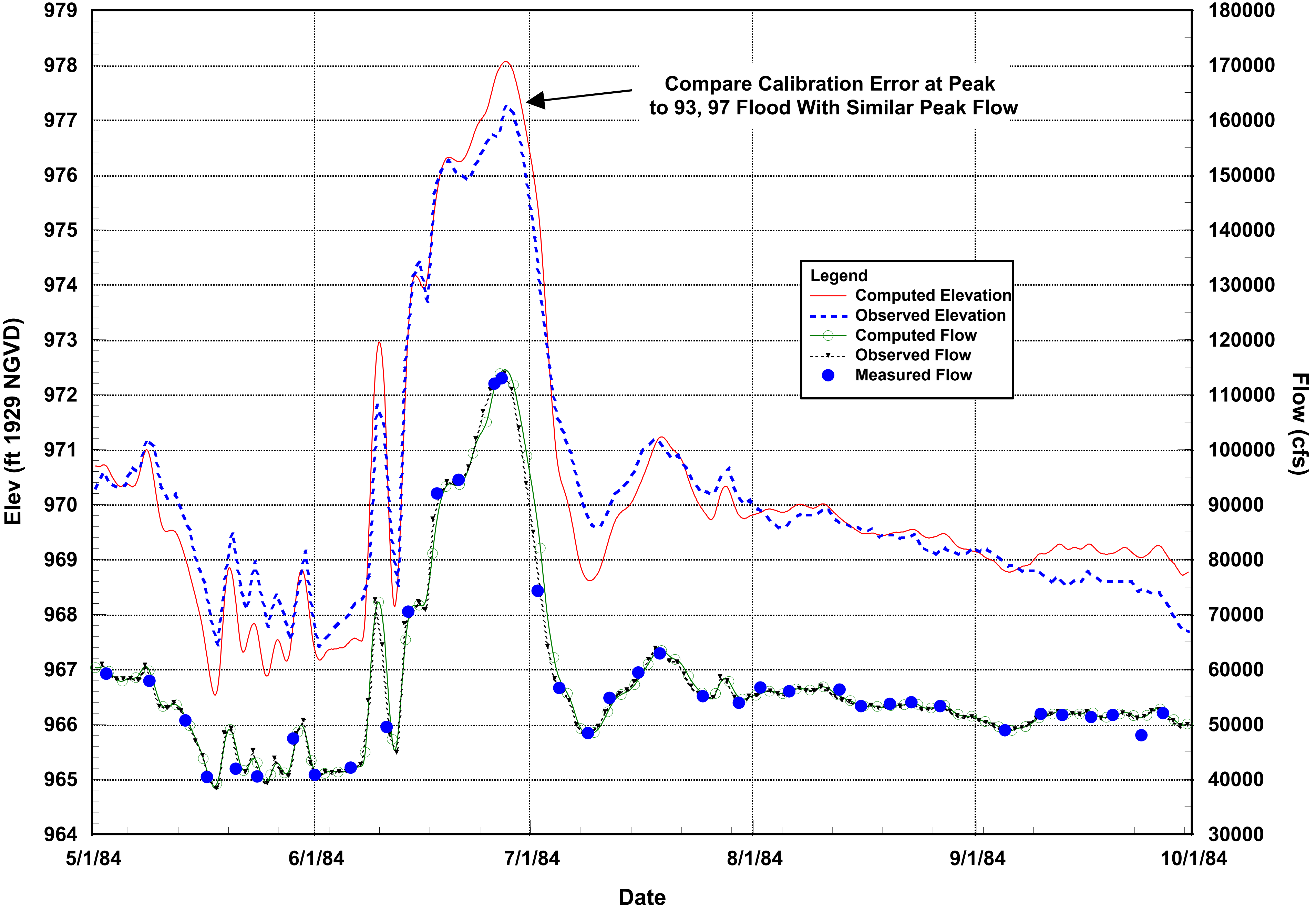


Missouri River at Blair, NE
1993 Computed vs. Observed Data
Elev (ft 1929 NGVD)
1005
1004
1003
1002
1001
1000
999
998
997
996
995
994
993
992
991
990
989
988
987
986
985
Flow (cfs)
200000
150000
100000
50000
0
5/1/93
6/1/93
7/1/93
8/1/93
9/1/93
10/1/93
Date
Compare Calibration Error at Peak
to 97 Flood With Similar Peak Flow
Legend
Computed Elevation
Computed Flow
Observed Elevation

Missouri River at Blair, NE
1997 Computed vs. Observed Data

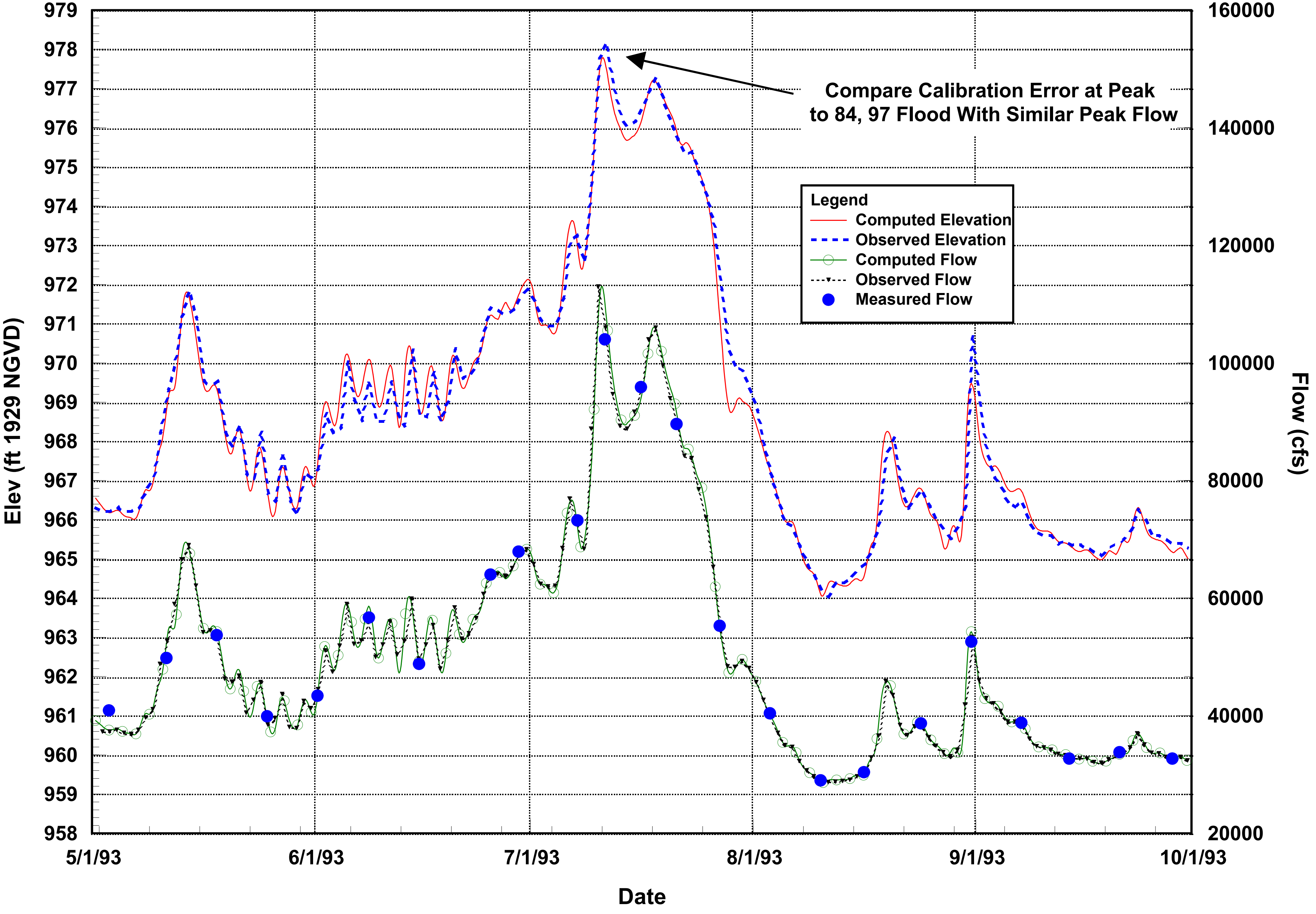


Missouri River at Omaha, NE
1984 Computed vs. Observed Data



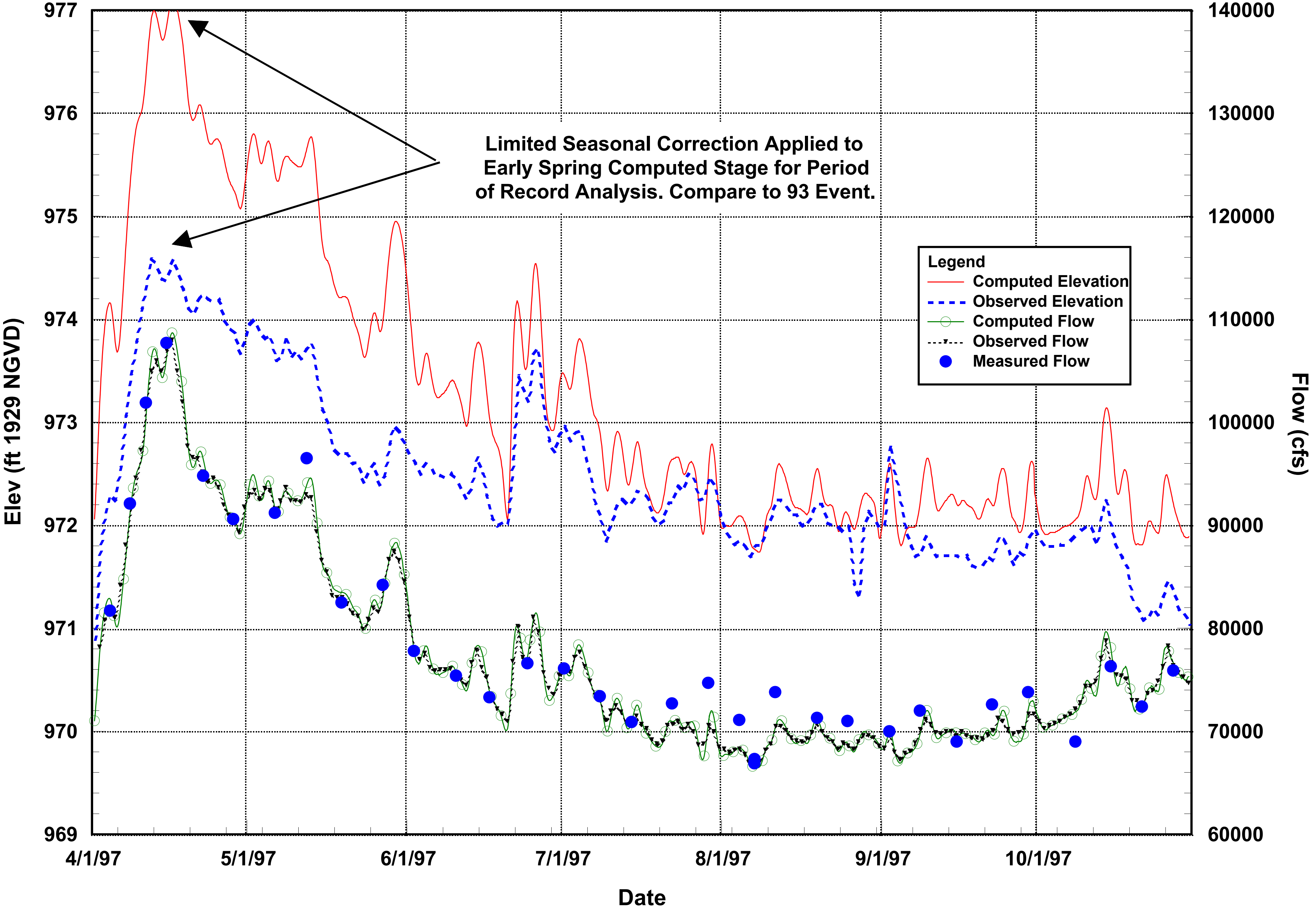
Compare Calibration Error at Peak to 93, 97 Flood With Similar Peak Flow

Missouri River at Omaha, NE
1993 Computed vs. Observed Data



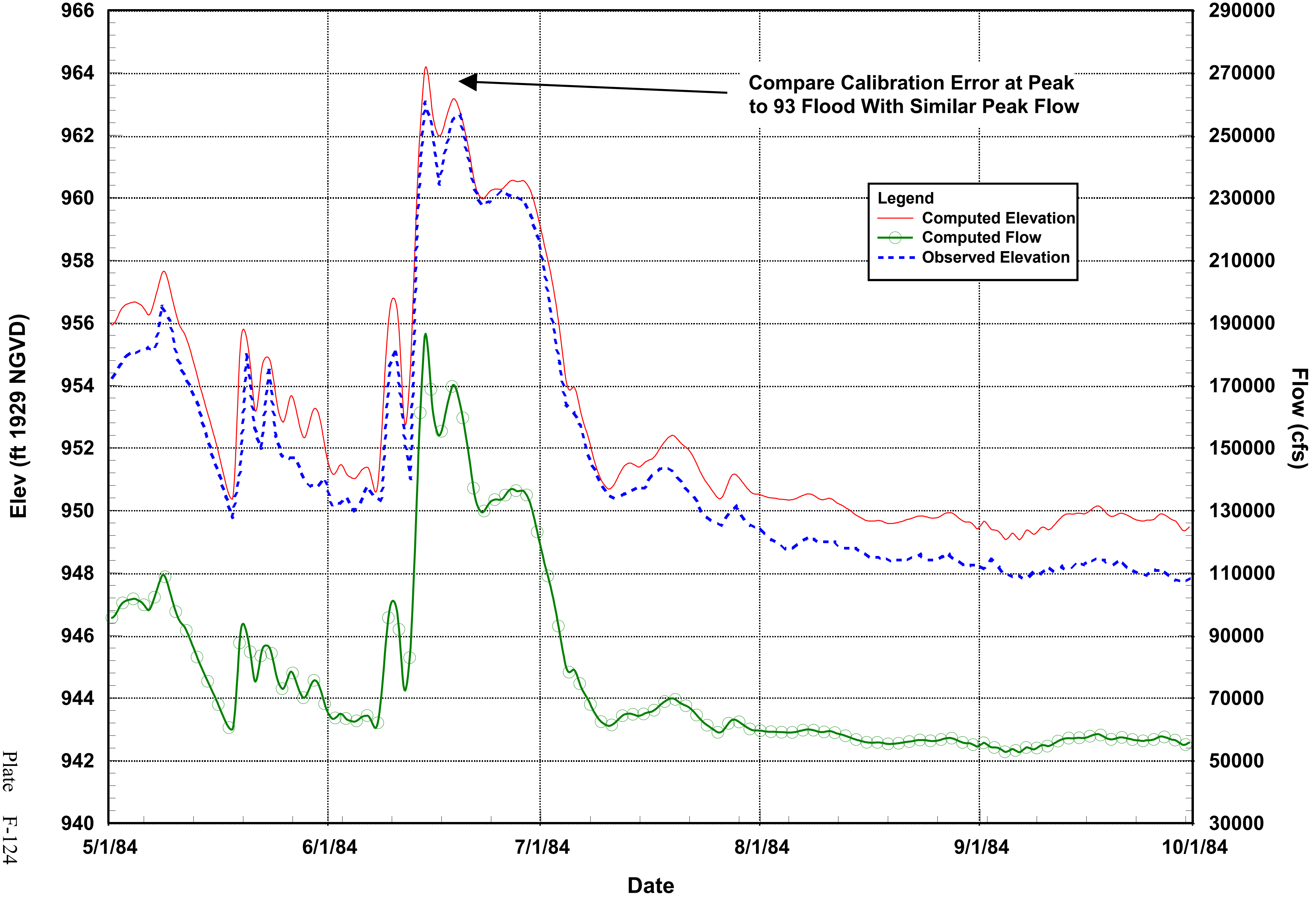
Compare Calibration Error at Peak to 84, 97 Flood With Similar Peak Flow

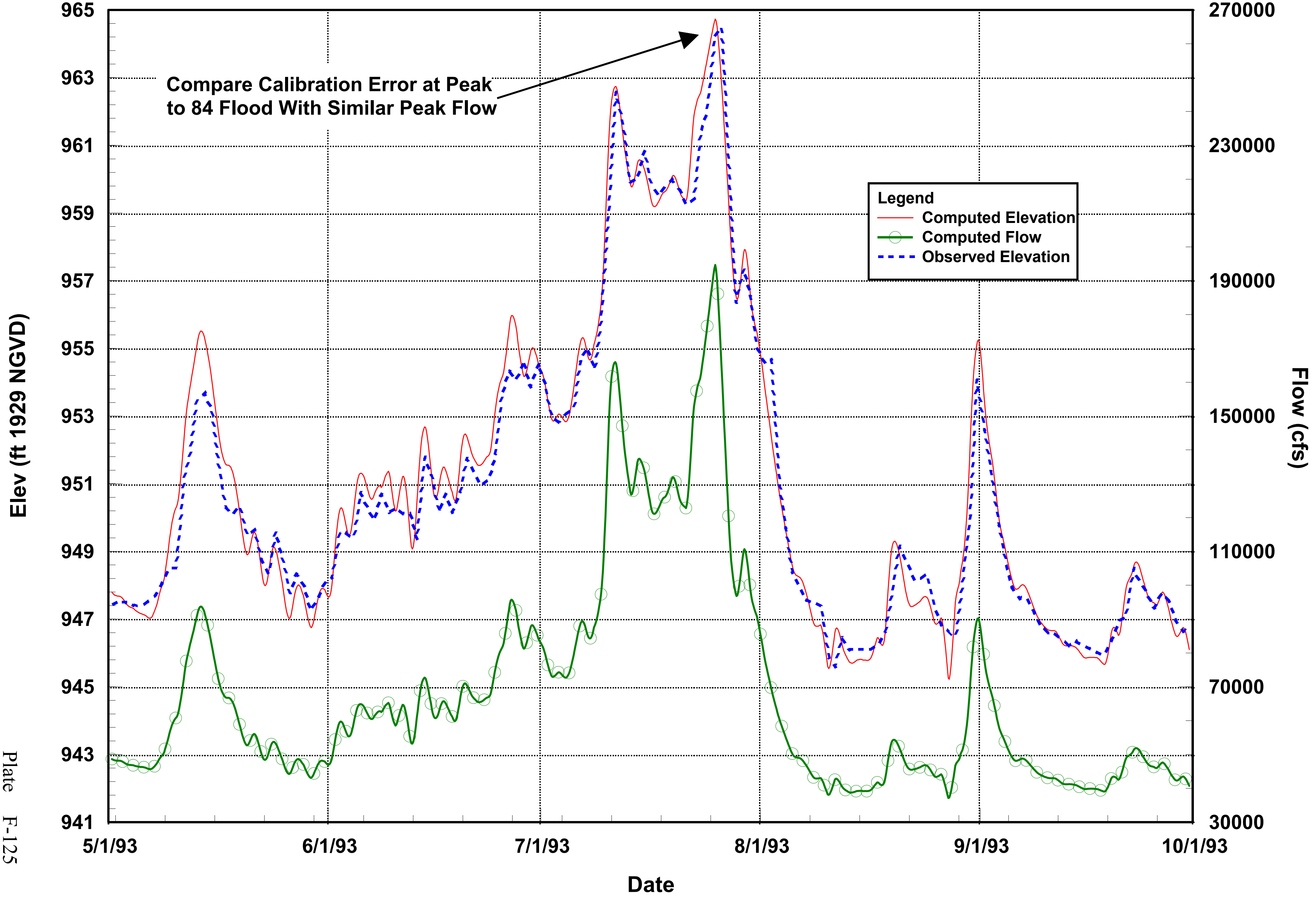
Missouri River at Omaha, NE
1997 Computed vs. Observed Data



Limited Seasonal Correction Applied to Early Spring Computed Stage for Period of Record Analysis. Compare to 93 Event.

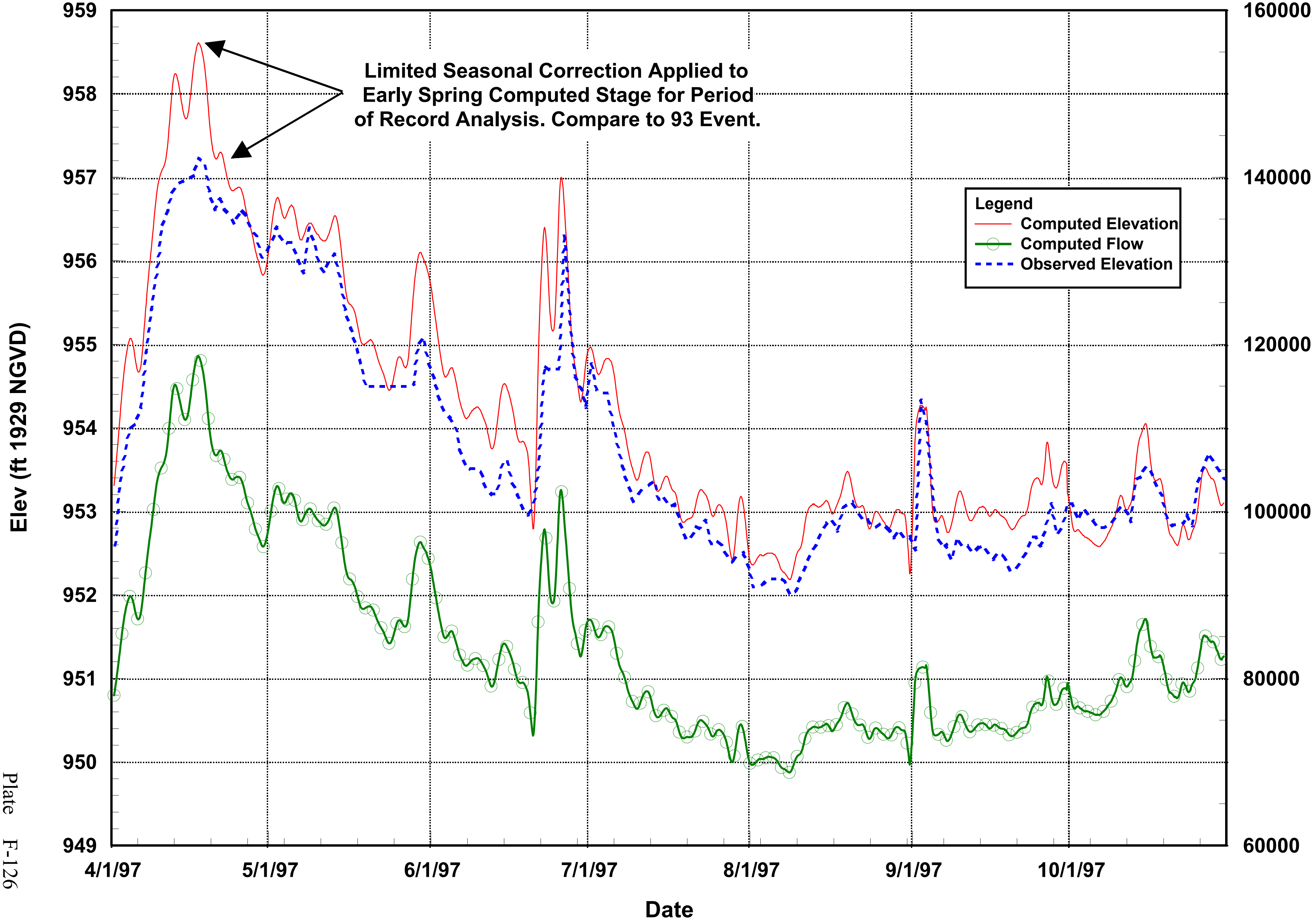
Missouri River at Plattsmouth, NE
1984 Computed vs. Observed Data

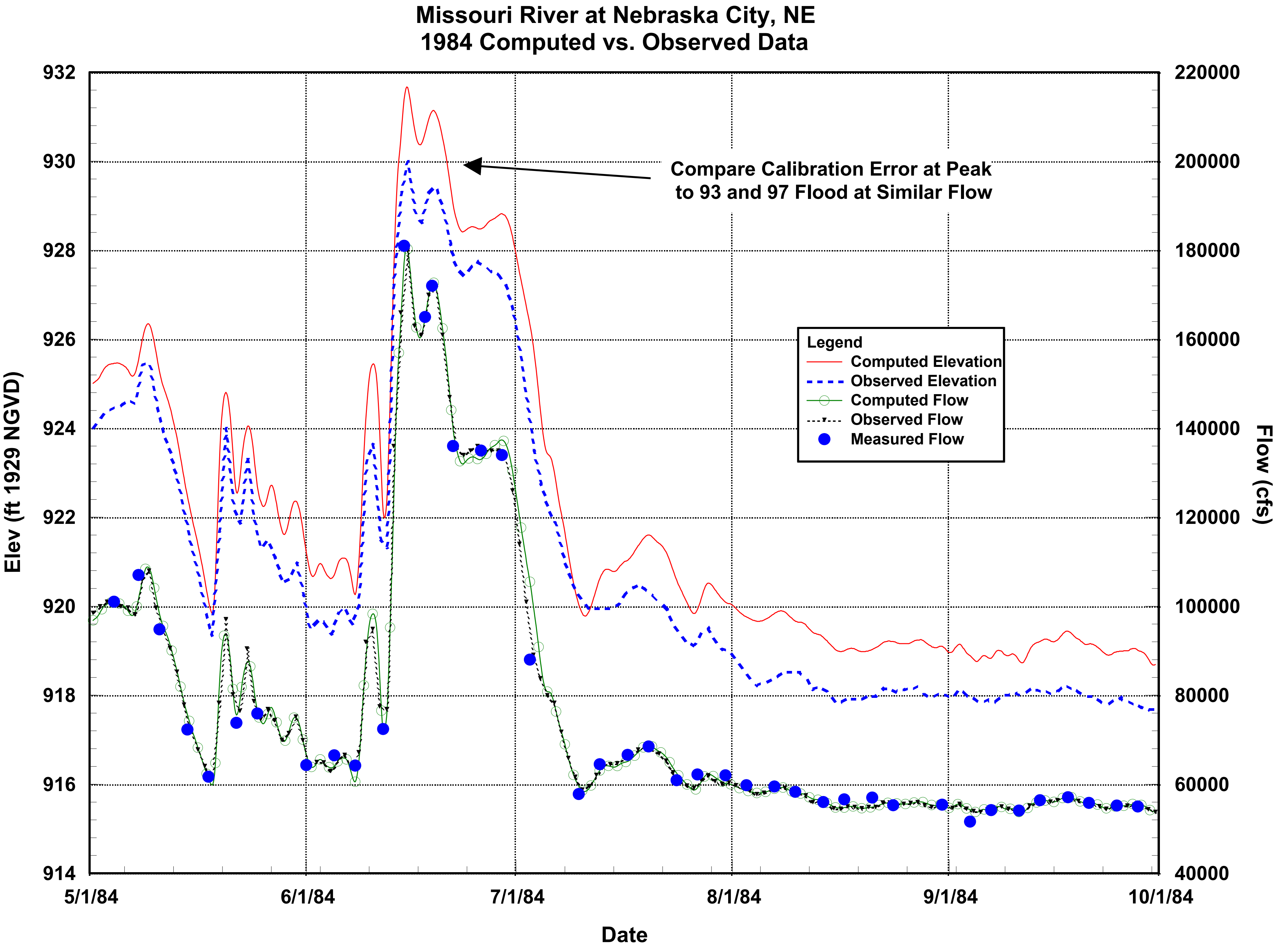




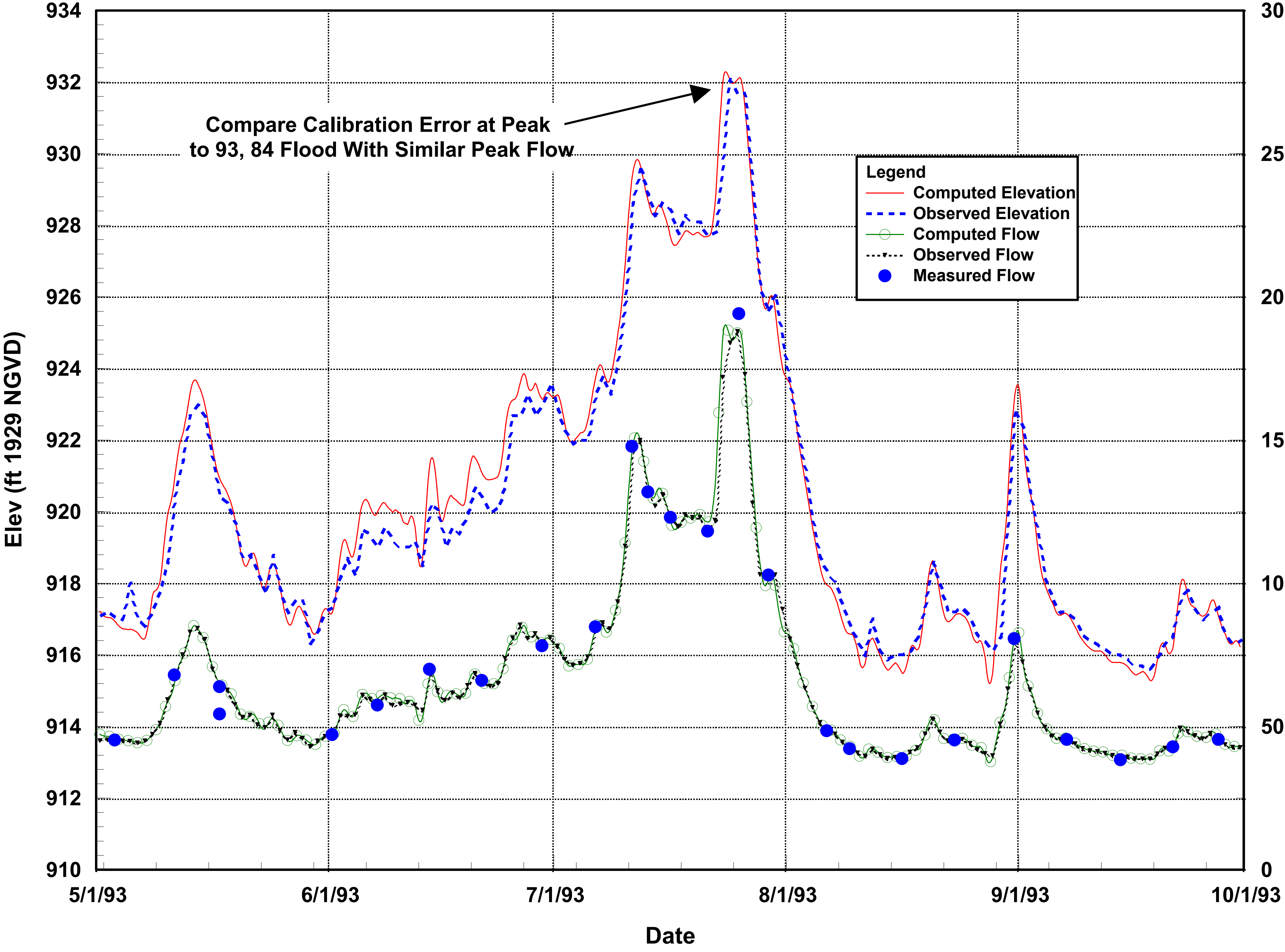
Missouri River at Plattsmouth, NE
1993 Computed vs. Observed Data

Missouri River at Plattsmouth, NE
1997 Computed vs. Observed Data

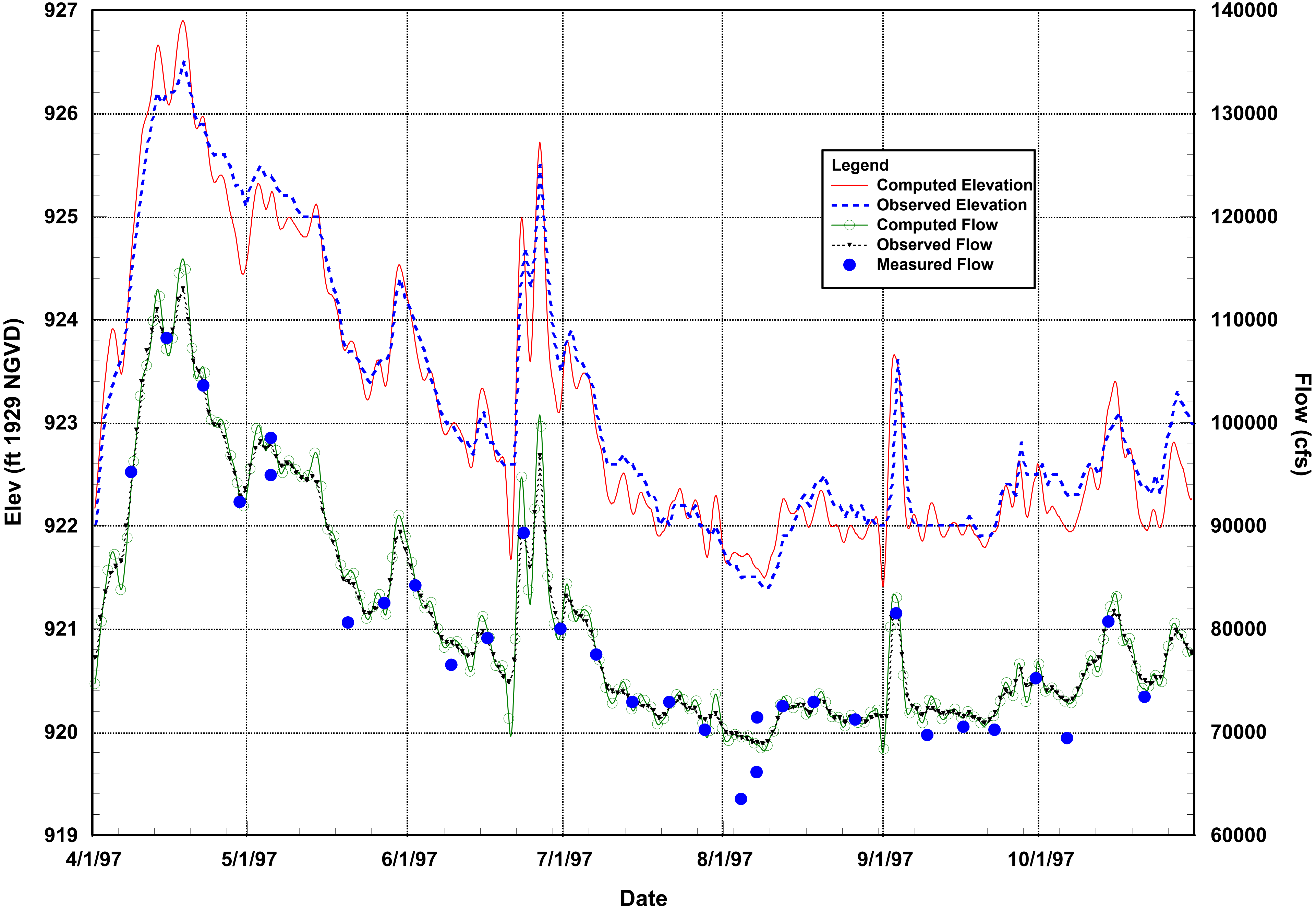




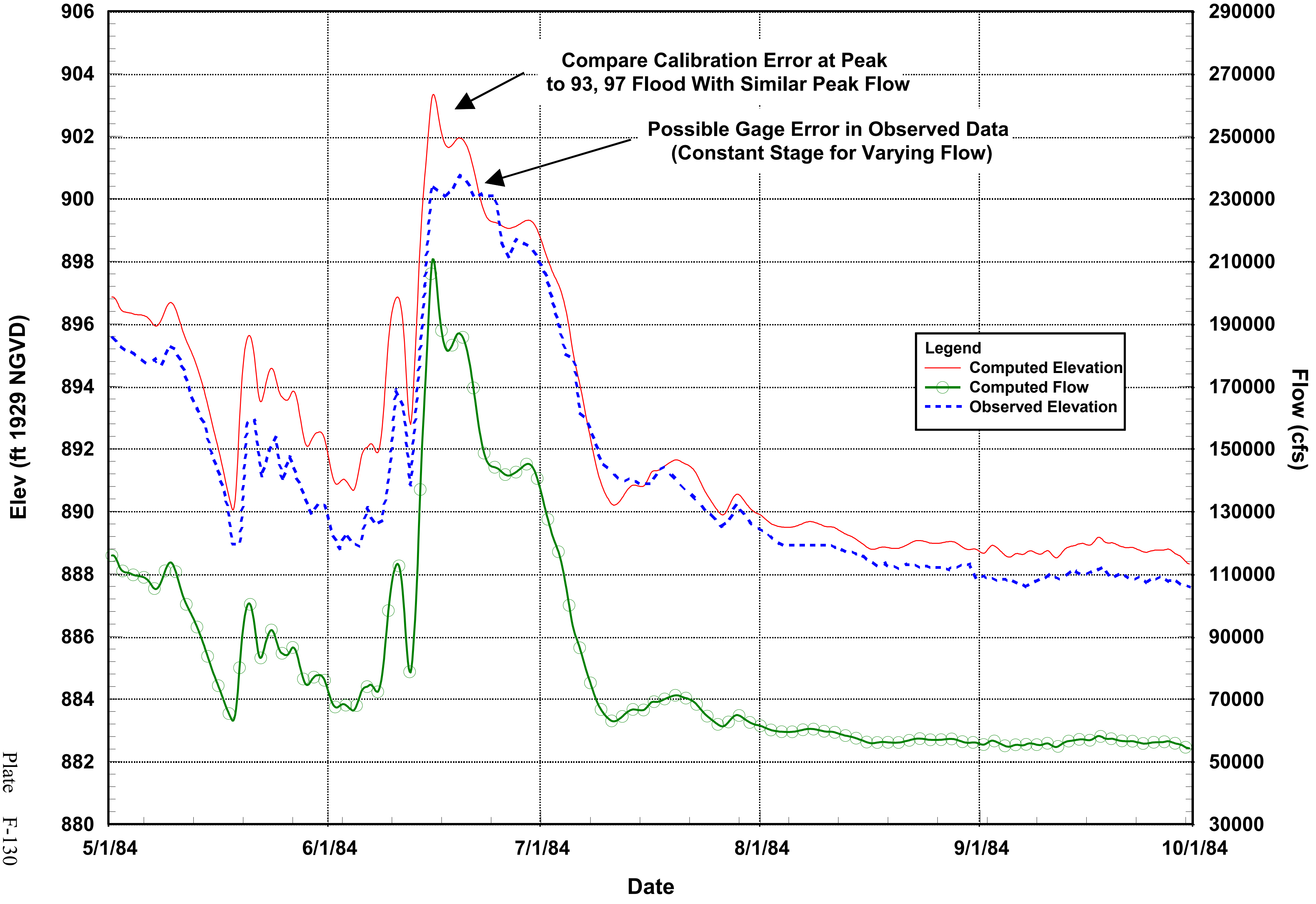
Missouri River at Nebraska City, NE
1993 Computed vs. Observed Data



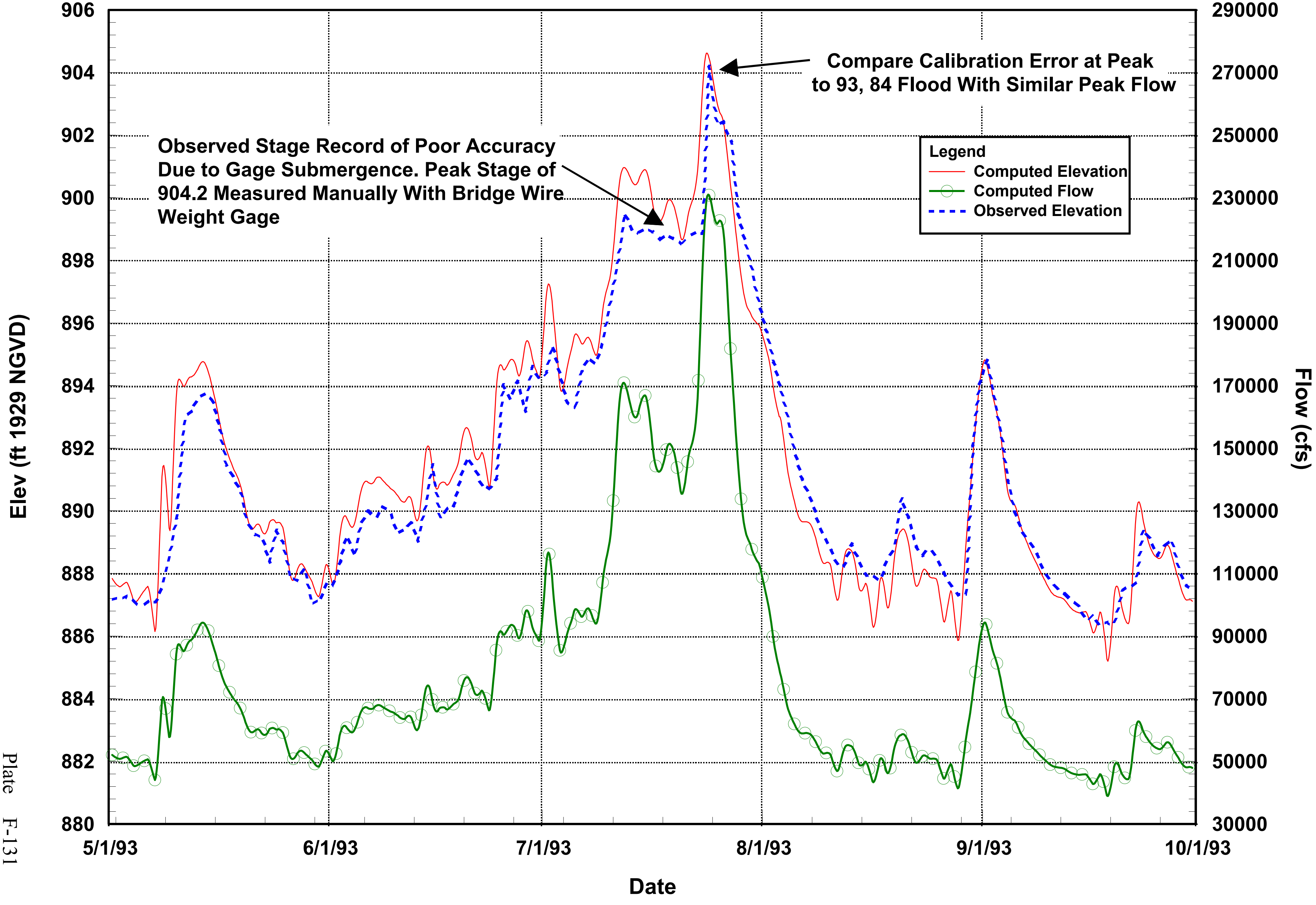
Missouri River at Nebraska City, NE
1997 Computed vs. Observed Data



Missouri River at Brownville, NE
1984 Computed vs. Observed Data



Missouri River at Brownville, NE
1993 Computed vs. Observed Data

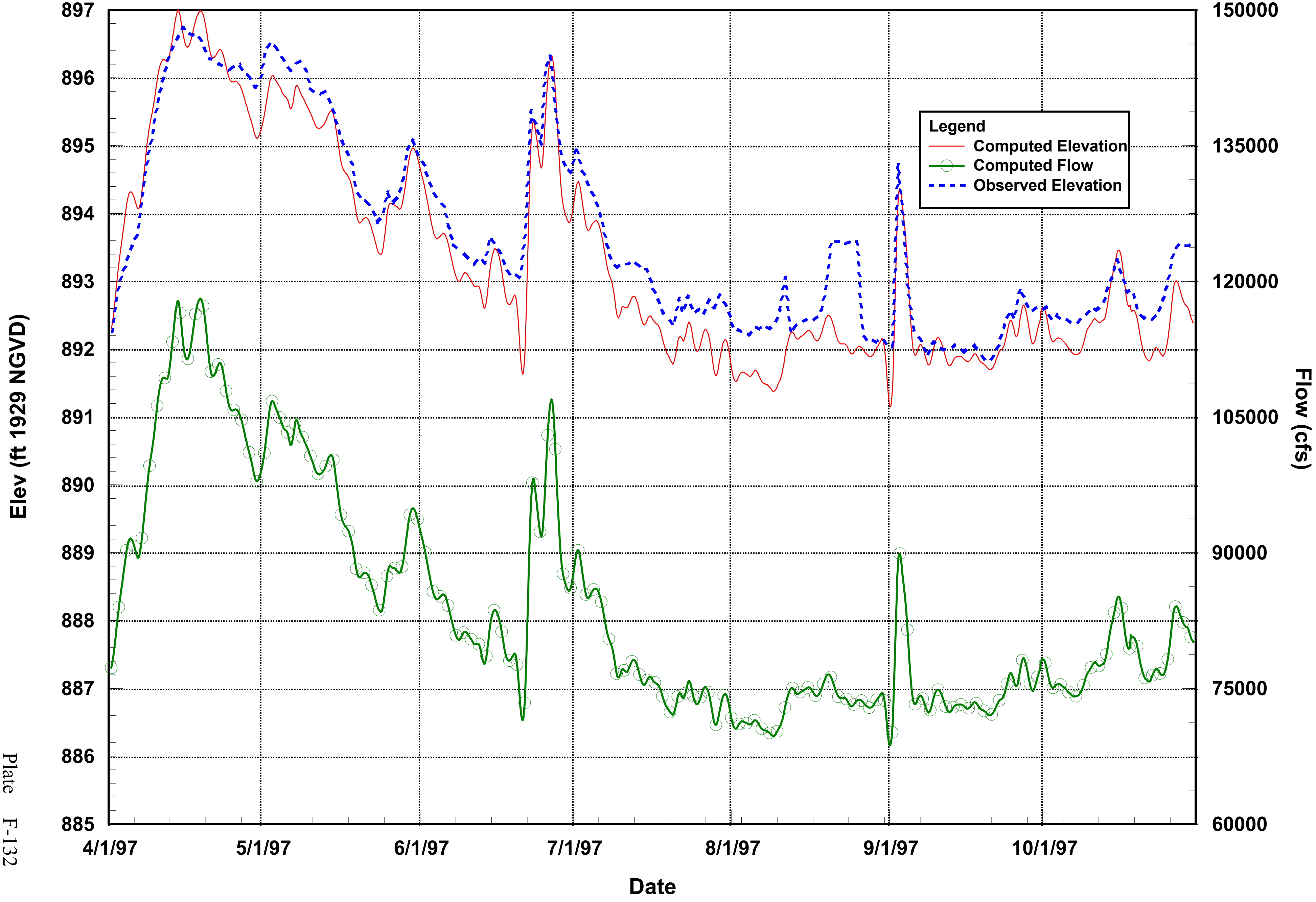


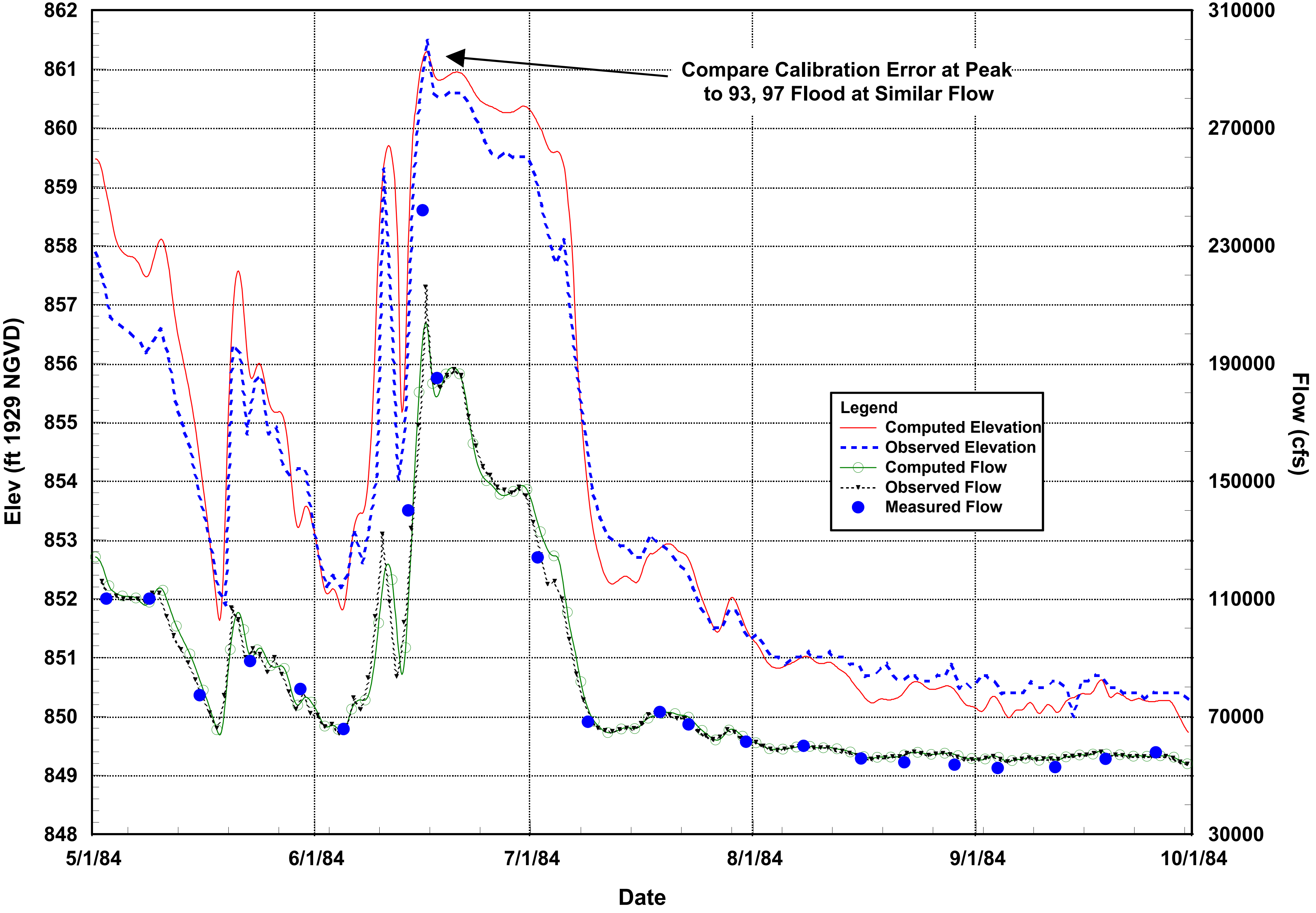
Compare Calibration Error at Peak to 93, 84 Flood With Similar Peak Flow

Observed Stage Record of Poor Accuracy Due to Gage Submergence. Peak Stage of 904.2 Measured Manually With Bridge Wire Weight Gage

Plate F-131

Missouri River at Brownville, NE
1997 Computed vs. Observed Data

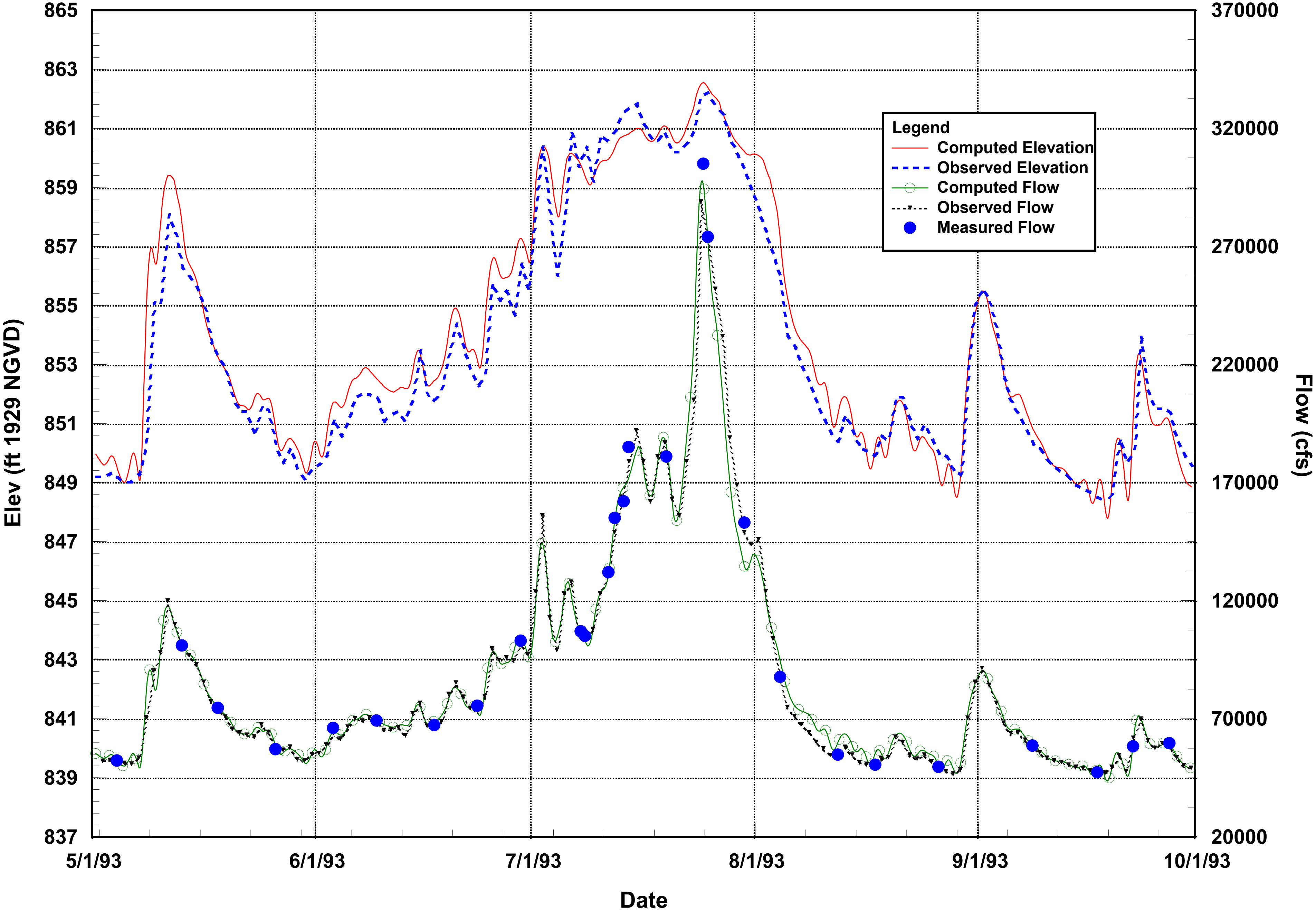




Missouri River at Rulo, NE
1984 Computed vs. Observed Data

Compare Calibration Error at Peak
to 93, 97 Flood at Similar Flow

Missouri River at Rulo, NE
1993 Computed vs. Observed Data



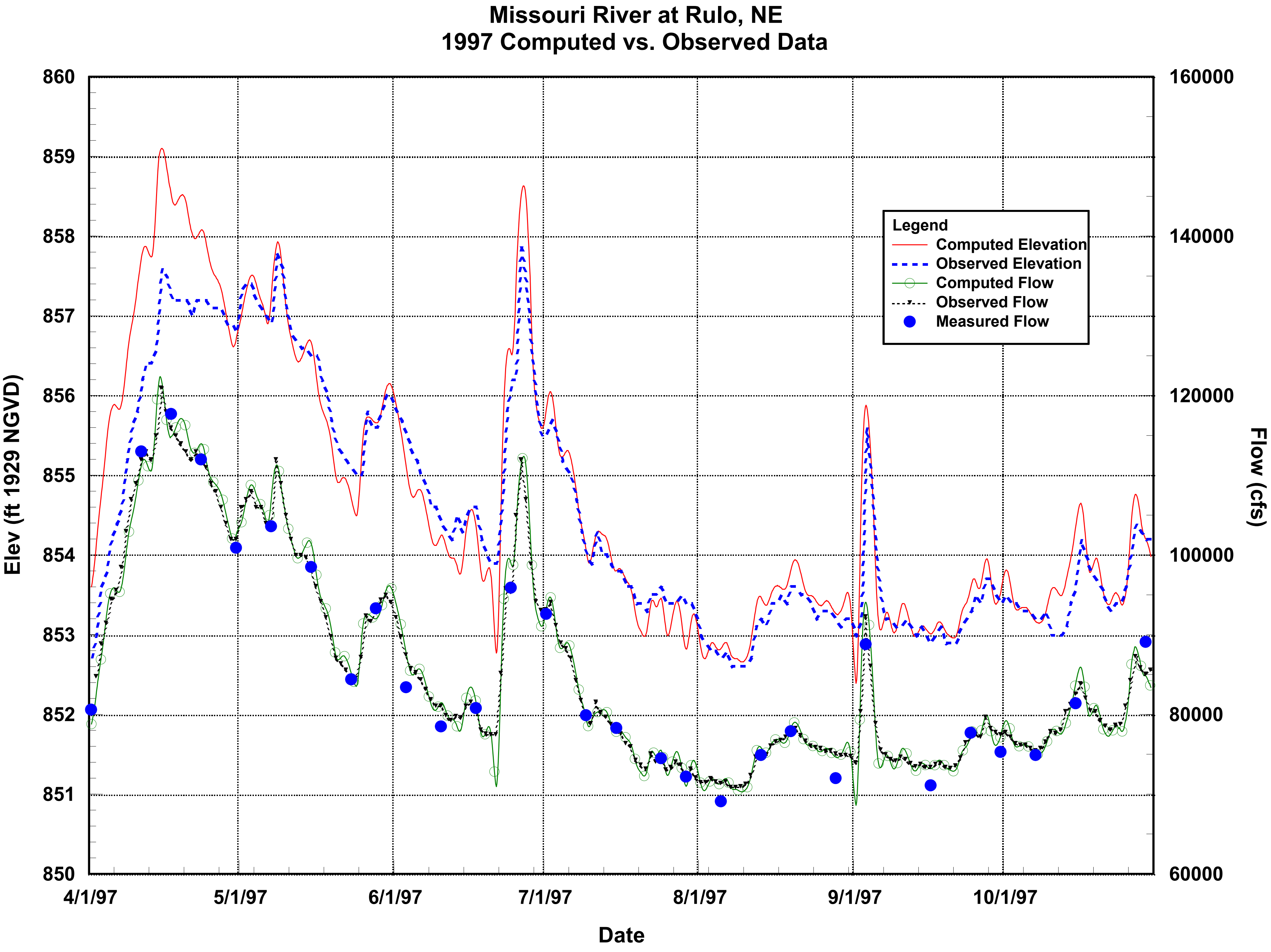
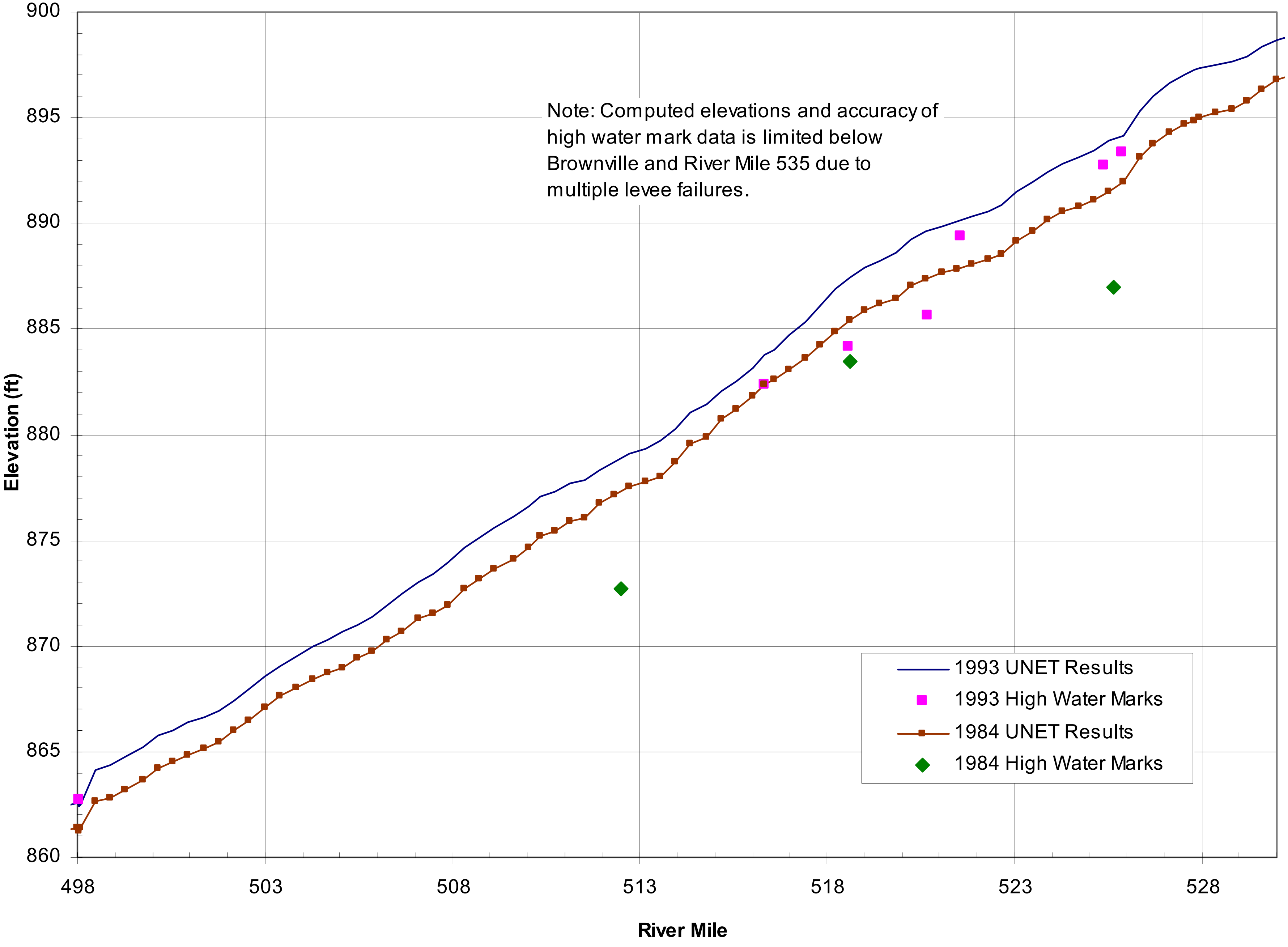
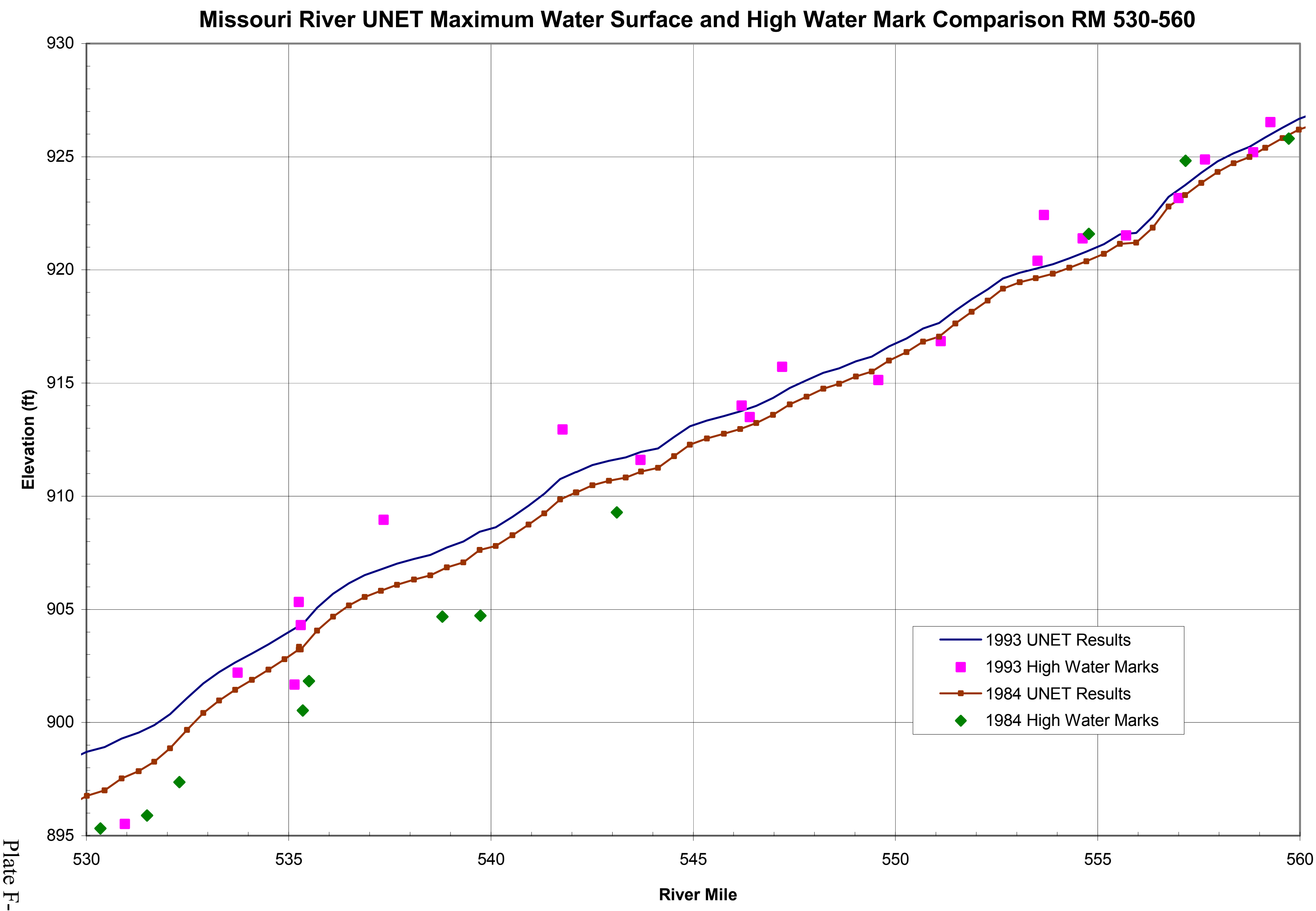

Missouri River at Rulo, NE
1997 Computed vs. Observed Data
Elev (ft 1929 NGVD)
860
859
858
857
856
855
854
853
852
851
850
Flow (cfs)
160000
140000
120000
100000
80000
60000
4/1/97
5/1/97
6/1/97
7/1/97
8/1/97
9/1/97
10/1/97
Date
Legend
Computed Elevation
Observed Elevation
Computed Flow
Observed Flow
Measured Flow

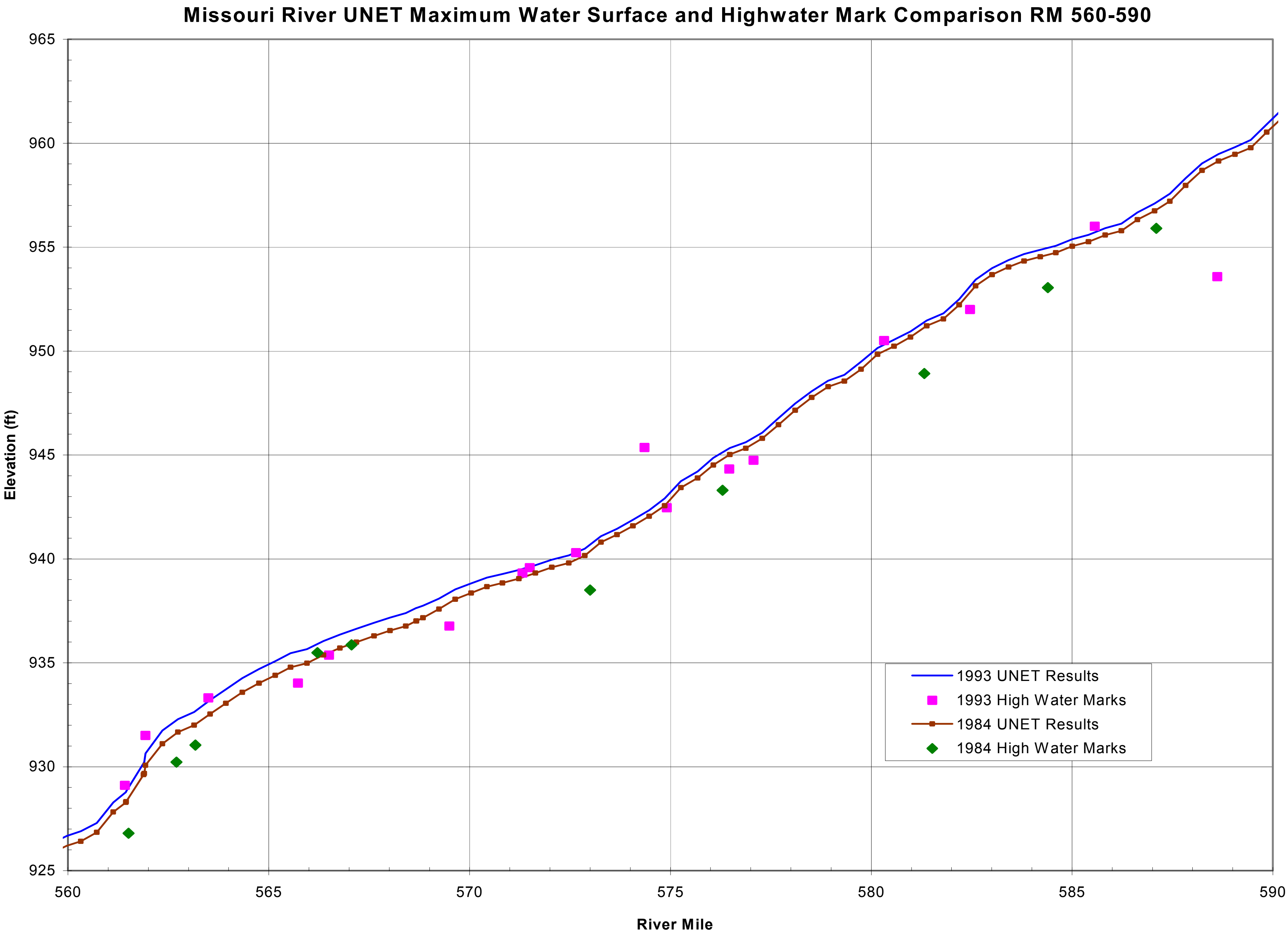
Plate F-135

Missouri River UNET Maximum Water Surface and High Water Mark Comparison RM 498-530

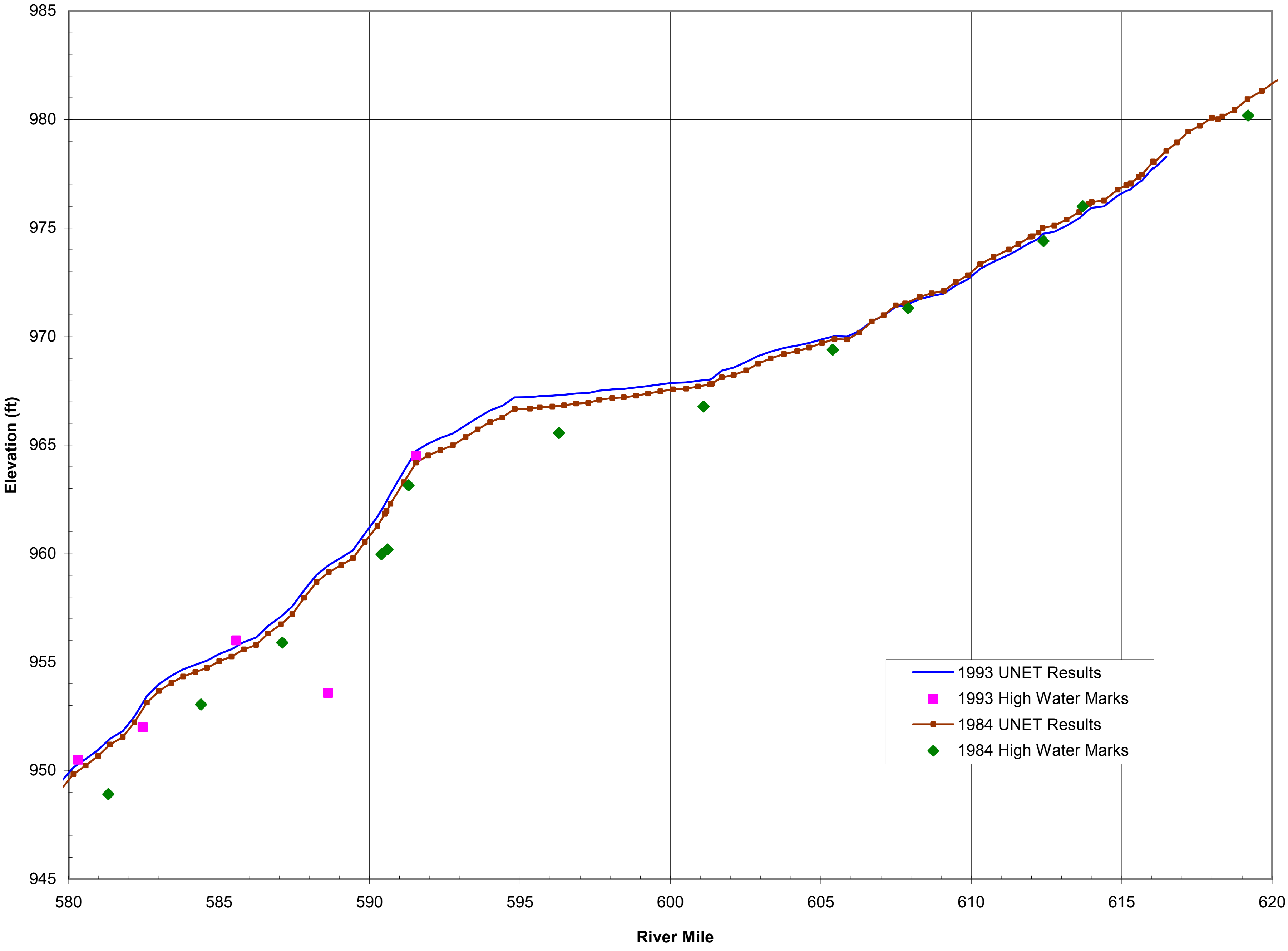


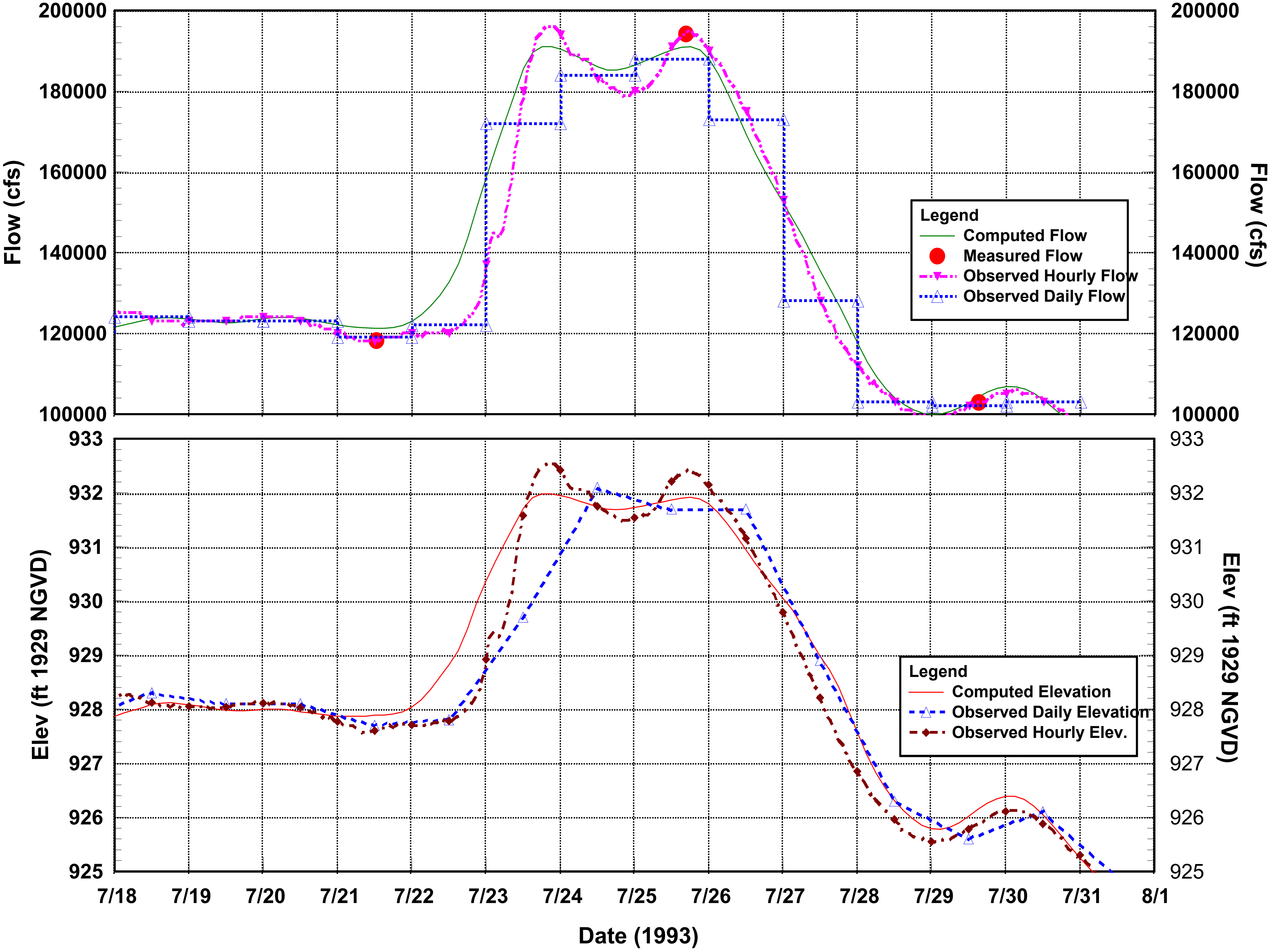
Note: Computed elevations and accuracy of high water mark data is limited below Brownville and River Mile 535 due to multiple levee failures.


Missouri River UNET Maximum Water Surface and High Water Mark Comparison RM 530-560

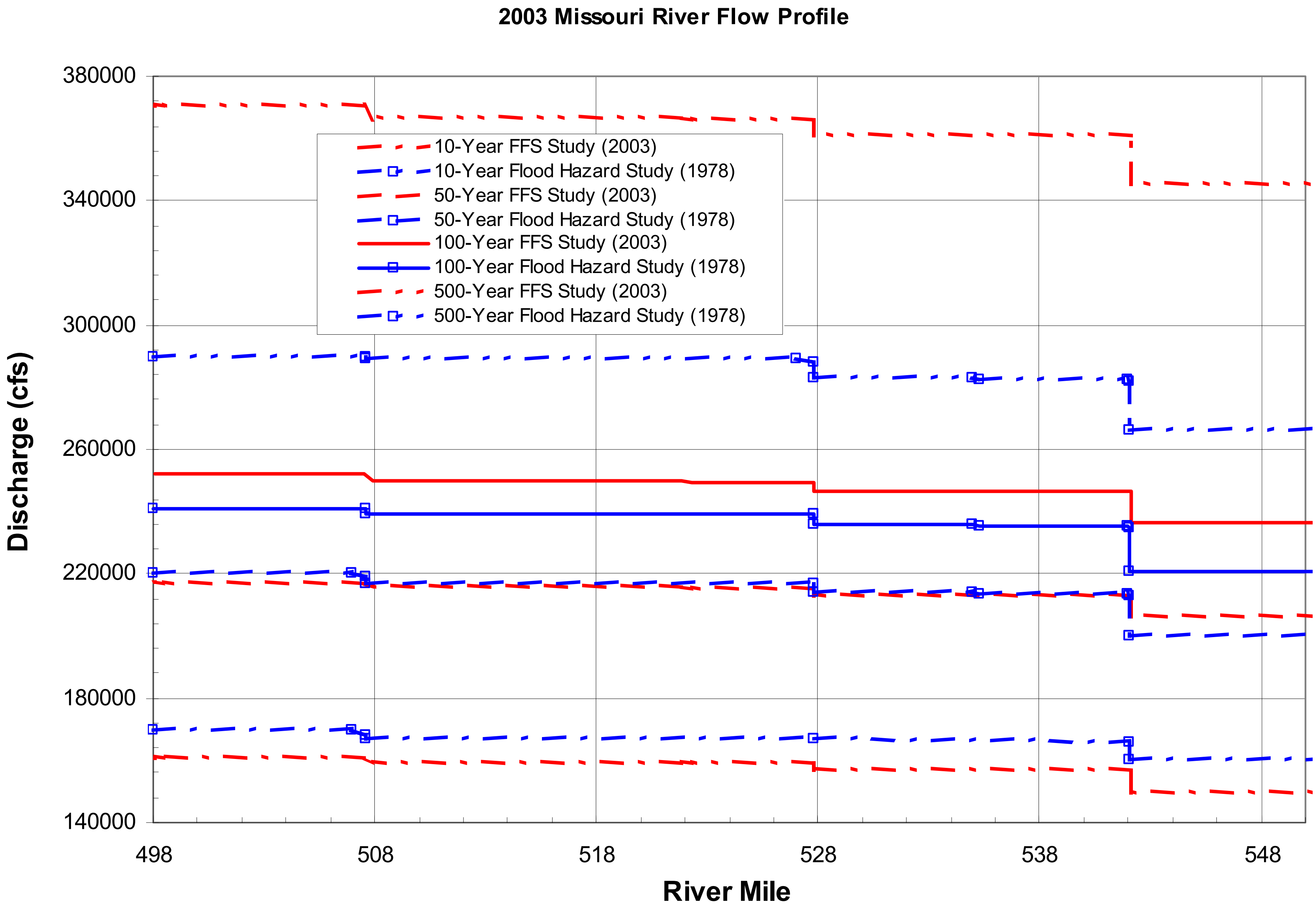

Missouri River UNET Maximum Water Surface and Highwater Mark Comparison RM 560-590
Elevation (ft)
965
960
955
950
945
940
935
930
925
River Mile
560
565
570
575
580
585
590
1993 UNET Results
1993 High Water Marks
1984 UNET Results
1984 High Water Marks

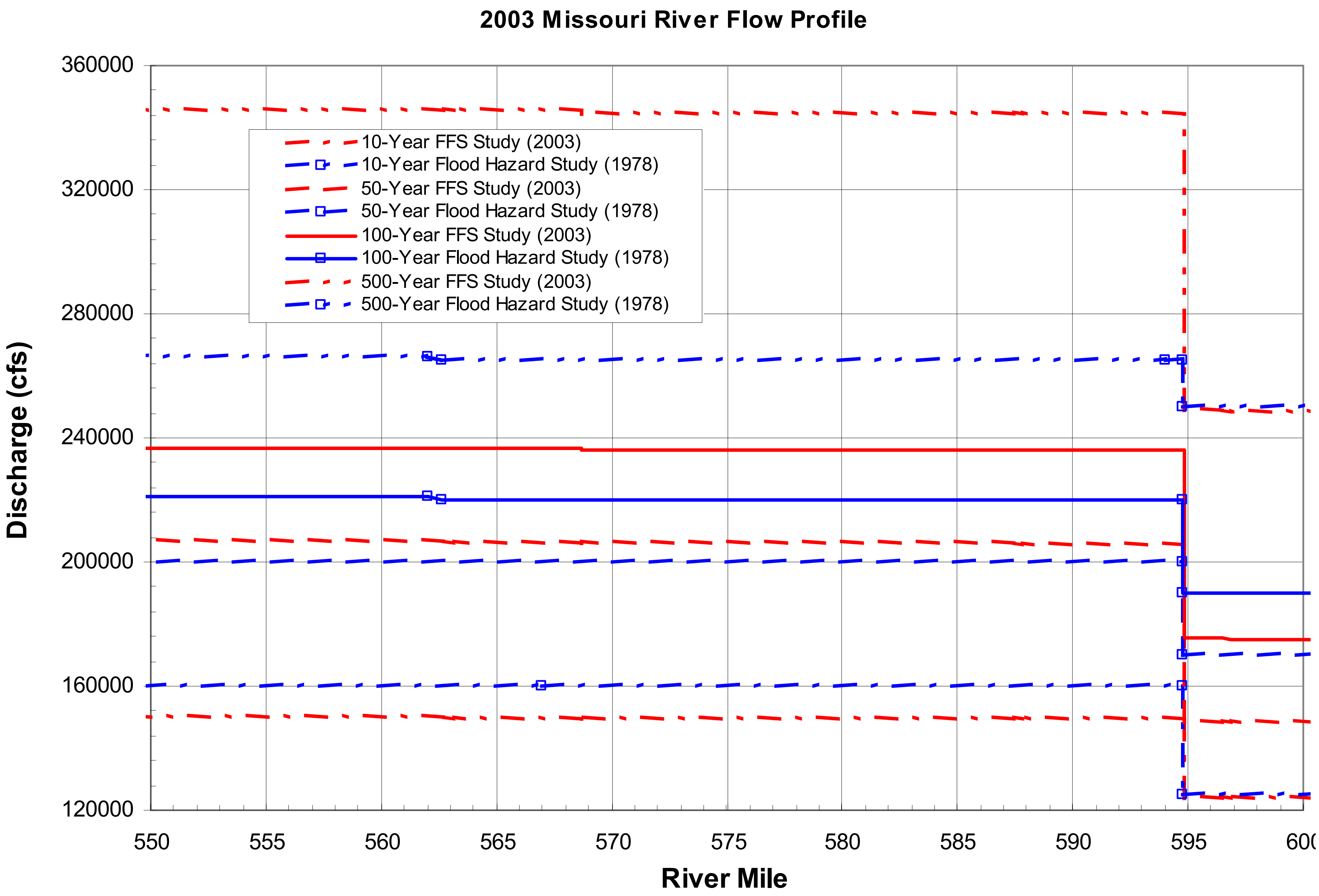
Missouri River UNET Maximum Water Surface and High Water Mark Comparsion RM 580-620

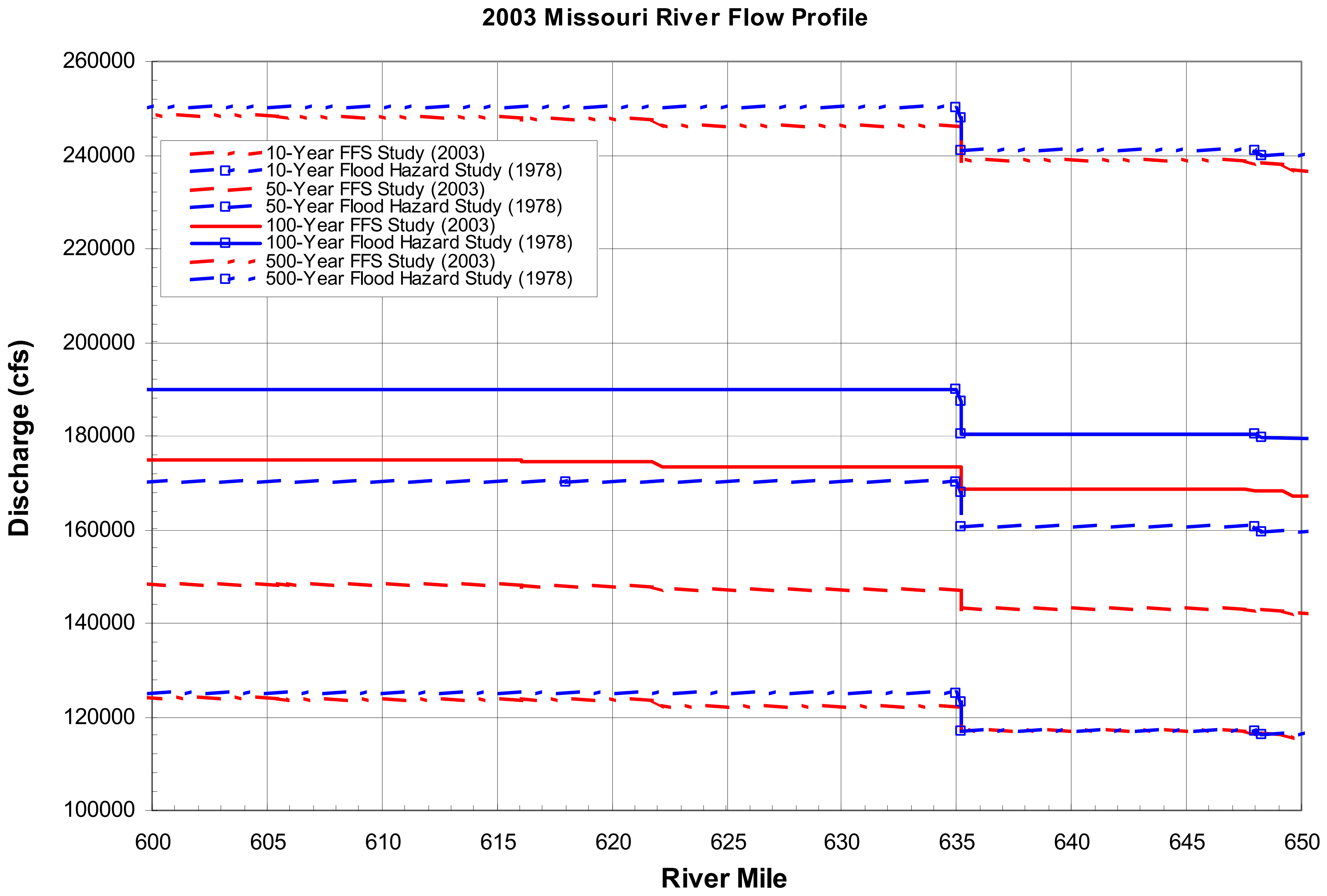


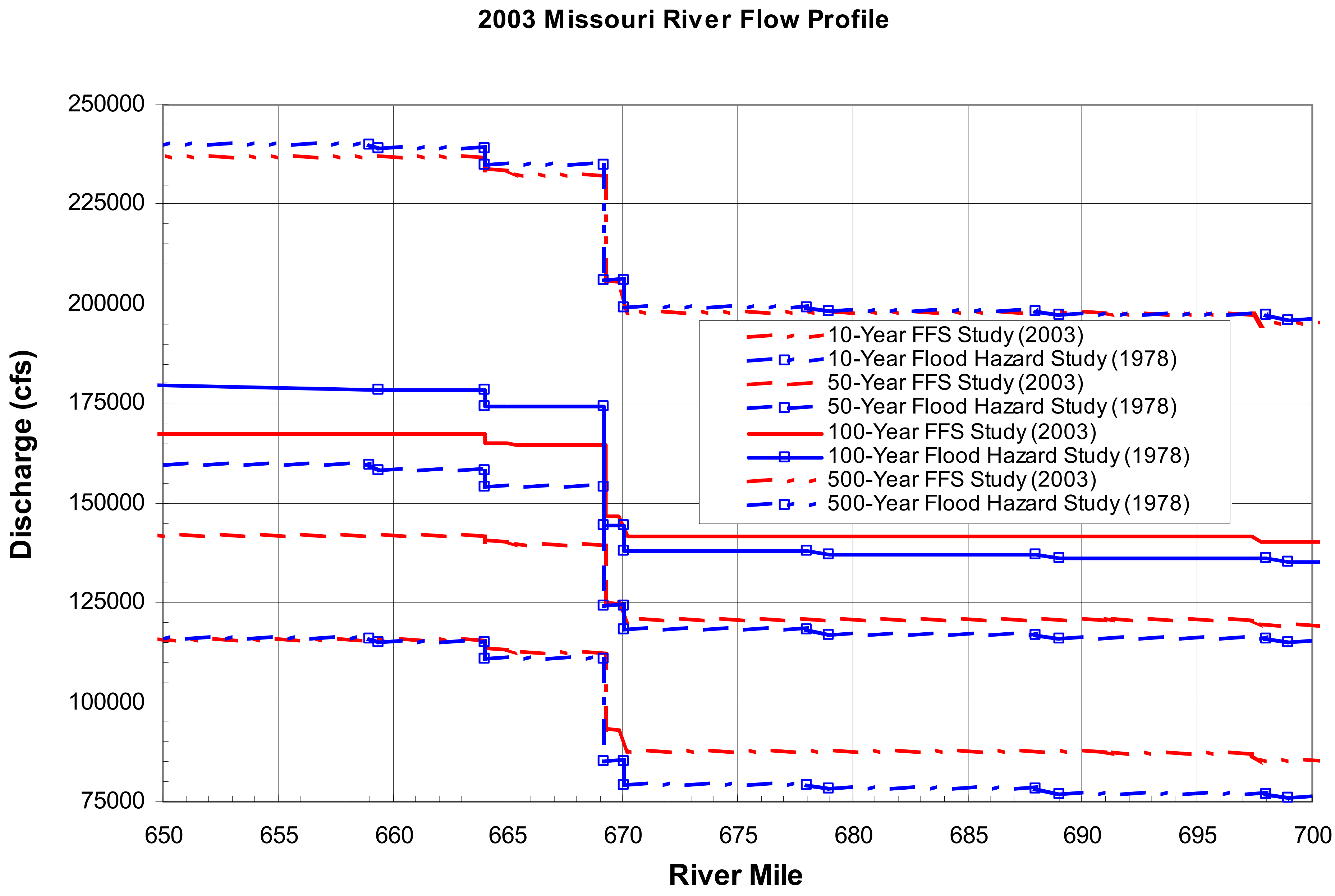


Missouri River at Nebraska City, NE
1993 Observed Hourly Data Compared to Daily Data

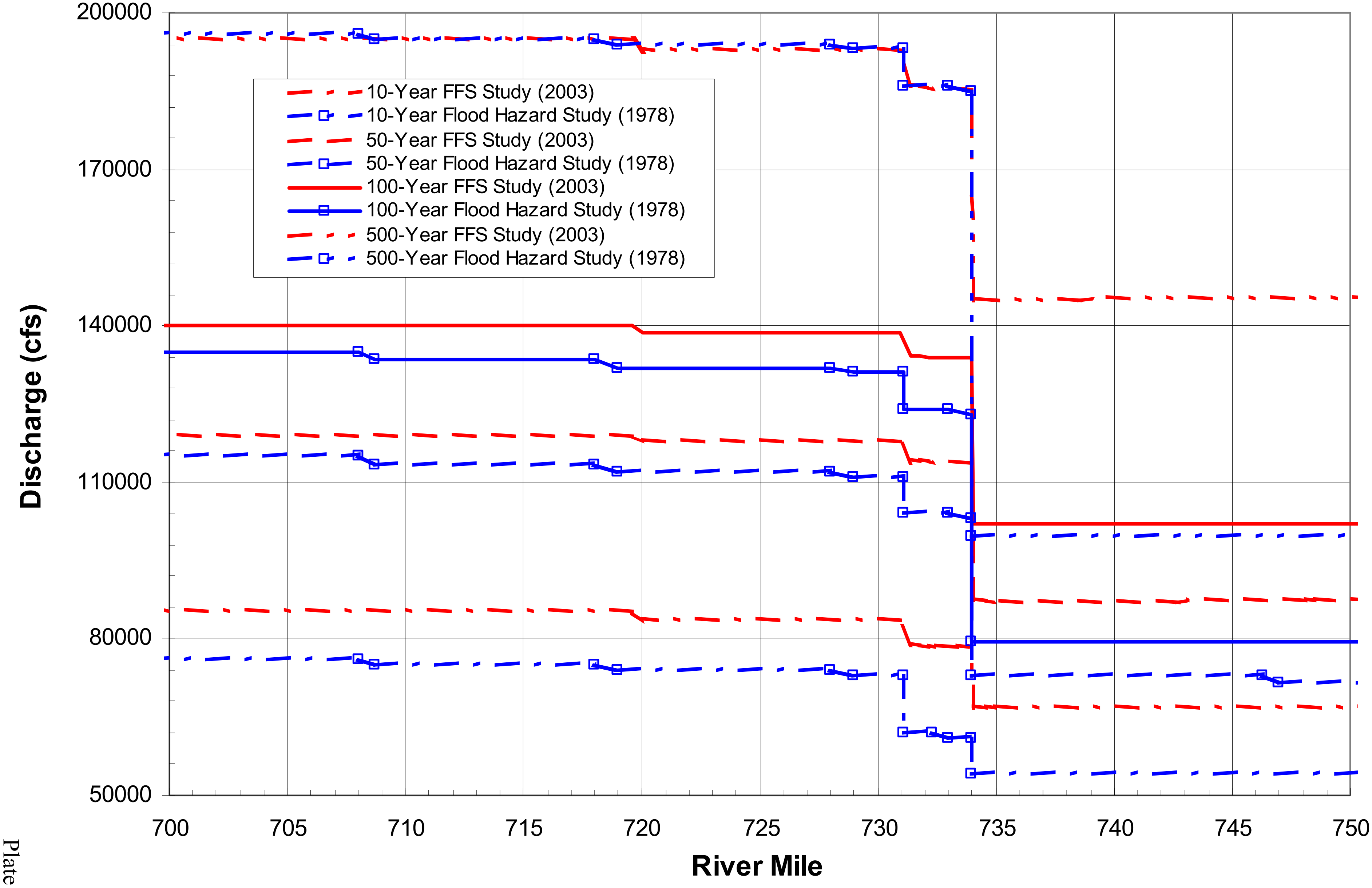

2003 Missouri River Flow Profile
Discharge (cfs)
380000
340000
300000
260000
220000
180000
140000
498
508
518
528
538
548
River Mile
10-Year FFS Study (2003)
10-Year Flood Hazard Study (1978)
50-Year FFS Study (2003)
50-Year Flood Hazard Study (1978)
100-Year FFS Study (2003)
100-Year Flood Hazard Study (1978)
500-Year FFS Study (2003)
500-Year Flood Hazard Study (1978)

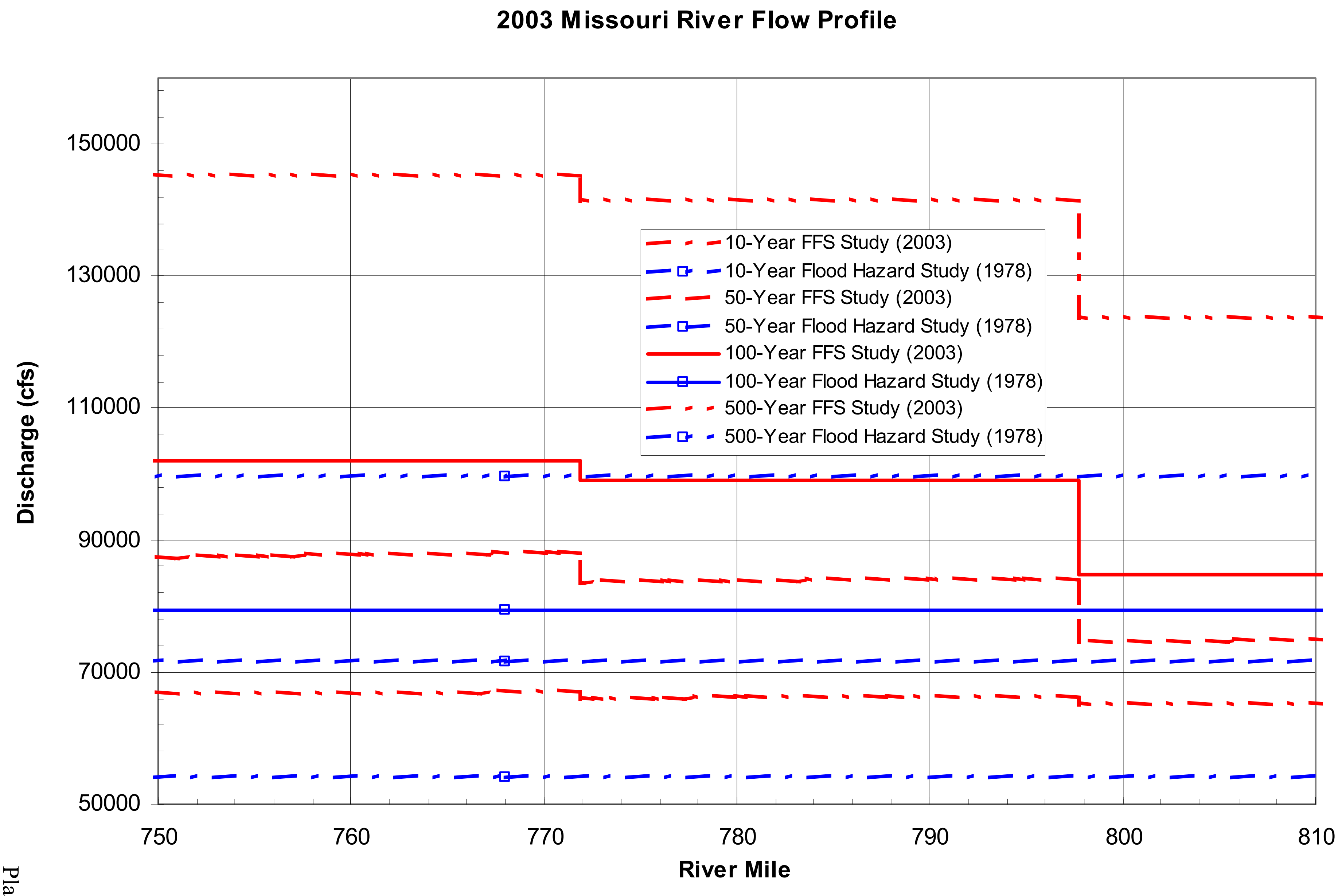

2003 Missouri River Flow Profile
10-Year FFS Study (2003)
10-Year Flood Hazard Study (1978)
50-Year FFS Study (2003)
50-Year Flood Hazard Study (1978)
100-Year FFS Study (2003)
100-Year Flood Hazard Study (1978)
500-Year FFS Study (2003)
500-Year Flood Hazard Study (1978)
Discharge (cfs)
360000
320000
280000
240000
200000
160000
120000
550
555
560
565
570
575
580
585
590
595
60
River Mile

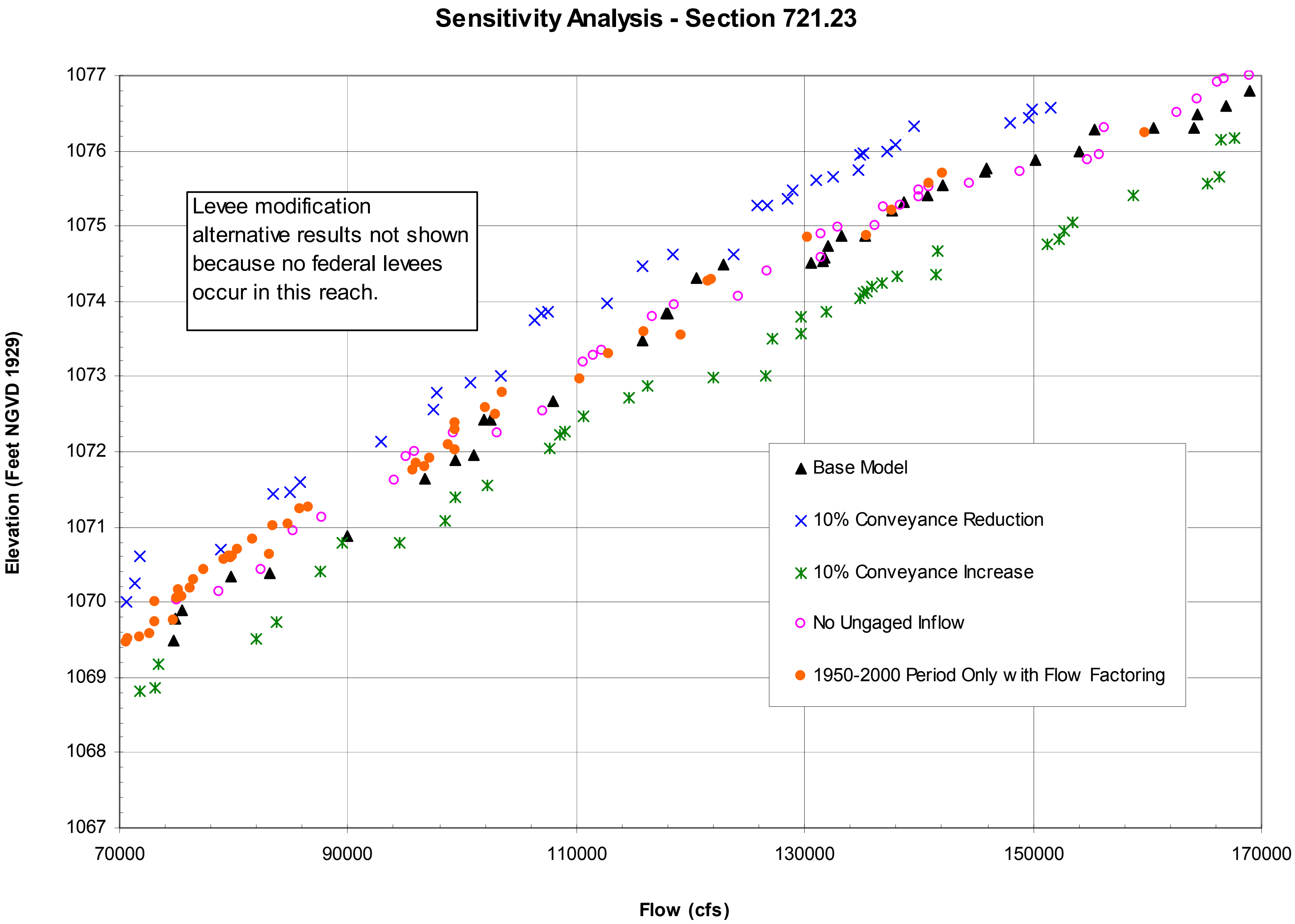

2003 Missouri River Flow Profile
Discharge (cfs)
260000
240000
220000
200000
180000
160000
140000
120000
100000
600
605
610
615
620
625
630
635
640
645
650
River Mile
10-Year FFS Study (2003)
10-Year Flood Hazard Study (1978)
50-Year FFS Study (2003)
50-Year Flood Hazard Study (1978)
100-Year FFS Study (2003)
100-Year Flood Hazard Study (1978)
500-Year FFS Study (2003)
500-Year Flood Hazard Study (1978)

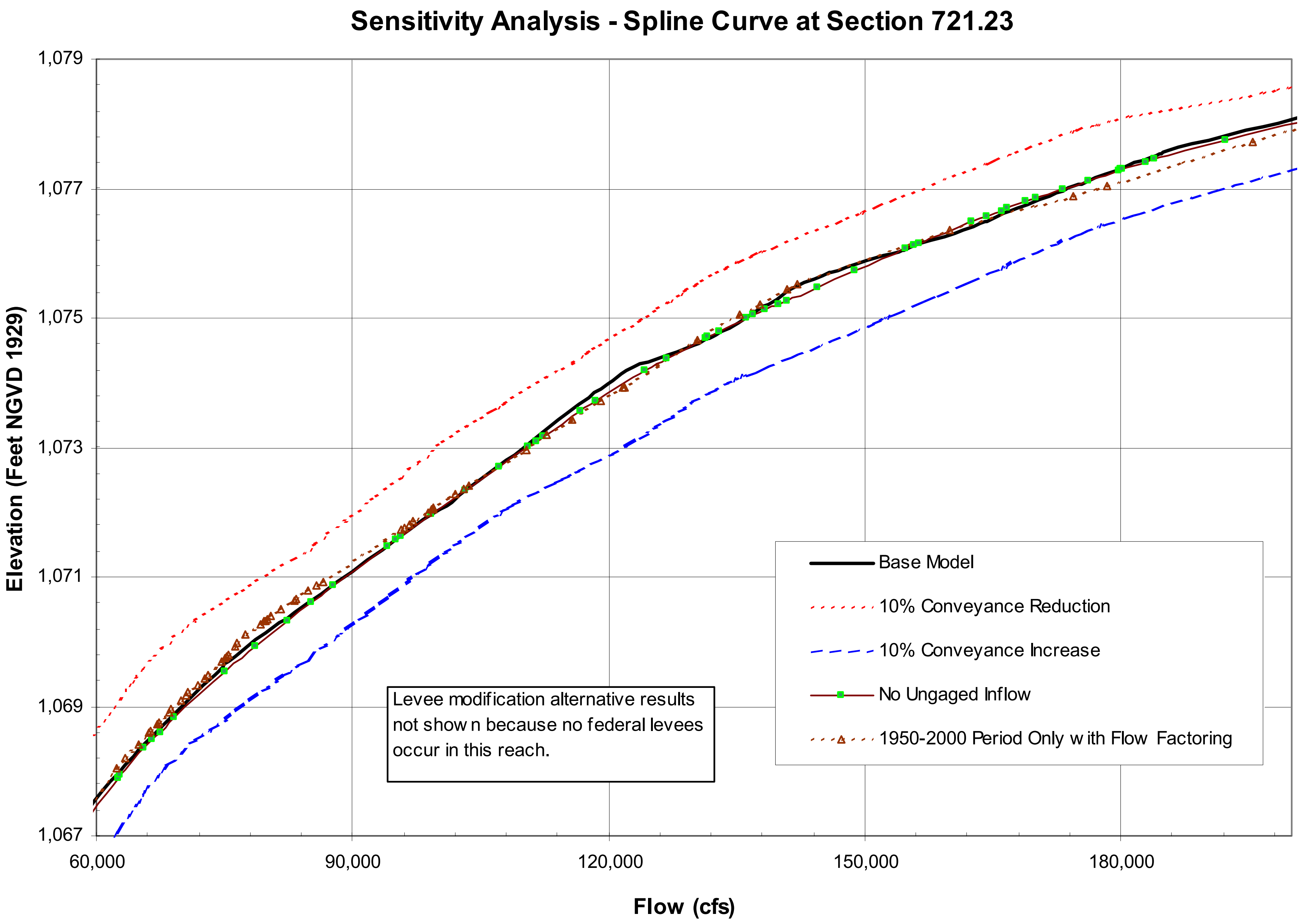

2003 Missouri River Flow Profile
Discharge (cfs)
250000
225000
200000
175000
150000
125000
100000
75000
River Mile
650
655
660
665
670
675
680
685
690
695
700
10-Year FFS Study (2003)
10-Year Flood Hazard Study (1978)
50-Year FFS Study (2003)
50-Year Flood Hazard Study (1978)
100-Year FFS Study (2003)
100-Year Flood Hazard Study (1978)
500-Year FFS Study (2003)
500-Year Flood Hazard Study (1978)

2003 Missouri River Flow Profile

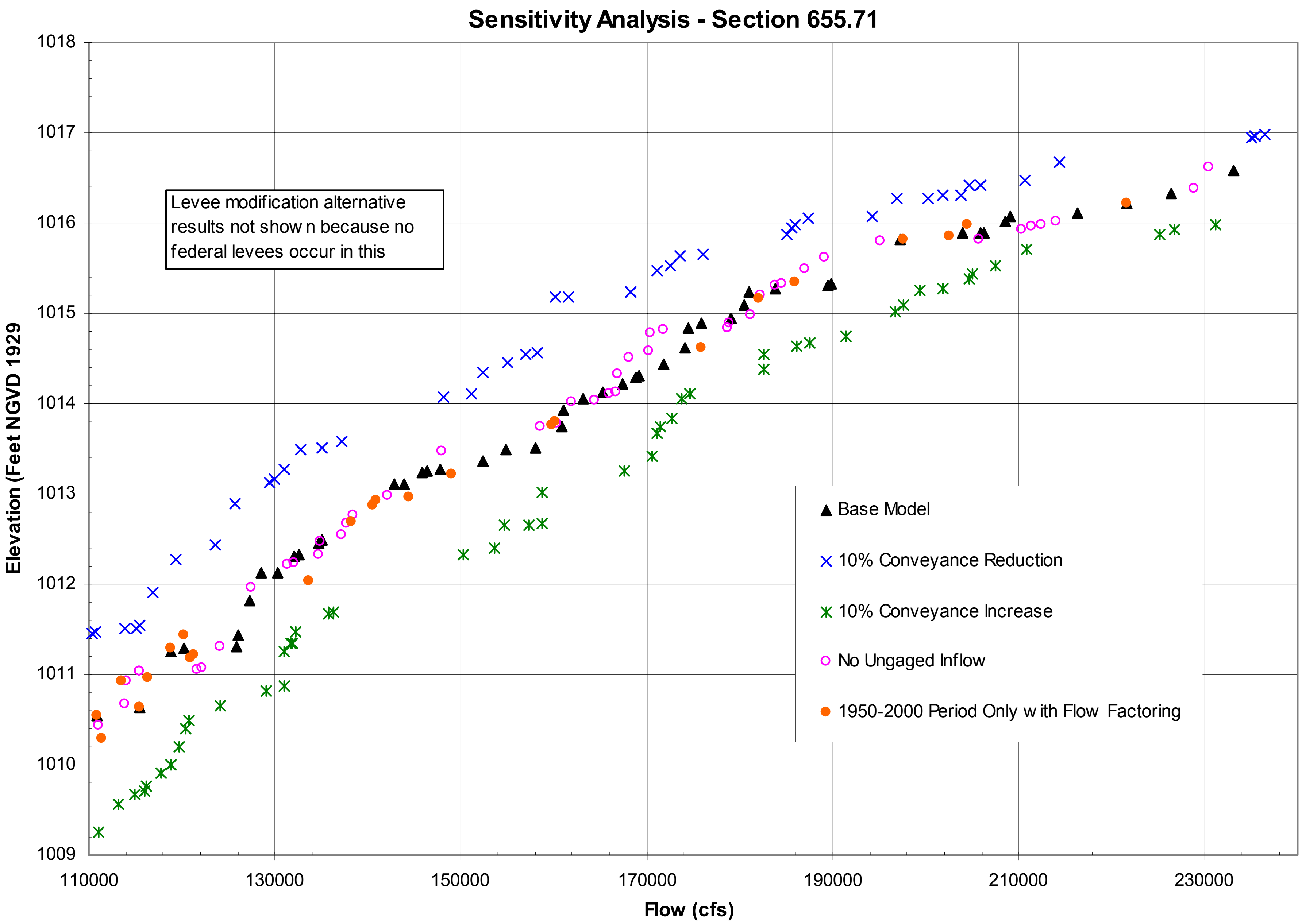



2003 Missouri River Flow Profile
Discharge (cfs)
150000
130000
110000
90000
70000
50000
750
760
770
780
790
800
810
River Mile
10-Year FFS Study (2003)
10-Year Flood Hazard Study (1978)
50-Year FFS Study (2003)
50-Year Flood Hazard Study (1978)
100-Year FFS Study (2003)
100-Year Flood Hazard Study (1978)
500-Year FFS Study (2003)
500-Year Flood Hazard Study (1978)

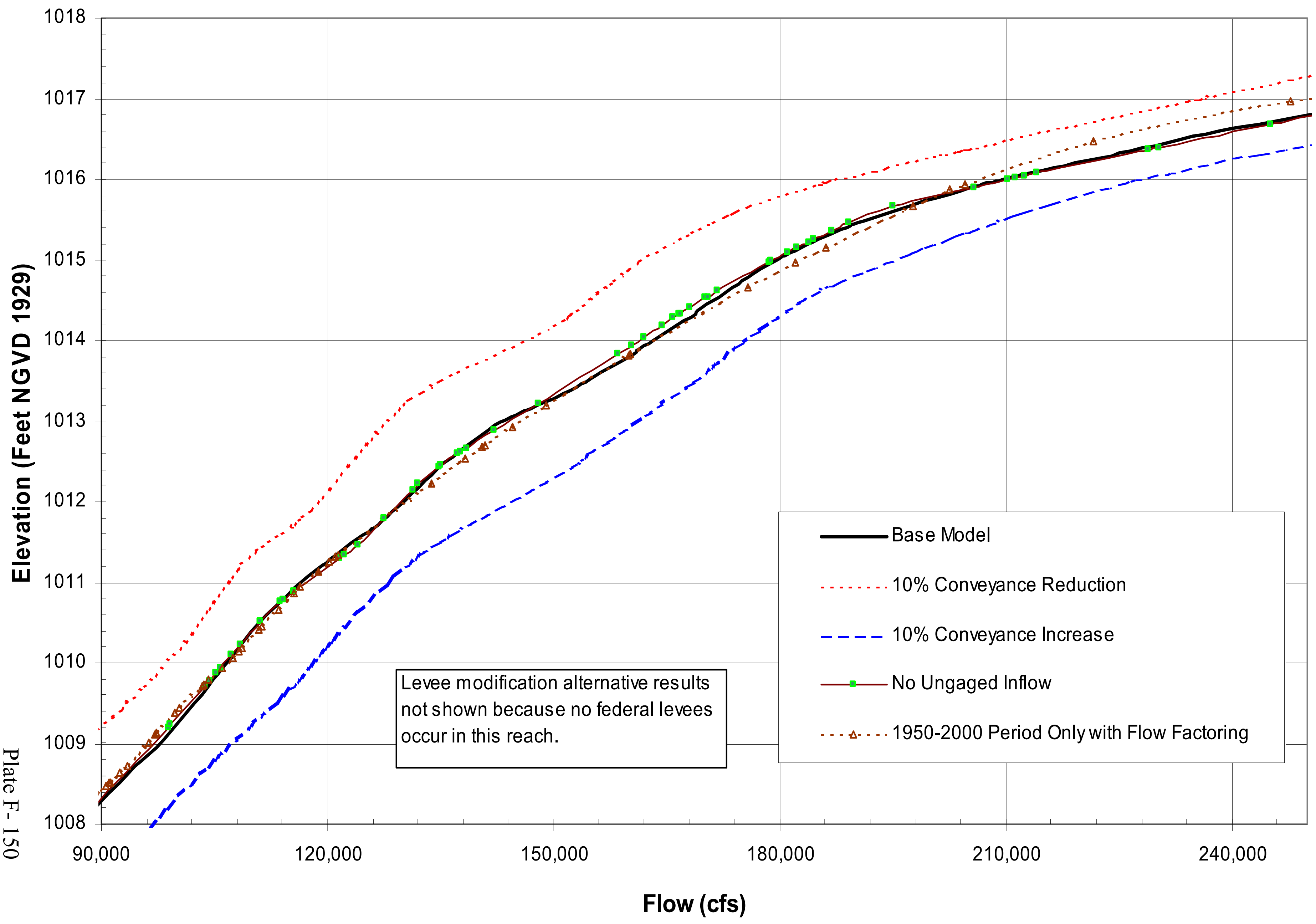

Sensitivity Analysis - Section 721.23
Elevation (Feet NGVD 1929)
Flow (cfs)
1077
1076
1075
1074
1073
1072
1071
1070
1069
1068
1067
70000
90000
110000
130000
150000
170000
Levee modification alternative results not shown because no federal levees occur in this reach.
▲ Base Model
× 10% Conveyance Reduction
✳ 10% Conveyance Increase
○ No Ungaged Inflow
● 1950-2000 Period Only w ith Flow Factoring



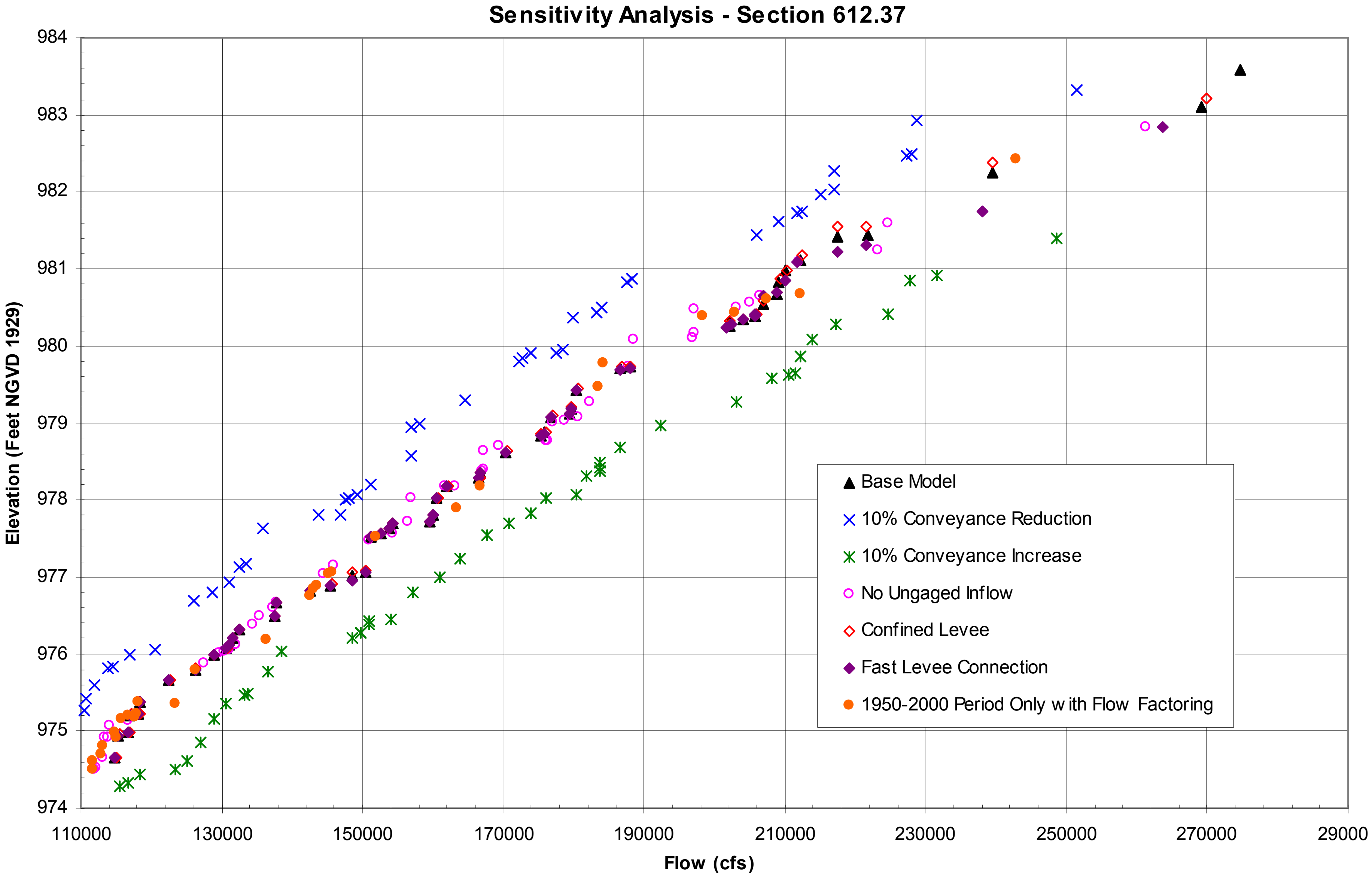
Levee modification alternative results not show n because no federal levees occur in this reach.

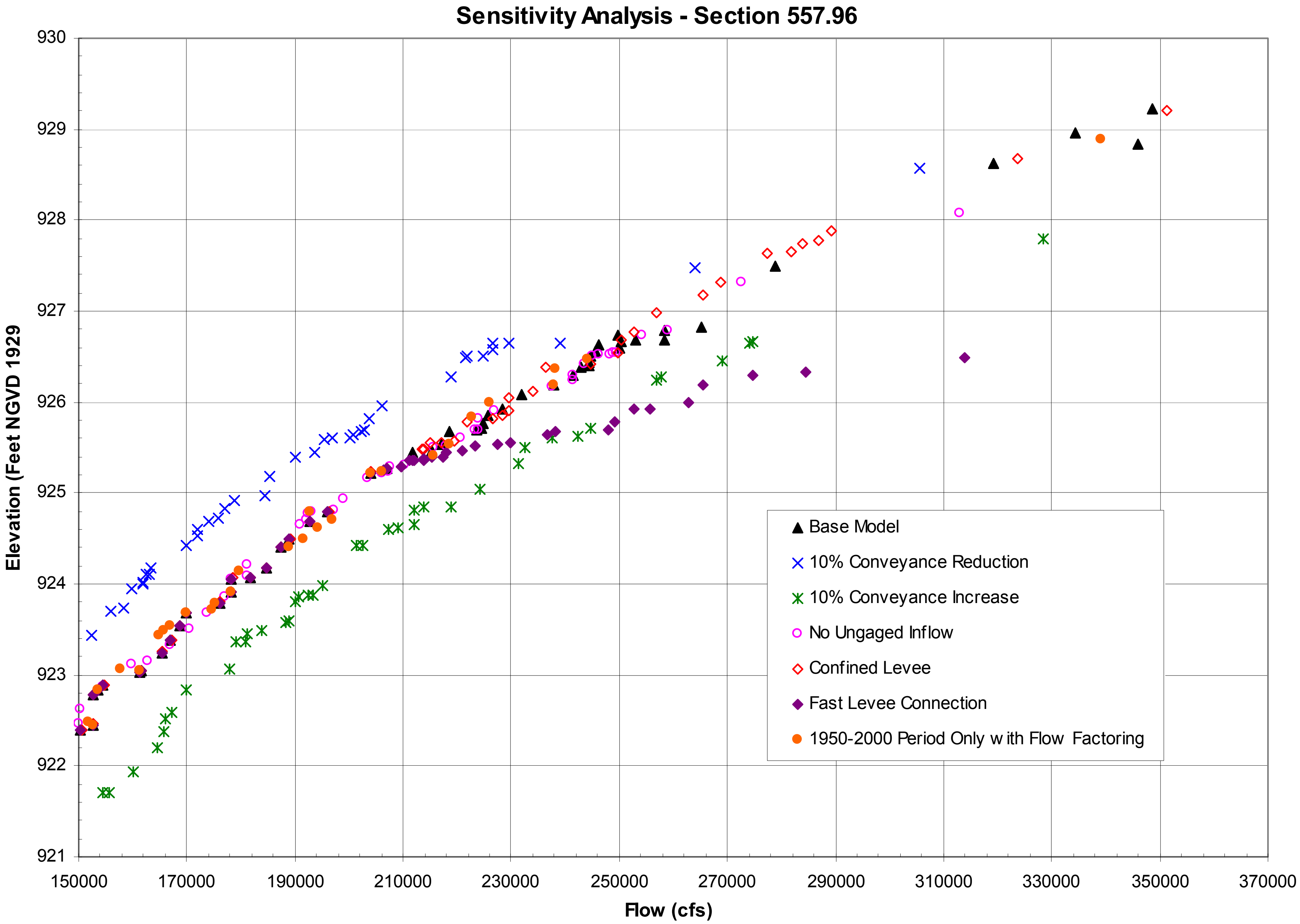

Sensitivity Analysis - Section 655.71
Elevation (Feet NGVD 1929
1018
1017
1016
1015
1014
1013
1012
1011
1010
1009
110000
130000
150000
170000
190000
210000
230000
Flow (cfs)
Levee modification alternative results not show n because no federal levees occur in this
▲ Base Model
× 10% Conveyance Reduction
✳ 10% Conveyance Increase
○ No Ungaged Inflow
● 1950-2000 Period Only w ith Flow Factoring

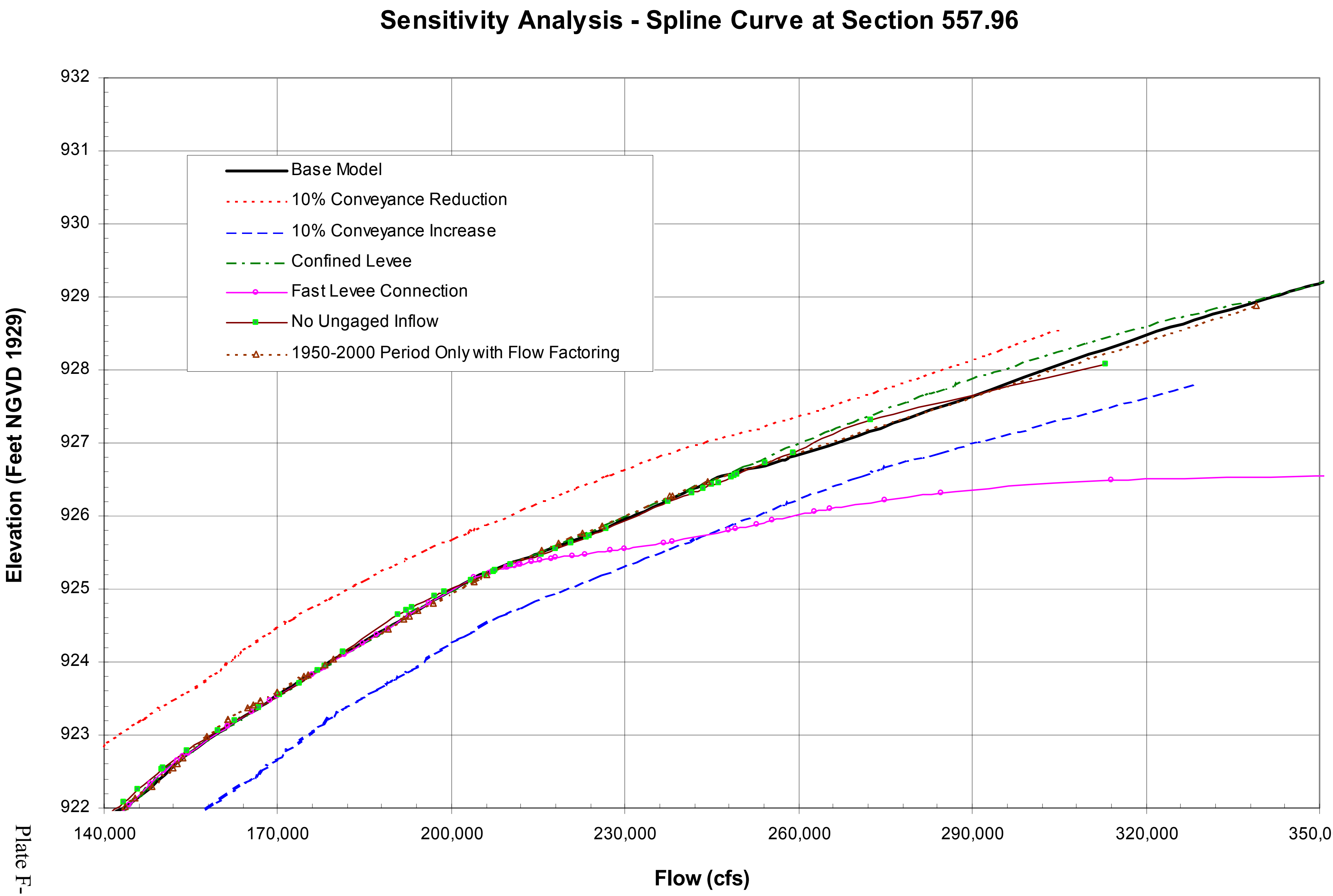
Sensitivity Analysis - Spline Curve at Section 655.71

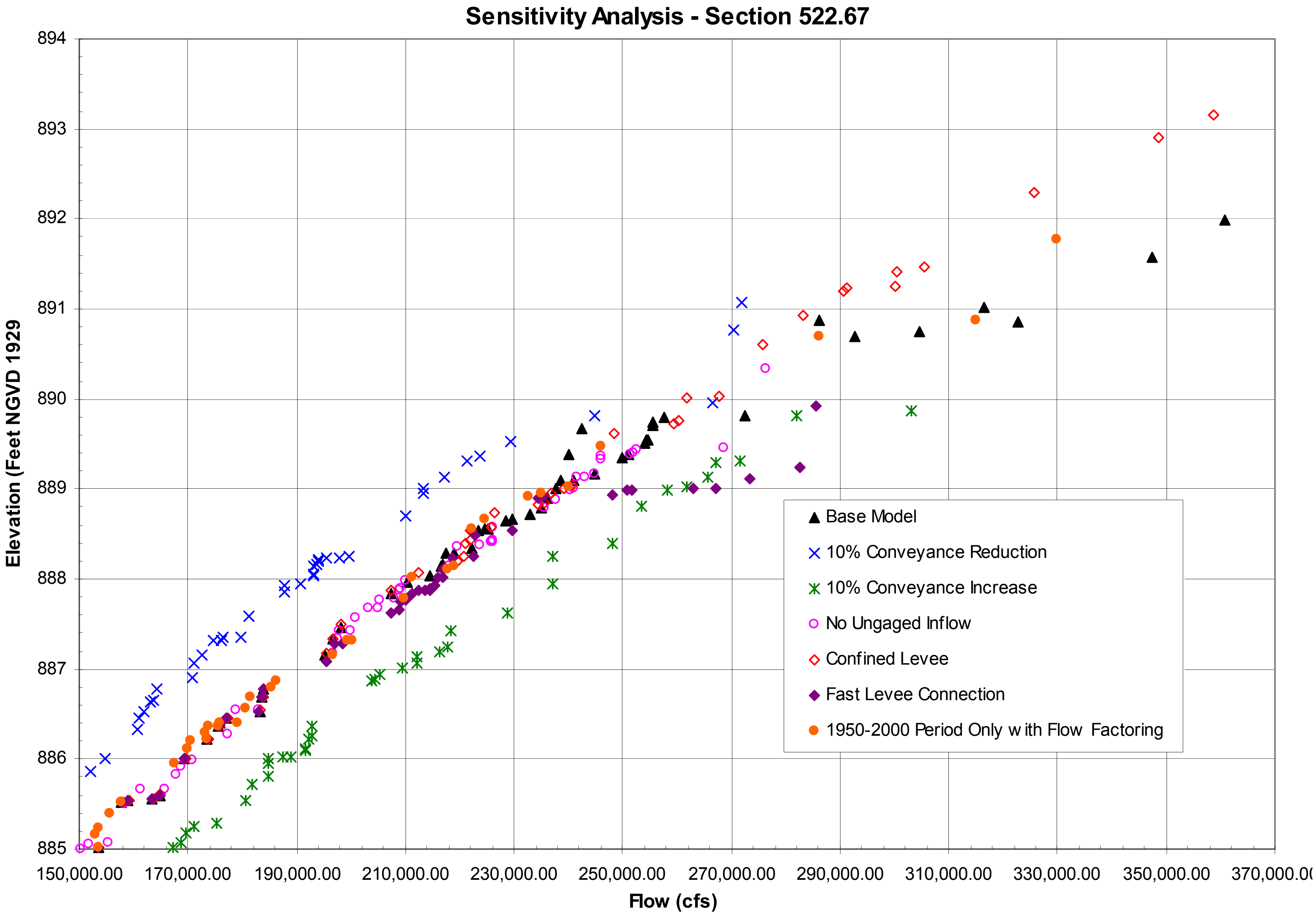


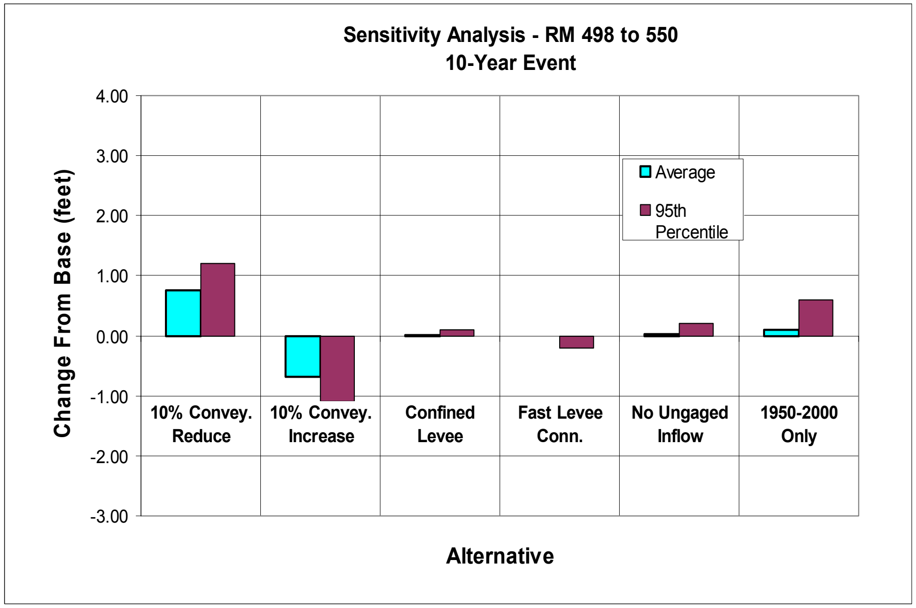
Levee modification alternative results not shown because no federal levees occur in this reach.

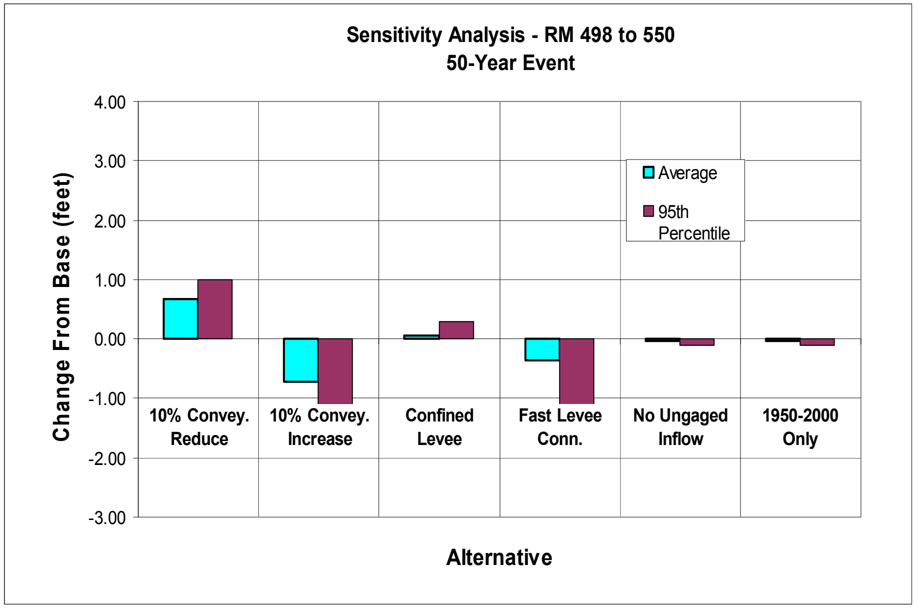

Sensitivity Analysis - Section 612.37
Elevation (Feet NGVD 1929)
984
983
982
981
980
979
978
977
976
975
974
110000
130000
150000
170000
190000
210000
230000
250000
270000
29000
Flow (cfs)
▲ Base Model
× 10% Conveyance Reduction
✱ 10% Conveyance Increase
○ No Ungaged Inflow
◇ Confined Levee
◆ Fast Levee Connection
● 1950-2000 Period Only w ith Flow Factoring

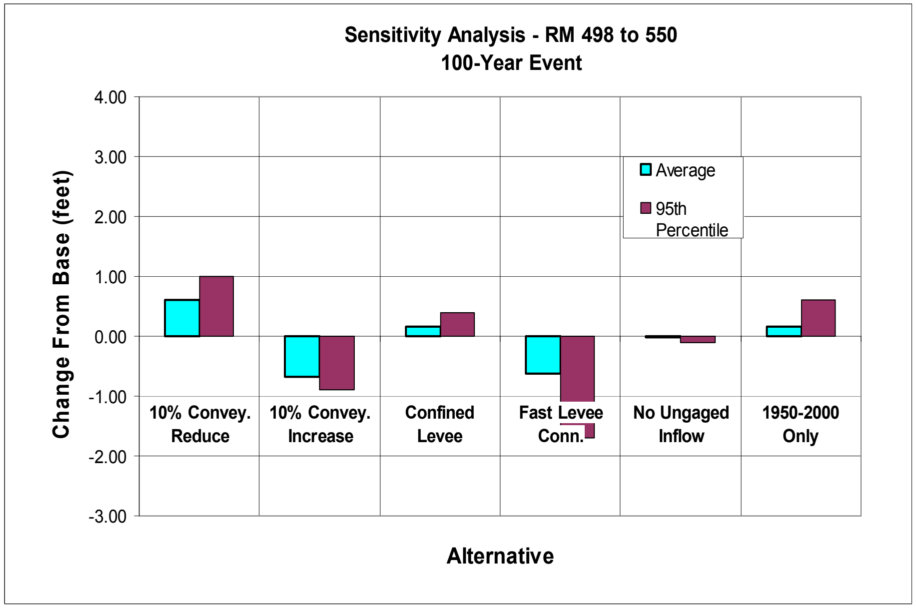

Sensitivity Analysis - Section 557.96
Elevation (Feet NGVD 1929)
930
929
928
927
926
925
924
923
922
921
Flow (cfs)
150000
170000
190000
210000
230000
250000
270000
290000
310000
330000
350000
370000
▲ Base Model
× 10% Conveyance Reduction
✳ 10% Conveyance Increase
○ No Ungaged Inflow
◇ Confined Levee
◆ Fast Levee Connection
● 1950-2000 Period Only w ith Flow Factoring

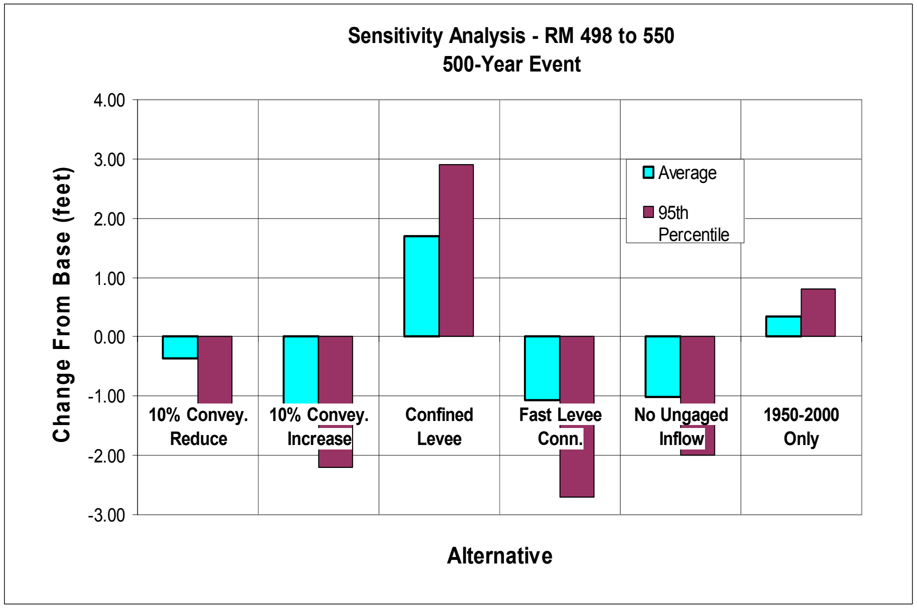

Sensitivity Analysis - Spline Curve at Section 557.96
Elevation (Feet NGVD 1929)
932
931
930
929
928
927
926
925
924
923
922
140,000
170,000
200,000
230,000
260,000
290,000
320,000
350,000
Flow (cfs)
Base Model
10% Conveyance Reduction
10% Conveyance Increase
Confined Levee
Fast Levee Connection
No Ungaged Inflow
1950-2000 Period Only with Flow Factoring

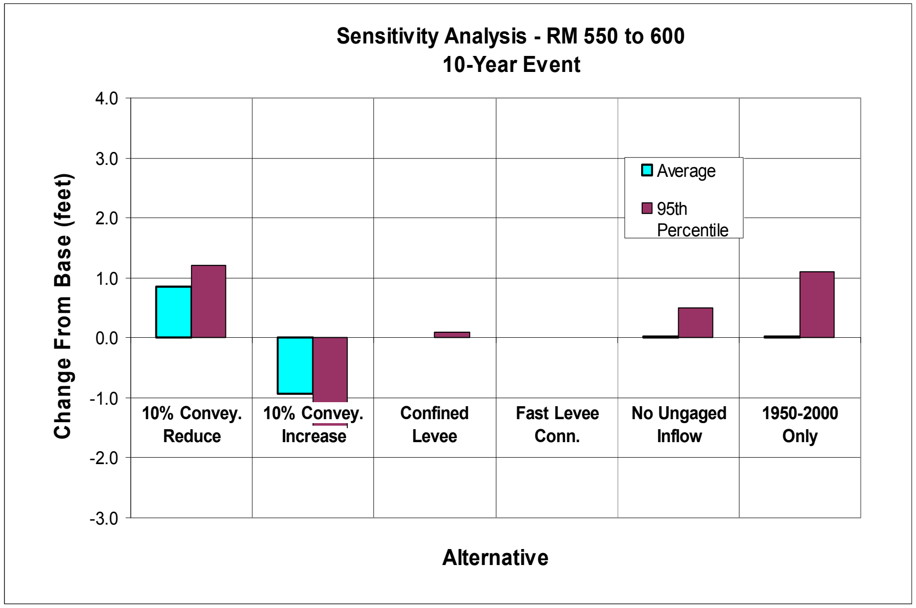

Sensitivity Analysis - Section 522.67
Elevation (Feet NGVD 1929)
894
893
892
891
890
889
888
887
886
885
Flow (cfs)
150,000.00
170,000.00
190,000.00
210,000.00
230,000.00
250,000.00
270,000.00
290,000.00
310,000.00
330,000.00
350,000.00
370,000.0
▲ Base Model
× 10% Conveyance Reduction
⋇ 10% Conveyance Increase
○ No Ungaged Inflow
◇ Confined Levee
◆ Fast Levee Connection
● 1950-2000 Period Only w ith Flow Factoring

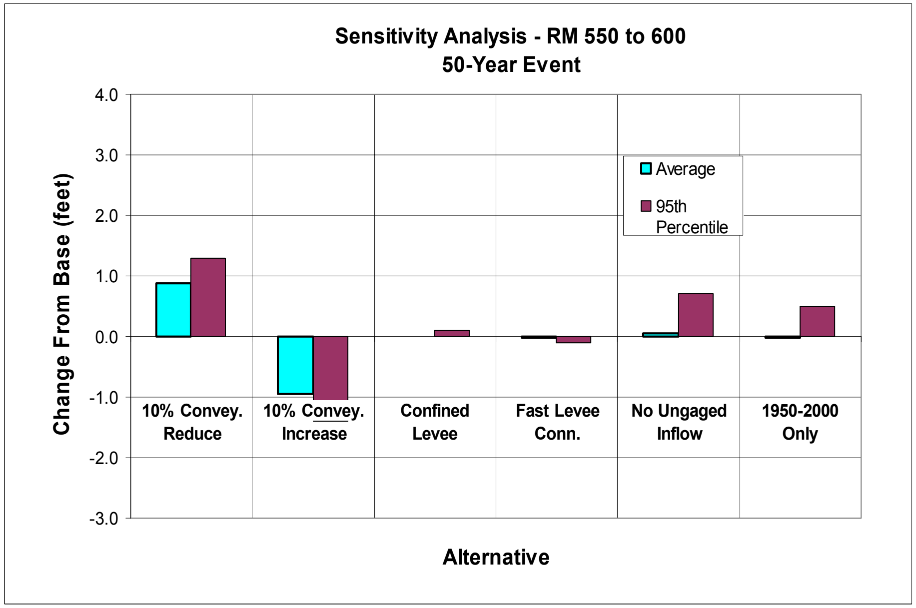

Sensitivity Analysis - RM 498 to 550
10-Year Event

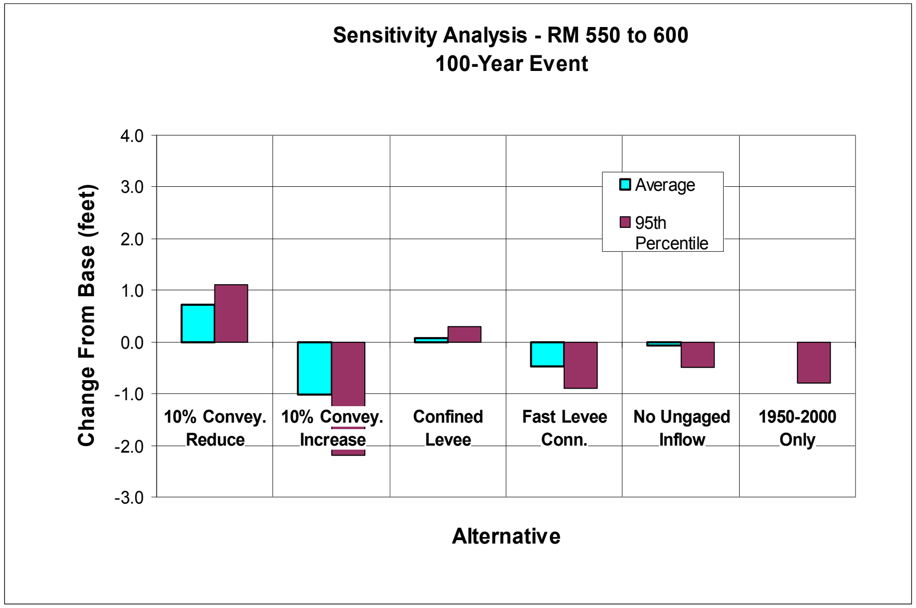

Sensitivity Analysis - RM 498 to 550
50-Year Event

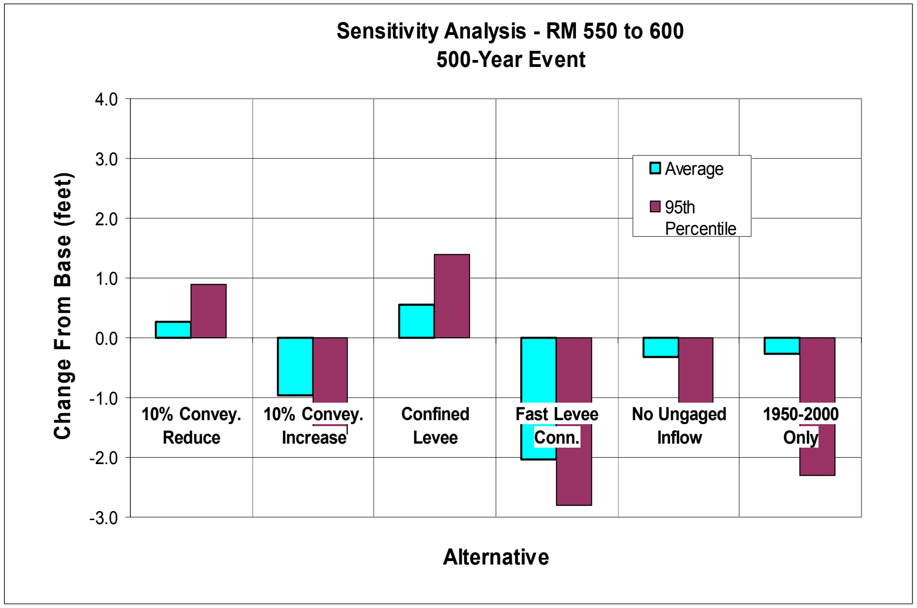

Sensitivity Analysis - RM 498 to 550
100-Year Event

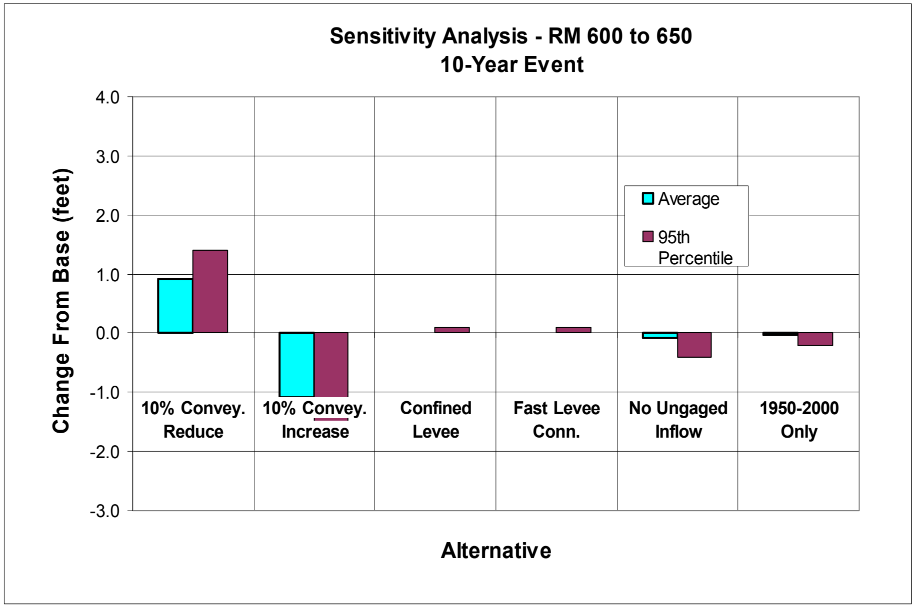

Sensitivity Analysis - RM 498 to 550
500-Year Event

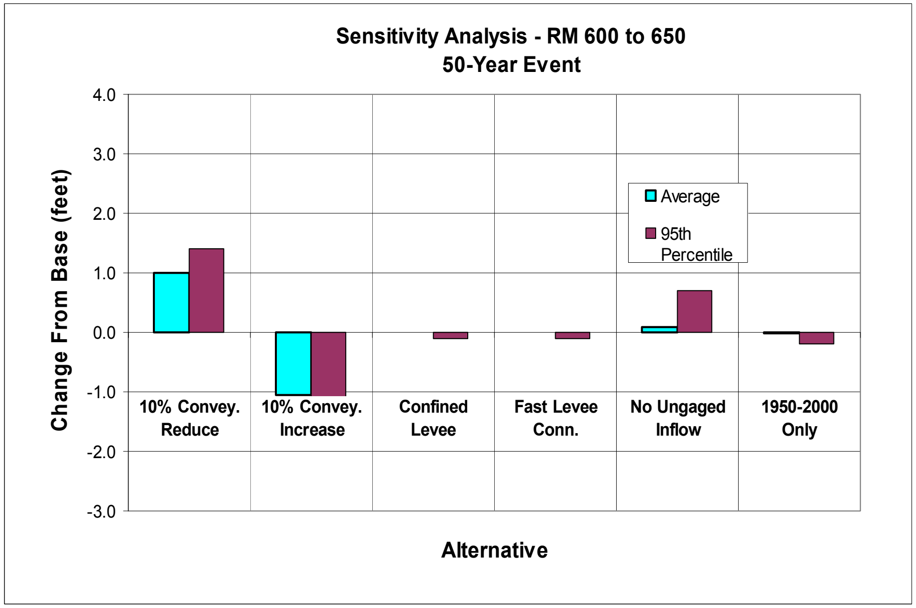

Sensitivity Analysis - RM 550 to 600
10-Year Event

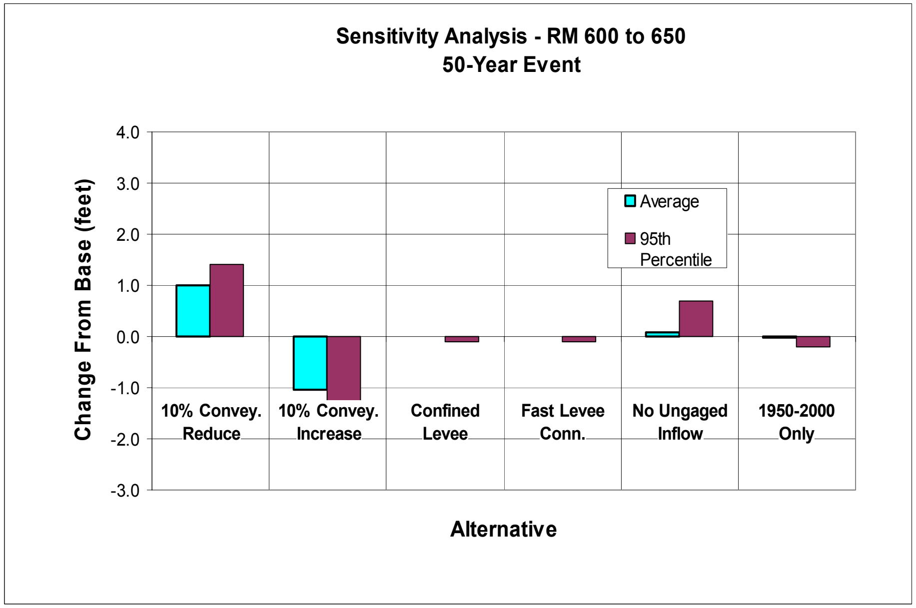

Sensitivity Analysis - RM 550 to 600
50-Year Event

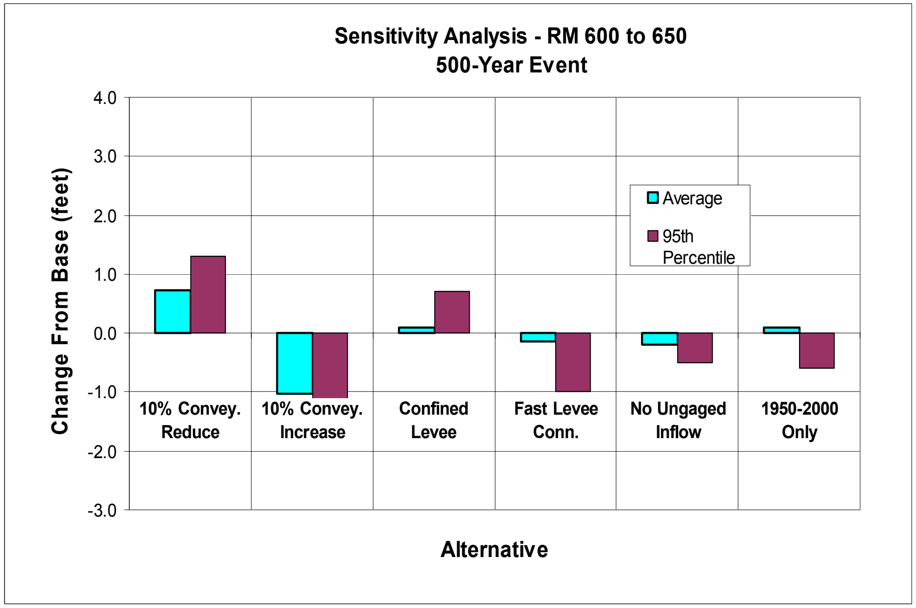

Sensitivity Analysis - RM 550 to 600
100-Year Event

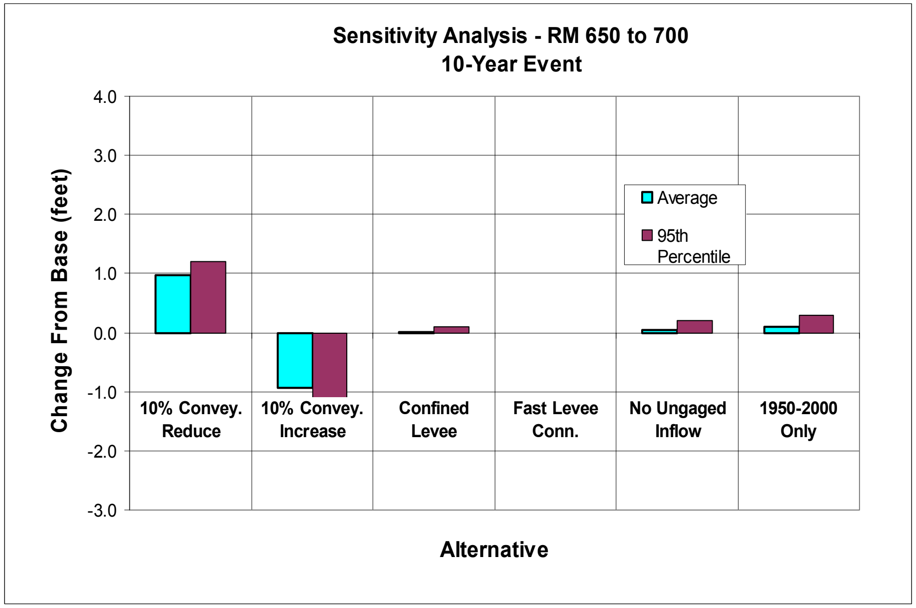

Sensitivity Analysis - RM 550 to 600
500-Year Event

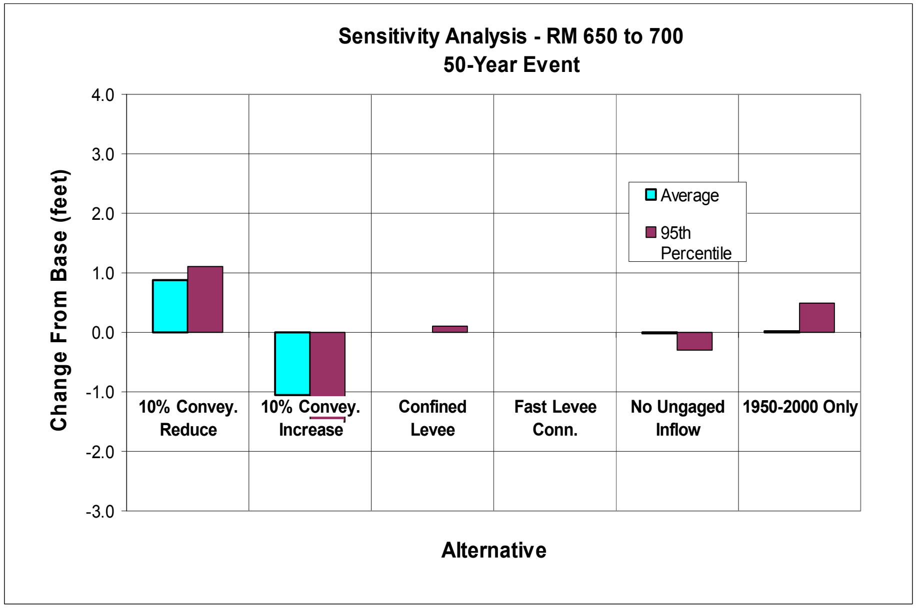

Sensitivity Analysis - RM 600 to 650
10-Year Event

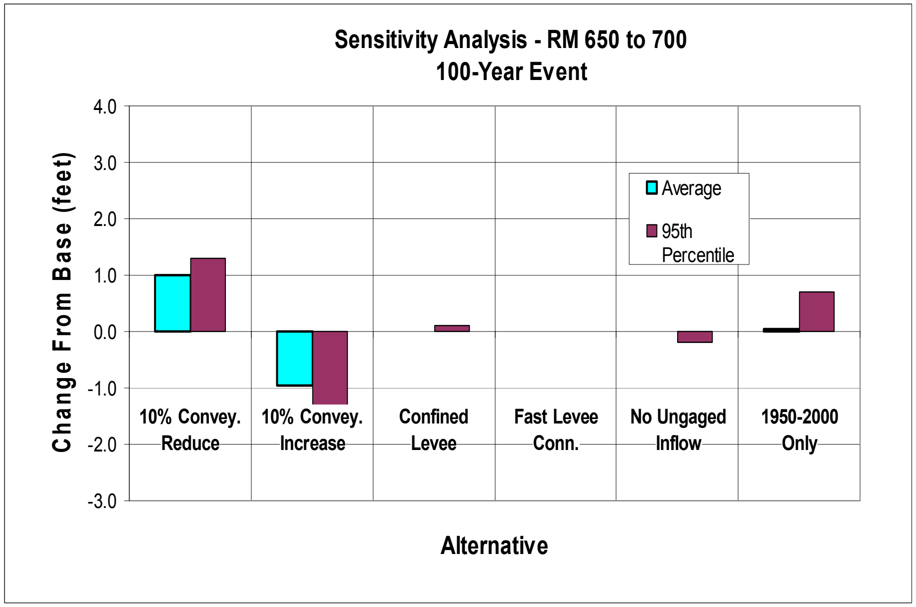

Sensitivity Analysis - RM 600 to 650
50-Year Event

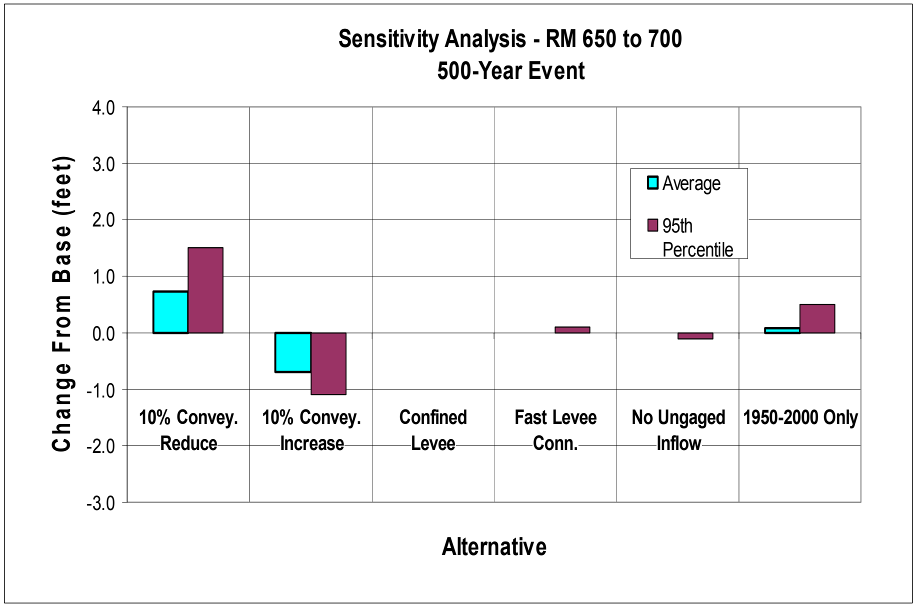

Sensitivity Analysis - RM 600 to 650
50-Year Event

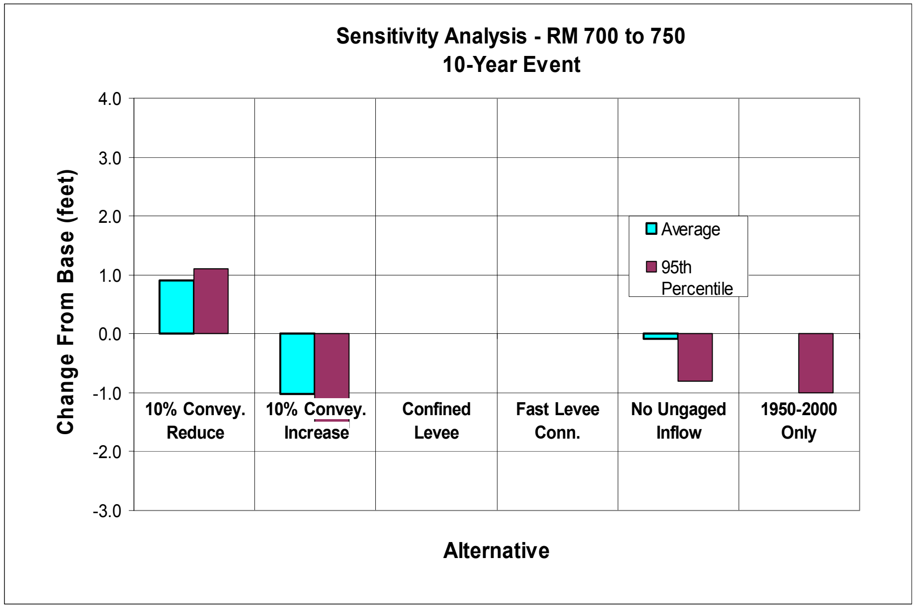

Sensitivity Analysis - RM 600 to 650
500-Year Event

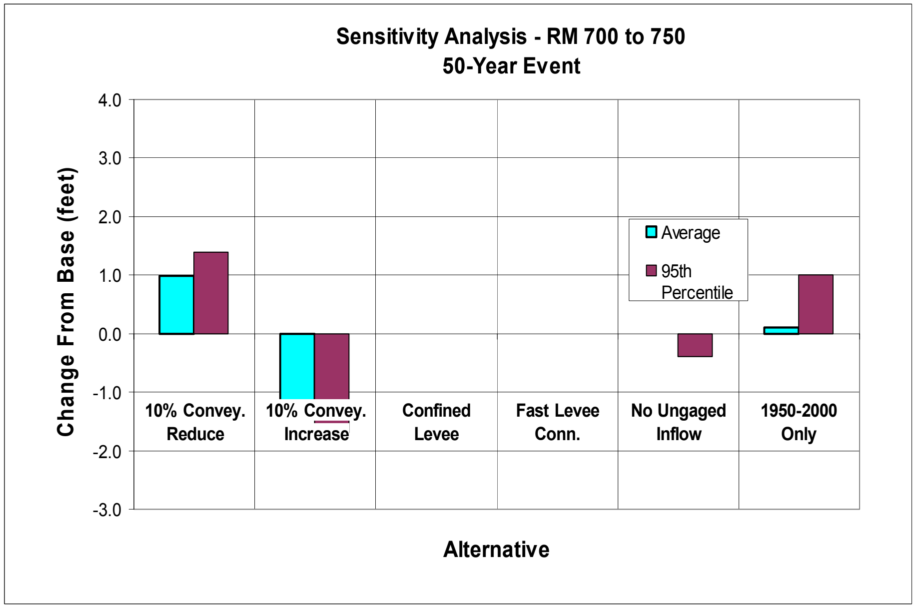

Sensitivity Analysis - RM 650 to 700
10-Year Event

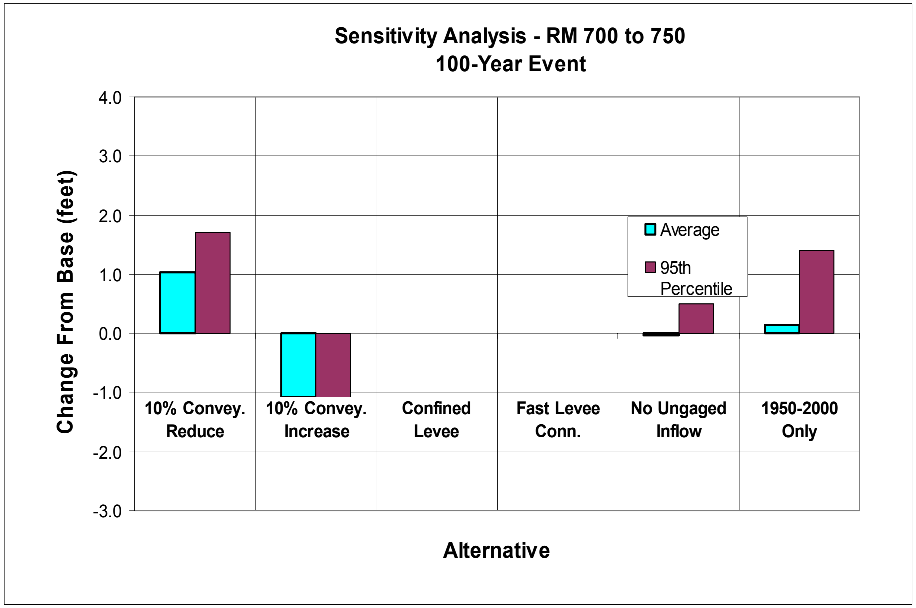

Sensitivity Analysis - RM 650 to 700
50-Year Event

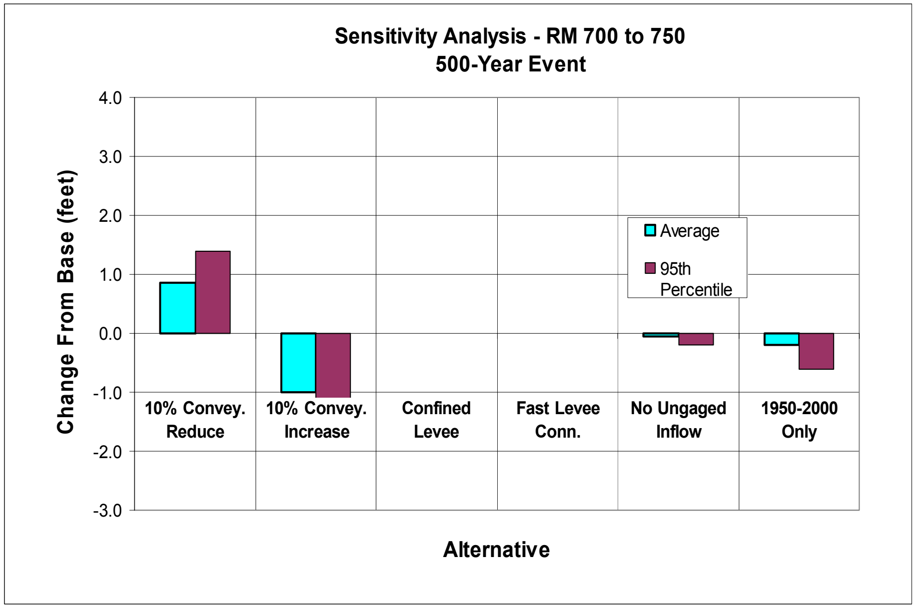

Sensitivity Analysis - RM 650 to 700
100-Year Event

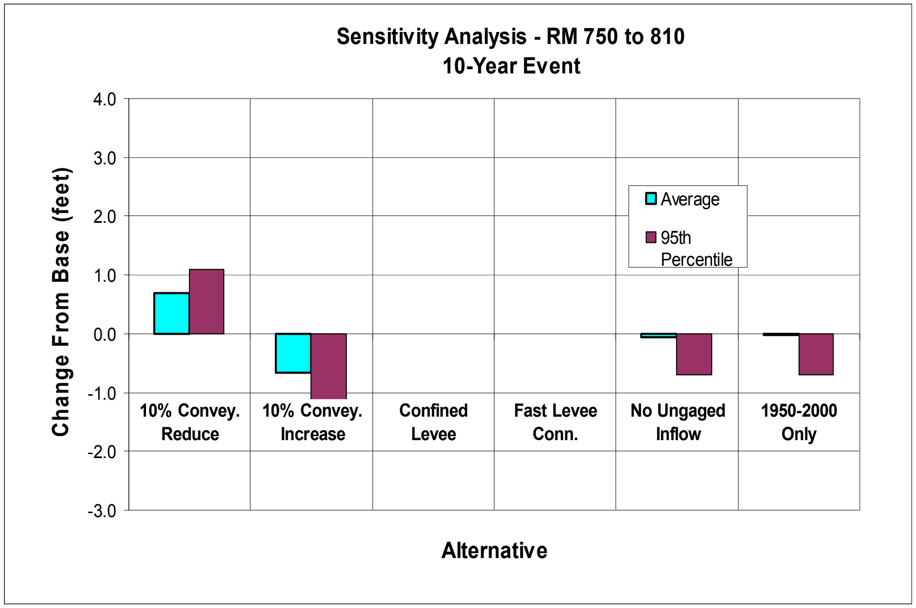

Sensitivity Analysis - RM 650 to 700
500-Year Event

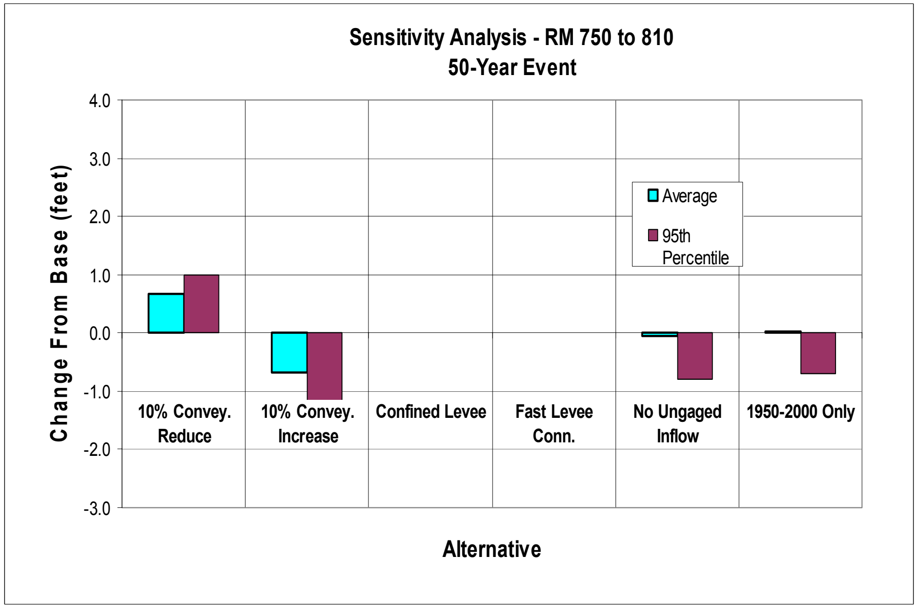

Sensitivity Analysis - RM 700 to 750
10-Year Event
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Change From Base (feet)
10% Convey. Reduce
10% Convey. Increase
Confined Levee
Fast Levee Conn.
No Ungaged Inflow
1950-2000 Only
Average
95th Percentile
Alternative

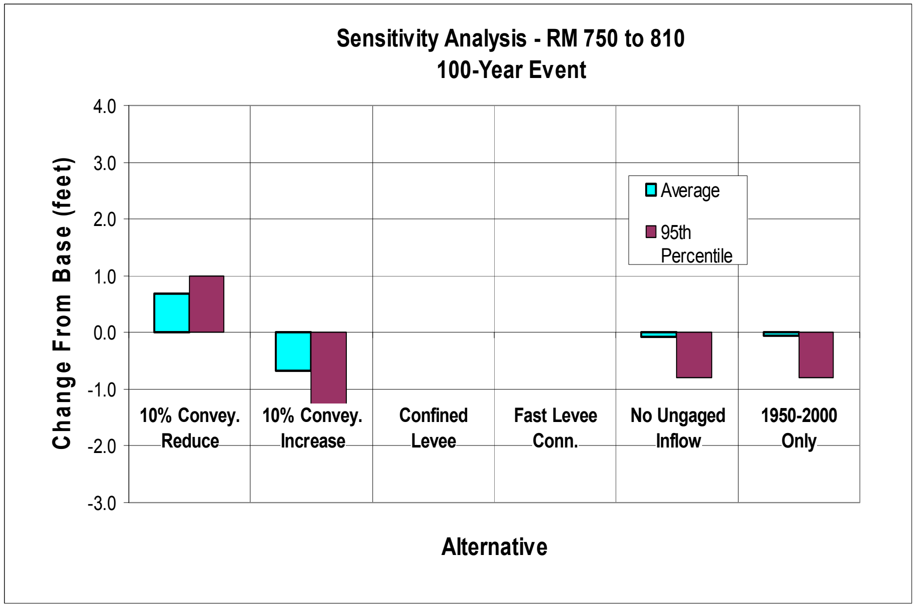

Sensitivity Analysis - RM 700 to 750
50-Year Event
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Change From Base (feet)
10% Convey. Reduce
10% Convey. Increase
Confined Levee
Fast Levee Conn.
No Ungaged Inflow
1950-2000 Only
Average
95th Percentile
Alternative

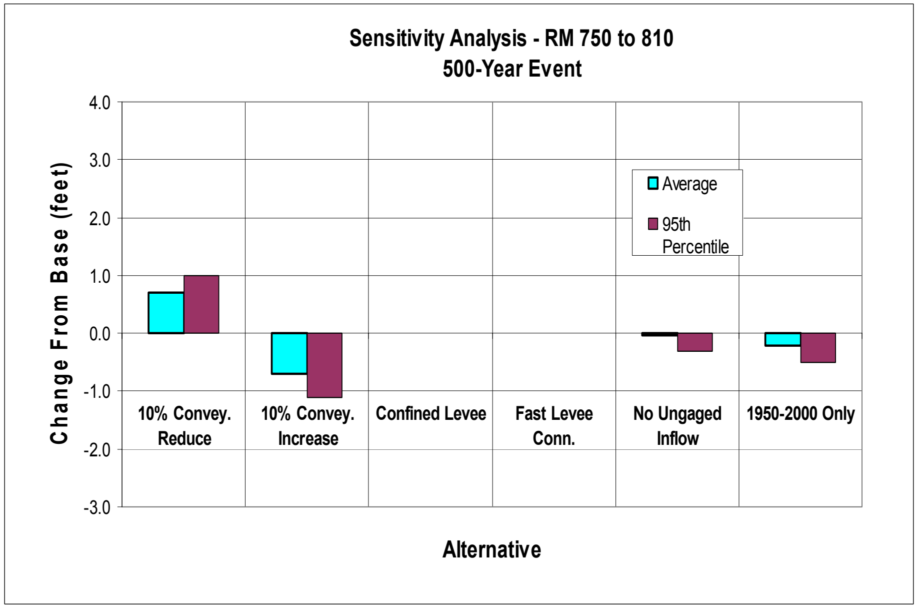

Sensitivity Analysis - RM 700 to 750
100-Year Event
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Change From Base (feet)
10% Convey. Reduce
10% Convey. Increase
Confined Levee
Fast Levee Conn.
No Ungaged Inflow
1950-2000 Only
Average
95th Percentile
Alternative


Sensitivity Analysis - RM 700 to 750
500-Year Event
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
Change From Base (feet)
10% Convey. Reduce
10% Convey. Increase
Confined Levee
Fast Levee Conn.
No Ungaged Inflow
1950-2000 Only
Average
95th Percentile
Alternative

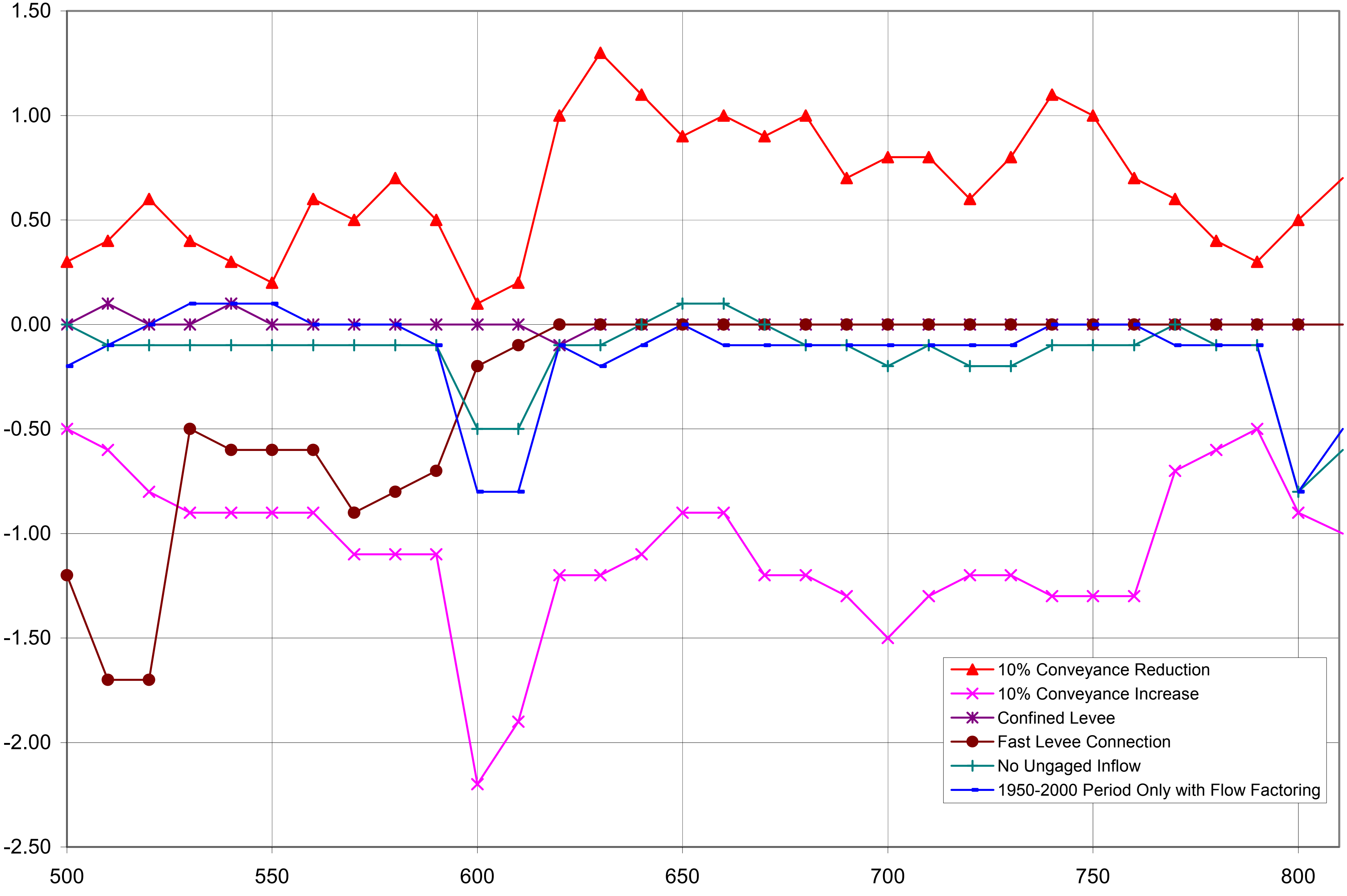

Sensitivity Analysis - RM 750 to 810
10-Year Event
Change From Base (feet)
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
10% Convey. Reduce
10% Convey. Increase
Confined Levee
Fast Levee Conn.
No Ungaged Inflow
1950-2000 Only
Average
95th Percentile
Alternative

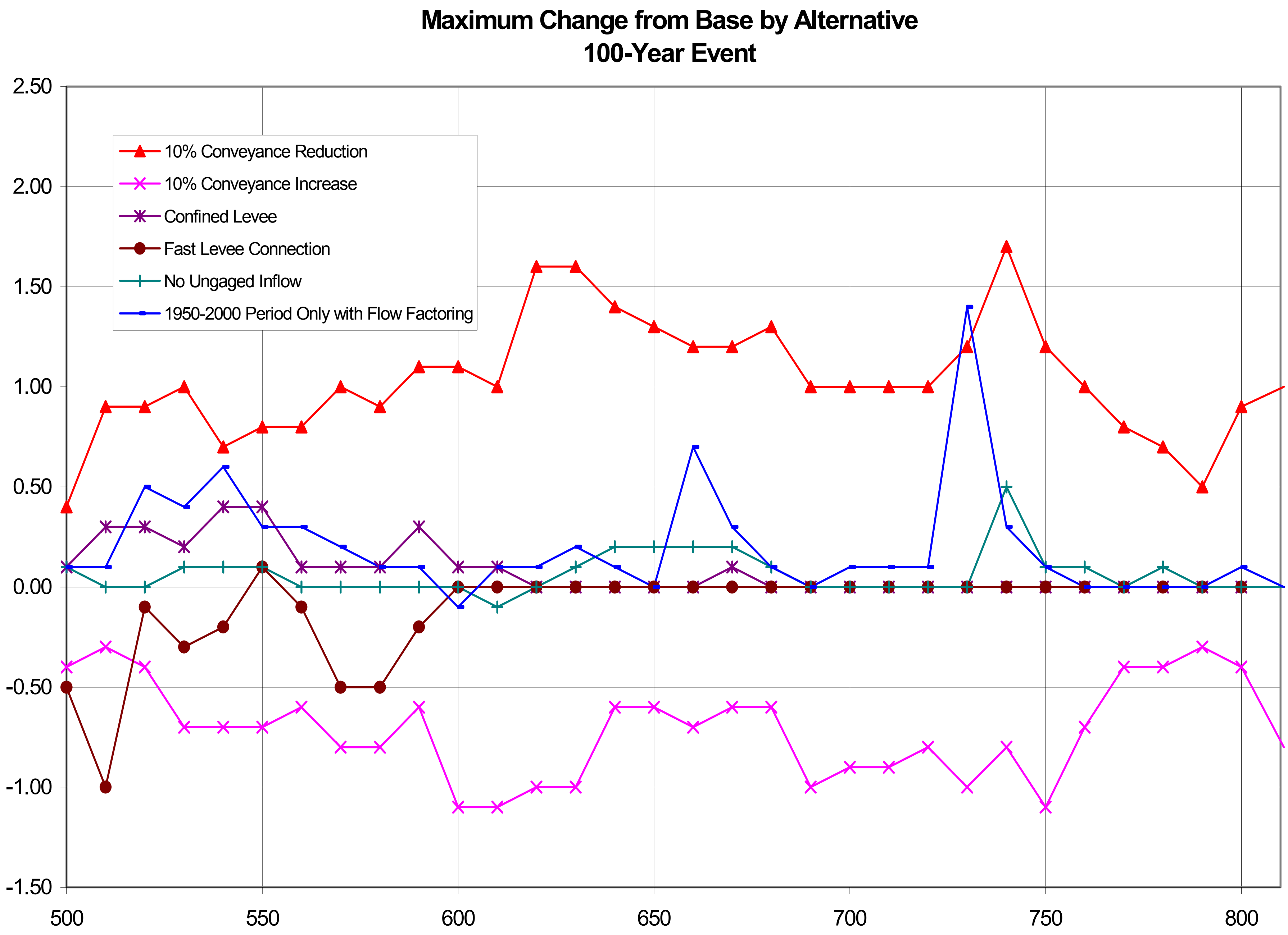

Sensitivity Analysis - RM 750 to 810
50-Year Event
Change From Base (feet)
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
10% Convey. Reduce
10% Convey. Increase
Confined Levee
Fast Levee Conn.
No Ungaged Inflow
1950-2000 Only
Average
95th Percentile
Alternative


Sensitivity Analysis - RM 750 to 810
100-Year Event
Change From Base (feet)
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
10% Convey. Reduce
10% Convey. Increase
Confined Levee
Fast Levee Conn.
No Ungaged Inflow
1950-2000 Only
Average
95th Percentile
Alternative

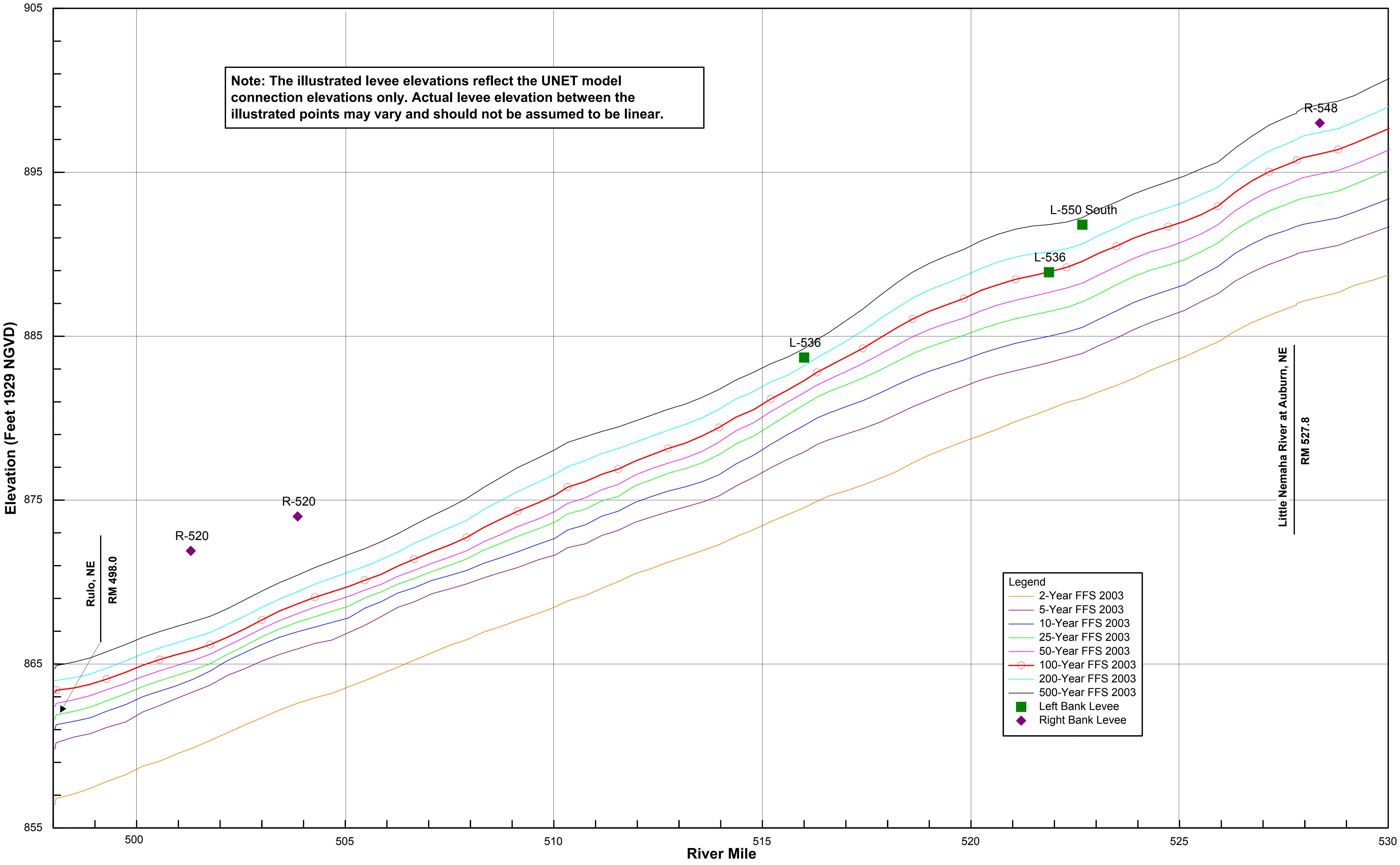

Sensitivity Analysis - RM 750 to 810
500-Year Event
Change From Base (feet)
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
-3.0
10% Convey. Reduce
10% Convey. Increase
Confined Levee
Fast Levee Conn.
No Ungaged Inflow
1950-2000 Only
Average
95th Percentile
Alternative

Minimum Change from Base by Alternative
100-Year Event

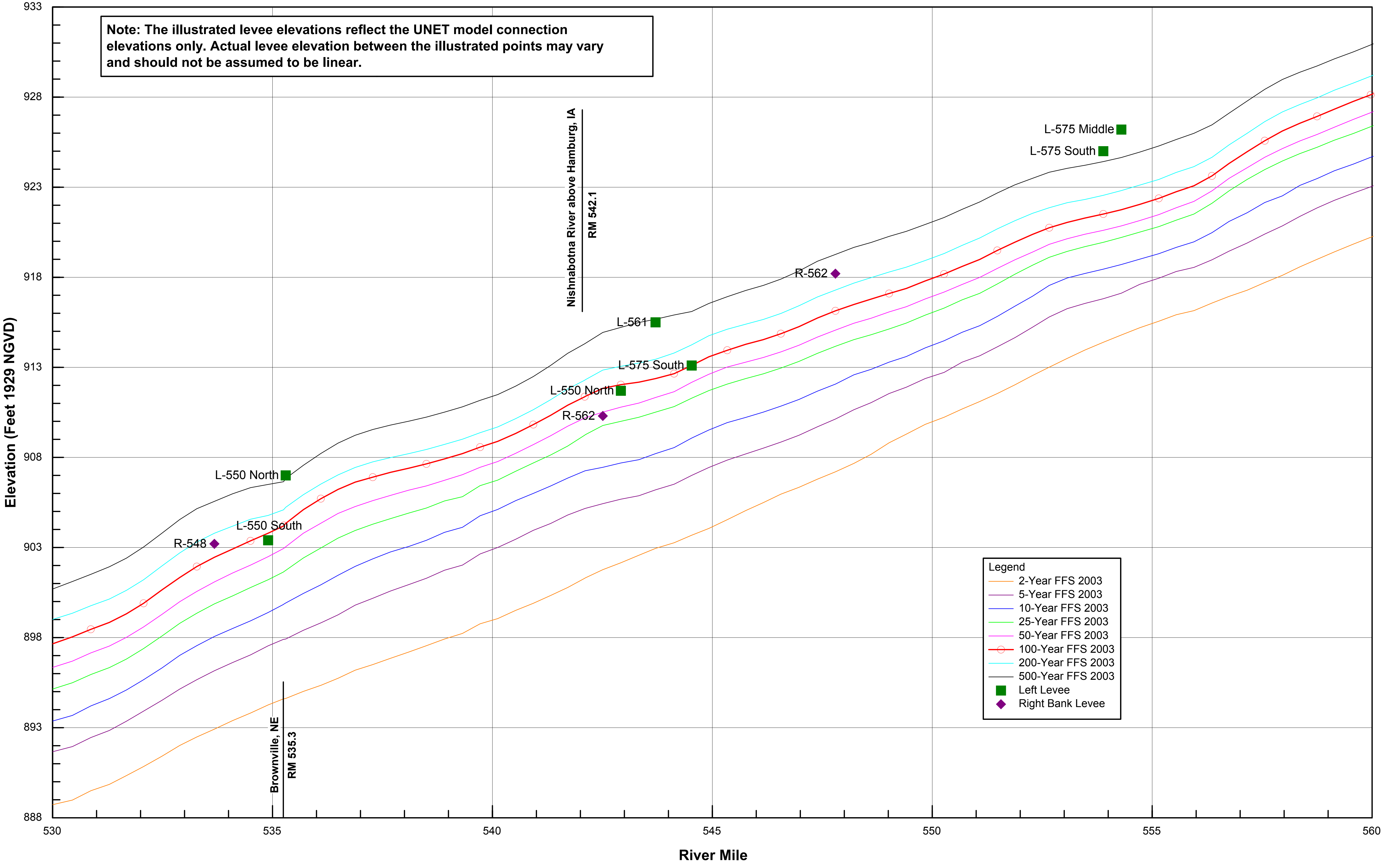



Maximum Change from Base by Alternative
100-Year Event
10% Conveyance Reduction
10% Conveyance Increase
Confined Levee
Fast Levee Connection
No Ungaged Inflow
1950-2000 Period Only with Flow Factoring
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
500
550
600
650
700
750
800

Missouri River Stage Frequency Profiles - River Mile 498-530



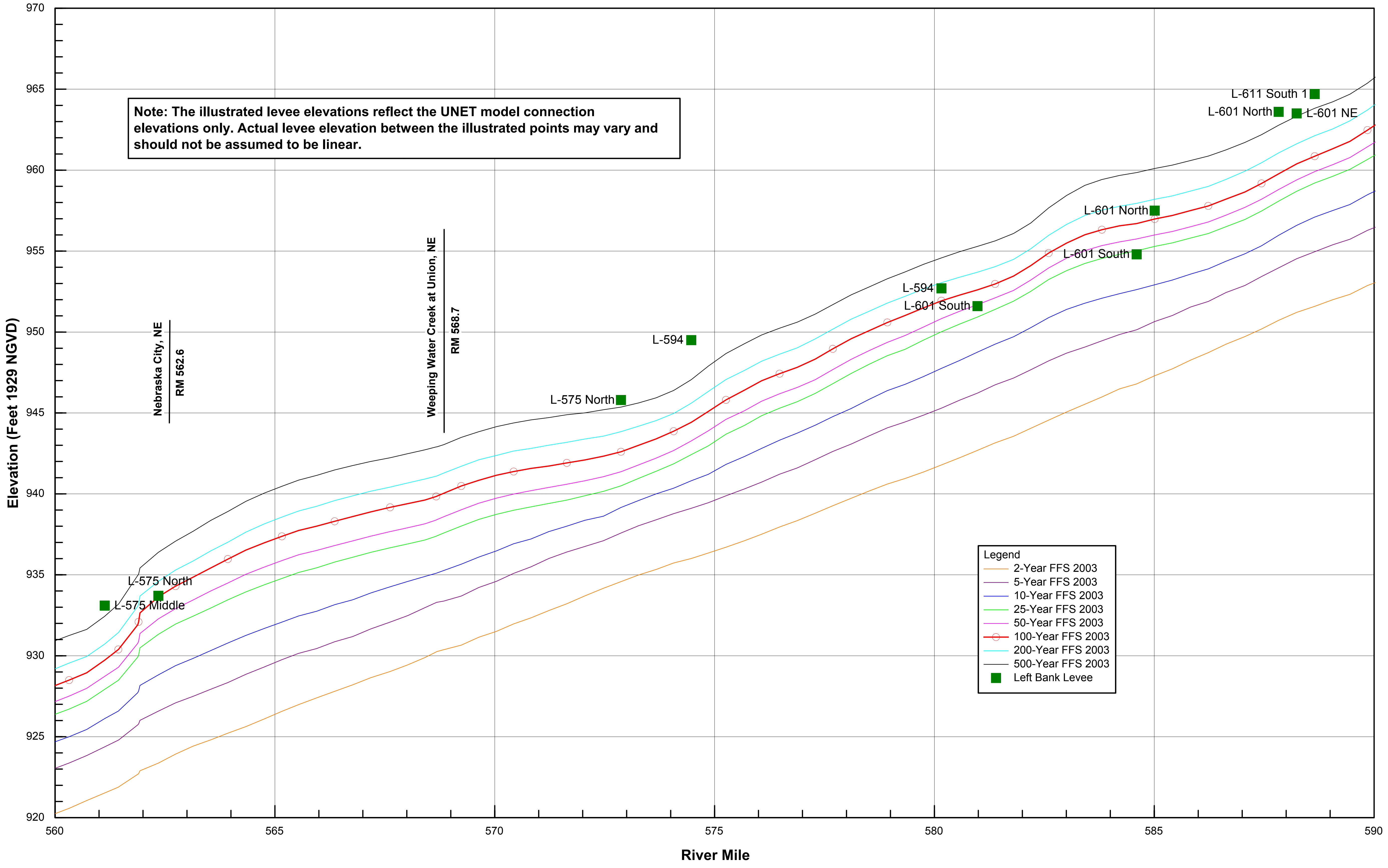
Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.



Missouri River Stage Frequency Profiles - River Mile 530-560

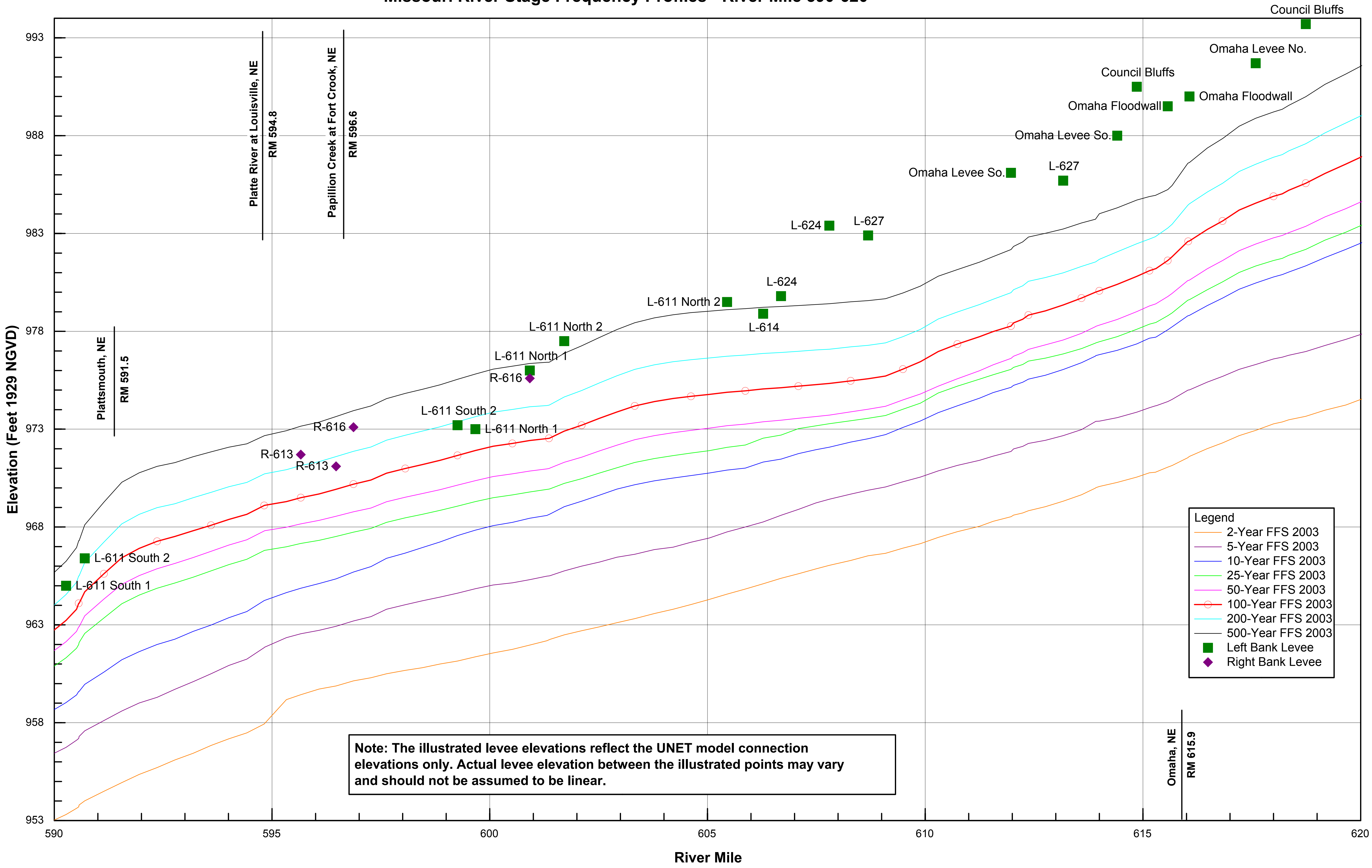
Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

Missouri River Stage Frequency Profiles - River Mile 560-590



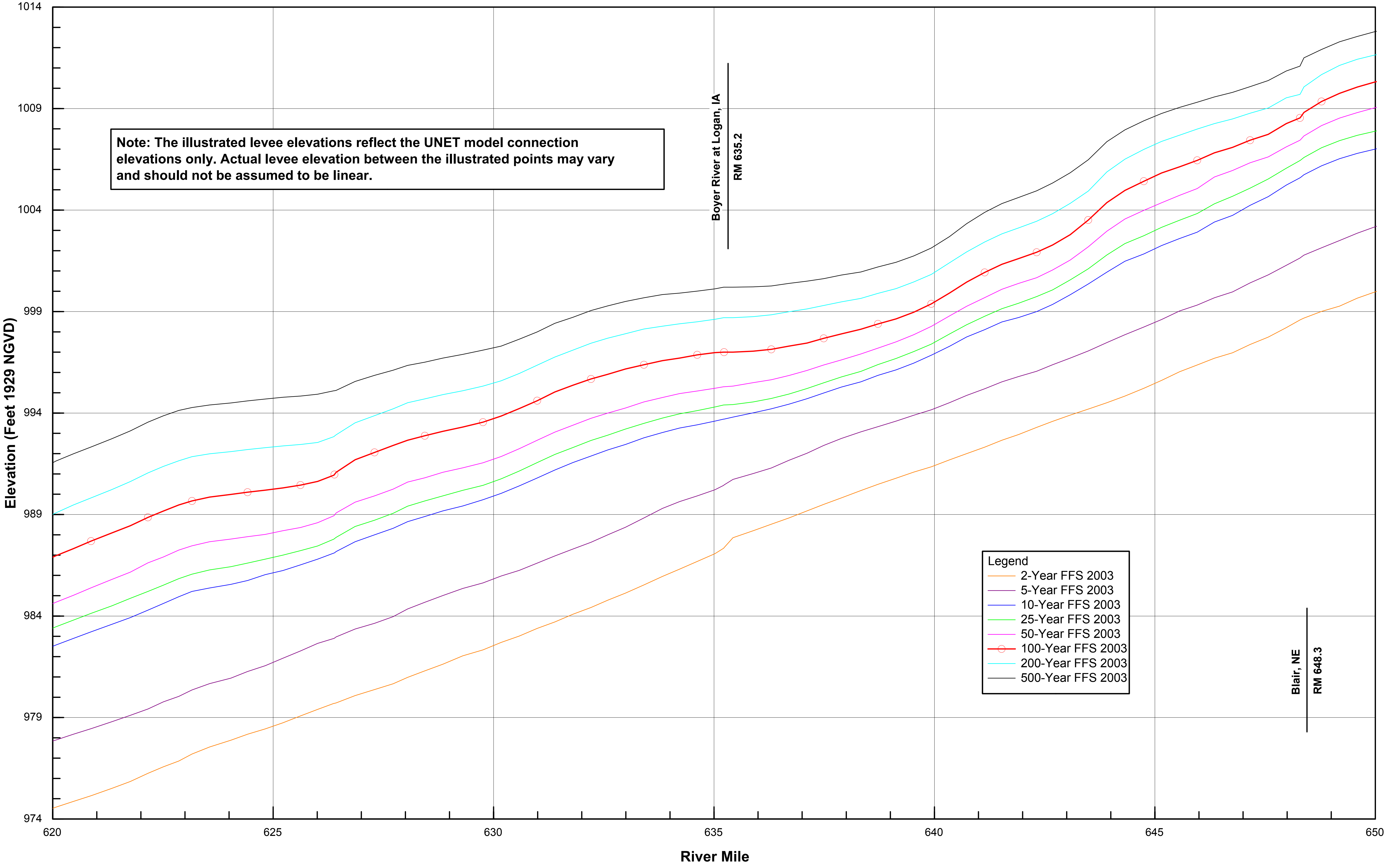
Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

Missouri River Stage Frequency Profiles - River Mile 590-620

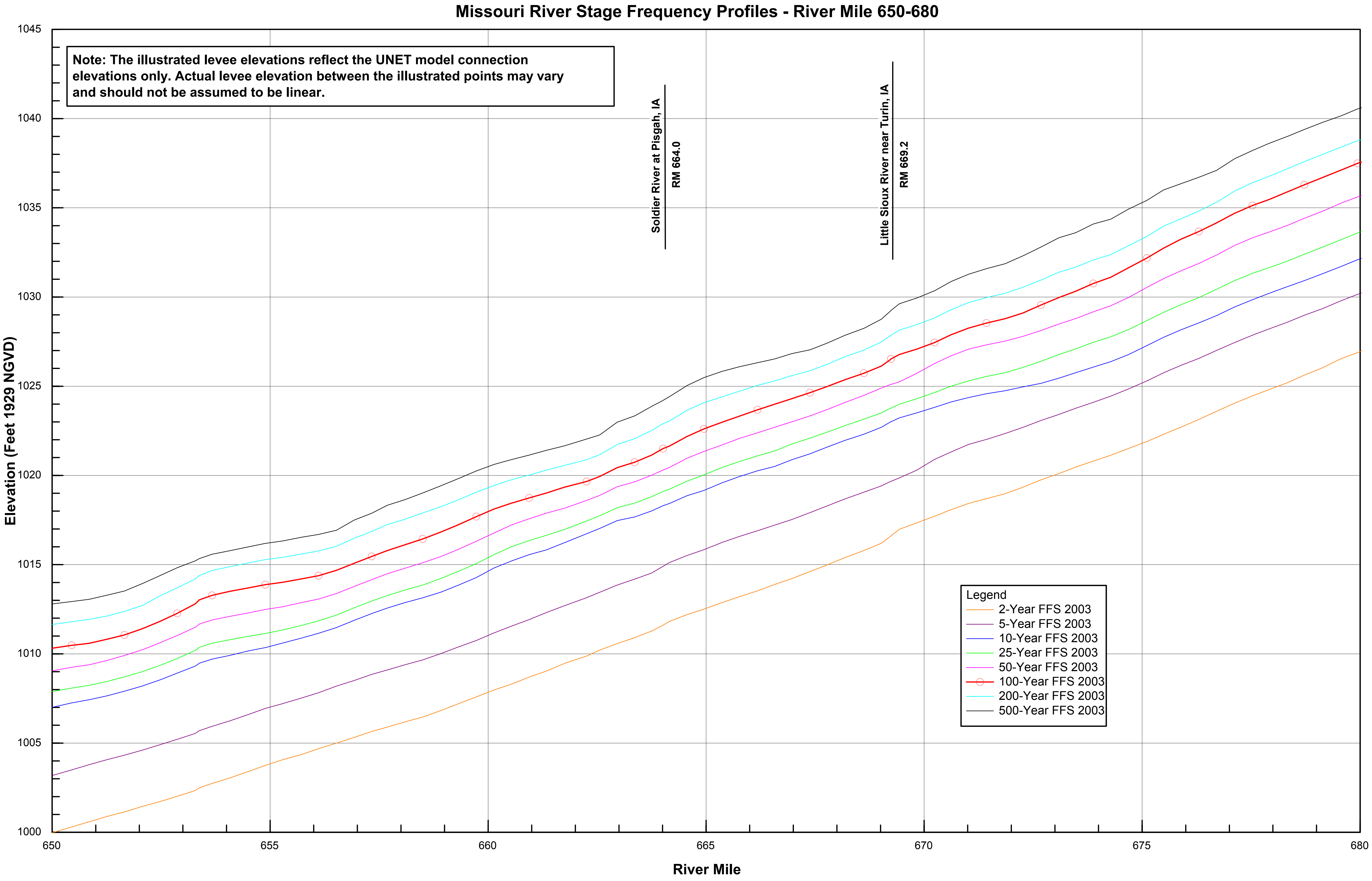


Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

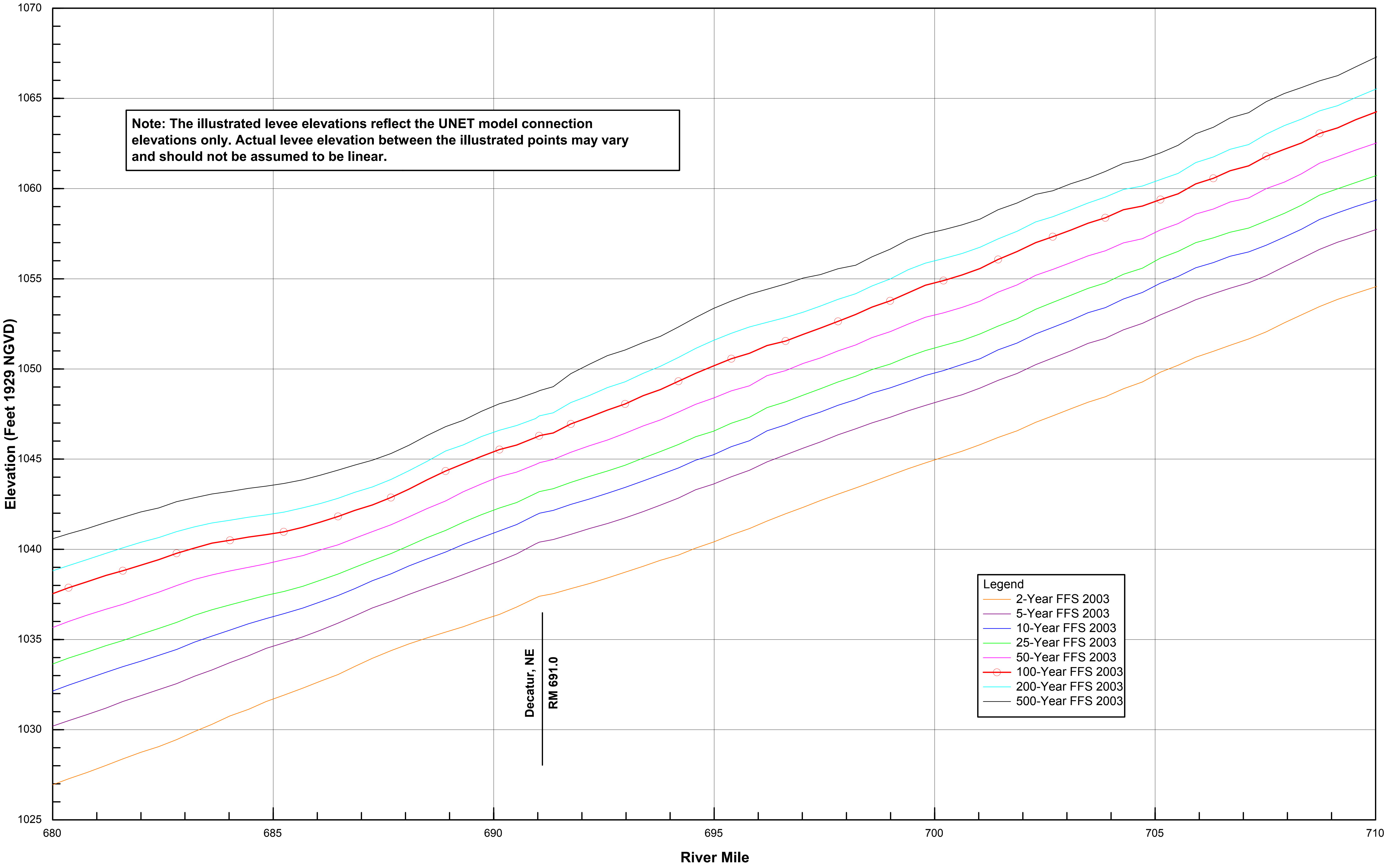
Missouri River Stage Frequency Profiles - River Mile 620-650



Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

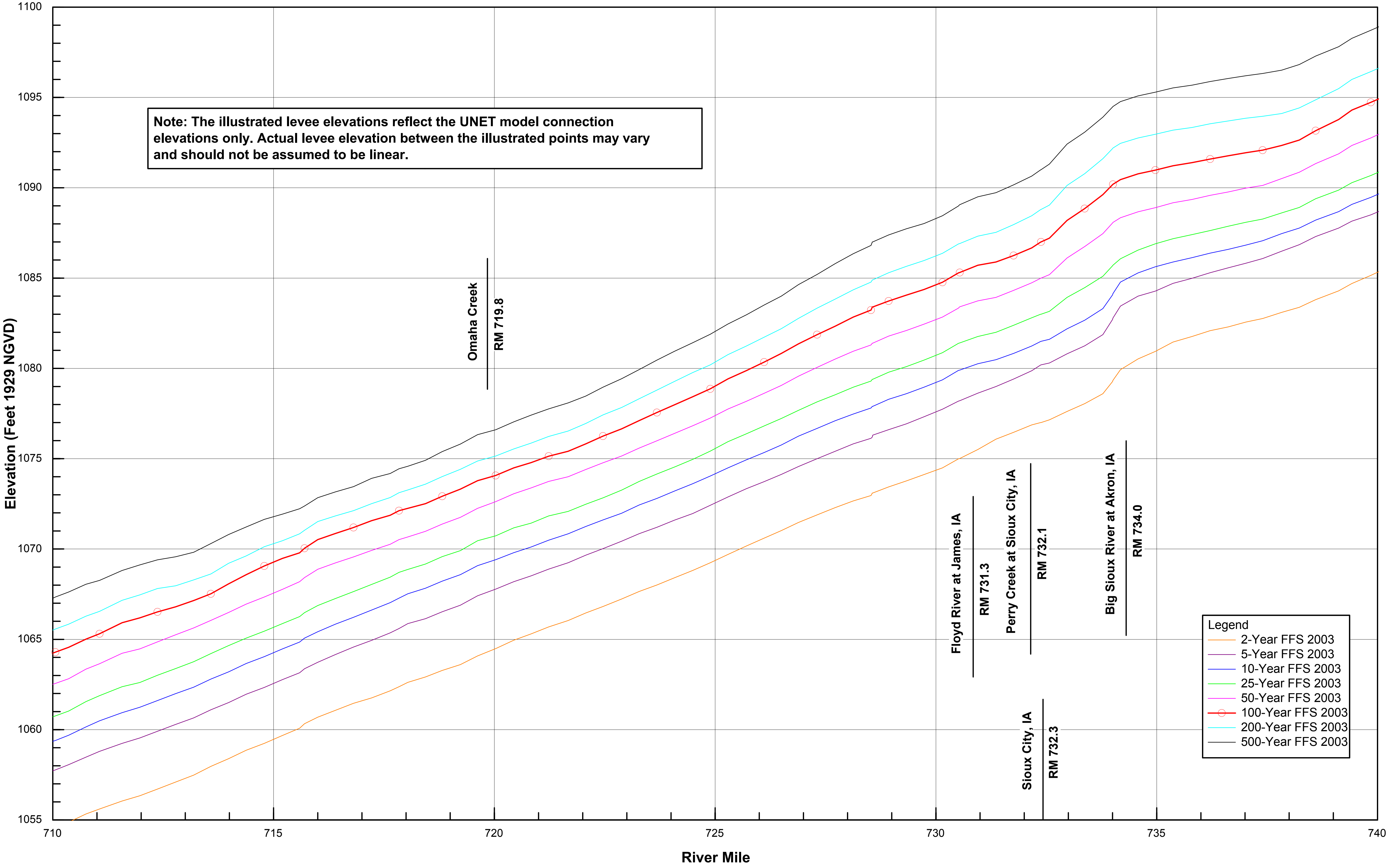

Missouri River Stage Frequency Profiles - River Mile 650-680
Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.
Soldier River at Pisgah, IA
RM 664.0
Little Sioux River near Turin, IA
RM 669.2
Elevation (Feet 1929 NGVD)
1045
1040
1035
1030
1025
1020
1015
1010
1005
1000
River Mile
650
655
660
665
670
675
680
Legend
2-Year FFS 2003
5-Year FFS 2003
10-Year FFS 2003
25-Year FFS 2003
50-Year FFS 2003
100-Year FFS 2003
200-Year FFS 2003
500-Year FFS 2003

Missouri River Stage Frequency Profiles - River Mile 680-710

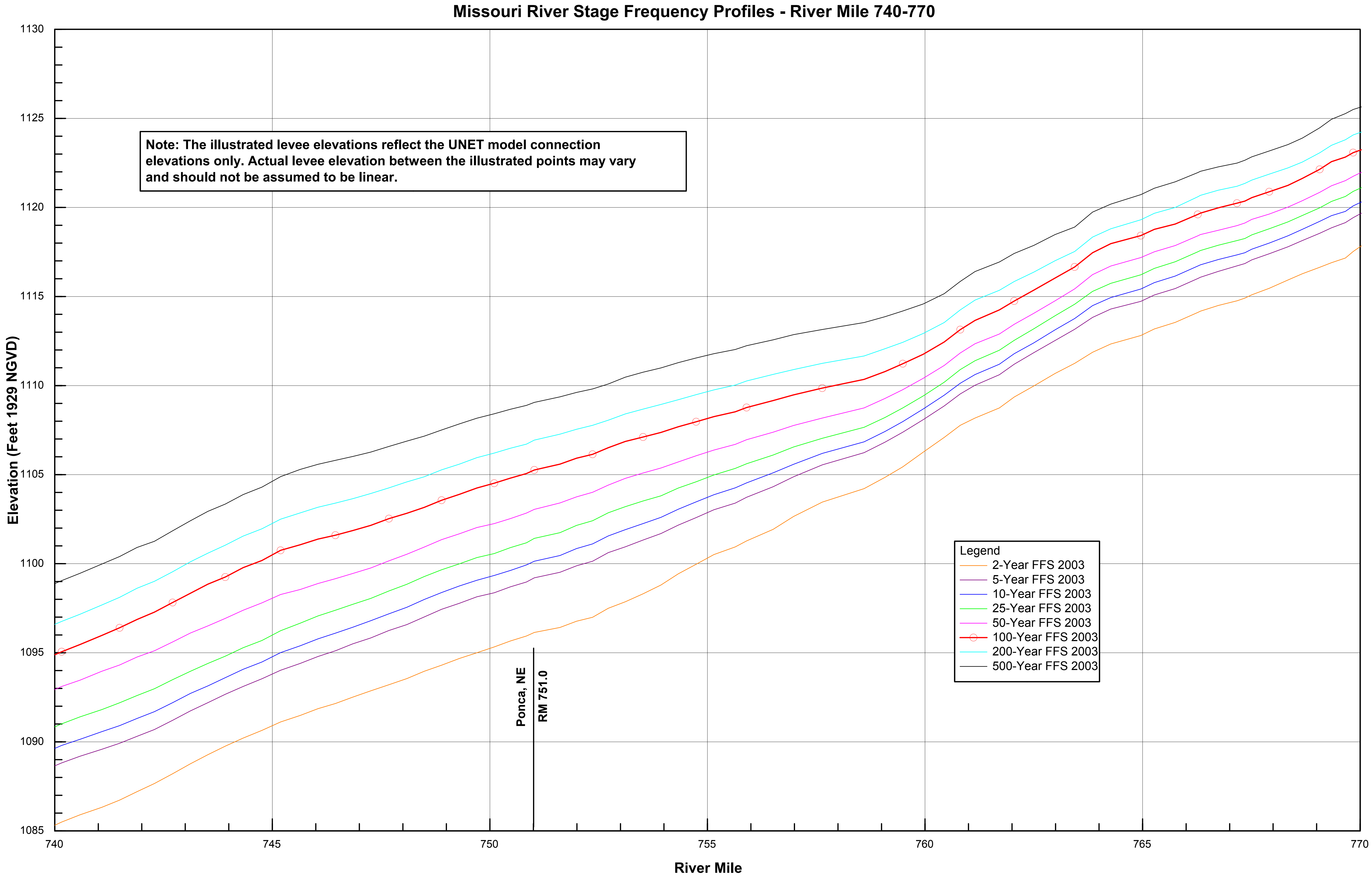


Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

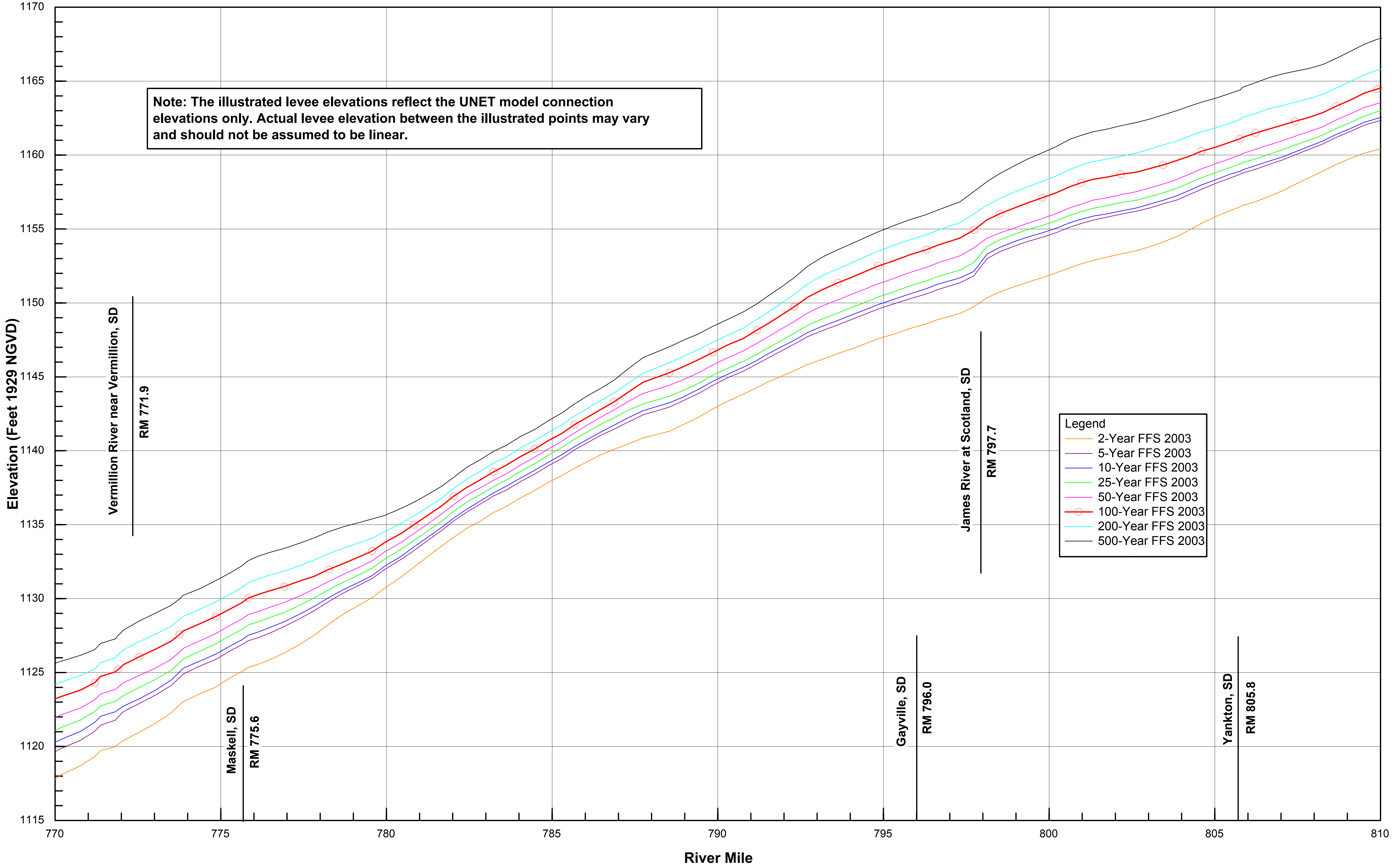
Missouri River Stage Frequency Profiles - River Mile 710-740



Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.


Missouri River Stage Frequency Profiles - River Mile 740-770
Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.
Elevation (Feet 1929 NGVD)
1130
1125
1120
1115
1110
1105
1100
1095
1090
1085
740
745
750
755
760
765
770
River Mile
Ponca, NE
RM 751.0
Legend
2-Year FFS 2003
5-Year FFS 2003
10-Year FFS 2003
25-Year FFS 2003
50-Year FFS 2003
100-Year FFS 2003
200-Year FFS 2003
500-Year FFS 2003

Missouri River Stage Frequency Profiles - River Mile 770-810


Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
Rulo NE	498	94,700	856.4	132,300	859.8	160,900	860.5	188,600	861.6	217,300	862.4	252,200	863.3	296,900	864.0	370,700	864.7
	499		857.5		860.9		861.8		862.5		863.2		863.9		864.5		865.5
	500		858.6		861.9		862.8		863.5		864.1		864.8		865.5		866.5
	501		859.6		862.9		863.7		864.3		864.9		865.6		866.3		867.3
	502		860.6		864.1		864.9		865.3		865.9		866.4		867.2		868.2
	503		861.7		865.2		866.2		866.7		867.2		867.7		868.5		869.5
	504		862.7		866.0		867.1		867.7		868.2		868.8		869.6		870.6
	505		863.5		866.8		867.8		868.5		869.1		869.7		870.5		871.6
	506		864.5		868.1		869.0		869.6		870.0		870.6		871.5		872.6
	507		865.6		869.2		870.0		870.6		871.1		871.8		872.8		873.9
Tarkio River	507.6	94,600		132,100		160,600		188,600		217,100		251,900		296,500		370,200	
	508	93,700	866.6	130,200	870.0	159,100	870.8	188,800	871.5	215,600	872.0	249,800	872.9	293,600	873.9	366,700	875.2
	509		867.5		870.8		871.7		872.7		873.2		874.2		875.3		876.8
	510		868.5		871.6		872.6		873.6		874.3		875.3		876.5		878.0
	511		869.5		872.6		873.8		874.8		875.5		876.4		877.7		879.1
	512		870.5		873.7		874.9		875.9		876.6		877.4		878.6		879.9
	513		871.4		874.5		875.7		876.8		877.5		878.4		879.5		880.7
	514		872.3		875.3		876.6		877.8		878.6		879.5		880.6		881.8
	515		873.4		876.7		878.1		879.2		880.1		880.9		881.9		883.1
	516		874.5		877.9		879.6		880.8		881.6		882.3		883.2		884.2
	517		875.6		879.0		880.7		882.0		882.8		883.7		884.7		885.9
	518		876.5		880.0		881.8		883.2		884.1		885.2		886.4		887.8
	519		877.7		881.1		882.9		884.3		885.4		886.5		887.8		889.4
	520		878.7		882.1		883.7		885.2		886.3		887.5		888.9		890.5
	521		879.7		882.9		884.5		886.0		887.1		888.4		889.8		891.5
Rock Creek	522.2	93,700		130,200		159,100		188,800		215,600		249,800		293,600		366,700	

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
	523	93,400	881.5	129,700	884.3	158,800	886.0	188,800	887.5	215,200	888.7	249,300	890.0	292,900	891.1	365,900	892.7
	524		882.5		885.5		887.2		888.7		889.8		891.1		892.2		893.8
	525		883.6		886.5		888.0		889.6		890.7		891.9		893.1		894.7
	526		884.8		887.7		889.4		890.8		892.0		893.1		894.3		895.8
	527		886.1		889.2		891.0		892.5		893.7		894.8		896.1		897.6
Little Nemaha	527.8	93,400		129,700		158,800		188,800		215,200		249,300		292,900		365,900	
	528	92,100	887.2	127,100	890.1	156,600	891.8	189,100	893.4	213,100	894.7	246,300	895.9	288,900	897.2	361,000	898.9
	529		887.9		890.7		892.4		894.1		895.3		896.6		897.9		899.5
	530		888.7		891.7		893.4		895.1		896.3		897.6		899.0		900.7
	531		889.6		892.6		894.3		896.1		897.3		898.6		899.9		901.6
	532		890.8		893.8		895.6		897.3		898.5		899.8		901.1		902.9
	533		892.1		895.3		897.2		899.0		900.2		901.5		902.9		904.7
	534		893.3		896.5		898.4		900.2		901.5		902.8		904.1		905.9
	535		894.4		897.6		899.5		901.3		902.6		903.9		904.9		906.5
Brownville, NE	535.3	92,100	894.6	127,100	897.9	156,600	899.9	189,100	901.7	213,100	903.0	246,300	904.3	288,900	905.2	361,000	906.8
	536		895.3		898.7		900.8		902.8		904.2		905.6		906.4		908.1
	537		896.3		899.9		902.1		904.0		905.4		906.7		907.5		909.3
	538		897.1		900.9		903.0		904.8		906.1		907.3		908.2		910.0
	539		898.0		901.8		903.9		905.6		906.8		908.0		908.8		910.6
	540		899.0		902.9		905.0		906.6		907.7		908.8		909.6		911.4
	541		900.0		904.0		906.1		907.8		908.8		909.9		910.7		912.6
	542		901.2		905.1		907.2		909.1		910.1		911.3		912.2		914.2
Nishnabotna River	542.1	92,100		127,100		156,600		189,100		213,100		246,300		288,900		361,000	
	543	88,000	902.2	118,700	905.7	149,800	907.7	189,900	910.0	206,400	910.8	236,700	912.1	275,900	913.1	345,400	915.3
	544		903.2		906.4		908.4		910.7		911.5		912.6		913.7		915.8

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)																	
		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
	545		904.1		907.5		909.6		911.8		912.7		913.7		914.8		916.6
	546		905.3		908.4		910.4		912.5		913.4		914.4		915.6		917.4
	547		906.4		909.3		911.3		913.4		914.3		915.3		916.5		918.4
	548		907.4		910.4		912.3		914.3		915.3		916.3		917.5		919.5
	549		908.8		911.5		913.3		915.1		916.1		917.1		918.3		920.3
	550		910.0		912.5		914.2		916.0		916.9		917.9		919.1		921.1
	551		911.0		913.6		915.2		917.0		917.9		918.9		920.1		922.1
	552		912.2		914.8		916.6		918.3		919.1		920.1		921.3		923.2
	553		913.4		916.2		917.9		919.4		920.1		921.0		922.1		924.0
	554		914.5		916.9		918.5		920.0		920.7		921.6		922.6		924.5
	555		915.4		917.8		919.2		920.7		921.4		922.3		923.3		925.2
	556		916.2		918.6		920.0		921.6		922.3		923.1		924.2		926.1
	557		917.1		919.7		921.4		923.2		923.8		924.7		925.7		927.5
	558		918.2		920.9		922.6		924.5		925.2		926.2		927.2		929.0
	559		919.3		922.1		923.8		925.5		926.2		927.2		928.2		930.0
	560		920.2		923.0		924.7		926.4		927.2		928.2		929.2		930.9
	561		921.4		924.2		925.9		927.7		928.5		929.5		930.5		932.2
	562		923.0		926.1		928.3		930.6		931.5		932.8		933.8		935.6
Nebraska City, NE	562.6	88,000	923.7	118,700	926.9	149,800	929.2	189,900	931.7	206,400	932.7	236,700	934.1	275,900	935.0	345,400	936.8
	563		924.2		927.4		929.7		932.3		933.3		934.7		935.7		937.5
	564		925.3		928.4		930.9		933.5		934.6		936.1		937.1		939.0
	565		926.4		929.6		931.9		934.6		935.7		937.2		938.4		940.3
	566		927.4		930.5		932.8		935.5		936.5		938.0		939.3		941.2
	567		928.5		931.5		933.7		936.3		937.3		938.8		940.0		941.9
	568		929.4		932.5		934.6		936.9		937.9		939.4		940.7		942.5

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
Weeping Water Creek	568.7	88,000		118,600		149,700		189,900		206,300		236,600		275,800		345,300	
	569	87,900	930.5	118,400	933.5	149,600	935.4	189,500	937.8	206,000	938.8	236,300	940.2	275,400	941.5	344,700	943.2
	570		931.5		934.6		936.4		938.7		939.7		941.1		942.4		944.1
	571		932.5		935.7		937.4		939.3		940.3		941.6		942.9		944.6
	572		933.6		936.7		938.3		939.9		940.8		942.1		943.4		945.0
	573		934.7		937.7		939.3		940.6		941.5		942.7		944.0		945.4
	574		935.7		938.7		940.3		941.8		942.6		943.8		944.9		946.3
	575		936.5		939.6		941.4		943.2		944.1		945.3		946.6		948.2
	576		937.4		940.7		942.7		944.7		945.6		946.9		948.1		949.7
	577		938.5		941.7		943.9		945.8		946.7		948.0		949.2		950.8
	578		939.6		943.0		945.1		947.3		948.2		949.4		950.6		952.1
	579		940.7		944.1		946.4		948.6		949.4		950.7		951.9		953.4
	580		941.6		945.1		947.6		949.8		950.6		951.8		952.9		954.4
	581		942.7		946.3		948.8		950.9		951.7		952.6		953.7		955.3
	582		943.8		947.4		950.0		952.2		952.9		953.8		954.8		956.4
	583		945.1		948.7		951.4		953.8		954.6		955.5		956.6		958.4
	584		946.2		949.6		952.2		954.7		955.5		956.4		957.6		959.5
	585		947.3		950.6		952.9		955.3		956.0		957.0		958.2		960.1
	586		948.5		951.7		953.7		955.9		956.6		957.6		958.8		960.7
	587		949.7		952.8		954.8		956.9		957.6		958.6		959.9		961.6
Watkins Ditch	587.5	87,900		118,400		149,600		189,500		206,000		236,300		275,400		344,700	
	588	87,800	950.9	118,300	954.2	149,500	956.2	189,300	958.3	205,800	959.1	236,100	960.0	275,200	961.3	344,400	963.0
	589		951.9		955.3		957.4		959.6		960.3		961.3		962.5		964.2
	590		953.0		956.4		958.7		960.9		961.7		962.7		964.0		965.7
	591		954.3		957.9		960.4		963.1		964.0		965.3		966.9		968.9

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
Plattsmouth, NE	591.5	87,800	954.9	118,300	958.5	149,500	961.1	189,300	964.0	205,800	965.0	236,100	966.3	275,200	968.0	344,400	970.2
	592		955.4		959.0		961.7		964.6		965.6		967.0		968.7		970.8
	593		956.3		959.9		962.5		965.3		966.3		967.7		969.4		971.5
	594		957.2		960.9		963.4		966.1		967.1		968.4		970.1		972.1
Platte River	594.8	87,800		118,300		149,500		189,300		205,800		236,100		275,200		344,400	
	595	64,400	958.4	85,700	962.0	123,800	964.4	133,300	966.9	148,500	967.9	175,400	969.2	205,200	970.8	249,000	972.8
	596		959.7		962.7		965.1		967.3		968.3		969.7		971.3		973.3
Big Papillion Cr	596.6	64,400		85,700		123,800		133,300		148,500		175,400		205,200		249,000	
	597	64,300	960.2	85,500	963.3	123,700	965.8	132,900	967.8	148,200	968.8	175,000	970.3	204,800	971.9	248,400	974.0
	598		960.7		964.0		966.6		968.4		969.5		971.0		972.7		974.8
	599		961.1		964.5		967.4		968.9		970.0		971.5		973.2		975.4
	600		961.5		965.0		968.0		969.5		970.5		972.1		973.8		976.0
	601		962.0		965.3		968.5		969.8		970.9		972.4		974.2		976.4
	602		962.6		965.9		969.2		970.4		971.5		973.1		974.9		977.2
	603		963.2		966.5		970.0		971.1		972.2		973.9		975.8		978.2
	604		963.7		966.9		970.4		971.6		972.7		974.5		976.4		978.8
	605		964.3		967.4		970.8		971.9		973.0		974.8		976.6		979.0
Mosquito Creek	605.4	64,300		85,500		123,700		132,900		148,200		175,000		204,800		248,400	
	606	64,200	964.9	85,300	968.1	123,600	971.1	132,700	972.3	147,900	973.3	174,700	975.0	204,500	976.8	247,900	979.2
	607		965.6		968.8		971.7		973.0		973.5		975.2		977.0		979.3
	608		966.1		969.5		972.2		973.3		973.8		975.4		977.1		979.4
	609		966.6		970.0		972.7		973.7		974.1		975.7		977.4		979.6
	610		967.2		970.6		973.5		974.5		974.9		976.6		978.2		980.4
	611		967.9		971.3		974.4		975.4		975.8		977.5		979.2		981.4
	612		968.6		971.9		975.2		976.1		976.7		978.3		980.1		982.3
	613		969.2		972.6		975.9		976.8		977.5		979.2		980.9		983.1

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
	614		970.1		973.4		976.8		977.5		978.3		980.1		981.7		984.0
	615		970.7		974.0		977.5		978.2		979.2		981.0		982.6		984.8
Omaha, NE	616	64,200	971.5	85,300	975.0	123,600	978.7	132,700	979.5	147,900	980.5	174,700	982.5	204,500	984.4	247,900	986.5
	616		971.5		975.0		978.8		979.6		980.6		982.6		984.4		986.6
	617		972.5		975.9		979.9		980.7		981.8		983.9		985.8		988.1
	618		973.3		976.6		980.8		981.6		982.8		984.9		986.9		989.2
	619		973.8		977.2		981.6		982.5		983.7		985.9		987.9		990.4
	620		974.5		977.8		982.5		983.4		984.6		986.9		989.0		991.6
	621		975.2		978.5		983.3		984.2		985.5		987.8		989.9		992.4
	622		976.1		979.3		984.1		985.1		986.4		988.7		990.9		993.4
	622		976.1		979.3		984.1		985.1		986.4		988.7		990.9		993.4
Pigeon Creek	622	64,100		85,200		123,400		132,500		147,800		174,600		204,300		247,700	
	623	63,700	977.0	84,700	980.2	122,100	985.1	131,400	985.9	146,800	987.3	173,400	989.6	202,900	991.7	245,900	994.2
	624		977.9		980.9		985.5		986.4		987.8		990.0		992.1		994.5
	625		978.6		981.7		986.1		986.9		988.1		990.2		992.3		994.7
	626		979.4		982.6		986.8		987.4		988.6		990.6		992.5		994.9
	627		980.2		983.4		987.8		988.5		989.7		991.8		993.6		995.7
	628		980.9		984.3		988.6		989.4		990.5		992.6		994.5		996.3
	629		981.8		985.1		989.3		990.0		991.2		993.2		995.0		996.8
	630		982.5		985.8		989.9		990.6		991.7		993.7		995.5		997.2
	631		983.4		986.6		990.8		991.6		992.7		994.6		996.4		998.0
	632		984.2		987.5		991.7		992.5		993.6		995.5		997.3		998.9
	633		985.1		988.4		992.5		993.2		994.3		996.2		997.9		999.5
	634		986.1		989.4		993.1		993.8		994.9		996.6		998.3		999.9
	635		987.0		990.2		993.6		994.3		995.2		997.0		998.6		1000.1
Boyer River	635.2	63,700		84,700		122,100		131,400		146,800		173,400		202,900		245,900	

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
	636	62,000	988.3	82,600	991.1	117,000	994.1	127,000	994.6	142,900	995.5	168,700	997.1	197,200	998.8	238,800	1000.2
	637		989.1		991.9		994.6		995.1		996.0		997.4		999.1		1000.5
	638		989.9		992.8		995.3		995.9		996.7		998.0		999.5		1000.8
	639		990.7		993.5		996.0		996.6		997.4		998.6		1000.1		1001.4
	640		991.4		994.2		996.9		997.5		998.4		999.5		1000.9		1002.2
	641		992.2		995.1		998.0		998.6		999.5		1000.8		1002.3		1003.7
	642		993.0		995.9		998.8		999.5		1000.5		1001.7		1003.2		1004.7
	643		993.8		996.6		999.7		1000.5		1001.4		1002.7		1004.2		1005.7
	644		994.6		997.6		1001.1		1001.9		1003.1		1004.5		1006.0		1007.5
	645		995.5		998.5		1002.1		1003.0		1004.2		1005.7		1007.2		1008.6
	646		996.4		999.4		1003.0		1003.9		1005.1		1006.5		1008.0		1009.3
	647		997.2		1000.2		1004.0		1004.9		1006.2		1007.3		1008.7		1010.0
Fish Creek	647.8	62,000		82,600		117,000		127,000		142,900		168,700		197,200		238,800	
	648	61,800	998.2	82,300	1001.3	116,200	1005.3	126,400	1006.1	142,400	1007.1	168,100	1008.3	196,500	1009.5	237,800	1010.9
Near Blair, NE	648.3		998.6		1001.7		1005.6		1006.5		1007.5		1008.6		1009.7		1011.1
	649		999.2		1002.3		1006.4		1007.3		1008.4		1009.6		1010.9		1012.1
Old Soldier R. Ditch	649.3	61,800		82,300		116,200		126,400		142,400		168,100		196,500		237,800	
	650	61,500	1000.0	81,900	1003.2	115,300	1007.0	125,600	1007.9	141,700	1009.0	167,200	1010.3	195,400	1011.6	236,500	1012.8
	651		1000.7		1003.9		1007.5		1008.3		1009.5		1010.7		1012.0		1013.1
	652		1001.4		1004.6		1008.2		1009.0		1010.2		1011.4		1012.7		1013.9
	653		1002.1		1005.3		1009.0		1009.9		1011.2		1012.4		1013.9		1015.0
	654		1003.0		1006.2		1009.9		1010.8		1012.1		1013.5		1014.8		1015.7
	655		1003.8		1007.0		1010.4		1011.2		1012.5		1013.9		1015.3		1016.2
	656		1004.6		1007.7		1011.1		1011.8		1013.0		1014.3		1015.7		1016.6
	657		1005.4		1008.6		1011.9		1012.6		1013.8		1015.1		1016.5		1017.6

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
	658		1006.1		1009.3		1012.8		1013.5		1014.7		1016.0		1017.5		1018.6
	659		1006.9		1010.1		1013.5		1014.3		1015.5		1016.9		1018.3		1019.5
	660		1007.8		1011.0		1014.6		1015.4		1016.6		1018.0		1019.3		1020.5
	661		1008.7		1012.0		1015.6		1016.4		1017.6		1018.8		1020.1		1021.2
	662		1009.7		1012.9		1016.5		1017.2		1018.4		1019.5		1020.7		1021.8
	663		1010.6		1013.9		1017.5		1018.2		1019.4		1020.5		1021.8		1023.0
	664		1011.6		1014.9		1018.3		1019.1		1020.3		1021.5		1022.9		1024.2
Soldier River	664	61,500		81,900		115,300		125,600		141,700		167,200		195,400		236,500	
	664	60,800	1011.6	81,000	1014.9	113,000	1018.3	123,600	1019.1	140,000	1020.3	165,200	1021.5	192,900	1022.9	233,300	1024.2
	665		1012.5		1015.8		1019.2		1020.0		1021.4		1022.6		1024.1		1025.5
Tekamah Div. Ditch	665	60,800		81,000		113,000		123,600		140,000		165,200		192,900		233,300	
	666	60,500	1013.4	80,700	1016.8	112,200	1020.1	123,000	1021.0	139,400	1022.3	164,400	1023.5	192,100	1024.9	232,200	1026.2
	667		1014.3		1017.6		1020.9		1021.8		1023.0		1024.3		1025.6		1026.8
	668		1015.2		1018.5		1021.8		1022.6		1023.9		1025.2		1026.5		1027.7
	669		1016.2		1019.4		1022.7		1023.5		1024.9		1026.1		1027.5		1028.7
Little Sioux River	669.2	60,500		80,700		112,200		123,000		139,400		164,400		192,100		232,200	
Monona Harr. Ditch	670	54,200	1017.5	72,700	1020.5	92,800	1023.6	106,300	1024.4	124,700	1025.9	146,800	1027.2	170,800	1028.6	205,400	1030.1
	671	52,400	1018.4	70,500	1021.7	87,200	1024.4	101,600	1025.3	120,500	1027.1	141,800	1028.2	164,800	1029.7	197,700	1031.3
	672		1019.1		1022.5		1024.8		1025.9		1027.6		1028.9		1030.3		1032.0
	673		1020.0		1023.3		1025.4		1026.7		1028.4		1029.9		1031.3		1033.2
	674		1020.9		1024.2		1026.2		1027.6		1029.3		1030.9		1032.2		1034.2
	675		1021.8		1025.2		1027.1		1028.5		1030.4		1032.1		1033.3		1035.3
	676		1022.8		1026.3		1028.3		1029.7		1031.6		1033.4		1034.5		1036.4
	677		1023.9		1027.3		1029.3		1030.8		1032.7		1034.5		1035.8		1037.6

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
	678		1024.9		1028.3		1030.3		1031.7		1033.7		1035.6		1036.9		1038.7
	679		1025.9		1029.2		1031.2		1032.7		1034.7		1036.6		1037.9		1039.7
	680		1026.9		1030.2		1032.1		1033.6		1035.7		1037.5		1038.8		1040.6
	681		1027.8		1031.0		1033.0		1034.5		1036.5		1038.4		1039.6		1041.3
	682		1028.7		1031.9		1033.8		1035.3		1037.3		1039.1		1040.4		1042.1
	683		1029.7		1032.7		1034.6		1036.1		1038.2		1039.9		1041.1		1042.7
	684		1030.7		1033.7		1035.5		1036.9		1038.8		1040.5		1041.6		1043.2
	685		1031.7		1034.6		1036.3		1037.5		1039.3		1040.9		1042.0		1043.6
	686		1032.6		1035.4		1037.0		1038.2		1039.9		1041.5		1042.5		1044.1
	687		1033.7		1036.5		1038.0		1039.1		1040.7		1042.3		1043.3		1044.8
	688		1034.7		1037.4		1039.0		1040.1		1041.7		1043.2		1044.3		1045.7
	689		1035.5		1038.3		1039.9		1041.2		1042.8		1044.4		1045.5		1046.9
	690		1036.3		1039.2		1040.9		1042.2		1043.9		1045.4		1046.5		1047.9
	691		1037.4		1040.4		1042.0		1043.2		1044.8		1046.3		1047.3		1048.8
Decatur, NE	691	52,400	1037.4	70,500	1040.4	87,200	1042.0	101,600	1043.2	120,500	1044.8	141,800	1046.3	164,800	1047.4	197,700	1048.8
	692		1038.0		1041.0		1042.7		1043.9		1045.6		1047.2		1048.4		1050.0
	693		1038.7		1041.8		1043.4		1044.7		1046.4		1048.1		1049.3		1051.1
	694		1039.5		1042.7		1044.3		1045.6		1047.4		1049.1		1050.4		1052.1
	695		1040.4		1043.6		1045.3		1046.6		1048.4		1050.2		1051.6		1053.4
	696		1041.4		1044.6		1046.3		1047.6		1049.3		1051.1		1052.5		1054.3
	697		1042.3		1045.6		1047.3		1048.5		1050.3		1051.9		1053.1		1055.0
Blackbird Creek	697.4	52,300		70,300		86,900		101,300		120,300		141,500		164,400		197,300	
	698	51,800	1043.2	69,600	1046.5	85,200	1048.1	99,800	1049.4	119,000	1051.2	140,000	1052.8	162,600	1054.0	195,000	1055.6
	699		1044.1		1047.3		1049.0		1050.3		1052.1		1053.8		1055.0		1056.7
	700		1045.0		1048.1		1049.8		1051.2		1053.0		1054.8		1056.0		1057.6
	701		1045.8		1048.9		1050.6		1051.9		1053.7		1055.5		1056.7		1058.3

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
	702		1046.7		1049.9		1051.6		1052.9		1054.8		1056.7		1057.8		1059.3
	703		1047.7		1050.9		1052.6		1054.0		1055.8		1057.6		1058.7		1060.2
	704		1048.6		1051.8		1053.6		1054.9		1056.7		1058.5		1059.7		1061.1
	705		1049.7		1052.9		1054.6		1056.0		1057.6		1059.3		1060.4		1061.9
	706		1050.7		1053.9		1055.7		1057.1		1058.6		1060.3		1061.5		1063.1
	707		1051.6		1054.7		1056.4		1057.7		1059.4		1061.2		1062.4		1064.1
	708		1052.6		1055.8		1057.4		1058.7		1060.4		1062.2		1063.6		1065.3
	709		1053.7		1056.9		1058.5		1059.9		1061.7		1063.3		1064.5		1066.2
	710		1054.6		1057.7		1059.4		1060.7		1062.5		1064.2		1065.5		1067.3
	711		1055.6		1058.7		1060.4		1061.8		1063.6		1065.3		1066.5		1068.2
	712		1056.4		1059.6		1061.3		1062.6		1064.5		1066.2		1067.5		1069.1
	713		1057.3		1060.5		1062.2		1063.6		1065.5		1067.0		1068.1		1069.7
	714		1058.4		1061.5		1063.2		1064.7		1066.5		1068.1		1069.2		1070.8
	715		1059.5		1062.6		1064.3		1065.7		1067.6		1069.3		1070.3		1071.8
	716		1060.7		1063.7		1065.4		1066.9		1068.9		1070.5		1071.5		1072.8
	717		1061.6		1064.7		1066.4		1067.8		1069.7		1071.4		1072.3		1073.7
	718		1062.6		1065.8		1067.5		1068.8		1070.6		1072.2		1073.2		1074.6
	719		1063.4		1066.7		1068.4		1069.7		1071.5		1073.1		1074.2		1075.6
Omaha Creek	719.9	51,800		69,600		85,200		99,800		119,000		140,000		162,600		195,000	
	720	51,300	1064.5	69,000	1067.8	83,700	1069.4	98,500	1070.7	117,900	1072.6	138,600	1074.0	160,900	1075.1	192,900	1076.6
	721		1065.5		1068.7		1070.3		1071.6		1073.5		1074.9		1076.0		1077.6
	722		1066.4		1069.6		1071.2		1072.4		1074.3		1075.8		1076.9		1078.4
	723		1067.4		1070.6		1072.1		1073.4		1075.3		1076.8		1078.0		1079.6
	724		1068.3		1071.5		1073.1		1074.5		1076.3		1077.9		1079.2		1080.9
	725		1069.4		1072.5		1074.2		1075.6		1077.4		1079.0		1080.4		1082.0
	726		1070.5		1073.6		1075.2		1076.7		1078.5		1080.2		1081.6		1083.4

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
	727		1071.6		1074.7		1076.4		1077.8		1079.7		1081.5		1082.9		1084.8
	728		1072.5		1075.7		1077.4		1078.8		1080.8		1082.7		1084.2		1086.2
	729		1073.5		1076.7		1078.3		1079.8		1081.8		1083.8		1085.4		1087.5
	730		1074.4		1077.6		1079.2		1080.7		1082.7		1084.6		1086.2		1088.3
	731		1075.6		1078.7		1080.3		1081.8		1083.8		1085.7		1087.3		1089.5
Floyd River	731.3	51,300		69,000		83,700		98,500		117,900		138,600		160,900		192,900	
	732	49,700	1076.7	67,000	1079.7	78,800	1081.1	94,300	1082.6	114,200	1084.6	134,200	1086.5	155,500	1088.2	186,100	1090.4
Perry Creek	732.2	49,600		66,900		78,400		94,000		113,900		133,900		155,100		185,600	
Sioux City, IA	732.4	49,500	1077.0	66,800	1080.2	78,300	1081.5	93,900	1083.0	113,800	1085.0	133,800	1087.0	155,000	1088.8	185,400	1091.0
	733		1077.7		1080.8		1082.2		1084.0		1086.2		1088.2		1090.2		1092.5
Big Sioux River	734	49,600		66,800		78,400		93,900		113,800		133,800		155,000		185,400	
	734	46,400	1079.3	64,100	1082.8	66,900	1084.1	72,400	1085.7	87,200	1088.1	101,900	1090.2	117,900	1092.2	145,000	1094.5
	735		1081.0		1084.3		1085.6		1086.9		1088.9		1091.0		1093.0		1095.3
	736		1081.9		1085.1		1086.2		1087.5		1089.5		1091.5		1093.4		1095.8
	737		1082.6		1085.8		1086.8		1088.1		1090.0		1091.9		1093.8		1096.2
Elk Creek	737.3	46,400		64,100		66,800		72,700		87,200		101,900		117,900		145,000	
	738		1083.2		1086.6		1087.6		1088.7		1090.7		1092.5		1094.2		1096.6
	739		1084.2		1087.7		1088.6		1089.8		1091.8		1093.6		1095.3		1097.7
	740		1085.3		1088.7		1089.6		1090.8		1092.9		1094.9		1096.6		1098.9
	741		1086.3		1089.5		1090.5		1091.7		1093.9		1095.9		1097.6		1099.9
	742		1087.3		1090.4		1091.4		1092.7		1094.9		1097.0		1098.7		1101.0
	743		1088.6		1091.6		1092.6		1093.8		1096.0		1098.2		1099.9		1102.2
	744		1089.8		1092.8		1093.7		1094.9		1097.0		1099.4		1101.1		1103.5
	745		1090.9		1093.8		1094.8		1096.0		1098.1		1100.5		1102.3		1104.6
Aowa Creek	745.2	46,500		64,100		66,800		73,000		87,200		101,900		117,900		145,100	
	746		1091.8		1094.7		1095.7		1097.0		1098.8		1101.3		1103.1		1105.5

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
	747		1092.6		1095.6		1096.6		1097.8		1099.6		1102.0		1103.8		1106.1
	748		1093.5		1096.5		1097.5		1098.8		1100.4		1102.8		1104.5		1106.8
	749		1094.4		1097.5		1098.5		1099.8		1101.4		1103.6		1105.4		1107.6
	750		1095.2		1098.3		1099.3		1100.5		1102.2		1104.5		1106.1		1108.4
Near Ponca, NE	751	46,600	1096.1	64,200	1099.2	66,800	1100.1	73,400	1101.4	87,300	1103.0	101,900	1105.2	117,900	1106.9	145,100	1109.0
	752		1096.8		1099.9		1100.9		1102.2		1103.8		1105.9		1107.6		1109.6
	753		1097.8		1100.9		1101.8		1103.1		1104.7		1106.8		1108.3		1110.4
	754		1098.9		1101.8		1102.7		1103.9		1105.4		1107.4		1109.0		1111.0
	755		1100.3		1102.9		1103.7		1104.8		1106.3		1108.2		1109.7		1111.7
	756		1101.4		1103.8		1104.6		1105.7		1107.0		1108.8		1110.3		1112.3
	757		1102.7		1104.9		1105.6		1106.6		1107.8		1109.5		1110.9		1112.9
	758		1103.7		1105.8		1106.4		1107.3		1108.4		1110.0		1111.4		1113.3
	759		1104.7		1106.7		1107.3		1108.1		1109.2		1110.7		1112.0		1113.8
	760		1106.3		1108.2		1108.8		1109.5		1110.5		1111.8		1113.0		1114.6
	761		1108.0		1109.8		1110.4		1111.2		1112.1		1113.4		1114.6		1116.2
	762		1109.3		1111.1		1111.7		1112.5		1113.4		1114.7		1115.8		1117.3
	763		1110.7		1112.5		1113.1		1113.9		1114.8		1116.1		1117.0		1118.5
	764		1112.0		1114.0		1114.6		1115.4		1116.4		1117.6		1118.5		1119.9
	765		1112.9		1114.8		1115.5		1116.3		1117.2		1118.5		1119.4		1120.8
	766		1113.8		1115.7		1116.4		1117.2		1118.1		1119.3		1120.3		1121.7
	767		1114.7		1116.6		1117.2		1118.0		1118.9		1120.1		1121.1		1122.4
	768		1115.6		1117.5		1118.1		1118.9		1119.7		1121.0		1121.9		1123.2
	769		1116.6		1118.5		1119.1		1119.9		1120.8		1122.1		1123.0		1124.4
	770		1117.8		1119.6		1120.3		1121.1		1121.9		1123.2		1124.2		1125.6
	771		1119.0		1120.7		1121.4		1122.1		1122.9		1124.1		1125.0		1126.4
Vermillion	771.9	46,900	1120.1	64,300	1122.0	66,900	1122.5	74,000	1123.2	88,000	1124.0	101,900	1125.2	117,900	1126.2	145,100	1127.5

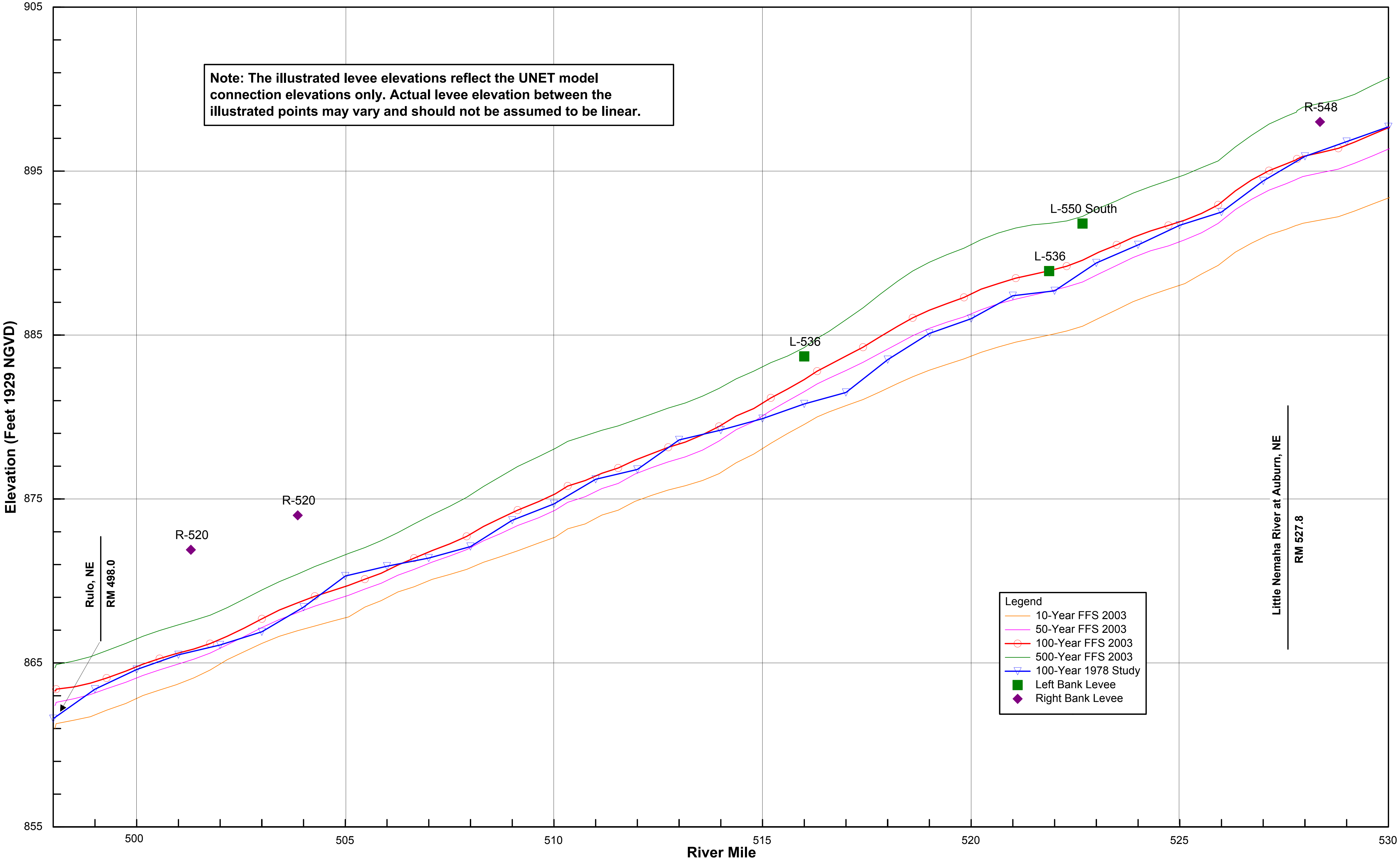
2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
River																	
	772	45,500	1120.3	64,000	1122.2	65,900	1122.6	70,200	1123.3	83,600	1124.2	99,100	1125.4	114,600	1126.4	141,500	1127.7
	773		1121.5		1123.4		1123.8		1124.5		1125.3		1126.5		1127.6		1129.0
	774		1123.2		1125.1		1125.4		1126.1		1126.8		1127.9		1128.9		1130.3
	775		1124.2		1126.1		1126.4		1127.1		1127.8		1129.0		1130.0		1131.4
Near Maskell, NE	775.6	45,500	1125.0	64,000	1126.8	65,900	1127.2	70,200	1127.9	83,600	1128.6	99,100	1129.7	114,600	1130.7	141,500	1132.2
	776		1125.5		1127.3		1127.6		1128.3		1129.0		1130.2		1131.2		1132.7
	777		1126.4		1128.2		1128.5		1129.2		1129.8		1130.9		1131.9		1133.5
	778		1127.8		1129.4		1129.7		1130.3		1130.9		1131.7		1132.8		1134.3
	779		1129.3		1130.7		1130.9		1131.4		1131.9		1132.7		1133.6		1135.0
	780		1130.8		1132.1		1132.3		1132.8		1133.2		1133.9		1134.6		1135.7
	781		1132.4		1133.5		1133.8		1134.2		1134.7		1135.3		1135.8		1136.7
	782		1134.1		1135.2		1135.4		1135.9		1136.3		1136.9		1137.4		1138.2
	783		1135.5		1136.6		1136.8		1137.3		1137.7		1138.3		1138.8		1139.6
	784		1136.8		1137.9		1138.1		1138.6		1139.0		1139.6		1140.1		1140.9
	785		1138.0		1139.1		1139.4		1139.9		1140.3		1140.8		1141.4		1142.2
	786		1139.2		1140.5		1140.7		1141.2		1141.7		1142.2		1142.8		1143.6
	787		1140.2		1141.6		1141.9		1142.4		1142.9		1143.5		1144.1		1145.0
Bow Creek	787.6	45,500	1140.7	64,000	1142.3	66,200	1142.6	70,300	1143.0	83,900	1143.7	99,100	1144.4	114,600	1145.0	141,500	1146.1
	788		1141.0		1142.6		1142.9		1143.3		1144.1		1144.8		1145.5		1146.5
	789		1141.8		1143.4		1143.7		1144.1		1144.9		1145.7		1146.4		1147.5
	790		1143.0		1144.6		1144.9		1145.3		1146.0		1146.8		1147.5		1148.6
	791		1144.1		1145.7		1145.9		1146.3		1147.0		1147.9		1148.6		1149.7
	792		1145.1		1146.8		1147.1		1147.6		1148.3		1149.3		1150.1		1151.2
	793		1146.1		1148.0		1148.3		1148.8		1149.6		1150.7		1151.6		1152.9

2003 Missouri River Stage and Flow Frequency Profiles (all elevations referenced to 1929 NGVD)

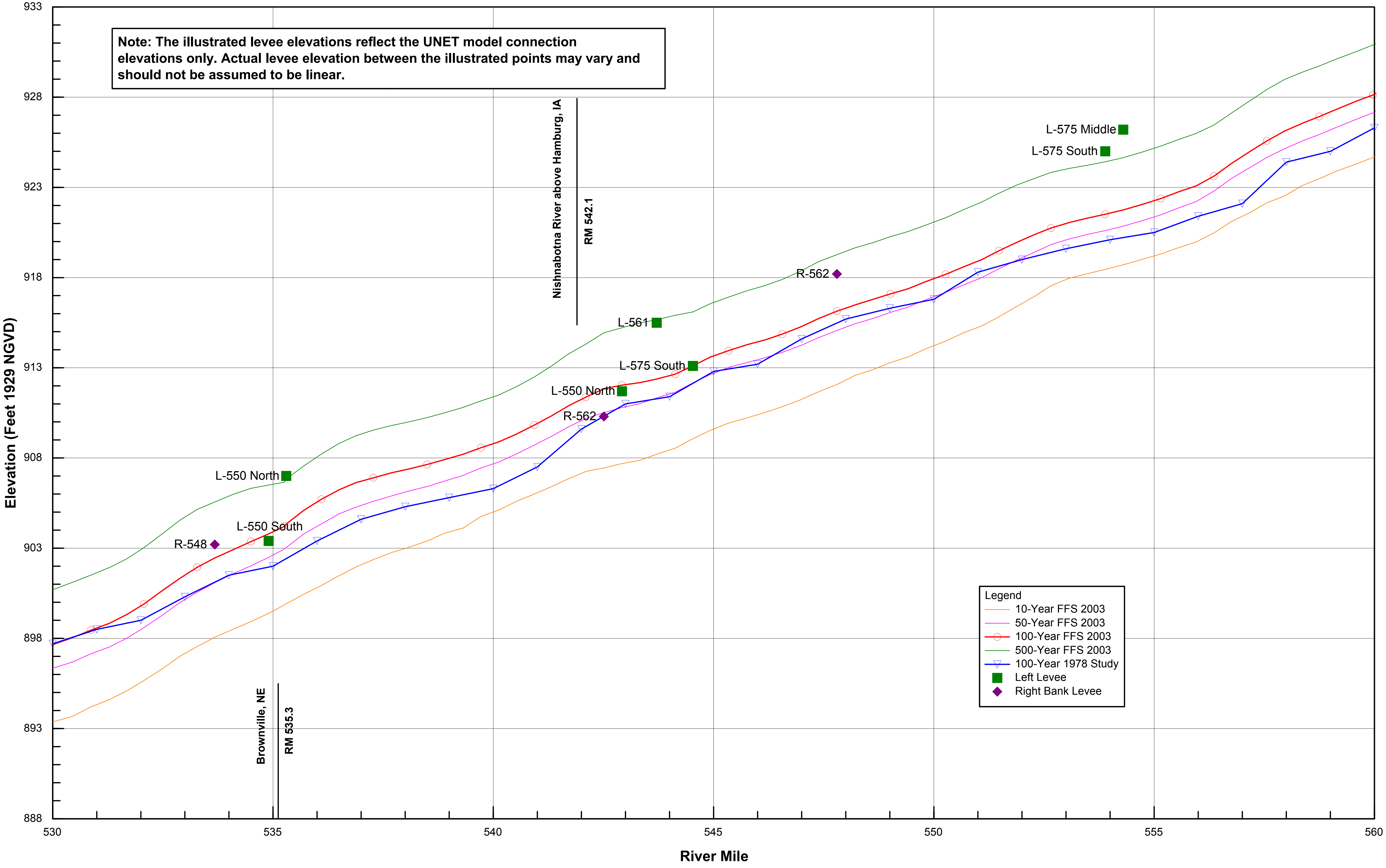
		2-Year Event		5-Year Event		10-Year Event		25-Year Event		50-Year Event		100-Year Event		200-Year Event		500-Year Event	
	River Mile	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation	Flow	Elevation
	1960 mi.	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(ft)
	794		1146.9		1148.9		1149.2		1149.7		1150.6		1151.7		1152.7		1154.0
	795		1147.7		1149.7		1150.0		1150.5		1151.4		1152.6		1153.6		1155.0
Near Gayville, SD	796	45,600	1148.4	64,000	1150.4	66,300	1150.8	70,300	1151.3	84,100	1152.2	99,100	1153.4	114,600	1154.4	141,500	1155.8
	797		1149.1		1151.2		1151.5		1152.0		1153.0		1154.2		1155.2		1156.6
James River	797.7	45,600	1149.7	64,000	1151.8	66,300	1152.1	70,400	1152.7	84,100	1153.7	99,100	1154.9	114,600	1156.0	141,500	1157.5
	798	45,300	1150.2	63,000	1152.6	65,000	1152.9	69,100	1153.5	74,700	1154.2	84,900	1155.4	98,000	1156.4	123,500	1158.0
	799		1151.1		1153.9		1154.2		1154.7		1155.1		1156.5		1157.5		1159.3
	800		1151.9		1154.6		1154.9		1155.4		1155.9		1157.3		1158.4		1160.4
	801		1152.7		1155.4		1155.7		1156.2		1156.7		1158.1		1159.3		1161.4
	802		1153.2		1155.9		1156.1		1156.7		1157.2		1158.6		1159.8		1161.9
	803		1153.8		1156.4		1156.7		1157.2		1157.8		1159.1		1160.4		1162.4
	804		1154.7		1157.1		1157.4		1157.9		1158.5		1159.7		1161.1		1163.1
	805		1155.8		1158.1		1158.3		1158.8		1159.4		1160.5		1161.8		1163.8
Yankton, SD	805.8	45,300	1156.5	63,000	1158.7	65,000	1158.9	69,100	1159.4	74,700	1160.0	84,900	1161.1	98,000	1162.4	123,500	1164.4
	806		1156.7		1158.9		1159.1		1159.6		1160.2		1161.3		1162.7		1164.7
	807		1157.5		1159.6		1159.8		1160.3		1160.9		1162.0		1163.3		1165.5
	808		1158.6		1160.5		1160.7		1161.1		1161.7		1162.7		1163.9		1166.0
	809		1159.7		1161.5		1161.7		1162.1		1162.7		1163.6		1164.9		1166.9
	810		1160.4		1162.3		1162.5		1163.0		1163.5		1164.5		1165.8		1167.9
Gavins Point Dam	810.9	45,300	1160.8	63,000	1162.9	65,000	1163.1	69,100	1163.6	74,700	1164.1	84,900	1165.2	98,000	1166.4	123,500	1168.6

2003 vs. 1978 Missouri River Stage Frequency Profiles - River Mile 498-530

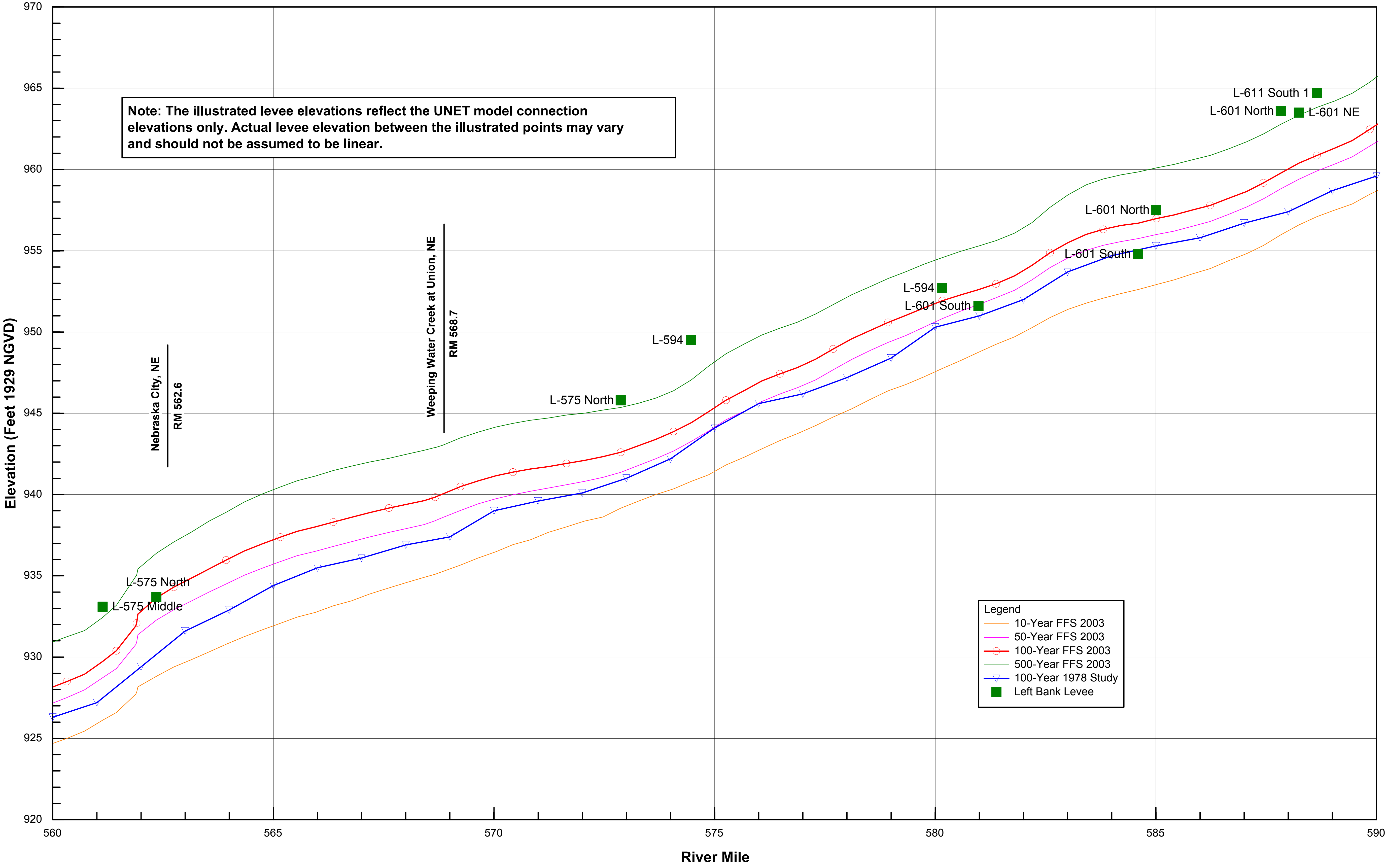


Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

2003 vs. 1978 Missouri River Stage Frequency Profiles - River Mile 530-560

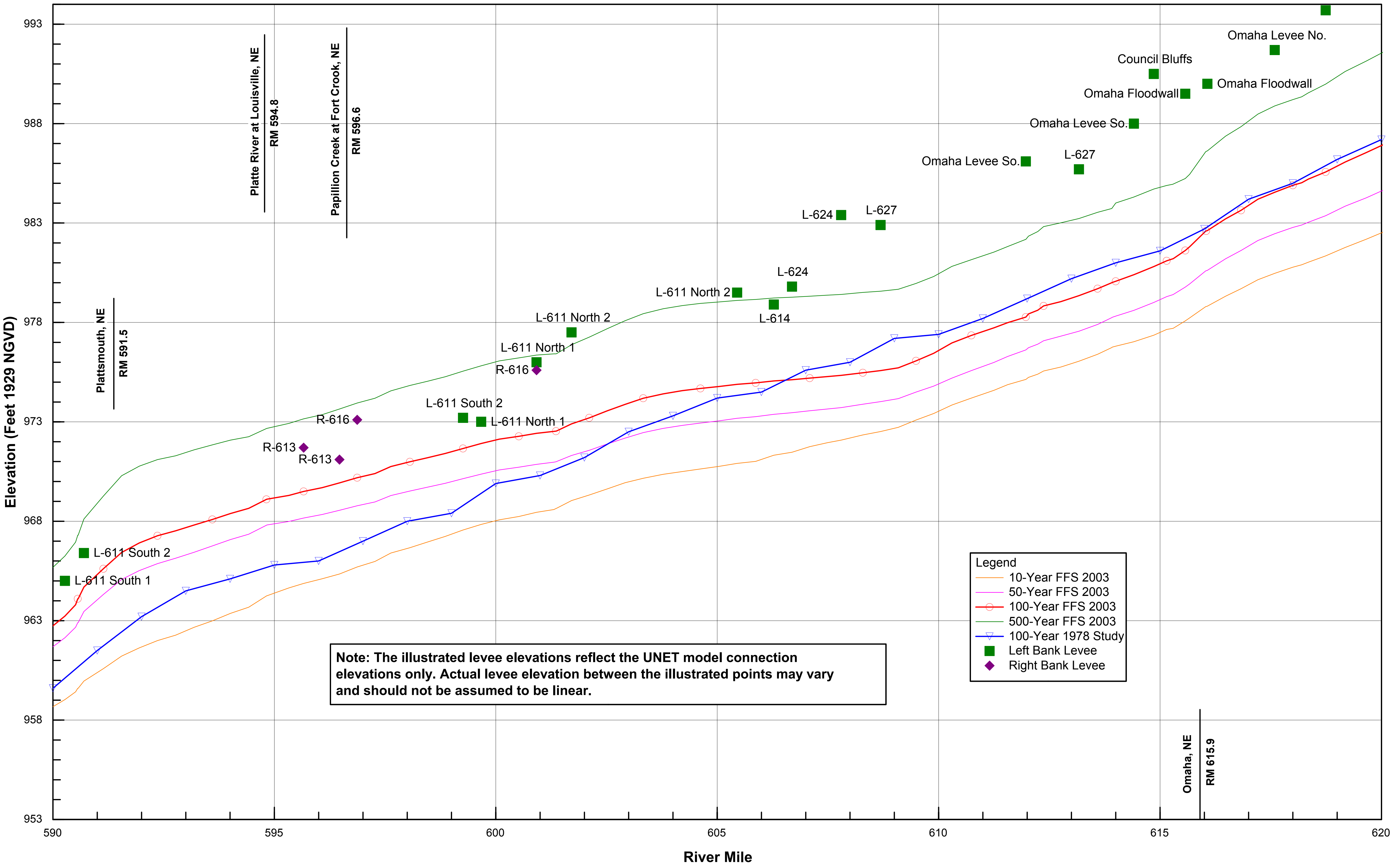


2003 vs. 1978 Missouri River Stage Frequency Profiles - River Mile 560-590



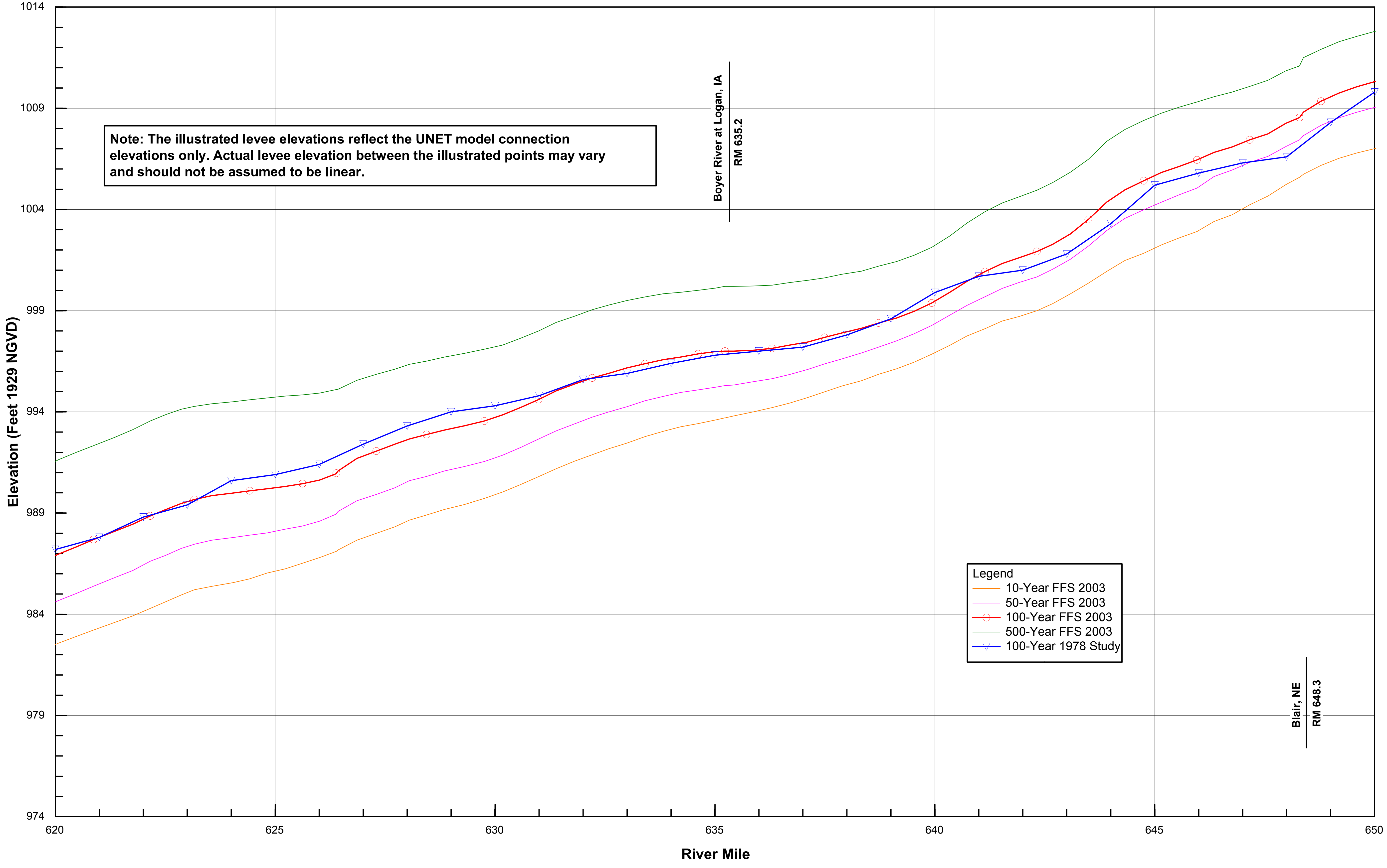
Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

2003 vs 1978 Missouri River Stage Frequency Profiles - River Mile 590-620



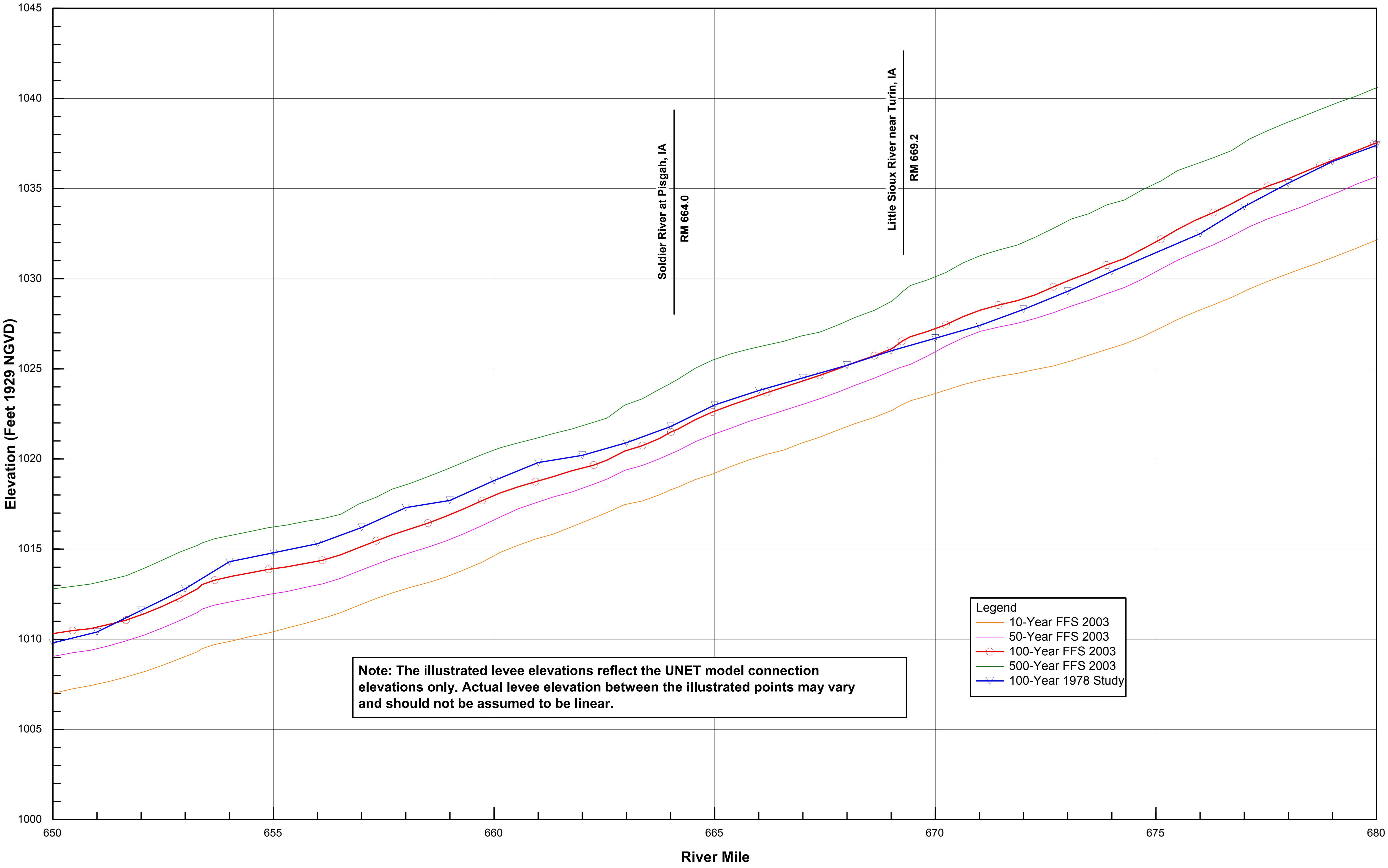
Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

2003 vs 1978 Missouri River Stage Frequency Profiles - River Mile 620-650



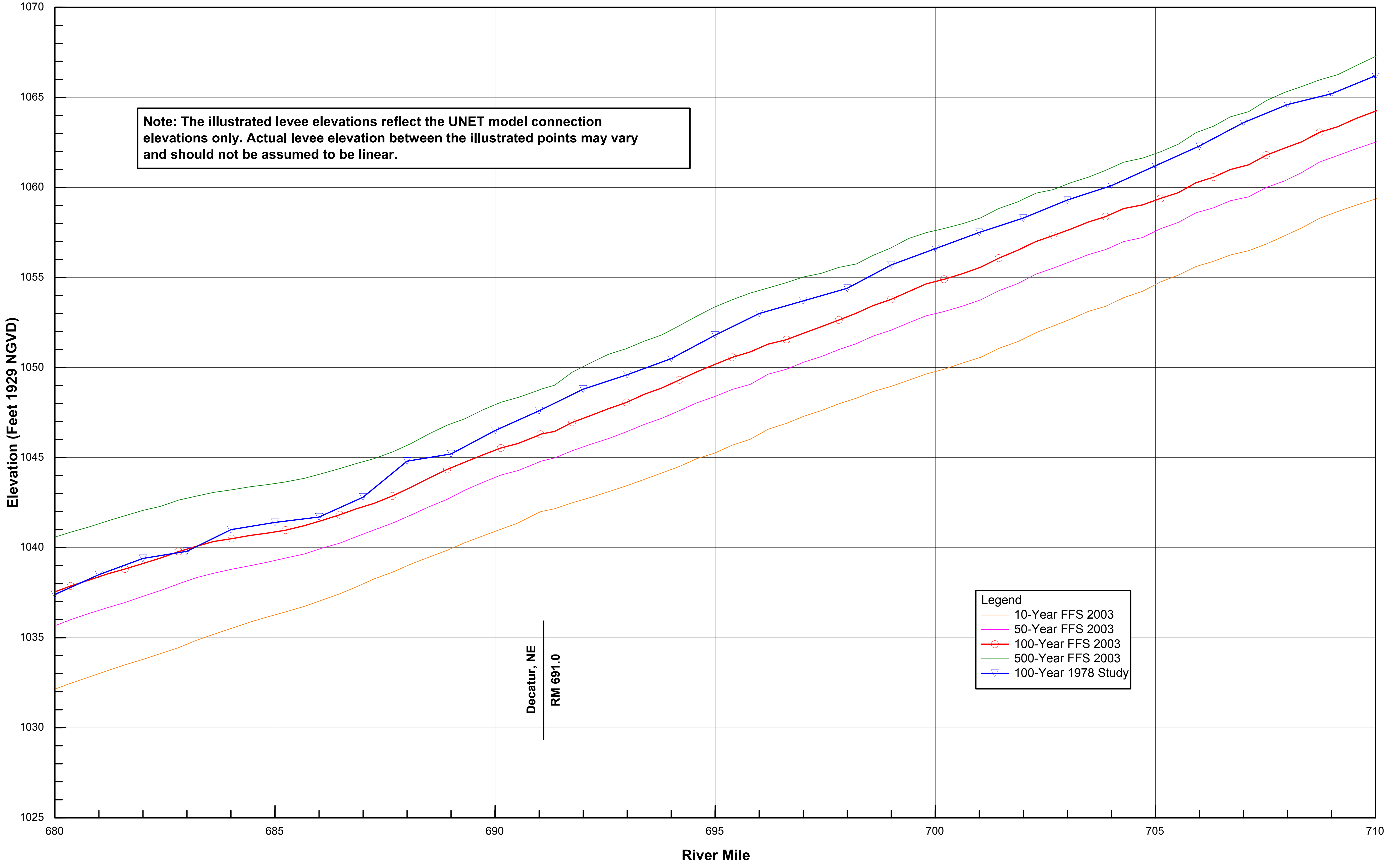
Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

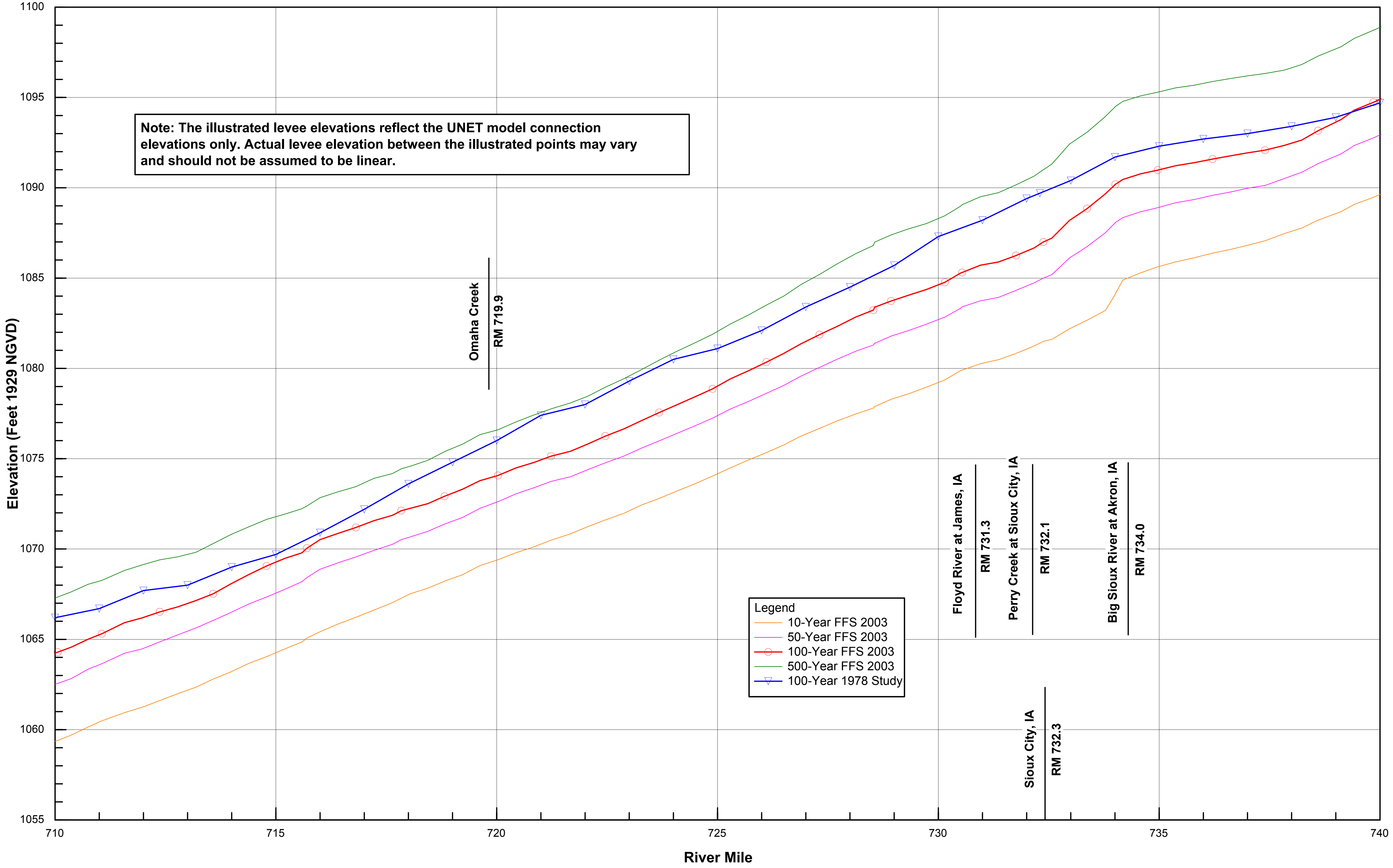
2003 vs 1978 Missouri River Stage Frequency Profiles - River Mile 650-680



Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

2003 vs 1978 Missouri River Stage Frequency Profiles - River Mile 680-710

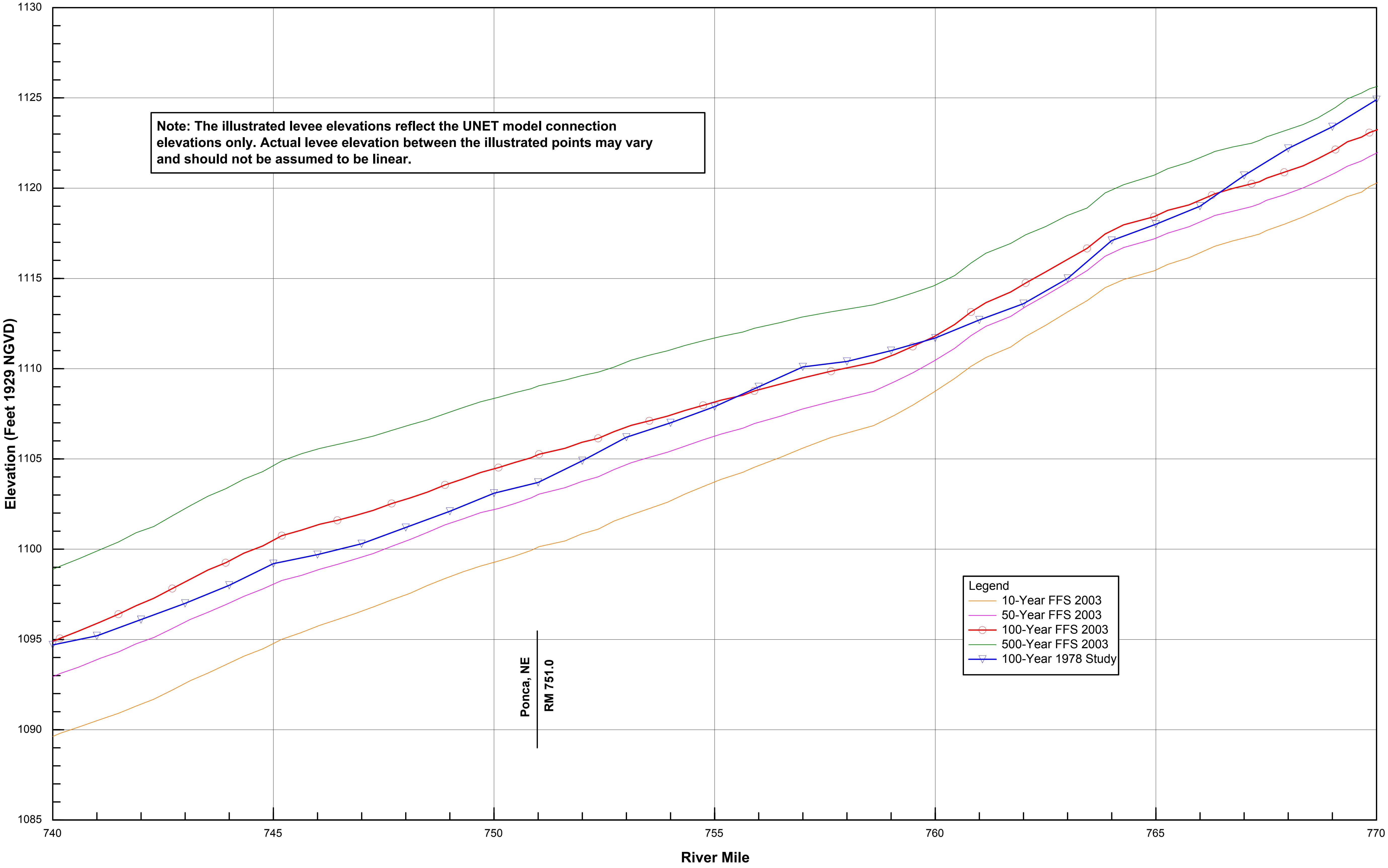




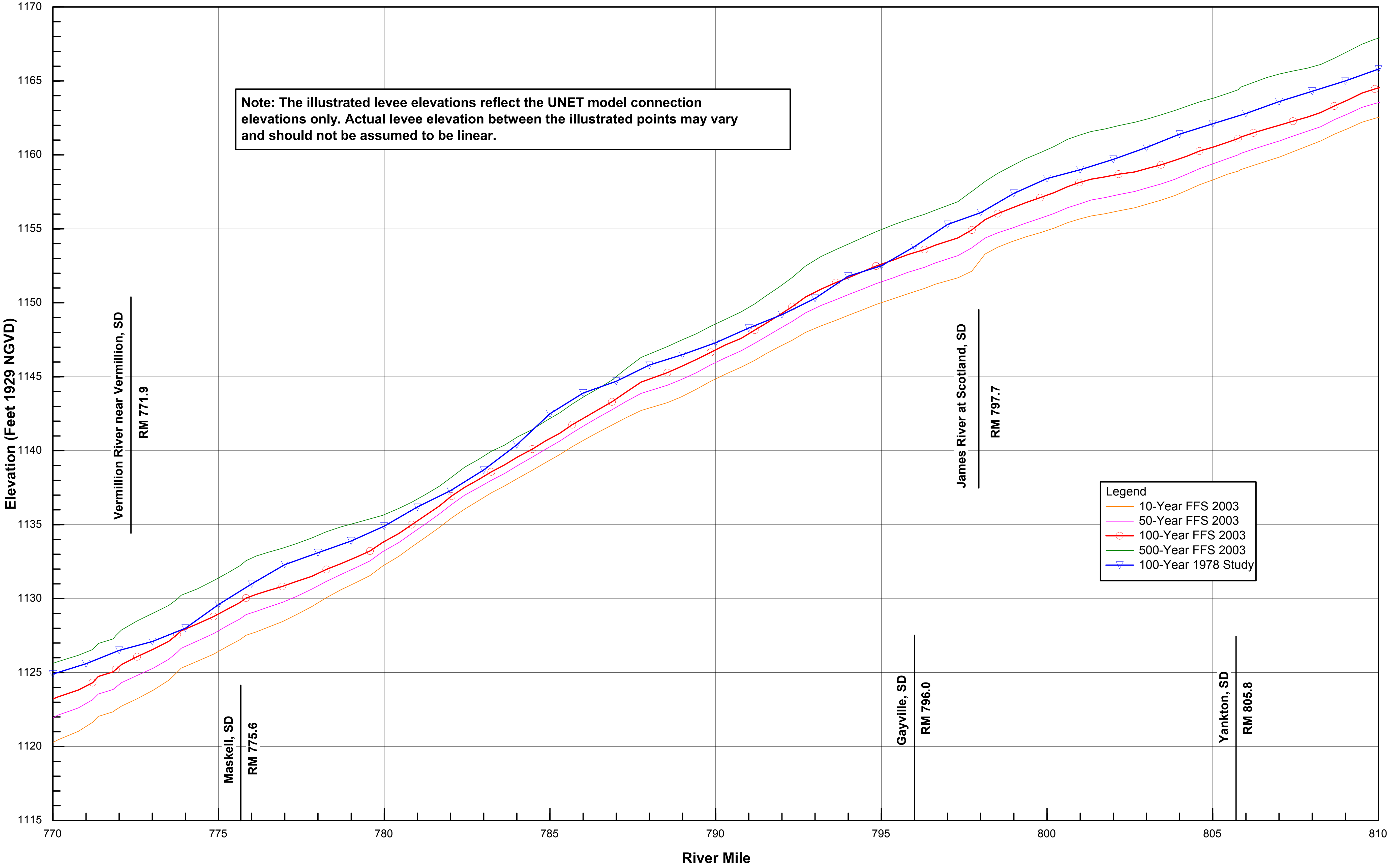
2003 vs 1978 Missouri River Stage Frequency Profiles - River Mile 710-740

Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

2003 vs 1978 Missouri River Stage Frequency Profiles - River Mile 740-770


Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.

2003 vs 1978 Missouri River Stage Frequency Profiles - River Mile 770-810



Note: The illustrated levee elevations reflect the UNET model connection elevations only. Actual levee elevation between the illustrated points may vary and should not be assumed to be linear.