DRAFT Hydrologic Analysis of the lower Platte River from 1954 - 2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon

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Chapter 1 – Hydrological Analysis of the lower Platte River from 1954 – 2002.

Introduction:

The lower Platte River is the section of the Platte River downstream from the confluence of the Loup River near Columbus, Nebraska. The lower Platte River is a unique and in high demand resource. The lower Platte River still retains its characteristic combination of braided channels and shifting sandbars once common in much of the Missouri River and its tributaries (NRC 2005). These habitats support the continued presence of at least three endangered species; Interior Least Tern, Piping Plover, and Pallid Sturgeon, yet the demand for water from the river remains high.

Much of the western portions of the Platte River have been extensively modified for the storage and distribution of irrigation waters (Bentall 1982, NRC 2005) and modifications to the natural flow regime have resulted in large changes to the characteristic habitats of the river. The flow of the central Platte River is influenced by the water releases from the 2.4 billion m^3 Lake McConaughy Reservoir and except at times when it is full and spilling water, the Central Nebraska Public Power and Irrigation District control the water release schedule (Anderson and Rodney 2006). As a result of this and other large reservoirs upstream of both the North and South Platte Rivers and the reduction in flow volume from water use for irrigation, drinking water, and power production, the channel morphology of central Platte River has changed due to the encroachment of trees in the channel (Williams 1978, Eschner et al., 1983, Simons and Associated, Inc., 2000). In comparisons of mean annual flows pre and post development, Simons and Associates (2000) estimated pre-development flows in the central Platte River to be at least 2.8 million acre feet, while Stroup et al.(2001) reported the mean annual flow near Grand Island between 1940 and 1998 to be near 1.15 million acre feet. This results in a loss of almost 60% of pre-development flows in the central Platte River.

In contrast to the central Platte River, major shifts in habitat and river channel morphology have yet to occur in the lower Platte River making this stretch of river unique in the region (Rodekor and Engelbrecht 1988, Eschner 1983, NRC 2005). There has been some narrowing of the river channel and stream bed degradation in the lower Platter River, although a small amount compared to sites in the central Platte River (Eschner et al. 1983, Chen et al. 1999). Although changes to the lower Platte River have not been as extensive as the central Platte River, analyses are necessary to understand the current hydrology and to predict the effects that future changes in flow may have on the endangered species that depend on it.

This report resulted from a request from the Nebraska Game and Parks Commission (NGPC) for an analysis of the daily flow gage records on select gages in and around the lower Platte River, NE. The lower Platte River in this analysis is defined as the stretch from the confluence with the Loup River to the confluence with the Missouri River. The hydrologic analysis is descriptive in nature. The main product requested was an analysis of magnitude, timing, frequency, duration, and rate of change of river discharge characteristics of the major gages associated with the lower Platte River and its tributaries over a comparable time period. This included the production of flow exceedance tables for each gage.

The role of natural flow variability and its important role in the ecological health of a river system has been well documented (Arthington et al. 1992, Poff et al 1997, Annear et al. 2004, Mathews and Richter 2007). Natural flow variability is also an important concern in Nebraska (NGPC 2005, NRC 2005). In the National Research Council review of the Platte River, it was recommended that the Department of Interior agencies begin moving toward a “normative” flow approach (NRC 2005). This analysis intended to provide a description of the flow characteristics of the lower Platte River and it main tributaries over the past 52 years. The goal is not to provide a recommendation of an appropriate normative flow, but to characterize different aspects of the flow regime. A description of the normative flow regime for the lower Platte will also require an description of pre-development flows as changes to the Platte River’s flow characteristics were extensive prior to 1954 (NRC 2005). Currently, no comparative flow records exist for pre-development flows on the lower Platte River, so this analysis will focus on flows over the past 52 years.

In addition to the analysis of the flow records for the lower Platte River over the last 52 years, NGPC was interested in understanding how the flows found in the lower Platte River may, or may not, support the habitats and needs of Least Terns, Piping Plovers, and Pallid Sturgeon. Models of habitat suitability were created for Least Terns and Piping Plovers based on past flow data (Chapter 2) and available information on Pallid Sturgeon was expanded in table format to better describe critical flow standards (Chapter 3).

Methods:

The gages chosen for analysis in this report were: Platte River near Duncan, NE (USGS gage 06774000); Loup River near Genoa, NE (USGS gage 06793000); Loup River Power Canal near Genoa, NE (USGS gage 06792500); Platte River near North Bend, NE (USGS gage 06796000); Elkhorn River near Waterloo, NE (USGS gage 06800500); Salt Creek near Greenwood, NE (USGS gage 06803555); and Platte River near Louisville, NE (USGS gage 06805500).

The mean daily flow data was downloaded from the USGS website at:

http://nwis.waterdata.usgs.gov/ne/nwis/dv/

To provide a consistent time period for analyzing the flow data, the time period from January 1, 1954 to December 31, 2005 was selected. This time period was available for each of the gages. Additionally, the status of the flow data was checked and approved for publication. No flow data was in the provisional status. The water year in these analyses runs from January to December at the request of NGPC. The flow data described in this chapter were used in the entire report.

All data was imported and stored in a Microsoft Access database to allow quick retrieval of data sets required for each analysis. Most basic statistics were calculated in a Microsoft Excel spreadsheet. Additionally, these results were double checked by the output from the software package Indicators of Hydrologic Alteration (IHA). Some of the more advanced statistics were derived only in IHA as noted in the individual sections below.

The main IHA web page was located at:

http://www.nature.org/initiatives/freshwater/conservationtools/art17004.html

The IHA software calculates 32 parameters thought to characterize the five main biologically relevant flow characteristics: magnitude, timing, duration, frequency, and rate of change (Richter et al. 1996). In addition to traditional hydrologic statistics, IHA uses a series of rules based on the flow percentiles compute statistics for a suite of “environmental flow components” (EFCs): extreme low flows, low flows, high flow pulses, small floods, and large floods (see IHA software for full description of the methodology). This approach differs from the traditional exceedance or monthly flow statistics in that it provides the statistics only associated with the river when it is in a particular state. For example, the large flood events are not averaged in with the low flow events obscuring the characteristics of each flow type.

IHA is considered a good tool for establishing baselines for describing hydrological regimes (Annear et al. 2004). IHA can compare pre- and post- impact conditions if an available pre-impact daily flow record exists. For this analysis, no pre-impact analysis was attempted as comparable daily flow records do not exist prior to 1954 for each site.

Changes to the Platte River's discharge were extensive prior to 1954 (NRC 2005). This analysis characterizes the discharge characteristics for the past 52 years.

Several metrics were derived from the raw flow data that were thought to be relevant in characterizing the lower Platte River's hydrology and capacity to provide habitat for endangered species. These metrics were calculated for each gage and are described below.

Exceedance Tables

Annual flow exceedance tables focus on the aspects of magnitude and frequency of the discharge record, while monthly exceedance tables also consider the timing of the discharge. Flow exceedance tables are a standard way of viewing the frequency at which a given discharge was equaled or exceeded. In an exceedance table, low flows are most often exceeded so they have high exceedance probabilities. The exceedance table can be used to determine the frequency at which different flow amounts occur in the river. Exceedance tables are useful in assessing flow availability. Caution should be used in interpreting the results of exceedance tables as reflecting naturally available flows as the tables reflect the conditions during the time period analyzed (Annear et al. 2004). In this report, exceedance tables are provided for annual and monthly flow conditions. Exceedance tables were created in an Excel spreadsheets using the percentile function on the full daily flow record from 1954 – 2004 for each gage site.

*Note an exceedance table is the inverse of a percentile table. For example a flow that is exceeded 80% of the time is considered to occur in the 20th percentile of all flows. An exceedance flow can be interpreted as the flow that is available as that percent of time. For example, an 80% exceedance flow is available (or is equaled or exceeded) 80% of the time. High exceedance percentages are generally low flows, while high percentiles are high flows. In this report, exceedance values are generally used, although for some statistics percentiles are given. For sake of clarity, percentages referring to exceedance flow values are termed exceedance percentages, while all other percentages are refer to as percentile flow values.

Coefficient of Dispersion

The coefficient of dispersion (CD) characterizes the consistency, timing, and rate of change of the flow regime, especially focusing on moderate flows. The CD is a measure of the distribution of the data about the median value in non-parametric statistics that is analogous to the coefficient of variation about the mean in parametric statistics. The CD is calculated as ((25th exceedance percentile - 75th exceedance percentile) / 50th exceedance percentile). A single value of the CD is not highly significant to understanding the discharge characteristics of the lower Platte River. CD measures are useful when comparing values among different datasets, such as, comparing the CD for recorded discharge rates in June vs. July, or comparing CD values for different gage sites. If the values for CD are different in the comparison, then it reflects some change in the dispersion of the discharge data. Possibly, there are more extreme flow events in June than July, and if so, the CD value for June would be higher than for July. Table 1.1 shows an example of how changes in the range influence observed CD values. While the standard has a value of 1 in this example, it is only for comparative purposes. When the range increased, the CD increased and similarly, when the range decreased the CD decreased.

Table 1.1. Examples of the measure of the coefficient of dispersion (CD).

% Exceeded	Standard	Range increasing		Range decreasing	
75%	500 cfs	250 cfs	500 cfs	750 cfs	500 cfs
Median	1,000 cfs	1,000 cfs	1,000 cfs	1,000 cfs	1,000 cfs
25%	1,500 cfs	1,500 cfs	2,000 cfs	1,500 cfs	1,250 cfs
CD	1	1.25	1.5	0.75	0.75
		Increase in CD		Decrease in CD	

Low Flow to Median Flow Ratio

The low to median flow ratio (LMR) also characterizes flow consistency and timing, but unlike the CD, the LMR focuses on low flows. While the CD is derived from the main body of the dataset (between the 25th and 75th exceedance percentiles), in some instances changes in more extreme values are of interest. For example, low flow events are of particular interest on the lower Platte River. Are low flows becoming more frequent? Are they more common during certain times of the year? These are common and important questions when trying to understand the discharge patterns observed in the river. In this case, a specifically designed ratio can be used to compare among datasets. For the lower Platte River analysis, a LMR was developed. This is simply defined as the ratio of the 95th exceedance percentile (low flow) to the 50th exceedance percentile (median). The 95th exceedance percentile is not intended to be a measure of baseflow in the river, yet it is an extreme value that will be highly influenced by changes in baseflow.

Here is a *hypothetical* example of how changes in LMR values may reflect changes observed on a river. Prior to construction of an upstream diversion, a river had a median discharge of 1000 cfs with a 95th exceedance percentile flow of 100 cfs resulting in a LMR of 0.1. After the diversion opened, 90 cfs was removed each day. Both the median and 95th exceedance percentile flows decreased by 90 cfs resulting in a decrease of the LMR statistic to 0.01. Alternatively, it is possible that a cessation of groundwater pumping may have increased the lowest flows in the river from the normal 100 cfs to 250 cfs at the 95th exceedance percentile. In this case an increase from 0.1 to 0.25 LMR would be observed. Table 1.2 shows the values and changes described in the examples. Just as in the CD value description, a single value of LMR is relatively uninformative. It is the comparison of different datasets that provides the utility of the LMR. Additionally, the LMR of 95th exceedance percentile to the 50th exceedance percentile is only one possibility. A ratio could be developed to look at changes in high flow events just as easily. However, the choice for the ratio percentiles used in the LMR calculations was based on the biological questions at issue.

Table 1.2. Examples of the measure of the Low Flow to Median Flow Ratio (LMR).

	Standard	Decreasing low flows	Increasing low flows
Low Flow	100 cfs	10 cfs	250 cfs
Median	1,000 cfs	900 cfs	1,000 cfs
LMR	0.1	0.01	0.25
		Decrease in LMR	Increase in LMR

Base flow Index

The base flow index characterizes low flow consistency. In this analysis, estimates of base flows were derived using the IHA software. The base flow index is an annual statistic which compared the 7-day minimum flow with the mean annual flow. The average of all years was provided as an estimate of the baseflow contribution to the river system. Given the annual nature of the statistic, it was not possible to examine changes in base flows during the year. The LMR statistic was used to examine changes in low flows (changes in the 95th exceedance percentage are expected to be reflective of changes in baseflow) throughout the year.

Flow Duration Curves

Flow duration curves characterize the magnitude and frequency of the discharge record. Flow duration curves are widespread in their use as they convey a wealth of hydrological information in a simple graphic display. (Voegel and Fennessey 1995). Flow duration curves have been used in “rule-of –thumb” to computerized incremental instream flow methods that translate the flow duration curve to a produce a habitat-duration curve (Gordon et al. 1992). A flow duration curve is a plot of discharge vs. percent of time that a particular discharge was equaled or exceeded, and is typically plotted on a log normal (discharge) to probability (exceedance value) scale. This changes typical sigmoid shape of the linear scaled plot to nearly a straight line. The flow-duration curve shape, especially in its upper and lower regions, is useful in evaluating of the characteristics of a river and its watershed. In the upper region, the shape of the curve denotes the flood regime characteristics (Moriwasa 1968). A steep curve is indicative of flashy floods usually resulting from rain events, while a flatter upper region could be the result of a steadier snowmelt runoff or upstream flood regulation by reservoir storage. In the lower region, the shape of the curve indicates low flow patterns. A steady falling line suggests the discharge in the river is mostly controlled by runoff as the longer time since last rainfall will result in lower flows. If the line flattens out then the low flows are sustained throughout the year due to groundwater adding to baseflow or to artificial flow regulation. A line that drops off quickly suggests water is being lost from the river channel possibly as a result of the surface water returning to groundwater or water being removed artificially for use outside of the river channel.

Minimum and Maximum Discharge, and Zero Flow Day Characteristics:

These statistics characterize the magnitude and frequency of extreme events. Minimum and maximum discharge characteristics were provided for the 1-day, 7-day, 30-day, and 90-day averages for the gage sites. In addition to the median values, ranges of exceedance percentages were calculated along with the coefficient of dispersion for the statistics. Statistics for 1-day flow represent the annual extreme condition, as compared to the week long (7-day), month long (30-day), or season long (90-day) extremes.

Bankfull flows:

Bankfull flows consider the magnitude and frequency of higher flows. Bankfull flows are high flow events that occur relatively frequently. The bankfull flows are considered to be flows that reach the top of the rivers banks. Larger flood occur and overtop the banks, but the bankfull flows have a large influence on the observed geomorphology of the river channel (Rosgen 1996). A generally accepted geomorphological definition of bankfull flow is:

> "The bankfull stage corresponds to the discharge at which channel maintenance is the most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing the work that results in average morphological characteristics of channels" (Dunne and Leopold 1978).

Bankfull discharge can also be named the effective discharge as it is the discharge that moves the most sediment over time. Large floods move substantial amounts of sediment, but they occur infrequently. In contrast, smaller floods move less sediment per flood, but occur much more frequently resulting in more overall sediment moved. To estimate bankfull discharge for the Platte River gages, a 1.5 year return period for small floods was chosen within the IHA software. Rosgen (1996) suggests that the 1.5 year flood event is typically close to the bankfull discharge. This can vary in different river types, but is the average of numerous rivers studies (Annable 1994).

Environmental Flow Characteristics:

Environment Flow Components (EFCs) and associated statistics characterize the magnitude, duration, frequency, timing, and rate of change of the discharge record. The Indicators of Hydrologic Alteration (IHA) software calculates a series of flow conditions that are intended to represent a spectrum of flow conditions that need to be maintained in order to support riverine ecological integrity. The five different types of Environment Flow Components are: low flows, extreme low flows, high flow pulses, small floods, and large floods.

The following description of the flow types is from the IHA software text "Analyzing Hydrologic Data Using the IHA - *Indicators of Hydrologic Alteration Version 7 help.*"

Low flows – This is the dominant flow condition in most rivers. In natural rivers, after a rainfall event or snowmelt period has passed and associated surface runoff from the catchment has subsided, the river returns to its base- or low-flow level. These low-flow levels are sustained by groundwater discharge into the river. The seasonally-varying low-flow levels in a river impose a fundamental constraint on a river's aquatic communities because it determines the amount of aquatic habitat available for most of the year. This has a strong influence on the diversity and number of organisms that can live in the river.

Extreme low flows – During drought periods, rivers drop to very low levels that can be stressful for many organisms, but may provide necessary conditions for other species. Water chemistry, temperature, and dissolved oxygen availability can become highly stressful to many organisms during extreme low flows, to the point that these conditions can cause considerable mortality. On the other hand, extreme low flows may concentrate aquatic prey for some species, or may be necessary to dry out low-lying floodplain areas and enable certain species of plants such as bald cypress to regenerate.

High-flow pulses – During rainstorms or brief periods of snowmelt, a river will rise above its low-flow level. As defined here, high-flow pulses include any water rises that do not overtop the channel banks. These pulses provide important and necessary disruptions in low flows. Even a small or brief flush of fresh water can provide much-needed relief from higher water temperatures or low oxygen conditions that typify low-flow periods, and deliver a nourishing subsidy of organic material or other food to support the aquatic food web. High-flow pulses also provide fish and other mobile creatures with increased access to up- and downstream areas.

Small floods – During floods, fish and other mobile organisms are able to move upstream, downstream, and out into floodplains or flooded wetlands to access additional habitats such as secondary channels, backwaters, sloughs, and shallow flooded areas. These usually inaccessible areas can provide substantial food resources. Shallow flooded areas are typically warmer than the main channel and full of nutrients and insects that fuel rapid growth in aquatic organisms. As used here, a "small flood" includes all river rises that overtop the main channel but does not include more extreme, and less frequent, floods.

Large floods – Extreme floods will typically re-arrange both the biological and physical structure of a river and its floodplain. These large floods can literally flush away many organisms, thereby depleting some populations but in many cases also creating new competitive advantages for some species. Extreme floods may also be important in forming key habitats such as oxbow lakes and floodplain wetlands.

Results:

The Louisville and North Bend sites are within the lower Platte River. The Duncan site was the most downstream on the central Platte River and describes conditions upstream of the lower Platte River and the central Platte River contribution to the lower Platte River. The North Bend site describes a combination of central Platte River discharge and Loup River discharge. The Louisville site describes the combination of discharge from the central Platte River, Loup River, Elkhorn River, and Salt Creek as well as other smaller tributaries.

*Note – The table and figures for the results section follow the written descriptions of each site. The tables and figures are not grouped by site, but grouped by analysis type and then ordered by site. This allows all sites to be compared for each type of result. The order of tables and figures is as follows:

- Average monthly median discharges comparing each site (Figure 1.1),
- Annual and monthly exceedance flows tables for each site (Tables 1.3 to 1.9),
- Flow duration curves for each site (Figures 1.2 to 1.8),
- Exceedance rates for minimum flow, maximum flow, and number of zero flow days for each site (Tables 1.10 to 1.16),
- Bankfull flow characteristics for each site (Table 1.17), and
- Proportion of flows from tributaries of the lower Platte River during moderately, high flows, low flows, and flood flows (Table 1.18).

In addition to these tables and figures, an additional group of figures showing results for numerous environmental flow characteristics are provide in Appendix 1. Information includes:

- Annual Peak Flow Exceedance Curves comparing sites,
- Monthly Median Discharge for each gage site,
- 1, 7, 30, and 90-day Annual Minimum Discharge for each gage site,
- 1, 7, 30, and 90-day Annual Maximum Discharge for each gage site,
- Annual Number of Zero Flow Days for each gage site,
- Annual Date, Number, and Duration of Low Flows for each gage site, and
- Annual Date, Number, and Duration of High Flows for each gage site.

General Site comparisons:

In terms of average median discharge, the Platte River sites for Louisville and North Bend had the highest annual and monthly discharge rates. The Loup River in combination with the Loup River Power Canal had the next largest flows, followed by the central Platte River and the Elkhorn River with comparable annual amounts, and Salt Creek being the lowest for annual and monthly median discharge. The Platte River sites displayed a spring rise and summer fall, while the Loup and Elkhorn Rivers, and Salt Creek had more stable flows throughout the year. Overall flows were the highest from February to June and lowest from July to October. Flood flows could happen throughout the year, but were most frequent in March and June, while the lowest flows of the years were generally in late July or August. The Platte River and its tributaries were not flashy rivers and they generally rose at twice the speed at which they fell and resulted in the length of time for flood waters to pass usually being measured in weeks to months. Not surprisingly, the smallest tributary, Salt Creek, displayed the flashiest flood characteristics. The magnitude of flood flows generally followed the overall median flow patterns with Louisville and North Bend having the largest flows followed by the Loup and Elkhorn Rivers. As a result of extensive flow modification, the central Platte River flood flows are now smaller than Salt Creek.

Platte River near Duncan, NE

On an annual basis, the mean discharge for the Platte River near Duncan, NE for the period of record from January 1, 1954 to Dec 31, 2005 was 1,867 cfs with a median flow of 1,250 cfs. The difference between the mean and median flows reflected the presence of high flow pulses recorded at the gage. Based on all daily flow recordings for the time period, the flow was greater than 417 cfs 80% of the time. Around 3% of the time the river was at zero flow. The river's discharge was greater than 1,000 cfs for 58% of the days, greater than 5,000 cfs for 6% of the days, and greater than 10,000 cfs for 1% of the days. The maximum flow recorded for the Platte River near Duncan was 23,800 cfs on 7/1/1983. For annual peak flows, the Platte River near Duncan exceeded 4,280 cfs in 8 out of 10 years, 7,000 cfs in 5 out of 10 years, and 13,800 cfs in 2 out of 10 years. The bankfull flows that occur every 1.5 years on average peaked at 7,130.

In terms of monthly median flow rates, the Platte River near Duncan, NE peaked in March (2,365 cfs) and was lowest in August (232 cfs). The river exceeded 1,000 cfs during February, March, and April more than 80% of the time. Zero flow days were possible from July until December, but were most frequent in August and September. The coefficient of dispersion (CD) reflected a change in flow characteristics between the winter and spring time period and late summer and fall. The low flow to median flow ratio (LMR) also reflected this pattern suggesting that base flow was missing from the river during the late summer and fall.

A description based on the median Environmental Flow Characteristics (EFC) for the middle Platte River near Duncan, NE resulted in the river as having the highest stable flows in March (1,618 cfs) dropping to lows in August (259 cfs) and with little change in discharge between October and January (1,000 cfs to 1,100 cfs). On an annual basis, the base flow was estimated to be 3% of the mean flow. The extreme low flows (less than 10% of annual mean) approached zero flow (1.9 cfs) during an 11 day event around August 25. Approximately 3 in 10 years would experience zero flow. There were 7 high flow pulses lasting 6 days per event. These pulses peaked at 2,650 cfs and occurred most commonly around the end of May. These high flow pulses rose nearly twice as fast as they fell (400 cfs and -233 cfs, respectively). Every other year there was a small flood event that approached a peak of 9,800 cfs lasting 63 days and was centered in mid May. Once every ten years a large flood would peak in late April near 22,500 cfs and last nearly 2 months (54 days) from beginning rise to return to low stable flow conditions. The flood waters would rise at 1,282 cfs per day and fall more slowly at -560 cfs per day.

Loup River near Genoa, NE

The Loup River near Genoa, NE had highly modified flow characteristics as it is downstream of the intake for the Loup Power Canal. The flow in the river at this site was influenced by seasonal flow as well as the amount of water needed for hydropower production. The median flow for the Loup River near Genoa was 120 cfs for the period of record between 1954 and 2005. Based on all daily flow recordings for the time period, the flow was greater than 28 cfs 80% of the time. Around 1% of the time the river was at zero flow. The river's discharge was greater than 1,000 cfs for 23% of the days, greater than 5,000 cfs for 1% of the days, and greater than 10,000 cfs for less than 1% of the days. The maximum flow recorded for the Loup River near Genoa was 70,800 cfs on 8/13/1966. Annual peak flows for the Loup River near Genoa exceeded 6,060 cfs in 8 out of 10 years, 8,880 cfs in 5 out of 10 years, and 16,200 cfs in 2 out of 10 years.

For median monthly flow, the Loup River near Genoa, NE was highest in December (1,000 cfs) and relatively high in January through March (840 to 957 cfs). The median monthly flows for the rest of the year were much lower with the only flow over 100 cfs occurring in April (271 cfs). The lowest median monthly flow occurred in August when median flow average 31 cfs. Zero flow days were possible from July until October, but were most frequent in July and August occurring on average 5% of the time.

The median Environmental Flow Characteristics (EFC) for the lower Loup River near Genoa, NE described the river as having the highest stable flows in January through March (289 to 204 cfs) with discharge less than 100 cfs the rest of the year with August having the lowest flows (28 cfs). The extreme low flows (less than 10% of annual mean) approached 3 cfs during a 4 days event around August 16. Approximately 1 in 10 years the Loup River near Genoa, NE would experience zero flow. There would be 16.5 high flow pulses lasting 4 days per event. These pulses would peak at 1,064 cfs around mid July. These high flow pulses would rise and fall at a similar rate (264 cfs and -200 cfs, respectively). Every other year there would be a small flood event that would approach 12,500 cfs lasting 23 days and centered in early May. Once every ten years a large flood would peak in mid June near 38,600 cfs and last 3 weeks from beginning rise to return to low stable flow conditions. The flood waters would rise at 3,637 cfs per day and fall more slowly at -2,903 cfs per day.

Loup River Power Canal near Genoa, NE

The Loup Public Power District (LPPD) has a hydropower station near Columbus, Nebraska that utilizes water diverted from the Loup River at Genoa, Nebraska. LPPD has been generating hydropower since March 5, 1937 and holds one of the most senior water rights in the basin. The power generating process is generally a pass through system and under their appropriation; the diversion facilities cannot pass more than 3,500 cubic feet per second. According to an agreement between LPPD and the Commission, LPPD always passes a minimum of 50-100 cfs of Loup River flow past their point of diversion.

The Loup River Power Canal withdrew an annual median flow of 1,800 cfs. This varied from a high of 2,190 cfs in April to a low of 761 cfs in December. It appeared from the monthly median flow rates that the Loup River Power Canal withdraws approximately 2000 cfs in most months with the other months around 1,000 cfs. Flows observed in the canal were greater than 3,020 cfs only 1% of the time on an annual basis. When flows were greater than 3,500 cfs in the Loup River above the Canal intake, the excess water flowed past the intake down the Loup River. In addition the flows captured by the Loup River Power Canal from the Loup River were returned to the Platte River several miles downstream of the confluence of the Loup and Platte Rivers. The intake flows are not directly correlated to the outfall flows into the Platte River, although as water is released through the power plant, water is added to the reservoir so that a similar flow pattern exists. On a daily basis the flows do not necessarily correspond, but the combination of the Loup River and Loup River Power Canal is an approximation of the water entering the Platte River from the Loup River system. Not included in this analysis were the hourly power peaking flows generated by power production. The daily mean flow was used in all calculations. The power peaking flows are an important issue, but beyond the scope of this analysis.

The median Environmental Flow Characteristics (EFC) for the lower Loup River Power Canal near Genoa, NE are inappropriate to describe flow conditions in the canal as it is controlled by the demand for energy not rainfall or groundwater flow. The Loup River Power Canal on average drew the most water in April (2,230 cfs) with December having the lowest flows (767 cfs). Most months the median canal flow was between 1,200 and 1,900 cfs. The 3-day minimum canal flow was 26 cfs and the 3-day maximum canal flow was 2,918 cfs. Overall, the Loup River Power Canal contained a large portion of the Loup River flow below Genoa for a good portion of the year.

Platte River near North Bend, NE

The gage site on the Platte River near North Bend, NE was the first gage on the lower Platte River. The annual median flow for the Platte River near North Bend was 3,630 cfs and was highest in March, April, and May with the peak in April at 5,880 cfs. The lowest monthly median flows were in August at 1,670 cfs. The coefficient of dispersion was generally stable with a value under 1 and the LMR was 0.27 annually. These metrics both suggest a large portion of base flow in this section of the river. Monthly flows approaching or exceeding 1,000 cfs were observed in all months greater than 80% of the time, with flows greater than 1,000 cfs 99% of the time in February to June and again in October. On an annual basis, flow of 5,000 cfs occurred more than 30 % of the time and more than 10,000 cfs 5% of the time. The maximum flow recorded for the Platte River near North Bend was 82,300 cfs on March 10, 1993. In terms of peak flows, flows greater than 21,000 cfs were observed in 1 out of 2 years and flows greater than 38,000 cfs were seen 1 out of every 5 years on average. The bankfull flows that occur every 1.5 years on average peaked at 21,280.

The median Environmental Flow Characteristics (EFC) for the lower Platte River near North Bend, NE described the river as having the highest stable flows in March and April (near 4,300 cfs) dropping to lows in August (1,815 cfs) and with another peak in November (3,545 cfs). On an annual basis, the base flow was estimated to be 19% of the mean flow. The extreme low flows (less than 10% of annual mean) typically occurred 5 times annually for 2 days per event. The lowest of these would be near 858 cfs around August 14. Only once in ten years would the extreme low flows reach 623 cfs. There would be 10 high flow pulses lasting 4 days per event. These pulses would peak at 6,085 cfs around June 20. These high flow pulses would rise nearly twice as fast as they would fall (1,044 cfs and -590 cfs, respectively). The bankfull flows that occur every 1.5 years on average peaked at 7,130 (Table 1.17). Every other year there would be a small flood event that would approach 26,950 cfs lasting 32 days and centered in early June. Once every ten years a large flood would peak in late April near 64,900 cfs and last nearly 1.5 months (46 days) from beginning rise to return to low stable flow conditions. The flood waters would rise at 6,244 cfs per day and fall more slowly at -1,686 cfs per day.

Elkhorn River near Waterloo, NE

The gage on the Elkhorn River near Waterloo, NE represented the contribution of the second largest tributary of the lower Platte River. The Elkhorn drained into the Platte River from the north and supplies a considerable amount of water to the Platte River. On an annual basis, the median flow of the Elkhorn River near Waterloo was 861 cfs. This made the contribution of the Elkhorn River approximately 45% of that of the Loup River system (Loup River and Loup River Power Canal combined). Median monthly flows in the Elkhorn River were highest from March to June with the peak in June at 1,620 cfs. In contrast to these values, the rest of the year's median monthly flow did not exceed 1,000 cfs and were more commonly around 600 cfs. The lowest median monthly flow was 524 cfs observed during September. The coefficient of dispersion and LMR (annual value of 0.33) suggested a stable base flow in the Elkhorn River near Waterloo. In terms of peak flows, the maximum discharge recorded during the time period of 1954 to 2005 was 44,500 cfs on March 29, 1962. On average the peak flow that occurred every other year was 14,200 cfs and once out of every five years the peak flow exceeded 23,100 cfs.

The median Environmental Flow Characteristics (EFC) for the lower Elkhorn River near Waterloo, NE described the river as having the highest stable flows in April (1,040 cfs) dropping to lows in September (503 cfs) and not rising substantially until the following March. On an annual basis, the base flow was estimated to be 26% of the mean flow. The extreme low flows (less than 10% of annual mean) typically occur once per year for 5 days. The low flow would be 251 cfs around November 17. Only once in ten years would the extreme low flows reach 128 cfs. There would be 7 high flow pulses lasting 5 days per event. These pulses would peak at 2,370 cfs around June 21. These high flow pulses would rise nearly twice as fast as they would fall (585 cfs and -282 cfs, respectively). Every other year there would be a small flood event that would approach 18,950 cfs lasting 35 days and centered in early June. Once every ten years a large flood would peak in early April near 41,000 cfs and last nearly 50 days from beginning rise to return to low stable flow conditions. The flood waters would rise at 4,354 cfs per day and fall more slowly at -1,098 cfs per day.

Salt Creek near Greenwood, NE

Salt Creek near Greenwood, NE was the largest tributary of the lower Platte River that drained into the river from the south. It was much smaller than the Loup or Elkhorn Rivers with an annual median flow of 146 cfs. Salt Creek near Greenwood had relatively stable flows throughout the year which peaked in March at 208 cfs and fell to a low of 116 cfs in October. The stable flow and large base flow are reflected in the coefficient of dispersion and LMR values during the months. June displayed the widest coefficient of dispersion as June flows were likely to be lower or higher than average. In terms of annual peak flows, Salt Creek near Greenwood reached 8,090 cfs in 1 out of 2 years and 20,300 cfs in 1 out of 5 years. The maximum flow recorded during the period between 1954 and 2005 was 37,100 cfs on June 13, 1984.

The median Environmental Flow Characteristics (EFC) for Salt Creek near Greenwood, NE described the river as having relatively stable flows all year ranging from a high of 168 cfs in March to a low of 99 in October. On an annual basis, the base flow was estimated to be 27% of the mean flow. The extreme low flows (less than 10% of annual mean) of 61 cfs occurred for 2 days in early October. Only once in ten years would the 1-day minimum flow reach 28 cfs. There would be 12 high flow pulses lasting 3.5 days per event. These pulses would peak at 357 cfs around July 12. These high flow pulses would rise nearly twice as fast as they would fall (140 cfs and -70 cfs, respectively). Every other year there would be a small flood event that would approach 13,230 cfs lasting 22 days and centered in late June. Once every ten years a large flood would peak in early July near 33,750 cfs and last nearly 78 days from beginning rise to return to low stable flow conditions. The flood waters would rise at 1,381 cfs per day and fall more slowly at -822 cfs per day.

Platte River near Louisville, NE

The gage near Louisville, NE on the Platte River was located downstream of all of the other gages previously discussed and was a combination of the waters received from these tributaries, direct runoff, as well as direct groundwater contributions. The median annual discharge at the gage was 5,230 cfs. Monthly median flows peaked in March at 8,355 cfs and reached their lowest during August at 2,720 cfs. Median monthly flows were greater than 5,912 cfs in March and greater than 1,470 cfs in August 80% of the time. A spring rise and late summer low was clearly observed in the monthly flow data. The annual coefficient of dispersion (0.93) and LMR (0.28) values reflected a large baseflow component to discharge. In terms of annual peak flows, the maximum flow recorded was 138,000 cfs on July 25, 1993. The median annual peak flow was 40,800 cfs and in 20% of the years a peak of 54,500 cfs was recorded. The bankfull flows that occur every 1.5 years on average peaked at 39,800.

The median Environmental Flow Characteristics (EFC) for the lower Platte River near Louisville, NE described the river as having the highest stable flows in March (6,360 cfs) dropping to lows in August (2,980 cfs) and rising again to peak in the next March. On an annual basis, the base flow was estimated to be 24% of the mean flow. The extreme low flows (less than 10% of annual mean) typically occur 3 or 4 times for 3.5 days per event. The lowest of these would near 1,320 cfs around August 19. Only once in ten years would the extreme low flows reach 1,122 cfs. There would be 9 high flow pulses lasting 5 days per event. These pulses would peak at 9,778 cfs around June 25. These high flow pulses would rise nearly twice as fast as they would fall (1,838 cfs and -954 cfs, respectively). Every other year there would be a small flood event that would approach 50,500 cfs lasting 25 days and centered in mid June. Once every ten years a large flood would peak in mid May near 114,000 cfs and last nearly 3 months (83 days) from beginning rise to return to low stable flow conditions. The flood waters would rise quickly at 7,926 cfs per day and fall more slowly at -3,506 cfs per day.

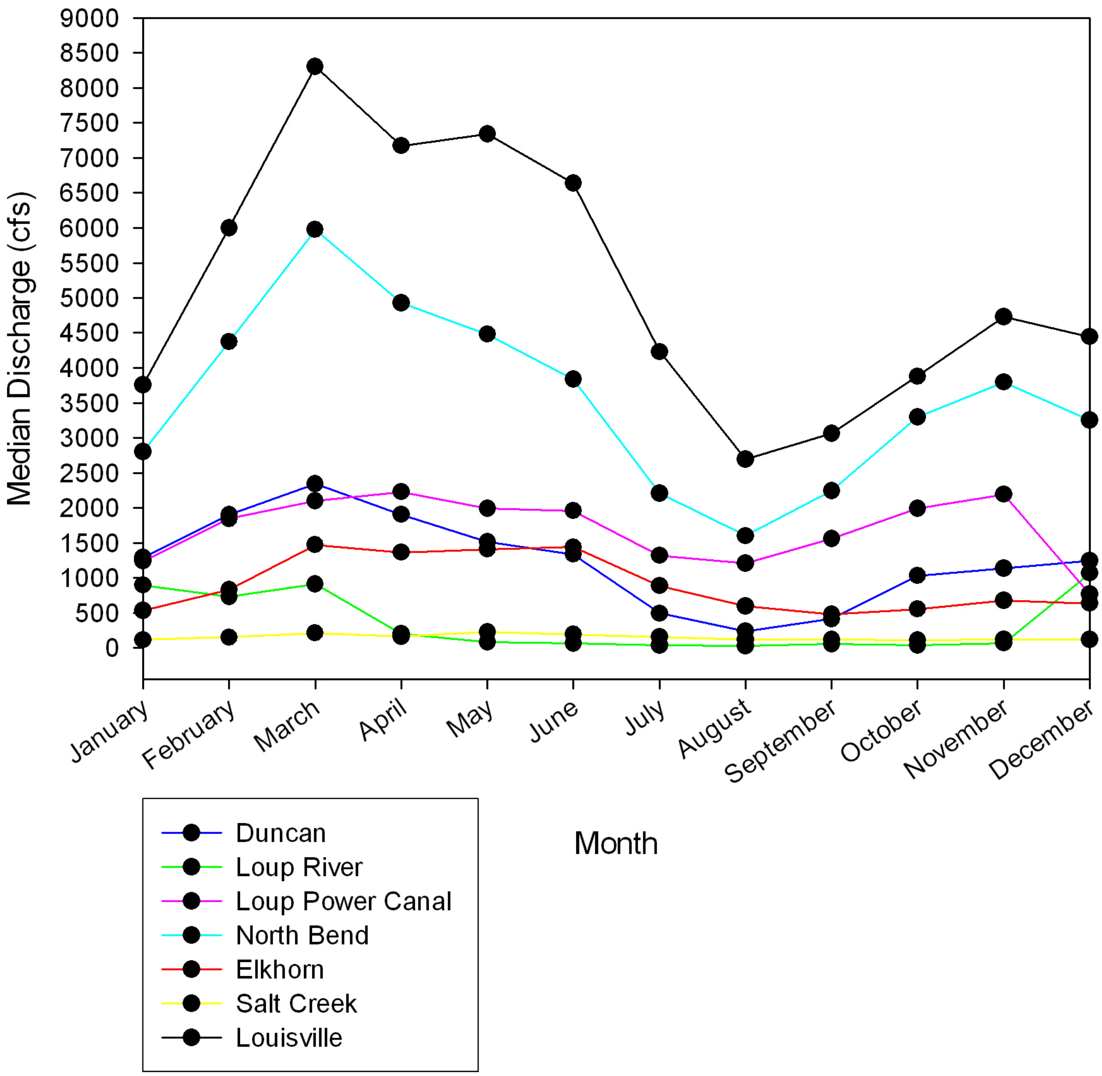

Figure 1.1. Average monthly median discharges (cfs) for the seven gage sites for 1954 – 2005.

Table 1.3. Annual and monthly exceedance flows (cfs) for the Platte River near Duncan, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	0	58	425	576	335	11	1	0	0	0	0	0	0
98%	0	268	540	643	405	106	7	0	0	0	0	0	135
97%	0	351	590	693	515	168	11	0	0	0	0	0	210
96%	1	400	620	747	566	207	27	0	0	0	0	0	270
95%	3	450	656	799	609	272	55	0	0	0	0	120	342
90%	85	558	799	1,051	785	423	149	5	0	0	8	414	480
85%	247	660	940	1,277	937	551	276	17	1	2	242	580	607
80%	417	740	1,060	1,400	1,060	692	383	38	6	8	328	712	725
75%	565	850	1,200	1,578	1,210	820	472	80	16	13	459	782	830
70%	704	939	1,364	1,730	1,410	951	617	129	43	77	565	838	900
65%	832	1,020	1,500	1,890	1,560	1,100	773	206	92	145	671	914	1,000
60%	973	1,100	1,600	2,000	1,690	1,250	934	288	139	204	767	982	1,060
55%	1,100	1,200	1,792	2,200	1,820	1,450	1,116	408	180	281	843	1,076	1,120
50%	1,250	1,300	1,900	2,365	1,950	1,620	1,265	533	232	388	959	1,165	1,210
45%	1,420	1,400	2,050	2,501	2,180	1,771	1,470	686	315	492	1,060	1,280	1,301
40%	1,610	1,546	2,200	2,710	2,350	2,020	1,710	824	397	594	1,170	1,474	1,500
35%	1,830	1,700	2,420	2,920	2,500	2,300	2,020	1,030	492	777	1,340	1,610	1,602
30%	2,100	1,897	2,650	3,094	2,650	2,597	2,455	1,247	608	1,030	1,570	1,780	1,800
25%	2,400	2,093	2,900	3,323	2,900	3,060	3,220	1,463	772	1,290	1,963	2,050	2,000
20%	2,740	2,300	3,100	3,588	3,220	3,558	4,302	1,868	1,068	1,720	2,348	2,322	2,300
15%	3,200	2,794	3,500	4,021	3,700	4,364	6,000	2,484	1,444	2,202	2,684	2,720	2,684
10%	4,000	3,200	4,182	5,314	4,611	5,864	8,758	3,804	2,149	3,001	3,310	3,071	3,098
5%	5,690	3,700	5,642	7,120	6,367	8,721	11,200	5,925	3,069	4,311	4,840	4,341	3,970
4%	6,300	3,900	6,000	7,860	7,186	9,899	12,264	6,557	3,506	4,838	5,162	4,550	4,100
3%	7,220	4,337	7,000	8,900	7,755	11,434	13,723	7,781	4,300	5,397	5,467	4,892	4,400
2%	8,766	4,700	8,200	9,898	9,978	13,678	15,464	9,996	5,546	5,876	5,859	5,303	4,700
1%	11,300	5,578	8,600	11,589	13,600	15,989	21,741	12,445	6,001	6,724	7,051	5,656	5,198
CD	1.47	0.96	0.89	0.74	0.87	1.38	2.17	2.60	3.26	3.30	1.57	1.09	0.97
LMR	0.00	0.35	0.35	0.34	0.31	0.17	0.04	0.00	0.00	0.00	0.00	0.10	0.28

Table 1.4. Annual and monthly exceedance flows (cfs) for the Loup River near Genoa, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	0	20	38	29	7	4	1	0	0	0	0	4	12
98%	1	35	44	37	10	6	2	0	0	0	1	6	16
97%	2	42	50	48	14	7	4	0	0	0	2	7	20
96%	4	47	60	51	17	9	6	0	0	2	3	9	25
95%	5	50	70	57	18	10	7	0	0	2	4	10	28
90%	12	72	120	78	34	14	15	2	2	7	6	18	51
85%	19	109	180	120	56	19	21	5	3	12	9	23	83
80%	28	170	250	188	68	25	28	9	4	16	12	28	140
75%	38	270	330	292	82	36	35	13	7	23	15	34	236
70%	48	350	410	391	94	45	44	17	9	30	19	40	350
65%	59	452	500	500	120	53	52	22	12	34	23	49	500
60%	73	580	600	653	153	62	57	28	16	42	26	56	700
55%	91	700	680	795	194	72	63	33	21	51	30	66	877
50%	120	840	840	957	271	81	71	38	31	59	36	80	1,000
45%	182	1,000	1,000	1,150	356	96	82	43	39	66	41	108	1,200
40%	300	1,100	1,150	1,300	477	122	100	49	50	75	48	165	1,400
35%	459	1,250	1,350	1,500	606	168	135	56	58	86	54	285	1,600
30%	653	1,414	1,500	1,727	721	260	211	67	71	103	67	447	1,760
25%	920	1,653	1,780	1,940	906	446	366	76	90	119	80	605	1,900
20%	1,240	1,876	2,100	2,248	1,150	727	656	101	108	152	115	835	2,080
15%	1,620	2,000	2,500	2,750	1,460	1,180	1,182	158	137	286	219	1,152	2,200
10%	2,100	2,327	3,000	3,427	2,151	1,830	2,002	358	367	681	394	1,630	2,500
5%	2,900	2,880	4,060	5,000	2,950	3,041	3,546	1,430	987	1,571	877	2,201	2,958
4%	3,080	3,000	4,500	5,924	3,143	3,511	4,176	1,886	1,252	2,003	1,050	2,350	3,000
3%	3,480	3,100	5,010	7,602	3,612	4,147	4,887	2,177	1,627	2,547	1,337	2,502	3,085
2%	4,160	3,300	6,902	9,985	4,185	5,036	6,367	2,808	1,988	2,978	1,856	2,700	3,206
1%	6,000	3,762	8,295	13,000	4,792	6,905	10,282	4,272	2,730	3,590	2,286	3,068	3,500
CD	7.35	1.65	1.73	1.72	3.05	5.06	4.66	1.66	2.69	1.63	1.81	7.13	1.66
LMR	0.04	0.06	0.08	0.06	0.07	0.12	0.10	0.00	0.00	0.04	0.10	0.13	0.03

Table 1.5. Annual and monthly exceedance flows (cfs) for the Loup River Power Canal near Genoa, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	23	15	53	64	1,060	142	532	226	123	46	245	16	10
98%	45	20	94	143	1,170	908	693	268	312	109	1,062	21	14
97%	64	24	121	193	1,258	1,110	798	315	345	540	1,140	42	17
96%	96	33	153	268	1,354	1,160	865	362	386	630	1,184	53	19
95%	139	38	230	370	1,440	1,220	948	377	435	687	1,230	65	22
90%	481	80	545	808	1,670	1,410	1,180	504	548	850	1,380	215	42
85%	747	143	836	1,120	1,780	1,490	1,310	587	668	948	1,490	750	58
80%	957	247	1,086	1,500	1,840	1,570	1,400	687	726	1,040	1,580	1,456	83
75%	1,150	406	1,280	1,690	1,900	1,660	1,500	795	800	1,160	1,670	1,760	126
70%	1,310	571	1,440	1,790	1,970	1,730	1,610	882	856	1,240	1,760	1,940	201
65%	1,450	764	1,548	1,840	2,020	1,820	1,720	979	922	1,317	1,830	2,020	308
60%	1,570	966	1,640	1,910	2,070	1,890	1,796	1,080	994	1,390	1,904	2,080	436
55%	1,690	1,100	1,726	2,000	2,130	1,960	1,870	1,180	1,090	1,476	1,970	2,130	595
50%	1,800	1,220	1,790	2,050	2,190	2,030	1,960	1,285	1,170	1,550	2,030	2,180	761
45%	1,890	1,350	1,840	2,100	2,250	2,091	2,040	1,390	1,240	1,630	2,110	2,210	928
40%	1,970	1,460	1,900	2,176	2,300	2,160	2,140	1,480	1,340	1,700	2,170	2,280	1,120
35%	2,050	1,552	1,932	2,260	2,360	2,250	2,230	1,560	1,440	1,780	2,240	2,330	1,300
30%	2,130	1,670	1,980	2,340	2,430	2,330	2,330	1,690	1,557	1,870	2,290	2,400	1,530
25%	2,220	1,800	2,020	2,440	2,490	2,440	2,470	1,860	1,670	1,970	2,360	2,470	1,763
20%	2,330	1,920	2,060	2,560	2,570	2,520	2,582	2,000	1,810	2,100	2,450	2,550	1,970
15%	2,460	2,010	2,120	2,650	2,662	2,630	2,720	2,194	1,970	2,200	2,540	2,610	2,130
10%	2,610	2,070	2,210	2,750	2,790	2,759	2,800	2,390	2,130	2,380	2,650	2,680	2,299
5%	2,790	2,190	2,460	2,880	2,890	2,905	2,920	2,710	2,405	2,720	2,780	2,790	2,570
4%	2,830	2,226	2,520	2,910	2,920	2,950	2,950	2,811	2,490	2,780	2,810	2,820	2,626
3%	2,870	2,260	2,610	2,930	2,970	3,003	3,000	2,870	2,580	2,840	2,840	2,850	2,697
2%	2,920	2,380	2,696	2,978	3,036	3,108	3,030	2,968	2,708	2,870	2,870	2,890	2,768
1%	3,020	2,549	2,790	3,010	3,100	3,179	3,080	3,088	2,870	2,918	2,939	2,940	2,880
CD	0.59	1.14	0.41	0.37	0.27	0.38	0.49	0.83	0.74	0.52	0.34	0.33	2.15
LMR	0.08	0.03	0.13	0.18	0.66	0.60	0.48	0.29	0.37	0.44	0.61	0.03	0.03

Table 1.6. Annual and monthly exceedance flows (cfs) for the Platte River near North Bend, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	470	575	1,090	2,156	2,232	1,423	1,016	219	231	501	1,301	864	611
98%	638	765	1,400	2,727	2,454	1,667	1,240	347	309	598	1,372	1,234	728
97%	775	925	1,671	2,903	2,625	1,810	1,400	394	361	733	1,463	1,600	823
96%	895	1,050	1,834	3,000	2,720	1,919	1,534	445	396	788	1,550	1,800	974
95%	984	1,126	2,000	3,161	2,780	2,036	1,620	500	441	842	1,630	1,960	1,067
90%	1,380	1,451	2,480	3,571	3,139	2,381	1,950	673	686	1,080	1,890	2,390	1,401
85%	1,740	1,700	2,754	3,877	3,389	2,630	2,210	821	864	1,230	2,030	2,690	1,700
80%	2,060	2,000	3,000	4,140	3,630	2,890	2,430	979	973	1,370	2,200	2,848	2,000
75%	2,340	2,150	3,200	4,488	3,840	3,090	2,688	1,170	1,060	1,490	2,368	2,980	2,200
70%	2,600	2,300	3,500	4,730	4,077	3,383	2,897	1,380	1,160	1,650	2,510	3,130	2,500
65%	2,840	2,500	3,664	5,000	4,297	3,607	3,150	1,590	1,260	1,807	2,650	3,330	2,700
60%	3,100	2,600	3,900	5,300	4,526	3,860	3,400	1,780	1,380	1,970	2,830	3,486	2,900
55%	3,380	2,700	4,200	5,560	4,740	4,160	3,730	2,030	1,510	2,140	3,010	3,620	3,100
50%	3,630	2,900	4,470	5,880	5,000	4,435	4,080	2,270	1,670	2,280	3,220	3,745	3,300
45%	3,920	3,100	4,700	6,191	5,295	4,800	4,510	2,570	1,850	2,455	3,441	3,905	3,510
40%	4,250	3,400	5,000	6,526	5,568	5,180	5,080	2,816	2,076	2,650	3,686	4,070	3,800
35%	4,620	3,600	5,400	6,872	5,950	5,652	5,700	3,212	2,310	2,910	4,000	4,280	4,062
30%	5,010	3,941	5,792	7,347	6,396	6,197	6,550	3,597	2,577	3,190	4,297	4,540	4,344
25%	5,520	4,378	6,160	8,030	6,860	6,890	7,980	4,113	3,003	3,613	4,710	4,850	4,653
20%	6,080	4,800	6,600	8,700	7,632	7,880	9,566	4,868	3,538	4,200	5,040	5,310	5,000
15%	6,900	5,200	7,396	9,607	8,543	9,214	11,700	5,774	4,214	4,917	5,520	5,840	5,500
10%	8,230	6,000	8,706	11,200	9,961	11,300	14,400	7,590	5,109	6,023	6,149	6,450	6,178
5%	10,800	7,041	11,000	15,045	12,000	14,000	18,400	10,915	6,612	8,151	8,009	7,442	7,000
4%	11,900	7,522	11,828	16,956	12,800	15,224	20,528	12,556	7,200	8,748	8,516	7,853	7,326
3%	13,200	7,800	12,700	19,067	13,946	17,000	24,492	14,734	7,800	9,266	9,107	8,232	7,867
2%	15,400	8,156	14,448	23,178	16,464	20,300	26,982	17,580	8,583	10,100	10,054	8,809	8,200
1%	20,200	8,400	17,000	30,545	20,969	25,089	33,928	21,879	10,189	11,841	11,000	9,840	8,629
CD	0.88	0.77	0.66	0.60	0.60	0.86	1.30	1.30	1.16	0.93	0.73	0.50	0.74
LMR	0.27	0.39	0.45	0.54	0.56	0.46	0.40	0.22	0.26	0.37	0.51	0.52	0.32

J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

Table 1.7. Annual and monthly exceedance flows (cfs) for the Elkhorn River near Waterloo, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	170	173	230	416	485	366	331	152	110	121	194	212	197
98%	212	196	240	447	553	406	366	199	134	131	212	250	216
97%	236	212	260	460	603	439	402	229	156	148	221	288	230
96%	260	235	273	480	630	481	436	249	173	168	252	299	247
95%	280	250	290	520	642	522	465	267	196	198	266	309	260
90%	350	300	359	700	712	614	599	363	249	244	299	356	310
85%	414	340	400	781	788	686	694	438	305	294	351	425	350
80%	469	366	460	851	872	778	770	497	358	334	392	480	400
75%	518	398	520	922	944	895	882	566	408	380	436	511	447
70%	571	430	580	998	1,020	974	1,020	643	458	410	461	548	470
65%	632	460	630	1,090	1,110	1,090	1,150	718	489	438	480	576	519
60%	696	490	700	1,180	1,190	1,180	1,296	801	520	464	510	610	560
55%	770	520	760	1,300	1,270	1,330	1,460	878	557	495	535	651	603
50%	861	560	880	1,400	1,390	1,520	1,620	964	596	524	563	673	640
45%	955	625	1,000	1,530	1,550	1,720	1,850	1,070	657	558	597	706	680
40%	1,060	700	1,100	1,720	1,750	2,000	2,120	1,190	715	620	640	757	730
35%	1,180	800	1,210	1,892	1,930	2,220	2,500	1,350	780	691	725	875	800
30%	1,330	860	1,350	2,140	2,193	2,540	2,930	1,530	849	802	843	972	880
25%	1,540	920	1,500	2,453	2,773	2,870	3,460	1,740	970	895	967	1,050	980
20%	1,830	1,000	1,700	2,858	3,370	3,360	4,132	2,038	1,140	975	1,120	1,120	1,118
15%	2,260	1,100	2,000	3,494	3,972	3,990	5,092	2,434	1,370	1,130	1,260	1,250	1,250
10%	3,040	1,249	2,500	4,589	4,901	4,848	6,841	3,039	1,800	1,430	1,540	1,541	1,480
5%	4,690	1,540	3,500	7,000	7,089	7,173	10,100	4,555	2,540	2,181	2,039	2,061	1,750
4%	5,420	1,700	4,028	7,505	7,996	7,800	11,400	5,507	2,974	2,526	2,182	2,146	1,810
3%	6,410	1,847	5,396	9,168	8,807	8,477	13,600	6,447	3,360	2,935	2,447	2,312	1,930
2%	8,000	2,039	7,000	12,512	11,128	9,656	15,846	8,526	3,966	3,448	2,938	2,673	2,076
1%	11,500	2,400	8,898	21,212	12,864	12,445	20,582	12,267	7,996	4,703	3,751	3,344	2,209
CD	1.19	0.93	1.11	1.09	1.32	1.30	1.59	1.22	0.94	0.98	0.94	0.80	0.83
LMR	0.33	0.45	0.33	0.37	0.46	0.34	0.29	0.28	0.33	0.38	0.47	0.46	0.41

Table 1.8. Annual and monthly exceedance flows (cfs) for Salt Creek near Greenwood, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	34	25	40	44	49	50	44	40	35	30	34	36	29
98%	40	28	44	62	54	54	54	45	40	34	36	39	36
97%	48	32	50	66	64	60	62	51	48	40	38	44	41
96%	54	34	54	72	68	64	66	54	55	45	42	52	45
95%	60	40	58	75	72	68	69	58	59	50	51	58	52
90%	75	60	75	91	93	87	86	72	74	73	71	78	68
85%	85	72	93	103	105	103	100	85	82	78	76	85	77
80%	93	80	102	113	112	114	114	95	88	84	81	93	87
75%	101	90	109	129	120	125	127	103	94	90	86	101	92
70%	108	94	117	140	129	137	139	112	99	95	92	106	98
65%	116	100	125	157	142	151	154	125	106	101	97	110	104
60%	124	105	132	171	152	168	171	140	117	107	101	114	109
55%	134	111	147	187	168	192	185	156	126	114	108	118	115
50%	146	120	160	208	186	233	213	175	133	123	116	123	120
45%	160	127	173	230	206	272	251	190	141	132	125	131	124
40%	178	138	190	255	230	317	296	210	150	141	138	140	130
35%	200	150	205	280	272	370	343	238	166	151	152	155	140
30%	226	163	233	308	310	430	407	271	185	170	166	169	150
25%	264	190	260	351	356	527	510	320	213	192	182	191	170
20%	317	205	295	422	439	655	634	395	249	232	211	214	185
15%	398	222	357	563	569	925	829	494	315	292	246	253	210
10%	569	260	448	922	776	1,328	1,212	782	414	407	333	325	249
5%	1,090	346	653	1,729	1,261	2,235	2,585	1,629	812	780	562	407	325
4%	1,330	354	763	2,186	1,470	2,557	3,053	1,948	1,066	919	710	469	349
3%	1,760	438	964	2,683	1,818	3,427	3,858	2,513	1,440	1,112	938	503	380
2%	2,402	564	1,386	3,510	2,631	4,330	5,958	3,349	2,286	1,478	1,198	592	430
1%	3,892	893	2,050	4,770	3,632	5,259	9,383	6,158	3,780	2,472	2,160	902	533
CD	1.12	0.83	0.94	1.07	1.27	1.73	1.80	1.24	0.89	0.83	0.83	0.74	0.65
LMR	0.41	0.33	0.36	0.36	0.39	0.29	0.32	0.33	0.44	0.41	0.44	0.47	0.43

Table 1.9. Annual and monthly exceedance flows (cfs) for the Platte River near Louisville, NE (1954-2005). CD is the coefficient of dispersion and LMR is the low flow (95%) to median flow (50%) ratio.

% Exceed	Annual	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
99%	744	1,004	1,750	3,027	3,210	2,072	1,606	513	366	366	1,543	1,416	718
98%	1,010	1,270	1,932	3,513	3,554	2,370	1,877	604	493	672	1,700	1,921	1,009
97%	1,220	1,433	2,442	3,793	3,728	2,483	2,088	710	573	932	1,820	2,300	1,210
96%	1,360	1,604	2,647	4,244	3,864	2,669	2,317	819	700	1,010	1,890	2,460	1,344
95%	1,490	1,750	2,800	4,411	3,979	2,816	2,490	900	763	1,050	1,980	2,550	1,496
90%	2,020	2,102	3,146	5,030	4,499	3,580	3,030	1,291	1,090	1,310	2,290	3,120	2,020
85%	2,510	2,400	3,500	5,450	5,000	4,007	3,489	1,600	1,330	1,550	2,527	3,420	2,400
80%	2,930	2,700	3,900	5,912	5,370	4,530	3,898	1,910	1,470	1,768	2,730	3,638	2,800
75%	3,300	2,990	4,200	6,310	5,695	5,000	4,418	2,200	1,600	1,970	2,880	3,830	3,100
70%	3,630	3,100	4,600	6,653	6,000	5,450	4,920	2,500	1,720	2,150	3,060	4,000	3,400
65%	4,000	3,300	5,032	7,000	6,220	5,930	5,357	2,880	1,900	2,420	3,259	4,187	3,700
60%	4,390	3,500	5,400	7,488	6,520	6,410	5,886	3,264	2,170	2,650	3,454	4,356	4,000
55%	4,780	3,749	5,800	7,870	6,980	6,889	6,550	3,660	2,450	2,920	3,650	4,530	4,300
50%	5,230	4,000	6,000	8,355	7,420	7,415	7,180	4,075	2,720	3,180	3,920	4,740	4,500
45%	5,790	4,221	6,400	8,881	7,920	7,941	7,912	4,551	3,030	3,405	4,270	4,990	4,750
40%	6,260	4,600	7,000	9,426	8,500	8,616	8,904	5,086	3,332	3,700	4,662	5,300	5,056
35%	6,800	5,000	7,600	10,200	9,268	9,320	9,944	5,842	3,700	4,044	5,092	5,820	5,400
30%	7,420	5,465	8,200	10,900	10,100	10,500	11,400	6,437	4,120	4,470	5,820	6,300	5,880
25%	8,160	6,153	8,940	11,700	11,100	11,600	13,300	7,203	4,818	5,193	6,515	6,773	6,400
20%	9,150	6,608	9,704	13,000	12,700	13,300	15,800	8,088	5,778	6,152	7,060	7,236	6,928
15%	10,500	7,400	10,800	15,000	14,700	15,600	19,645	9,514	7,000	7,013	7,670	7,770	7,440
10%	12,700	8,510	12,420	17,700	17,600	19,090	24,000	12,490	8,480	8,331	9,098	8,811	8,229
5%	18,000	10,000	16,860	24,945	22,905	25,900	31,700	17,745	10,400	11,000	11,000	10,300	9,625
4%	20,132	10,400	18,000	28,112	25,264	27,868	34,692	19,312	10,900	11,764	11,756	10,900	9,939
3%	23,000	11,000	19,296	33,400	28,922	32,000	40,492	22,501	12,867	13,346	12,700	11,200	10,100
2%	27,316	11,178	21,976	39,546	33,082	35,890	46,728	27,578	16,556	15,064	14,078	11,700	10,656
1%	36,008	12,000	30,096	52,746	39,300	40,589	58,000	38,090	25,156	19,641	16,789	12,900	11,178
CD	0.93	0.79	0.79	0.65	0.73	0.89	1.24	1.23	1.18	1.01	0.93	0.62	0.73
LMR	0.28	0.44	0.47	0.53	0.54	0.38	0.35	0.22	0.28	0.33	0.51	0.54	0.33

J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

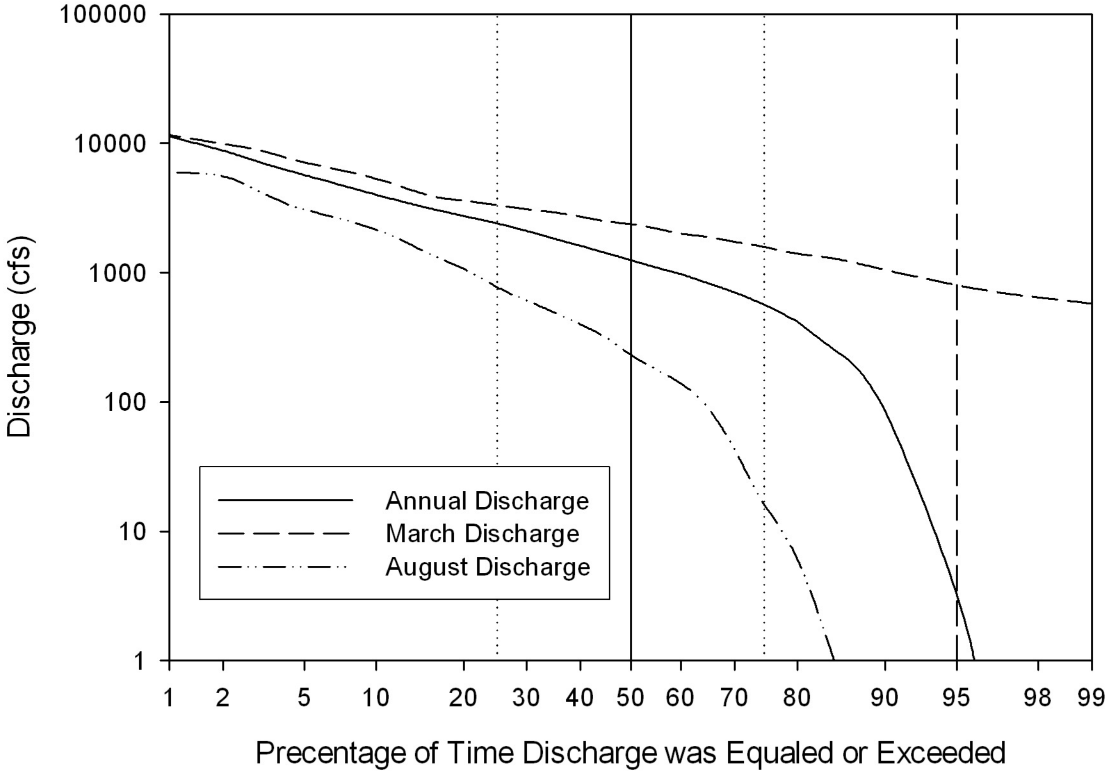

Figure 1.2. Flow duration curve for the Platte River near Duncan, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

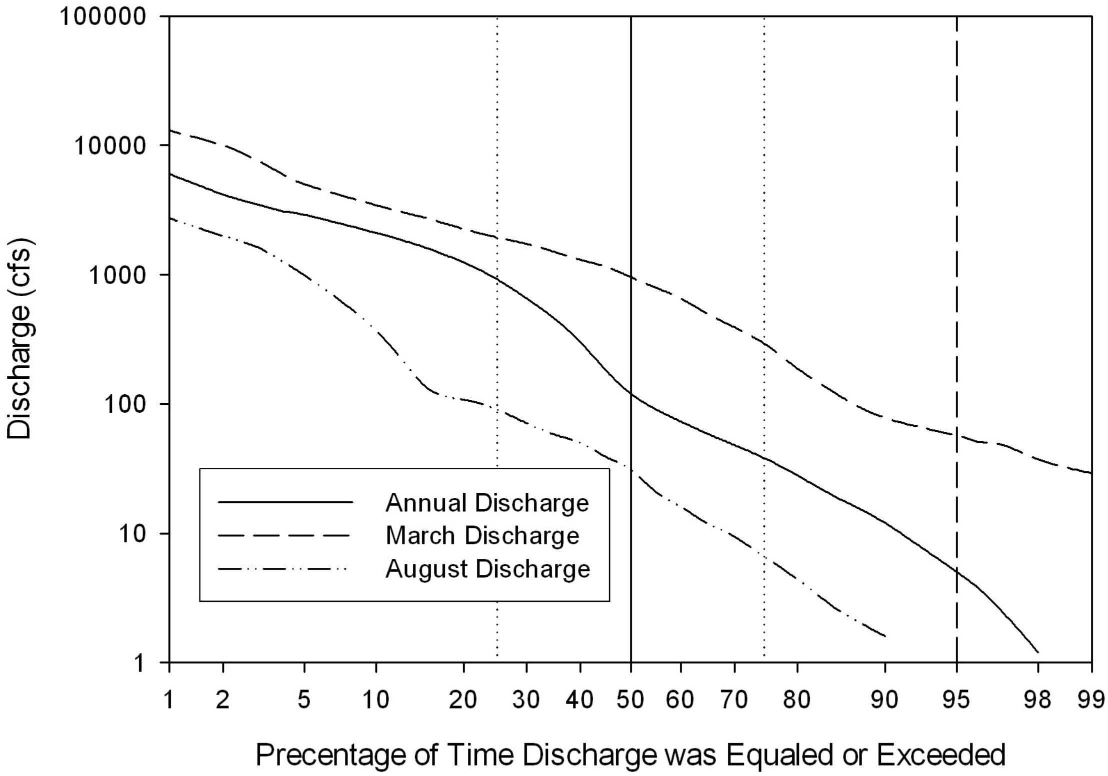

Figure 1.3. Flow duration curve for the Loup River near Genoa, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

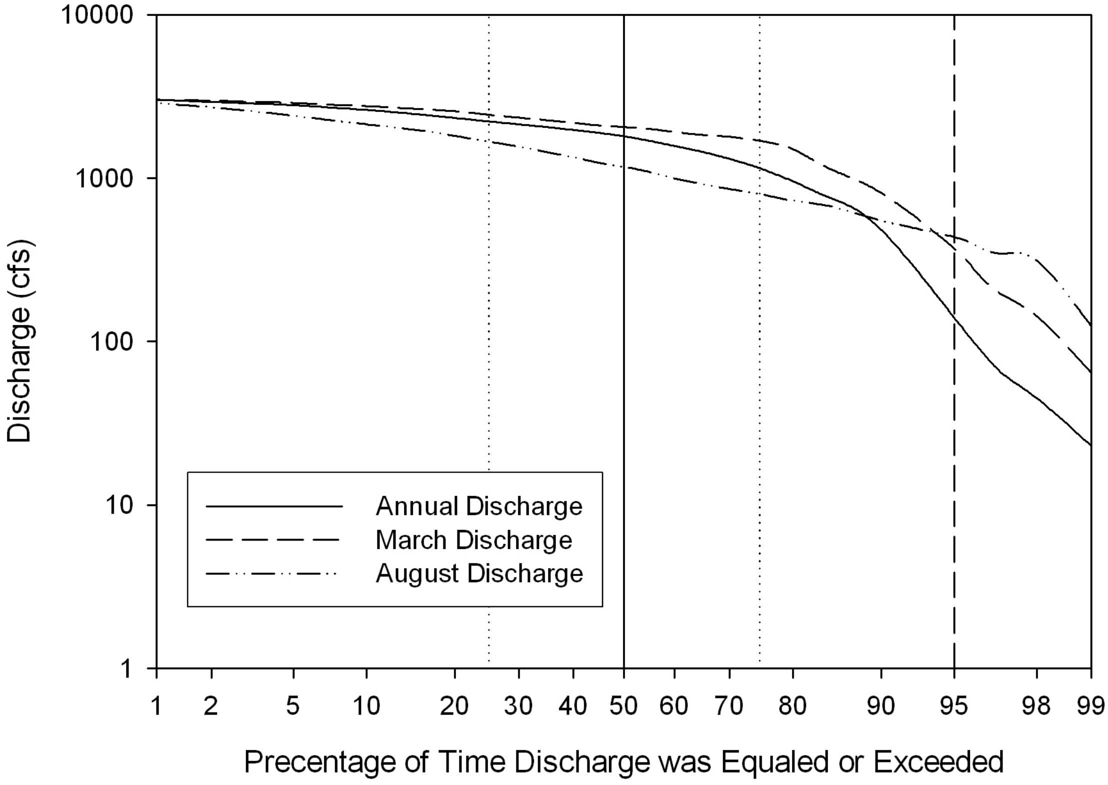

Figure 1.4. Flow duration curve for the Loup River Power Canal near Genoa, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

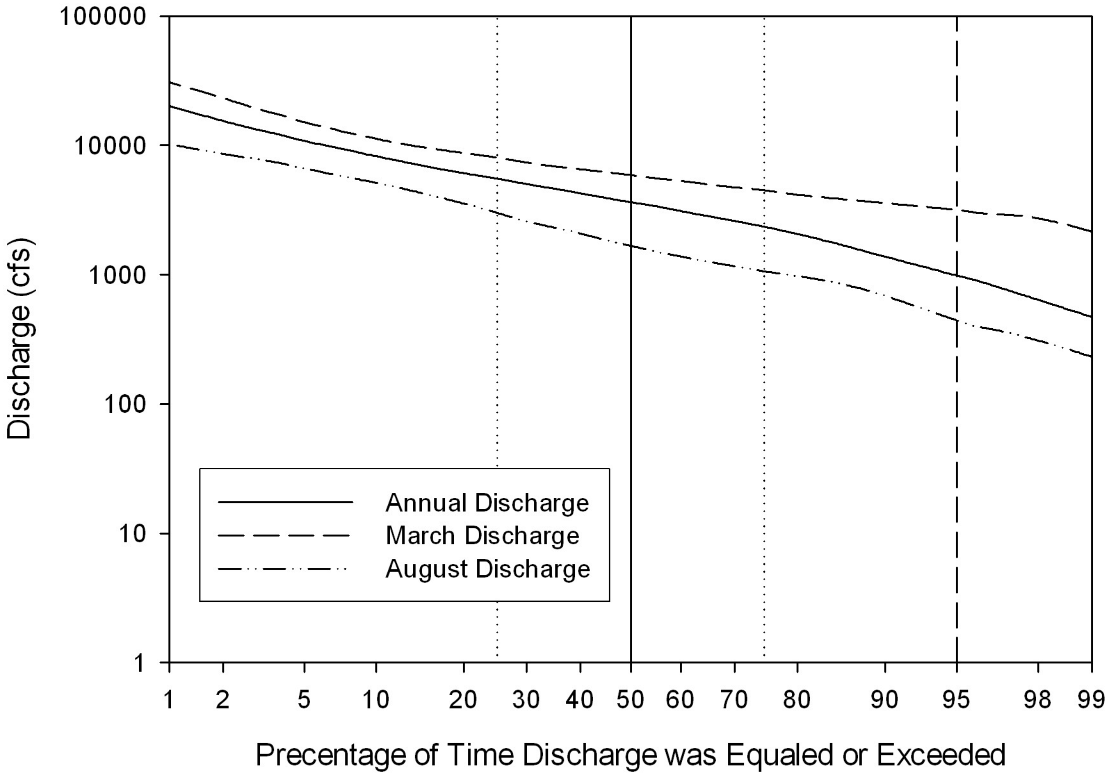

Figure 1.5. Flow duration curve for the Platte River near North Bend, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

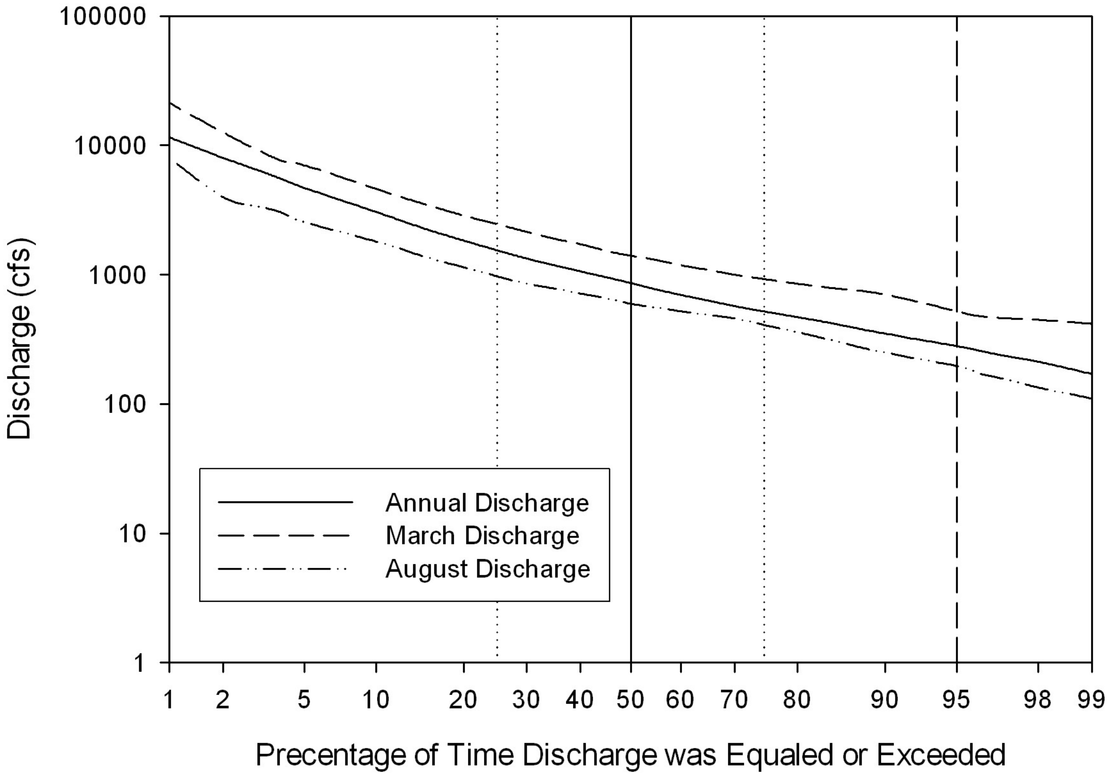

Figure 1.6. Flow duration curve for the Elkhorn River near Waterloo, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

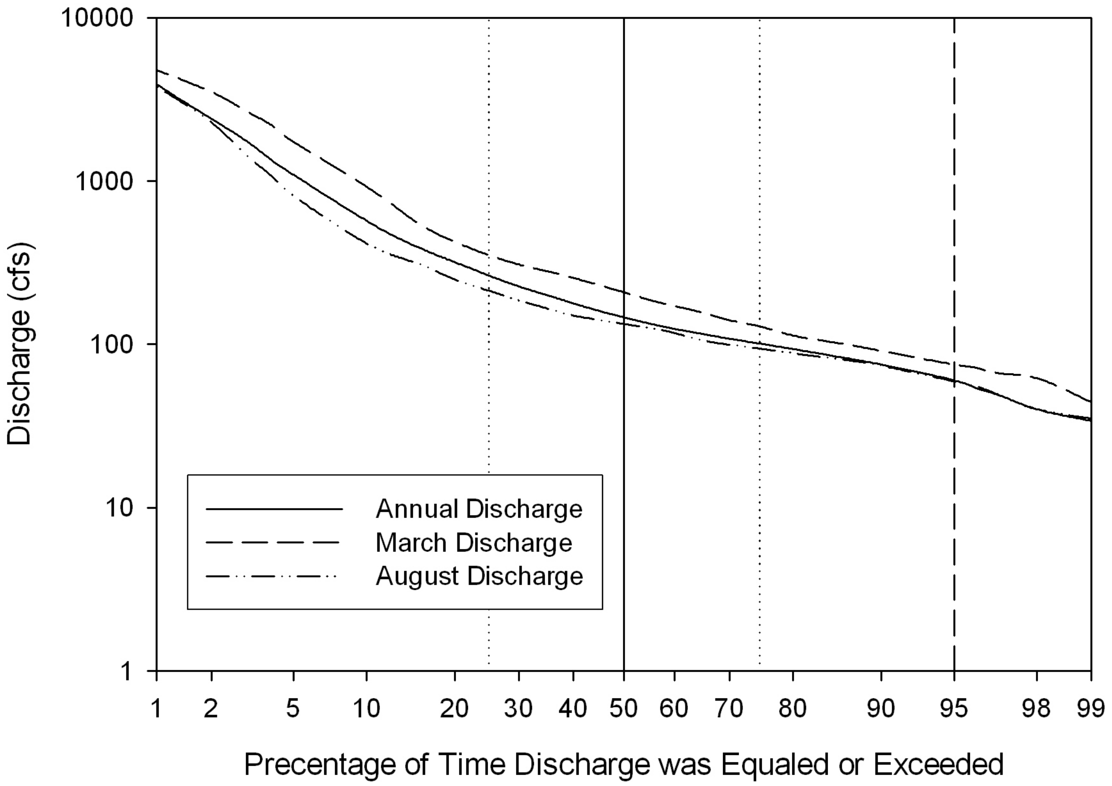

Figure 1.7. Flow duration curve for Salt Creek near Greenwood, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

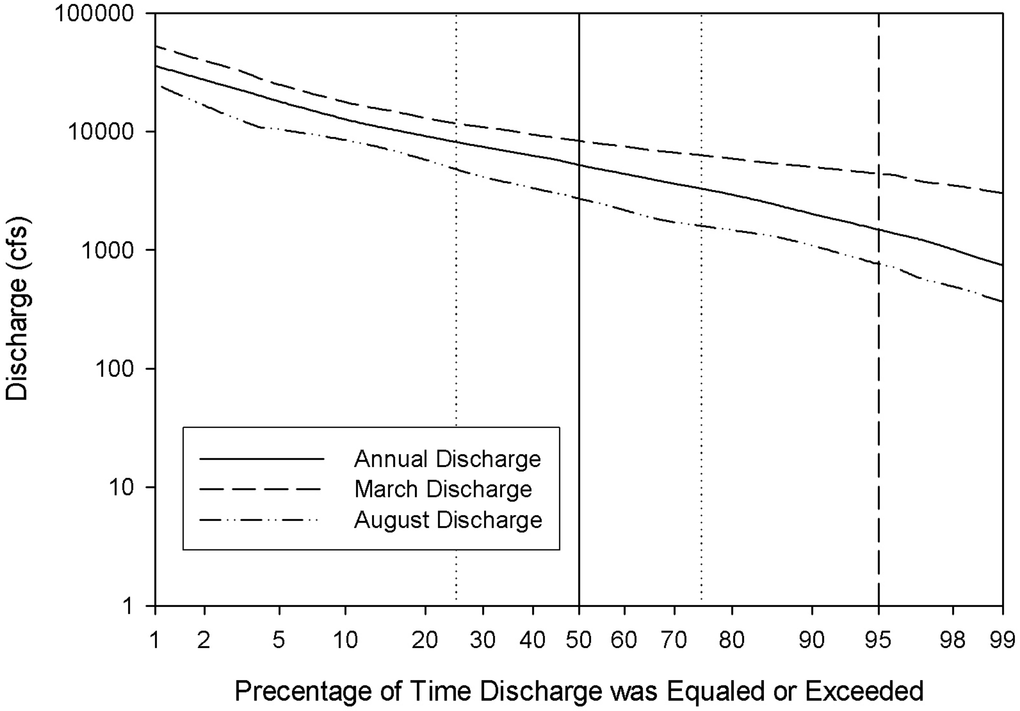

Figure 1.8. Flow duration curve for the Platte River near Louisville, NE for 1954 – 2005. The solid vertical line at 50 % exceedance is the median discharge and the dotted vertical line is the 95% exceedance discharge. 95% exceedance discharges / 50% exceedance discharges = Low to Median discharge Ratio (LMR).

Table 1.10. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Platte River near Duncan, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	0	0	24	227	450	9.46
3-day minimum	0	0	27	237	478	8.87
7-day minimum	0	1	43	281	674	6.47
30-day minimum	0	9	132	489	1,141	3.64
90-day minimum	4	88	457	1,010	2,068	2.02
1-day maximum	3,432	4,305	7,015	11,830	17,900	1.07
3-day maximum	3,264	3,950	6,373	10,770	17,390	1.07
7-day maximum	2,728	3,428	5,439	10,100	14,040	1.23
30-day maximum	1,863	2,481	3,455	6,229	10,530	1.09
90-day maximum	1,419	1,924	2,595	4,078	6,845	0.83
Number of zero days	0	0	0	2	69	0.00

Table 1.11. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Loup River near Genoa, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	0	1	5	12	22	2.19
3-day minimum	0	1	7	14	27	1.97
7-day minimum	0	2	8	21	30	2.25
30-day minimum	1	5	14	40	81	2.47
90-day minimum	9	24	59	97	214	1.22
1-day maximum	4,179	6,365	8,995	14,980	30,000	0.96
3-day maximum	2,987	4,179	6,443	11,090	23,330	1.07
7-day maximum	2,327	3,008	4,279	7,294	13,520	1.00
30-day maximum	1,161	1,626	2,366	3,907	4,549	0.96
90-day maximum	644	899	1,469	2,073	2,585	0.80
Number of zero days	0	0	0	0	29	0.00

Table 1.12. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Loup River Power Canal near Genoa, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	4	9	17	32	62	1.38
3-day minimum	7	14	26	44	102	1.13
7-day minimum	20	32	55	111	308	1.45
30-day minimum	199	370	527	788	951	0.79
90-day minimum	765	986	1,204	1,397	1,574	0.34
1-day maximum	2,800	2,893	2,980	3,120	3,285	0.08
3-day maximum	2,728	2,810	2,918	3,053	3,181	0.08
7-day maximum	2,615	2,717	2,829	2,974	3,062	0.09
30-day maximum	2,275	2,465	2,579	2,736	2,818	0.11
90-day maximum	1,972	2,152	2,276	2,419	2,503	0.12
Number of zero days	0	0	0	0	0	0.00

Table 1.13. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Platte River near North Bend, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	249	354	532	714	1,292	0.68
3-day minimum	290	427	684	904	1,464	0.70
7-day minimum	333	519	781	1,065	1,633	0.70
30-day minimum	612	938	1,294	1,909	2,918	0.75
90-day minimum	1,095	1,366	2,034	3,283	4,109	0.94
1-day maximum	10,480	13,280	21,150	32,280	59,630	0.90
3-day maximum	8,522	11,390	16,970	28,300	48,690	1.00
7-day maximum	7,452	9,493	14,940	19,710	36,840	0.68
30-day maximum	5,447	6,249	9,145	12,000	18,740	0.63
90-day maximum	4,084	5,391	6,570	8,929	11,930	0.54
Number of zero days	0	0	0	0	0	0.00

Table 1.14. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Elkhorn River near Waterloo, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	128	186	261	441	668	0.98
3-day minimum	134	198	278	455	714	0.93
7-day minimum	141	217	319	501	753	0.89
30-day minimum	187	277	415	636	879	0.86
90-day minimum	304	409	546	998	1,371	1.08
1-day maximum	4,314	7,878	14,550	21,600	37,180	0.94
3-day maximum	3,440	6,424	10,960	16,620	32,700	0.93
7-day maximum	2,596	4,559	8,099	10,720	20,770	0.76
30-day maximum	1,517	2,327	4,103	6,319	10,290	0.97
90-day maximum	1,189	1,757	2,482	4,044	5,855	0.92
Number of zero days	0	0	0	0	0	0.00

Table 1.15. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Salt Creek near Greenwood, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	28	51	70	97	129	0.66
3-day minimum	31	55	72	98	134	0.60
7-day minimum	34	61	75	100	136	0.51
30-day minimum	54	74	92	113	183	0.43
90-day minimum	76	92	123	153	244	0.49
1-day maximum	2,300	3,800	8,145	15,780	23,900	1.47
3-day maximum	1,309	2,288	4,337	9,638	13,620	1.70
7-day maximum	697	1,285	2,477	4,769	7,075	1.41
30-day maximum	316	529	1,139	2,022	3,042	1.31
90-day maximum	235	354	590	1,162	1,520	1.37
Number of zero days	0	0	0	0	0	0.00

Table 1.16. Exceedance rates for minimum flow (cfs), maximum flow (cfs), and number of zero flow days for the Platte River near Louisville, NE during the period 1954-2005.

	% exceedance					CD
	90%	75%	50%	25%	10%	(25-75)/50
1-day minimum	411	690	1,110	1,633	3,008	0.85
3-day minimum	475	802	1,212	1,913	3,336	0.92
7-day minimum	589	904	1,355	2,290	3,543	1.02
30-day minimum	945	1,343	1,919	3,363	4,928	1.05
90-day minimum	1,493	2,256	2,999	5,119	6,627	0.95
1-day maximum	17,480	24,350	40,950	52,750	94,850	0.69
3-day maximum	15,350	20,330	33,450	42,810	82,640	0.67
7-day maximum	11,970	15,660	24,230	32,850	61,650	0.71
30-day maximum	7,880	9,986	14,380	21,370	34,330	0.79
90-day maximum	6,757	7,554	10,190	14,630	21,060	0.69
Number of zero days	0	0	0	0	0	0.00

Table 1.17. Bankfull flow characteristics for the Platte River gage sites.

Site	Peak (cfs)	Duration (days)	timing	rise rate (cfs)	fall rate (cfs)
Duncan	7,130	32	5/26	555	-463
Loup River	10,930	21	5/7	1,514	-1,094
North Bend	21,280	35	5/15	1,387	-1,465
Elkhorn River	16,700	35	6/9	2,672	-940.5
Salt Creek	9,520	20.5	6/22	2,041	-570.3
Louisville	39,800	22.5	6/4	4,177	-2,331

* approximately 3,000 cfs could be added to the peak flow statistics for Loup River as an approximation of the water diverted through the Loup River Power Canal.

Table 1.18. Proportion of flows from tributaries of the lower Platte River during moderately high flows, low flows, and flood flows (cfs).

Site	Period Higher flows May 80% exceed	% of Louisville flow Period Higher flows May 80% exceed
Central Platte River (Duncan)	692	15.3%
Loup River (Loup River +Loup Power canal)	1,595	35.2%
Elkhorn River	778	17.2%
Salt Creek	114	2.5%
Lower Platte River (Louisville)	4,530	100.0%

Site	Period of lower flows July 80% exceed	% of Louisville flow Period of lower flows July 80% exceed
Central Platte River (Duncan)	38	2.0%
Loup River (Loup River +Loup Power canal)	696	36.4%
Elkhorn River	497	26.0%
Salt Creek	95	5.0%
Lower Platte River (Louisville)	1,910	100.0%

Site	Bankfull flows 1.5 year return flood	% of Louisville flow Bankfull flows 1.5 year return flood
Central Platte River (Duncan)	7,130	17.9%
Loup River (Loup River +Loup Power canal)	13,955	35.1%
Elkhorn River	16,700	42.0%
Salt Creek	9,520	23.9%
Lower Platte River (Louisville)	39,800	100.0%

Conclusions:

The hydrologic analysis of the lower Platte River showed a river that retains its most natural characteristics as one travels further downstream. The central Platte River is highly modified and its hydrograph bears little resemblance to historical estimates (Figure 1.9). The central Platte River contributes approximately 15 % of the water volume of the lower Platte River at Louisville during non-irrigating seasons, but only 2% in the summer (Table 1.16). Flood flows have also been decreased as the central Platte River now provides less water than Salt Creek in terms of bankfull flood flows (17.9% to 23.9% of Louisville bankfull flows.) Additionally, the Platte River is a sandbed river with interaction between surface and subsurface flows. There are areas of gaining and losing flows on the Platte River (NRC 2005). When observing seasonal changes in LMR values for the central Platte River at Duncan, modification of the river's low flow regime becomes apparent. While it is beyond the scope of this analysis to estimate the gaining or losing nature of different sections of river, it is unlikely that this geologically controlled aspect of the river bed changes substantially with in the seasons in a natural setting. While some variation is expected and probably natural as a result in seasonal changes in evapotranspiration, broad shifts from a river with baseflows (LMR near 0.35 for January to May) to a river without baseflows during irrigating seasons (LMR near 0 for June to November) likely reflects the withdrawal of water for irrigation.

The addition of the Loup River water and that of the Loup River Power Canal are important in providing substantial amounts of water to the lower Platte River. The Loup River contributes approximately 35% of the water to the lower Platte River (Table 1.16) The Loup River is not without modification, yet its contribution to the lower Platte River is substantial and important. The effect of the hydropower return on the lower Platte River was obvious. From the daily variation in flow volume (Figure 1.10) to the overall steady contribution of baseflow to the lower Platte River (nearly a median of 2,000 cfs daily in most months) the power return has a large effect on the downstream sections of the Platte River. While the hydropeaking may cause some environmental damage due to the rapid wetting and drying of shallow river areas, it may also serve to mobilize sediment at higher rates during the pulses keeping sandbars free from vegetation (Ed Peters, personal communication). It is beyond the scope of this analysis to assess the role of hydropower peaking on the lower Platte River, but it may be an important factor in the observed habitats on the lower Platte River.

With the addition of the Elkhorn River and then Salt Creek, the lower Platte River in the vicinity of Louisville, NE seems to retain much of the important flow characteristics of its natural hydrograph. The spring rise and summer low flows exist at Louisville, yet the peak observed in mid June during the 1895- to 1905 time period near Duncan is not as pronounced. (Figures 1.1 and 1.9) The variable timing of water inputs from the upstream sources provide baseflow throughout much of the year with no large shift in CD or LMR values during the seasons. Additionally, peak flows exist at frequent and relatively large magnitudes (bankfull flows near 40,000 cfs occurring at a 1.5 year return period and ten year floods averaging nearly 114,000 cfs). As a result, the channel of the lower Platte River still contains a wide range of habitats from large sandbars and woody islands to shallow sandbars and swift channels. The combination consistent low flows and frequent high flows support the development of the different habitats (Figure 1.11).

It is important to remember that the range of flows in this analysis were all modified flows. The analysis only covers the years 1954 – 2005, and the major upstream dams were in place prior to this period. The last of large upstream reservoir, Lake McConaughy began filling in 1941, and Calamus Reservoir on a tributary of the Loup River was completed in 1985. As a result, the conditions observed today may not resemble historical natural conditions, but at least in the Louisville area, many of the important riverine habitats still exist in the river.

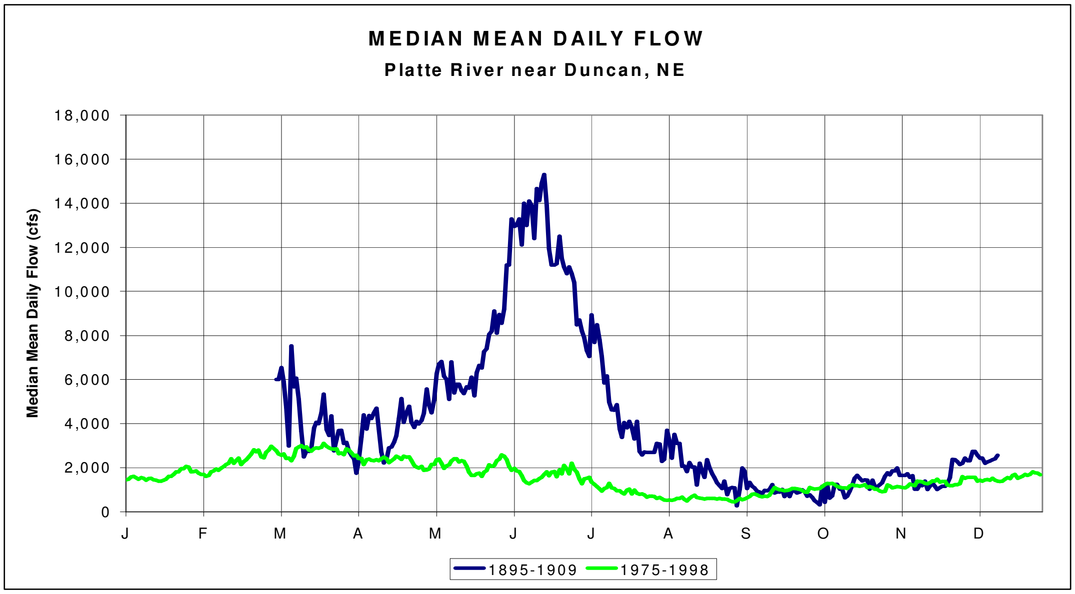

Figure 1.9. Median mean daily flow in the Platte River at Duncan, Nebraska, in 1895-1909 vs. 1975-98. (USGS gage data, as presented in Platte River FEIS, USDOI (2006)).

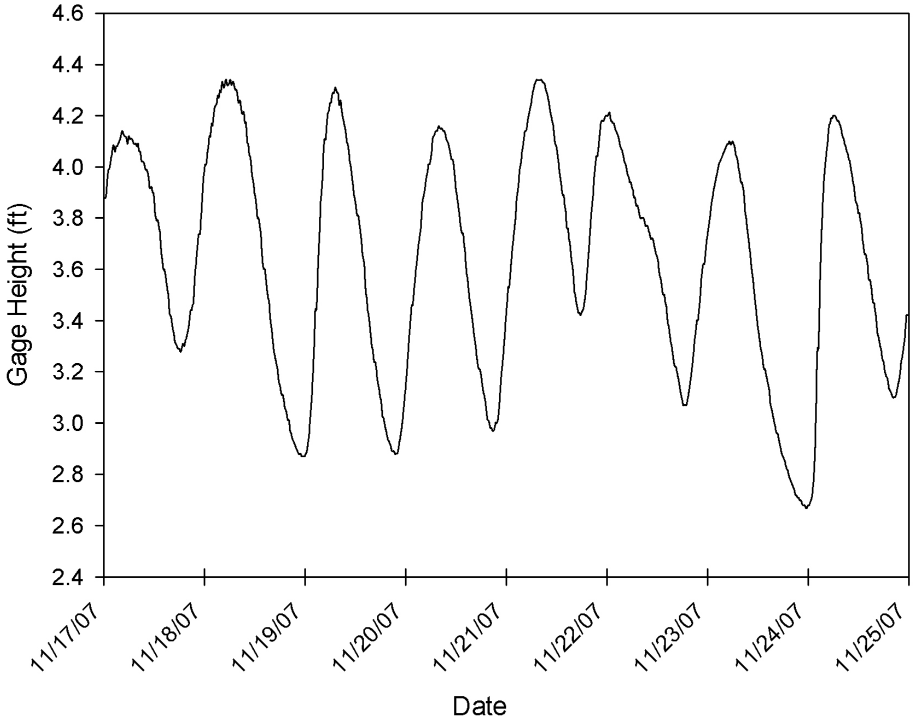

Figure 1.10. Water depth (ft) fluctuations in the Platte River near North Bend, NE (USGS Gage No 0679600) during November 17 – 25, 2007. Data is in provisional status.

Figure 1. 11. The lower Platte River downstream of the Louisville gage site during low flow conditions. Note the presence of exposed sandbars, shallow sandbar complexes, as well as deeper channels near the shorelines.

Chapter 2 - Estimation of Least Tern and Piping Plover nesting habitat in relation to river discharge

Introduction:

Least Terns and Piping Plovers are endangered birds that nest on the sandbars of the lower Platte River. These birds typically select nest sites on dry, unvegetated sandbars and unvegetated portions of sandbars. Exposed sandbars are created during periods of higher flows where the river waters erode, move, and deposit the sandy bed materials into the mosaic of scalloped sandbars and braided channels. As the discharge falls after a flood period, the water depth decreases and much of the channel is exposed in the form of newly created sandbars. Sandbars vary in size, shape, and height, and in depositional areas of the river (wider and lower slope than average) large sandbars are common. Over time, the sandbars erode naturally from the effects of wind, water, and ice although some may be stabilized by vegetation. The natural process of sandbar formation, erosion, and stabilization with vegetation are illustrated in Figures 2.1, 2.2, and 2.3.

Figure 2.1. Moderately high water on the lower Platte River near North Bend on June 14, 2007. Note the ripples in the center of the photograph. These reflect the presence of shallow sandbars not far beneath the surface. Compare this to the smooth water seen on left side of the photograph, where water was deeper. Higher flows scour channels, move sand downstream, deposit it in lower velocity areas, and clear overtopped sandbars of vegetation. (Photo by Joel Jorgensen, NGPC).

Figure 2.2. A large sandbar near Valley, NE on July 13, 2007 exposed during a period of lower water discharge. Note the lack of vegetation on the sandbar and the relative height of the sandbar above the waterline. This sandbar would provide nesting habitat for Least Terns or Piping Plovers if future water discharge did not rise to a level that would flood nests. (Photo by Joel Jorgensen, NGPC).

Figure 2.3. Vegetated sandbars in the Platte River near Columbus, NE on September 9, 2007. If higher water discharge does not occur, the exposed sandbars will become

covered by vegetation. Note the swath of dark green woody sapling vegetation, only a few years old, established mid-channel. Vegetated sandbars are not suitable nesting habitat for Least Terns or Piping Plovers. (Photo by Joel Jorgensen, NGPC).

This chapter provides an analysis of the timing, duration, and magnitude of river discharge that creates and sustains nesting habitat for Least Terns and Piping Plovers. To accomplish this, several aspects of discharge and nesting requirements were considered. These include:

1. Define Least Tern and Piping Plover nesting requirements with respect to river discharge

2. Estimate of the height of sandbars created by river discharge

3. Determine the relationship between past high water flows and current sandbar height

4. Estimate the potential for nest inundation under historical discharge conditions

5. Estimate the surface area of large sandbar habitat, that is disconnected from the shoreline, in relation to river discharge

6. Estimate overall historical nesting habitat suitability from discharge records.

7. Describe the discharge characteristics of years with high habitat suitability.

Methods:

The data used to describe the timing, duration, and nesting habitats of Least Terns and Piping Plovers was based on a review of the literature (Haig 1992, Kirsch 1992, Sidle et al. 1992, Ziewitz et al. 1992, Kirsch 1996, Thompson et al. 1997, Aron 2005, and NRC 2005) and in consultation with NGPC biologists. The models presented here associate descriptions of the habitats used by breeding birds to past discharge records of the lower Platte River.

The characteristics of sandbars used to describe nesting habitat with respect to river discharge were assumed to be similar for Least Terns and Piping Plovers. Consequently, only one set of calculations is used to estimate the amount of nesting habitat for these two species on the lower Platte River. Two metrics were created to describe different aspects of river sandbars, the first termed habitat quality and the second termed habitat quantity. These two metrics were combined to characterize nesting habitat suitability.

Several of the analytical methods used to create the habitat quality and quantity metrics, and to estimate suitability were similar. The analyses all used the mean daily flow record available for the time period 1954 – 2005 from the USGS website: (http://nwis.waterdata.usgs.gov/ne/nwis/sw). The analyses follow identical methodology for each of the river gage sites, near Louisville (Site Number 6805500), North Bend (Site Number 6796000), and Duncan (Site Number 6774000). The Louisville and North Bend sites are within the lower Platte River. The Duncan site was the most downstream on the central Platte River and describes conditions upstream of the lower Platte River. The Duncan site describes the central Platte River contribution to the lower Platter River. The North Bend site describes a combination of central Platte River discharge and Loup River discharge. The Louisville site describes the combination of discharge from the central Platte River, Loup River, Elkhorn River, and Salt Creek.

The *breeding season* is defined as the period from May 1 to August 31 in each year (a total of 123 days). The breeding season covered the period of time when the majority of nesting occurs for Least Tern and Piping Plover on the river. Additionally, a 60-day nesting period was established to cover nest initiation, nesting, hatching, and fledging. A *nesting period* is defined as 60 consecutive days during the breeding season. The first nesting period was May 1 to June 30, the second was May 2 to July 1, and so on until the final nesting period from July 2 to August 31. The nesting periods are a 60-day moving window with the breeding season. There were a total of 63 nesting periods in each breeding season.

The nesting period reflects a period of time that terns or plovers have an opportunity to successfully fledging young. Breeding season arrival, nest initiation, incubation periods, and hatch-to-fledgling periods vary between the two species and between individuals. Piping Plovers arrive in late April and early May, earlier than Least Terns which arrive in late May. Piping Plover incubation averages 28 days (Haig 1992) and chicks fledge 21–35 days post-hatching (Aron 2005). Least Tern incubation is shorter, generally 18–21 days, but can also be as long as 28 days (Thompson et al. 1997, Aron 2005). Juvenile terns are capable of flight approximately 21 days post-hatching (Thompson et al. 1997). The average incubation to fledging time for Least Terns is estimated to be 42 days and 56 days for Piping Plovers. Additional time is required prior to incubation for pairs to form pair bonds, engage in courtship, make nest scrapes, select a nest site, and lay eggs. It generally takes 6 days for the typical 4 egg Piping Plover clutch to be completed (Haig 1992). Least Terns typically have 3 egg clutches, laying one egg every one or two days (Thompson et al. 1997). Overall, the average arrival to fledging time for Least Terns was estimated around 55 days to 65 days for Piping Plovers. The nesting period is assumed to be 60 days for both species given the variation in length of time needed for each step in the breeding season.

Habitat Quality

Habitat quality measured the possibility of nest inundation. More specifically, the *habitat quality* metric is a combination of the height of the sandbars created by the highest flows in the preceding 1.5 years with the height of the water surface during a 60-day nesting period. This metric estimates the likelihood that acceptable flow conditions were present during a given 60-day nesting period.

Five assumptions were developed after consultation with NGPC biologists and the relevant literature.

1. The highest discharge in the preceding 1.5 years was considered the current "habitat forming flow." This is roughly analogous to the bankfull discharge which is considered the 1.5 return flood flow (Rosgen 1996). The bankfull discharge corresponds to the discharge which generally does the work that results in average morphological characteristics of channels (Dunne and Leopold 1978). Additionally, the maximum height of the sandbars available to the birds was controlled by the past flood events. The 1.5 year window also accounts for the natural revegetation processes. It is assumed sandbars that are not flooded will become unsuitable nesting habitat as vegetation grows up on the sandbar after 1.5 years. Least Terns generally select sites that lack vegetative cover (Dirks 1990, Ziewitz et al. 1992), but may nest on sites with up to 30 percent vegetative cover (Schulenberg and Placek 1984, Dryer and Dryer 1985, Rumancik 1985). The optimum range for vegetative cover on Piping Plover nesting habitat has been estimated at 0–10 percent (Armbruster 1986). The estimate that sandbars remain unvegetated for 1.5 years is likely longer than actually occurs. Sandbars are colonized quickly by grasses and fast growing species such as cottonwood trees and willows in the absence of higher flow. Cottonwood trees are a fast growing species and can grow 10 meters in four years (Putnam et al. 1960). Estimating the rate of growth and amount of vegetative cover on a sandbar was outside the scope of this analysis; therefore sandbar habitat was considered unvegetated for the whole 1.5 year period.

2. The maximum water surface elevation during the 60-day nesting period was at least 1.5 foot lower than the height of the sandbars created by the habitat forming flow. The 1.5 foot height is based on reported minimum sandbar elevations at nesting sites (Ziewitz et al., 1992). This height is a conservative estimate for several reasons. First, natural erosion (Bauer and Schmidt, 1993) and erosion associated with hydropower peaking (Dexter and Cluer, 1999) would decrease the overall height of sandbars created by peak flows (up to 1.5 years without erosion is assumed in this analysis). Second, the analysis uses mean daily discharge values and does not account for the daily flow fluctuations resulting from the hydropower peaking discharges from the Loup Power Plant Canal (Figure 2.4). Least Terns and Piping Plovers nest on dry sandbars and do not place nests on moist substrates (Thompson et al. 1997, Haig 1992), therefore the sandbar elevation must be high enough to avoid inundation during flow fluctuations.

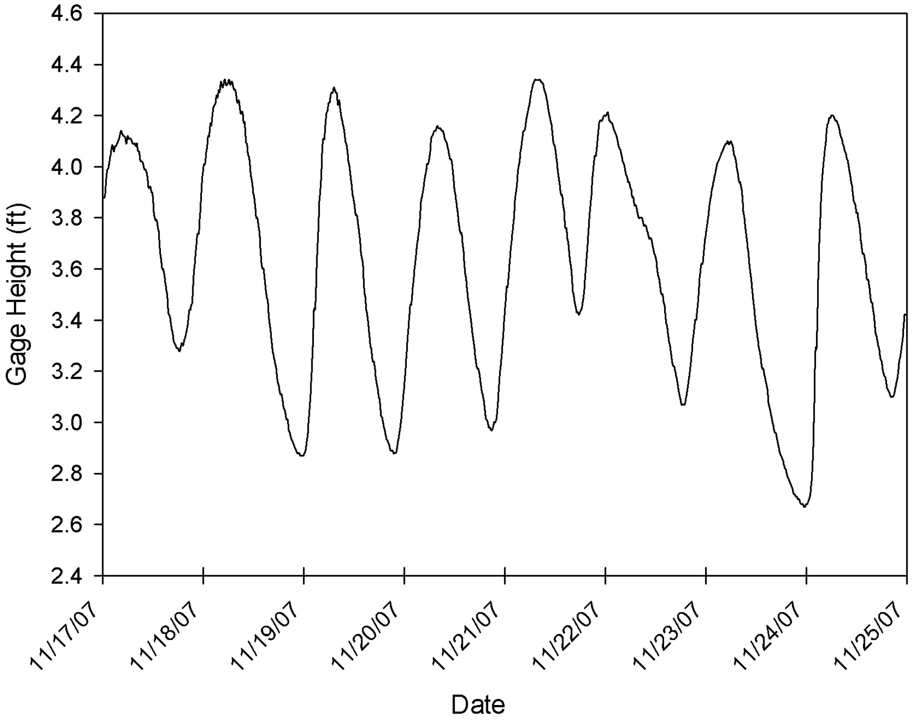

Figure 2.4. Water depth (ft) fluctuations in the Platte River near North Bend, NE (USGS Gage No 0679600) during November 17 – 25, 2007. Data is in provisional status.

3. If all days in a nesting period had a maximum sandbar elevation greater than or equal to1.5 ft above the water surface elevation, then the nesting period is considered acceptable for nesting. Conversely, if a nesting period had any day with maximum sandbar elevations less than 1.5 ft above water surface elevation, then the entire period is considered unacceptable for nesting.

4. It is also assumed that birds would renest if conditions were appropriate after a nest inundating flood. Any nesting period could be used by the birds even if preceded by unsuitable conditions. While the model assumes unlimited renesting, in reality the number of times a pair of birds can renest is limited. For example, upon the loss of eggs or newly hatched chicks, a pair of Piping Plovers may renest up to four times, but renesting efforts usually result in fewer eggs being produced (Lingle 1988, USFWS 1990). The likelihood of renesting decreases with progression of the breeding season. New nests are rarely initiated after the first week of July (NGPC database).

5. The overall habitat quality for a single breeding season is the sum of the nesting periods considered acceptable for nesting. A single 60-day nesting period would allow the birds to have a successful breeding season. This presupposes that the birds “know” on which date they should begin nesting for acceptable flow conditions during the future 59 days. As the number of acceptable nesting periods increase, the chance of nesting with acceptable conditions increases. For example, if 10 nesting periods were acceptable, the birds would have a 10 out of 63 (maximum number of nesting periods in a breeding season) chance of selecting an acceptable nest initiation date.

To estimate the height of sandbars created by the 1.5 year peak flow, the USGS discharge data was converted to estimate the channel characteristics created by the flows. Mussetter Engineering, Inc. (2002) calculated the channel characteristics and sediment transport capabilities of the lower Platte River in the vicinity of the mouth of the Elkhorn River. Nine transects crossing the width of the river were located up and downstream of the mouth of the Elkhorn River. The discharge to channel depth data for each of the nine transects was averaged to provide a general description of discharge to channel depth to be used to represent the conditions for the lower Platte River as a whole. A line was fit to the data to create an equation to estimate channel depth from the discharge using Table Curve 2D 5.01 (Systat, 2002). Selection of the most appropriate curve followed methods outlined in the curve-fitting software. This process generally followed the criteria simultaneously increasing adjusted r^2 values, reducing parameterization, eliminating unstable or undefined regions, and examining the curve with the goal of choosing the simplest equation that describes the curve. The equation for the channel depth to discharge relationship was used to determine channel depth for each daily discharge record.

The height of the sandbars created by the discharge is considered the inverse of channel depth. For example, if a discharge of 10,000 cfs creates a channel depth of 2.4 ft, then areas outside of the main channel will deposit sand to nearly the surface of the water. It was assumed that the currently active channel (the area underwater) will have a range of depths from nearly 0 inches to 2.4 ft in the channel. If the discharge fell to 5,000 cfs, the new channel depth of 1.7 ft would result in exposed sandbars of 0.7 ft. This is likely a maximum estimate of sandbar height as some smoothing of the exposed sandbars is expected to occur by natural erosion and some infilling of the bottom of channel. It is also expected that sandbars are not evenly distributed throughout the river channel, being more common in depositional areas, but that average conditions were similar in each river reach.

To determine the daily values for the habitat quality metric during the 4-month breeding season, the mean daily flow for each day and the maximum daily flow for the preceding 1.5 year period were recorded. These discharge values were converted to sandbar heights using the depth to discharge equation provided above. The difference between the maximum sandbar height during the preceding 1.5 year period and the daily value was calculated. If this difference was greater or equal to 1.5 ft, then the daily value was set to 1; if the difference was less than 1.5 ft then the daily value was set to 0. The minimum value for the 60-day nesting period was determined. If the minimum value for habitat quality was 0 during the 60-day nesting period, the nesting period was considered to be unacceptable. If the minimum value for habitat quality was 1 during the 60-day nesting period, then habitat conditions were considered to be acceptable for successful nesting. For each year, the number of all acceptable nesting periods was tallied and the percent of the total number of nesting periods during each breeding season was calculated.

Habitat Quantity

While *habitat quality* measures the height of sandbars and the possibility of nest inundation, *habitat quantity* is a measure of the amount of exposed sandbars at different discharge rates. This metric does not determine if the flow conditions are acceptable, but rather gives an estimate of the amount of available habitat over the 60-day nesting period.

To estimate the area of exposed sandbars available to Least Terns and Piping Plovers in relation to discharge, aerial photographs of different reaches of the lower Platte River were analyzed. Digital orthoquadrangle (DOQ) images were collected for the area covering the lower Platte River for 1993, 1994, and 1999. These DOQs were provided by the National Aerial Photography Program (NAPP). The 1:40,000 scale aerial photographs were taken at 20,000 ft above the land surface with a 6-inch focal length camera. The scanned images were rectified to orthographic projections of 1 m resolution based on the National Mapping Standards and cast on the Universal Transverse Mercator Projection (UTM) on the North American Datum of 1983 (NAD83). The images for the NAPP within each year were acquired over a number of different days as the flight lines for the images covered the segment of the state in a north-south direction. A portion of the images for the 1993 state coverage were reacquired in 1994, presumably as a result of unsatisfactory image quality. A total of 7 different dates were used to develop the 1993 (1994) images and 5 dates for the 1999 images. Since the images were acquired on different days, discharge values were not consistent across the combined image of the 103 RM river segments; therefore, contiguous image groups were developed for individual dates. An additional flight on was made on August 15, 2003 to acquire images during drought conditions. The images were acquired from approximately 6,000 ft above the land surface with a Nikon F4 digital camera with images taken from a port in the bottom of a small aircraft. Each contiguous image group was digitized, classified, and post-processed individually. Each image group was projected into NAD83 UTM zone 14 prior to digitizing.

The aerial images were classified at the 1:5000 scale using on-screen digitizing methods in ArcGIS 9.2 (ESRI 2007) following the procedure in Peters and Parham (*in press*). The habitat in the images was classified using the following criteria.

1. Sandbars were at least 3.58 acres in surface area. This size was recommended by Ziewitz et al. (1992).

2. Sandbars were mostly free of seasonal or woody vegetation. The determination of whether the sandbar had too much vegetation was based on the size of the unvegetated area. If the area was greater than 3.58 acres, then the sandbar was considered acceptable. For example, if a sandbar was 6 acres with 4 acres unvegetated, than the sandbar was considered suitable.

3. Sandbars were disconnected from the shoreline. Isolated sandbars provide protection from mammalian predators and increased distance from perch locations of avian predators. Lingle (1993b) reported that about 53 percent of Least Tern and Piping Plover deaths along the central Platte River were due to predation, and Ivan and Murphy (2005) found that mammals were more important predators of piping plover eggs than avian predators.

After classification, the total area of acceptable sandbar habitat was determined and then converted to a percentage of the total channel area. Mean daily discharge was recorded from the USGS gage sites chosen with respect to distance from and the locations of major tributaries. In locations where tributaries entered downstream of an upstream main river gage, discharge readings from more than one gage were combined. The aerial images covered a range of river discharges from 0 to 21,000 cfs and covered sections of the river from near Columbus to the mouth near Plattsmouth.

To provide a generalized pattern for the area of sandbars meeting the necessary criteria vs. discharge, the data were arranged from lowest to highest discharge and a line was fit to the data using Table Curve 2D 5.01 (Systat, 2002). Selection of the most appropriate curve followed methods described above for the discharge to channel depth estimate in the habitat quality analysis. For each day, the percent habitat available was calculated from the daily mean flow discharge using the modeled relationship. The average available habitat for the 60-day nesting period, rounded to the nearest whole value, is used as an estimate of overall percent habitat available during the nesting period.

Suitable Habitat

Suitable habitat is calculated as a combination of *habitat quality* and *habitat quantity*. To calculate the occurrence of suitable habitat, the value for habitat quality (0 or 1 acceptable nesting period) was multiplied by the value for habitat quantity (0 to 6% total river area) for the nesting period in the breeding season. This resulted in a range of 0 to 6 for suitable habitat. The units for suitable habitat are percent area by percent time for a given nesting period. This reflects a range of conditions from no suitable habitat to the maximum available suitable habitat for nesting Least Terns and Piping Plovers. The average of the values was calculated for each breeding season.

Determining Favorable Flow Characteristics

To estimate the discharge characteristics that resulted in “favorable” years for Least Terns and Piping Plovers, the discharge statistics for the best scoring years at each site are described. The favorable year groups were separated by selecting the top one third of the non-zero suitable habitat data distribution, including ties. The average 1.5 year maximum discharge and average monthly flow statistics were calculated using this data to estimate suitable flow characteristics that resulted in Least Terns and Piping Plovers nesting habitat with the greatest likelihood of successful nesting. To determine which months contributed to the overall favorable score for the year, a criterion was established that the monthly average habitat suitability scores would be equal or greater than the minimum habitat suitability score for any year in the favorable year group at that site. This was to avoid averaging in characteristics for a poor month from an overall good year.

Results:

The relationship between discharge and channel depth (and it's inverse, sandbar height) was based on the river transect data in Mussetter Engineering, Inc. (2002). The average discharge and channel depths for the reported nine Platte River transects are shown in Table 2.1.

Table 2.1. Averaged data from Mussetter Engineering, Inc. (2002) for the lower Platte River transects.

Discharge (cfs)	Depth (ft)
5,000	1.7
10,000	2.4
20,000	3.3
50,000	5.7

An additional point located at zero discharge and zero depth was added prior to solving the equation. A line was fit to the data to create an equation to estimate channel depth from the discharge data (Figure 2.5). The line fit the data closely with $r^2 = 99.6$ (Equation 1).

Equation 2.1. The relationship for the curve of discharge (x in cfs) vs. channel depth (y in ft) (where: $a = 0$ and $b = 0.024723028$).

$$y = a + bx^{0.5}$$

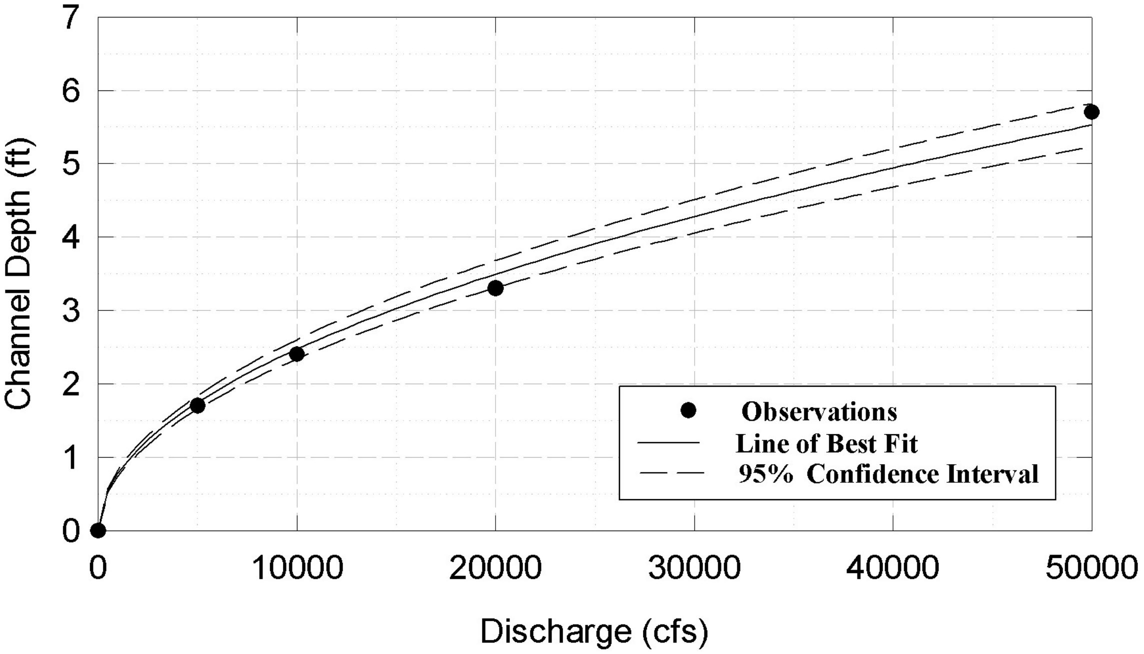

Figure 2.5. The modeled relationship between channel depth (ft) and river discharge (cfs) (Equation 2.1).

The average habitat conditions found in the Platte River changed as a function of the increase in discharge from near Duncan, to North Bend, and to Louisville. Habitat forming flows (estimated by the 1.5 year return flood flow) increased from approximate 7,000 cfs near Duncan to nearly 40,000 cfs near Louisville. These higher flows carry larger amounts of sediment which results in the development of higher sandbars. Channel depths (and their inverse, sandbar height) range from 2.1 ft at Duncan to nearly 5 ft at Louisville. The median discharge in June at the three sites was approximately 1/5 of the habitat forming flows. The depths and the sandbar heights that would be flooded by the median June discharge range from 0.9 to 2.1 ft at Duncan and Louisville, respectively (Table 2.2). Average height of sandbars at these three gage sites would range from about 1.2 ft above the median June discharge for Duncan to nearly 2.8 ft for Louisville (Table 2.3). Sandbar height increased in a downstream direction. Sandbars with the requirements of at least 1.5 ft of sandbar height (Ziewitz et al. 1992) were only available from North Bend downstream and with higher sandbars available downstream from Louisville.

Table 2.2. Flow profiles for habitat forming discharge (estimated as 1.5 year return flood flow), median June discharge from (1954 – 2005) and estimate channel depths at the corresponding discharges near the three Platte River gages.

Site	Discharge at 1.5 year return (cfs)	Channel Depth (ft) at 1.5 year return	Median June Discharge (cfs)	Channel Depth (ft) at June Median Discharge
Duncan	7,130	2.1	1,265	0.9
North Bend	21,280	3.6	4,080	1.6
Louisville	39,800	4.9	7,180	2.1

Table 2.3. Estimated sand bar height in river near the three Platte River gage locations based on the difference between habitat forming discharge and median June discharge.

	Sandbar Height (ft)
Duncan	1.2
North Bend	2.0
Louisville	2.8

Habitat Quality:

While the general characteristics of the different river reaches are interesting, they reveal little about the actual conditions that the nesting birds encounter in a given breeding season. Although on average, sandbars of 1.5 ft above median June flow rate may be available, for a successful nesting to occur the nest location must stay dry during the 60-day nesting period. The habitat quality estimate compares the height of the sandbars created by the last 1.5 year high flow event with the maximum depth of water during the preceding 60-day period. In this analysis, the year begins in 1956, not 1954, as 1.5 year of flow record was required before an estimate could be created.

Several patterns for habitat quality were apparent. First, the percent of acceptable nesting periods was higher in the downstream sections of the Platte River (Figures 2.6, 2.7, and 2.8). This was consistent with the trend of increased sandbar height in downstream reaches. Second, downstream reaches were not always the best in every year. For example, in 1960 the habitat quality indices for Duncan and North Bend (63) each were much higher than for Louisville (8) (Table 2.4). Flood waters from the Elkhorn River probably inundated nests downstream from it's confluence with the Platte River. Differing flow conditions from the Platte, Loup, and Elkhorn River, and Salt Creek all contribute to shifting availability of sufficiently high sandbars on the lower Platte River in different years. In some years, all reaches had acceptable habitat quality and in other years, all reaches had poor habitat for nesting birds. In 1978, all reaches had good conditions, while in 1977, all sites had poor conditions. The high flows of 1977 would have inundated most nests during the summer, but resulted in favorable conditions the following year. The timing, duration, and magnitude of the flows are key to the habitat quality in any given year.

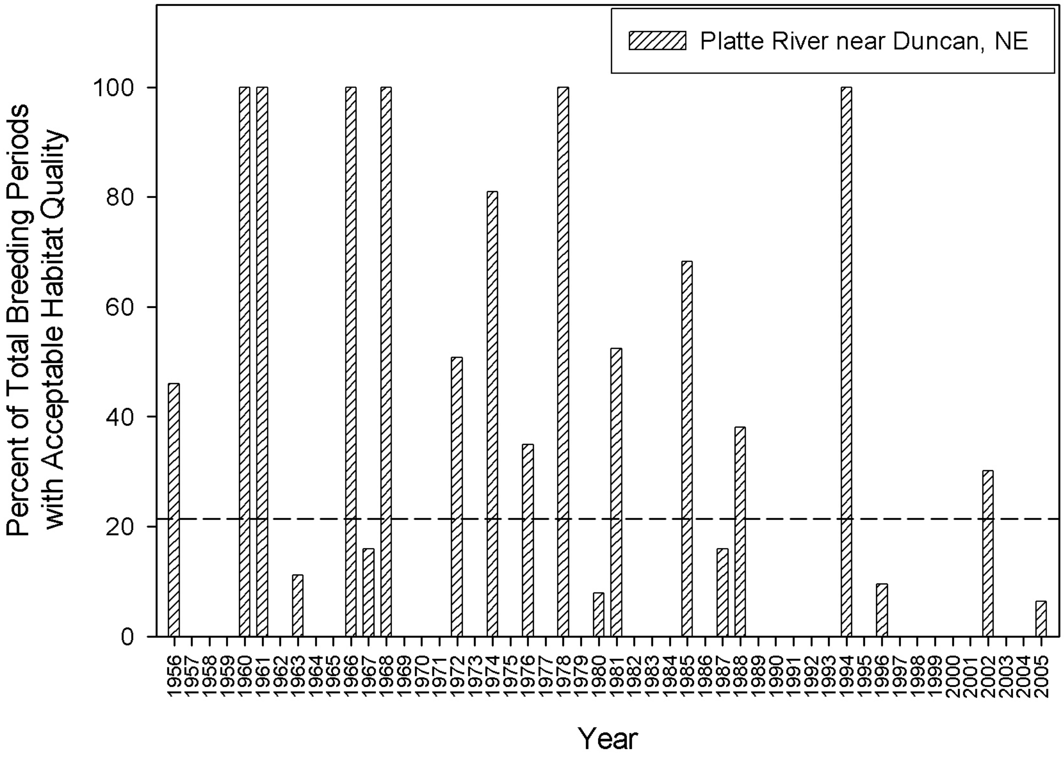

Figure 2.6. Habitat quality estimates for the Platte River near Duncan, NE. The bars represent the percent of the total acceptable nesting periods within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

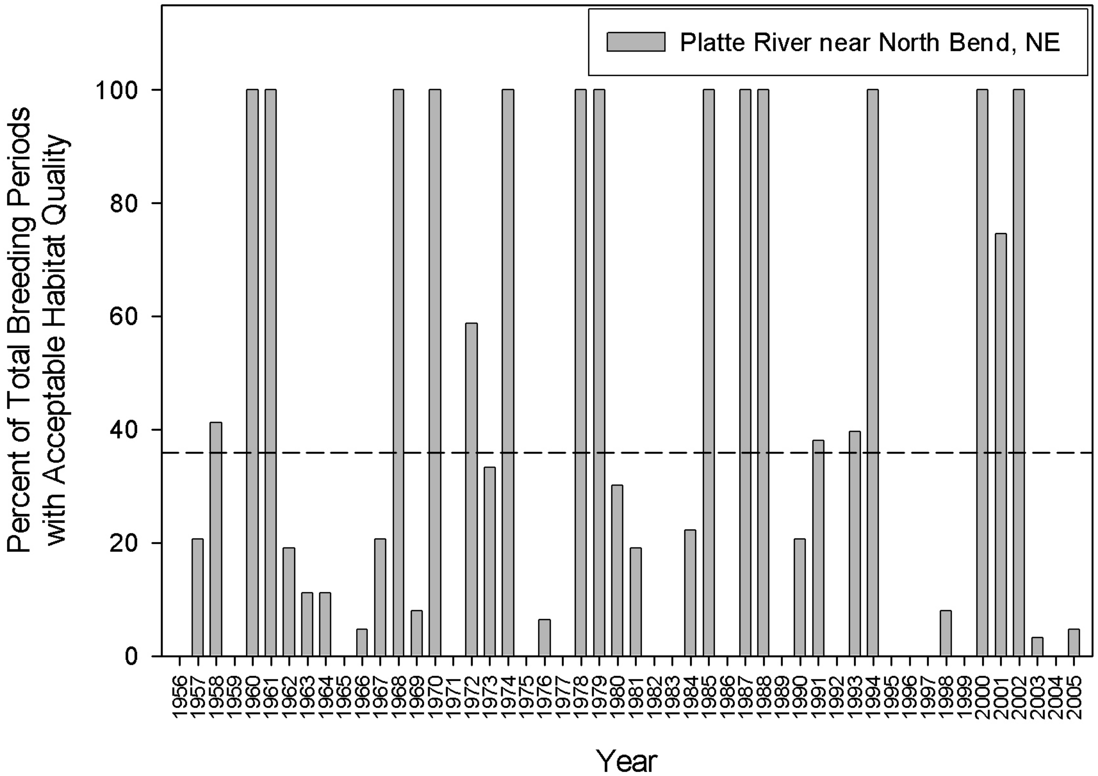

Figure 2.7. Habitat quality estimates for the Platte River near North Bend, NE. The bars represent the percent of the total acceptable nesting periods within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

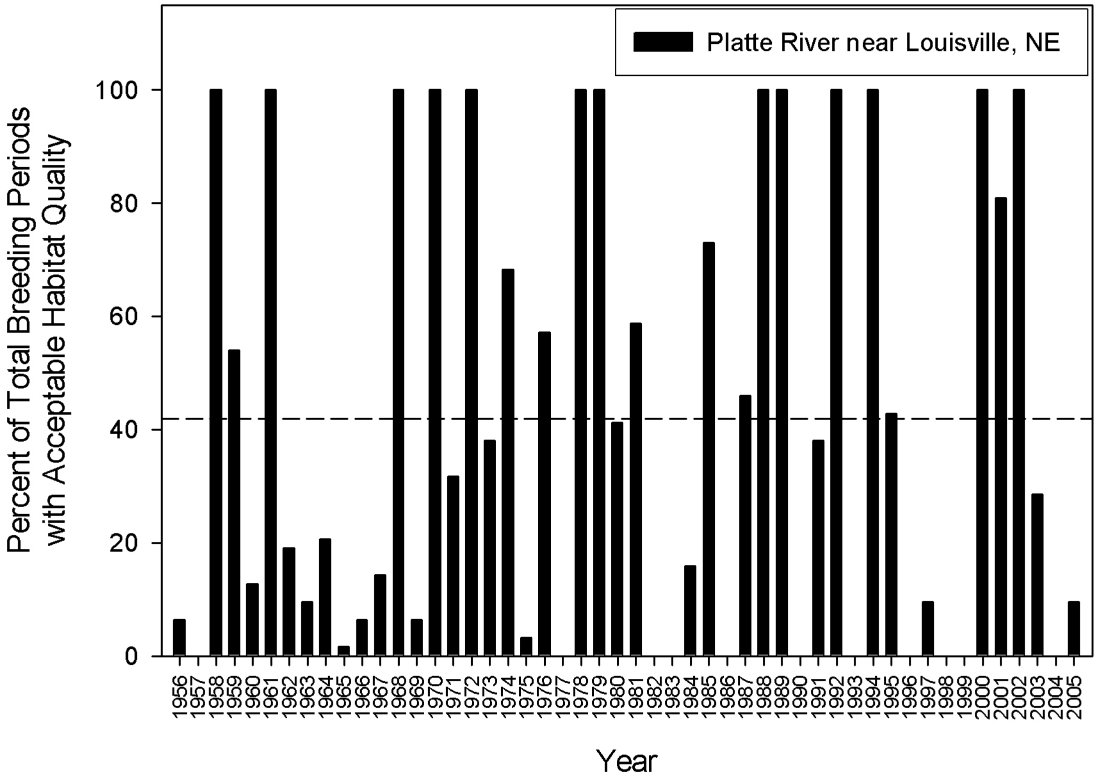

Figure 2.8. Habitat quality estimates for the Platte River near Louisville, NE. The bars represent the percent of the total acceptable nesting periods within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

Table 2.4. Habitat quality estimate comparisons for the Platte River reaches near the three gage sites for the time period from 1956 to 2005. The units are the number of acceptable nesting period in a given breeding season with the maximum number of possible nesting periods equal to 63.

Year	Habitat Quality for Platte River near Duncan, NE	Habitat Quality for Platte River near North Bend, NE	Habitat Quality for Platte River near Louisville, NE
1956	29	0	4
1957	0	13	0
1958	0	26	63
1959	0	0	34
1960	63	63	8
1961	63	63	63
1962	0	12	12
1963	7	7	6

1964	0	7	13
1965	0	0	1
1966	63	3	4
1967	10	13	9
1968	63	63	63
1969	0	5	4
1970	0	63	63
1971	0	0	20
1972	32	37	63
1973	0	21	24
1974	51	63	43
1975	0	0	2
1976	22	4	36
1977	0	0	0
1978	63	63	63
1979	0	63	63
1980	5	19	26
1981	33	12	37
1982	0	0	0
1983	0	0	0
1984	0	14	10
1985	43	63	46
1986	0	0	0
1987	10	63	29
1988	24	63	63
1989	0	0	63
1990	0	13	0
1991	0	24	24
1992	0	0	63
1993	0	25	0
1994	63	63	63
1995	0	0	27
1996	6	0	0
1997	0	0	6
1998	0	5	0
1999	0	0	0
2000	0	63	63
2001	0	47	51
2002	19	63	63
2003	0	2	18
2004	0	0	0
2005	4	3	6
Average	**13.5**	**22.6**	**26.4**

Habitat Quantity:

A total of 26 different image groups were classified. They ranged in length from 2.8 to 38.3 km and appropriate habitat quantity ranged 0 to 9.3% of the total river area (Table 2.5). The relationship between the amount of large, unvegetated, disconnected sandbars and discharge shows a pattern where large sandbars are more common at moderate discharge rates than at low or high rates and is illustrated in Figure 2.9. The equation describing the relationship between large disconnected sandbars and discharge had a moderately good fit with an $r^2 = 0.45$ (Equation 2). The distribution of large sandbars was associated with wider areas of the river channel (typical deposition areas) and discharge and channel morphology influenced the amount of observed sandbar habitat. Local channel morphology accounts for some of the scatter in the data. The maximum amount of large disconnect sandbar habitat was observed around 5,480 cfs (Figure 2.10).

The relationship between large sandbars and river discharge displayed several additional patterns. Large, unvegetated, and disconnected from the shoreline sandbars were not common at any discharge rate. At high discharge rates, a large amount of the channel was underwater in either shallow sandbar complexes or open water. While at low discharge levels, small exposed sandbars were common and the larger sandbars were generally connected to the shore. Overall, it appears that the large sandbars selected by nesting Least Terns and Piping Plovers made up a maximum of only 6% to 7% of the overall habitat in the lower Platte River. Large, disconnected sandbars are available at a wide range of discharge rates. The maximum of 6.7% available habitat occurred at 5,480 cfs with 50% of the maximum available habitat available between 3,910 and 11,900 cfs. This general picture of the availability of large sandbars for nesting birds was developed for the lower Platte River from discharge rates between 0 and 21,000 cfs, but the actual amount available to nesting birds also depends on the recent discharge history at the site, as well as local channel morphology.

The general pattern of habitat availability as related to discharge is important, yet does not control the actual conditions encountered by birds during a given nesting period. Habitat was available for nesting birds in each reach during most years (Figures 2.11, 2.12, and 2.13). Percent available habitat ranged from 0 to 5 % in any given nesting period in a breeding season.

The pattern for habitat quantity was similar to that for habitat quality. Habitat quantity increased in a downstream direction. Rarely were there more large sandbars near Duncan than near Louisville under the discharge patterns over the last 50 years. The exception was in 1983 which had high flows most of the summer, and where the relatively lower flows at Duncan resulted in more available habitat than at downstream sites (Table 2.6). In most years, there appeared to be areas with large sandbars in the lower Platte River. In low flow years of 1956 and 1976, sandbar habitat was limited or unavailable.

Table 2.5. Descriptive information for the aerial images used for habitat classification from the lower Platte River, NE. The gage site represents the nearest USGS gage for classified image. In some cases, discharge was determined from a combination of USGS gages. Gage sites are as follows: LSV = Platte River at Louisville, NE; ASH = Platte River at Ashland, NE; LES = Platte River at Leshara; ELK = Elkhorn River at Waterloo, NBD = Platte River at North Bend, NE; LPC = Loup Power Canal at Genoa, NE; LPR = Loup River at Genoa, NE; DCN = Platte River at Duncan, NE. GPS coordinates are in decimal degrees and are located approximately mid-channel at the upstream and downstream ends of the river section. UPGPSW = upstream GPS west, UPGPSN = upstream GPS north, DGPSW = downstream GPS west, DGPSN = downstream GPS north.

Date	Gage Site	Discharge (cfs)	Length (km)	UPGPSW	UPGPSN	DGPSW	DGPSN	Bird Habitat (m2)	Bird Habitat (%)
15-Aug-02	DCN	0	5.7	-97.3801	41.3962	-97.3218	41.397	0	0.0
15-Aug-02	LES	953	4.5	-96.3578	41.2468	-96.3605	41.2191	0	0.0
15-Aug-02	LSV	1413	4.7	-96.2254	40.9979	-96.1718	41.0079	96,342	3.0
1-Apr-99	DCN	2437	5.1	-97.3801	41.3962	-97.3218	41.397	0	0.0
22-Apr-93	DCN	2825	11	-97.4431	41.3748	-97.3211	41.3965	74,128	1.2
1-Apr-99	DCN+LPR	4097	3.3	-97.3218	41.397	-97.2836	41.3965	25,089	1.7
21-Mar-94	DCN+LPR+LPC	4697	2.8	-97.3175	41.3985	-97.2833	41.3996	118,442	9.3
18-Apr-94	NBD	5615	5	-96.8182	41.4497	-96.7599	41.4526	87,959	3.2
4-Apr-99	LES	5686	16.4	-96.3534	41.2537	-96.313	41.1209	89,078	1.0
4-Apr-99	LES	5686	13.9	-96.5665	41.4357	-96.4318	41.3664	437,824	5.4
1-Apr-99	DCN+LPR+LPC	5827	3.5	-97.2836	41.3965	-97.2459	41.3845	196,651	8.7
16-Apr-93	NBD	6357	38.3	-97.2419	41.3833	-96.8235	41.4487	1,302,921	6.7
6-Apr-99	NBD	6569	15.8	-97.1304	41.3859	-96.9672	41.4408	655,448	6.7
21-Mar-94	DCN+LPR	6569	3.7	-97.2833	41.3996	-97.2462	41.3838	127,495	5.8
4-Apr-99	ASH	7769	11.8	-96.3182	41.1281	-96.3072	41.0368	69,875	1.0
14-Apr-93	ASH-ELK	7840	12.1	-96.3532	41.2536	-96.3203	41.1581	357,002	4.9
4-Apr-99	LSV	8476	31.3	-96.2557	41.0172	-95.9338	41.0586	1,151,315	6.1
6-Apr-99	LES	8793	8.3	-96.4417	41.3713	-96.3985	41.3089	10,316	0.2
22-Apr-93	NBD	10383	24.4	-96.7555	41.4525	-96.4903	41.3992	694,013	4.8
2-Apr-93	ASH-ELK	10736	6.5	-96.3794	41.2995	-96.3562	41.2469	223,550	5.2
6-Apr-99	LSV	10806	4.5	-96.2343	41.0041	-96.185	41.003	161,168	5.4
14-Apr-99	ASH	14408	7.2	-96.3172	41.0463	-96.2488	41.0157	16,029	0.3
16-Apr-93	ASH	15009	21	-96.3187	41.1279	-96.1837	41.0048	266,331	2.0
26-Mar-93	LSV	15503	29.4	-96.194	41.001	-95.881	41.0532	1,245,981	6.9
22-Apr-93	ASH-ELK	18929	12.7	-96.4547	41.3782	-96.3698	41.2911	172,940	2.2
19-Apr-99	LSV	21012	5.6	-95.9438	41.0579	-95.8808	41.0531	0	0.0

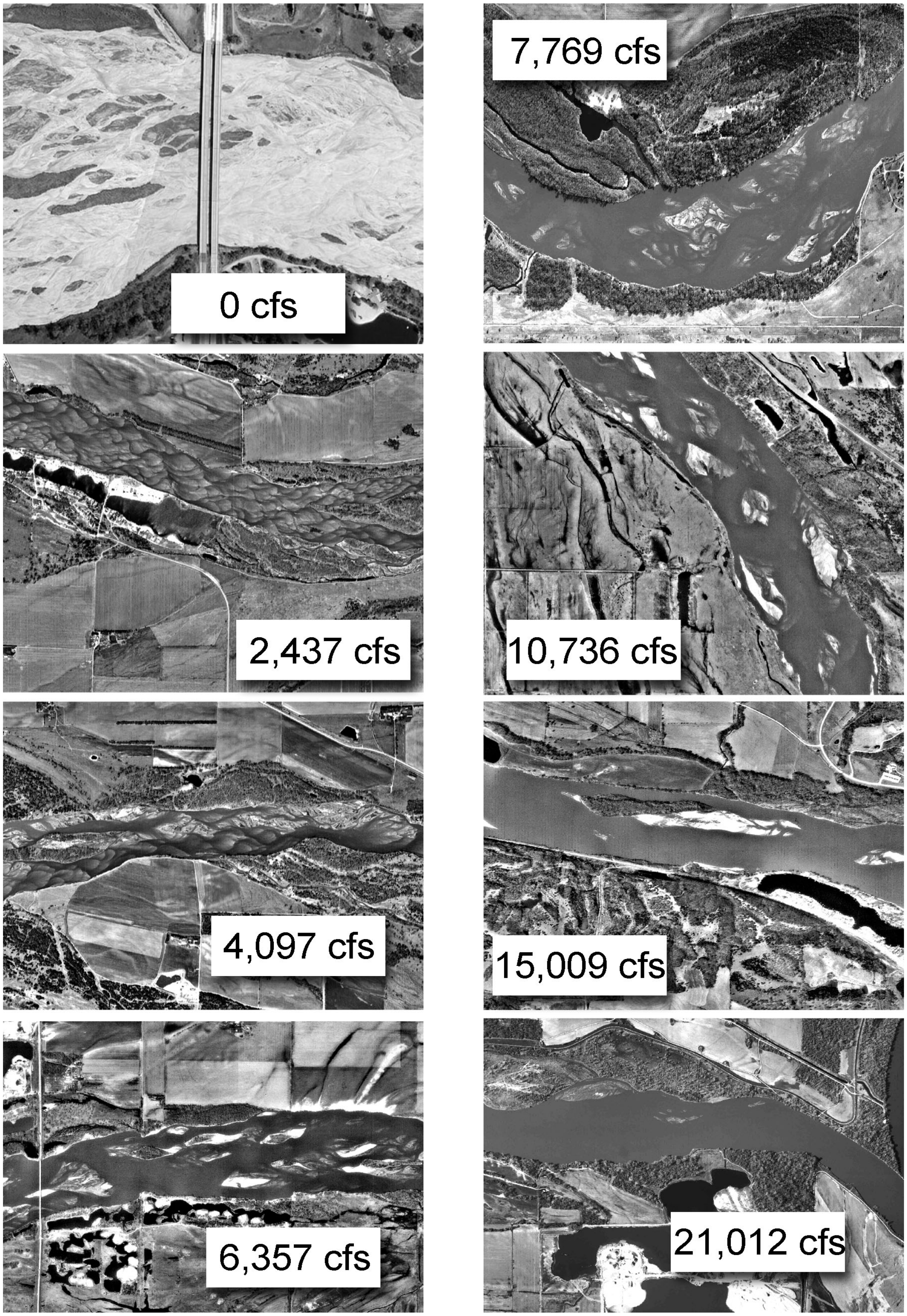

Figure 2.9. A series of aerial images from the lower Platte River showing changes in habitat in relation to discharge. The images were from a range of locations and a range of dates and are not all to the same scale. Note the change in the amount of large disconnected sandbars in the series of images.

J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

Equation 2.2. The relationship for the curve of discharge (x in cfs) vs. percent available habitat (y) in the lower Platte River (where: a = 0.40534102, b = -0.000452565512, c = -9.4516773E-5, d = 7.3450789E-8, e = 7.9143834E-9, f = -4.9137201E-12, g = 3.2904805E-12, and h = 2.027508E-16).

$$y = \frac{a + cx + ex^2 + gx^3}{1 + bx + dx^2 + fx^3 + hx^4}$$

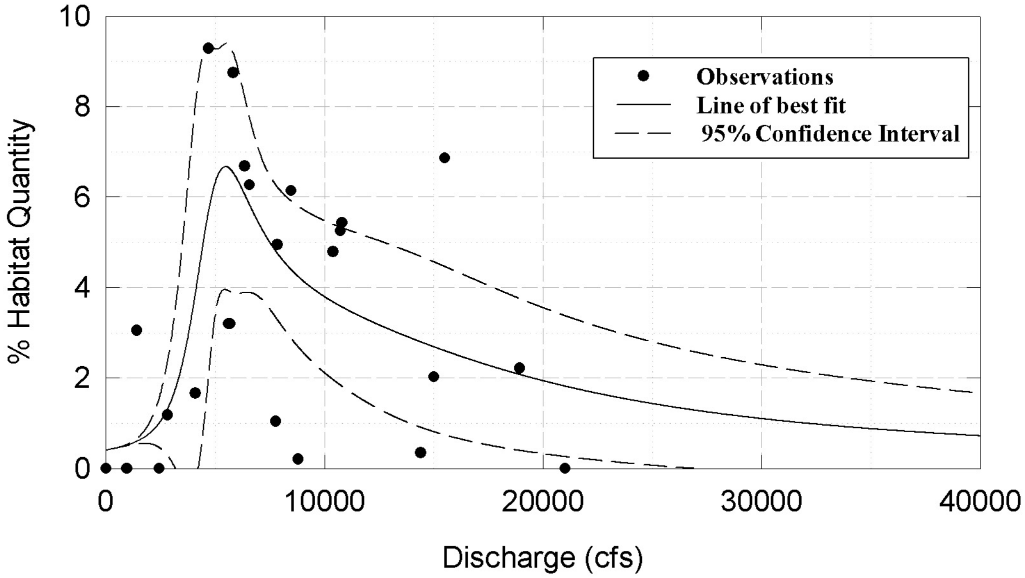

Figure 2.10. Modeled relationship between discharge (cfs) and percent habitat quantity for the lower Platte River (Equation 2.2). Habitat for Least Terns and Piping Plovers is defined as large, exposed sandbars that were disconnected from the shoreline.

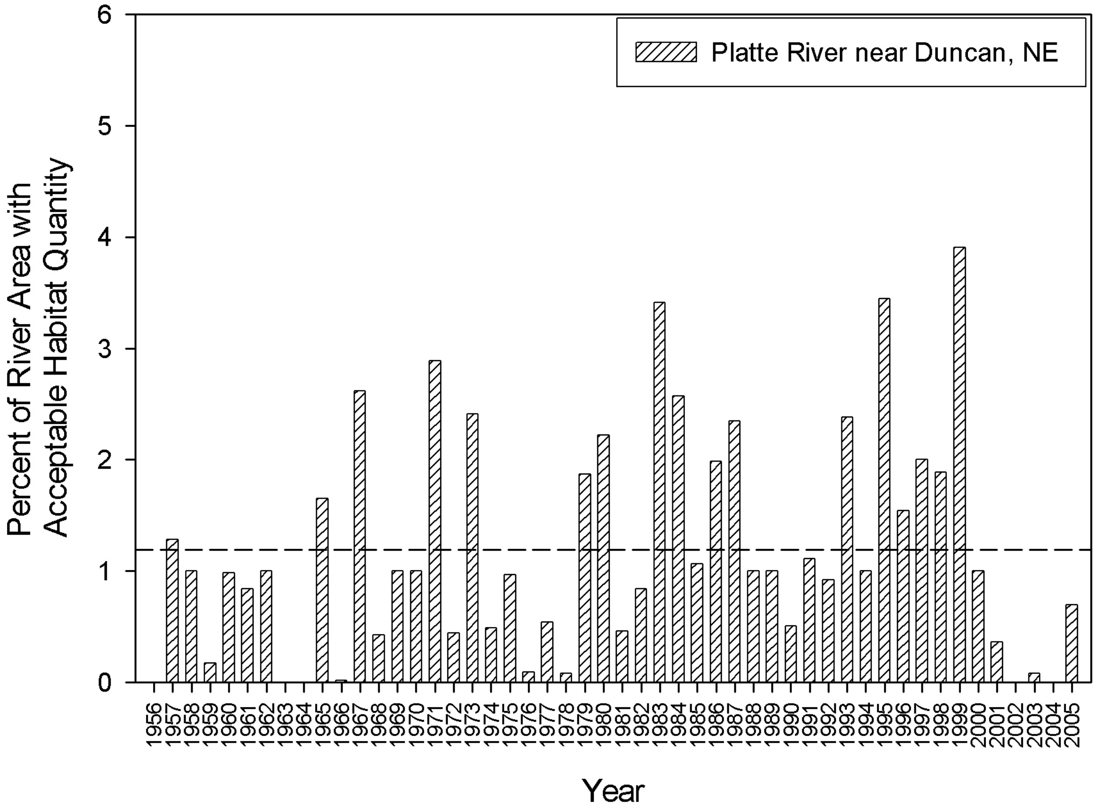

Figure 2.11. Habitat quality estimates for the Platte River near Duncan, NE. The bars represent the average percent of river area available to nesting birds within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

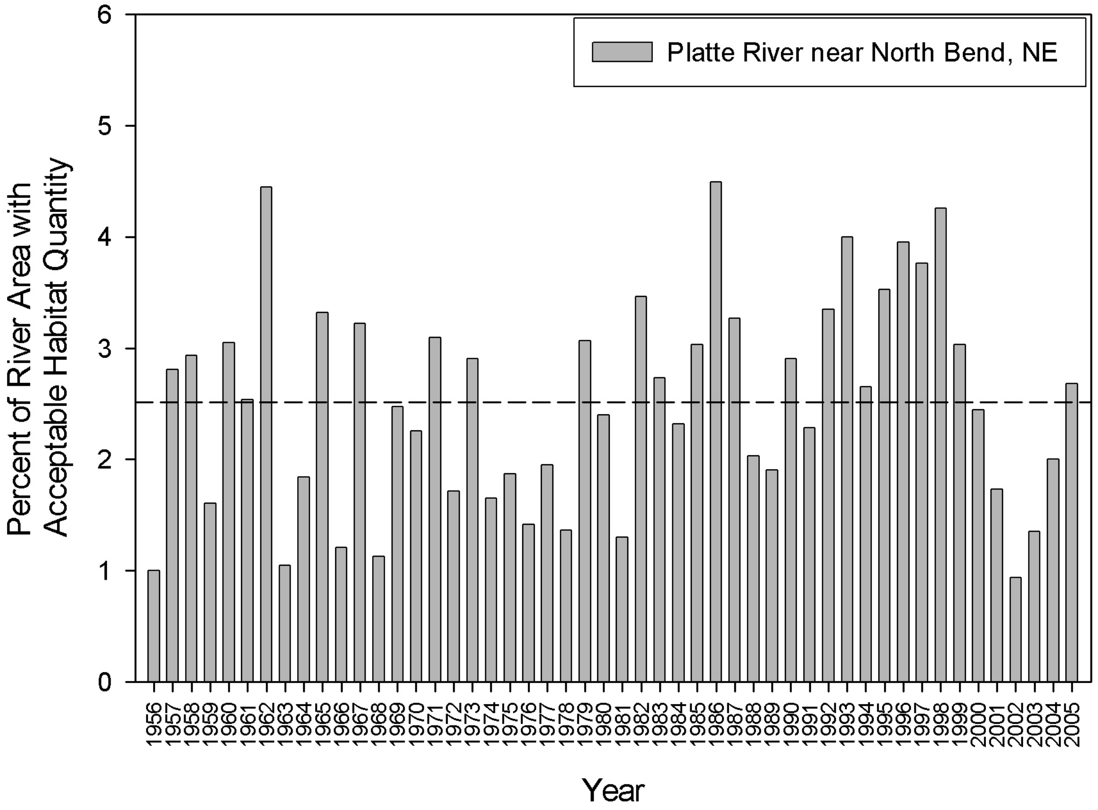

Figure 2.12. Habitat quality estimates for the Platte River near North Bend, NE. The bars represent the average percent of river area available to nesting birds within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

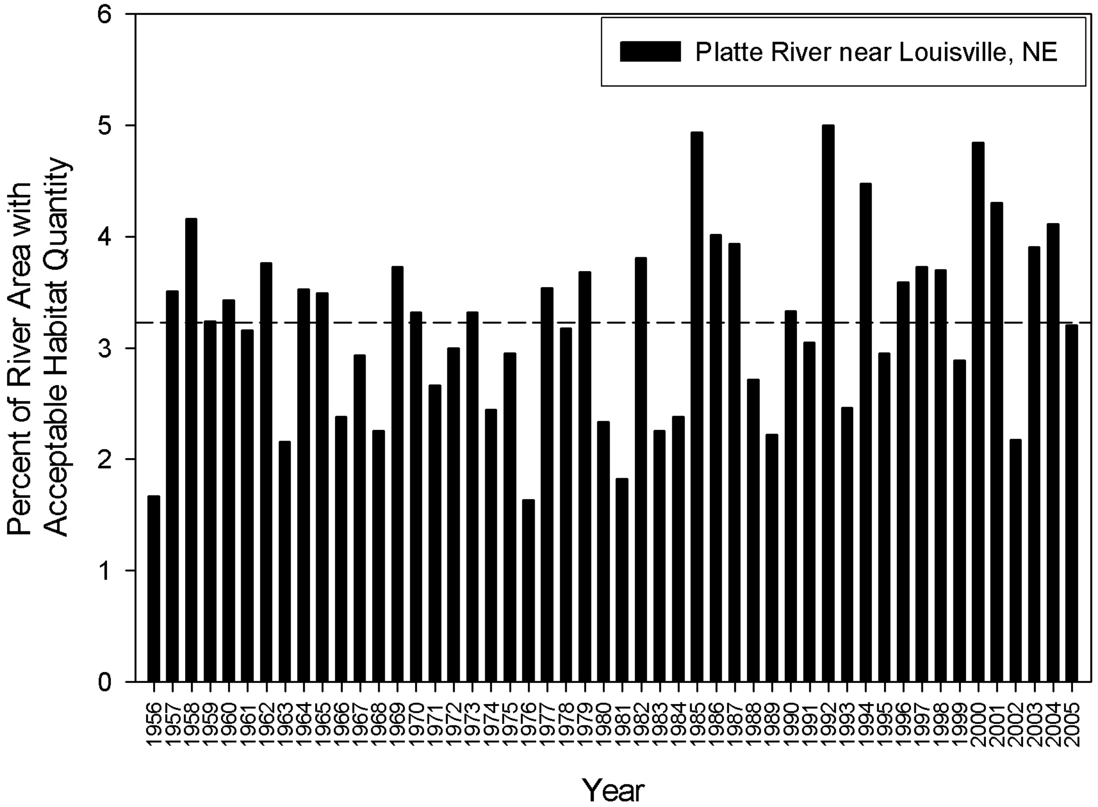

Figure 2.13. Habitat quantity estimates for the Platte River near Louisville, NE. The bars represent the average percent of river area available to nesting birds within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

Table 2.6. Habitat quantity estimate comparisons for the Platte River reaches near the three gage sites for the time period from 1956 to 2005. The units are the average percent of habitat available for each nesting period in a given breeding season.

Year	Percent Habitat Quantity for Platte River near Duncan, NE	Percent Habitat Quantity for Platte River near North Bend, NE	Percent Habitat Quantity for Platte River near Louisville, NE
1956	0.00	1.00	1.67
1957	1.29	2.81	3.51
1958	1.00	2.94	4.16
1959	0.17	1.60	3.24
1960	0.98	3.05	3.43
1961	0.84	2.54	3.16
1962	1.00	4.44	3.76
1963	0.00	1.05	2.16

1964	0.00	1.84	3.52
1965	1.65	3.32	3.49
1966	0.02	1.21	2.38
1967	2.62	3.22	2.94
1968	0.43	1.13	2.25
1969	1.00	2.48	3.73
1970	1.00	2.25	3.32
1971	2.89	3.10	2.67
1972	0.44	1.71	3.00
1973	2.41	2.90	3.32
1974	0.49	1.65	2.44
1975	0.97	1.87	2.95
1976	0.10	1.41	1.63
1977	0.54	1.95	3.54
1978	0.08	1.37	3.17
1979	1.87	3.06	3.68
1980	2.22	2.40	2.33
1981	0.46	1.30	1.83
1982	0.84	3.46	3.81
1983	3.41	2.73	2.25
1984	2.57	2.32	2.38
1985	1.06	3.03	4.94
1986	1.98	4.49	4.02
1987	2.35	3.27	3.94
1988	1.00	2.03	2.71
1989	1.00	1.90	2.22
1990	0.51	2.90	3.33
1991	1.11	2.29	3.05
1992	0.92	3.35	5.00
1993	2.38	4.00	2.46
1994	1.00	2.65	4.48
1995	3.44	3.52	2.95
1996	1.54	3.95	3.59
1997	2.00	3.76	3.73
1998	1.89	4.25	3.70
1999	3.90	3.03	2.89
2000	1.00	2.44	4.84
2001	0.37	1.73	4.30
2002	0.00	0.94	2.17
2003	0.08	1.35	3.90
2004	0.00	2.00	4.11
2005	0.70	2.68	3.21
Average	**1.19**	**2.51**	**3.23**

Suitable Habitat:

The combination of habitat quality and habitat quantity provides an index of the amount of suitable habitat available to nesting Least Terns and Piping Plovers during the late spring and summer breeding season on the lower Platte River. The suitable habitat metric reflects the history of preceding high flow events, the flow patterns during the breeding season, as well as the average amount of appropriate habitat. The suitable habitat metric has units that are a combination of time and area. Time is a function of the percentage of time quality habitat exists during the breeding season, while area is a function of the habitat quantity estimates.

Once again, suitable habitat appeared to occur more frequently in downstream reaches, with the most suitable habitat in the Louisville area and below (Figures 2.14). North Bend (Figure 2.15) had suitable habitat in many years but suitable habitat was not common near Duncan (Figure 2.16). There were years that more suitable habitat was found near Duncan and North Bend., than near Louisville, depending on flow from the tributaries (Table 2.7). For example, in 1960, river reaches near Duncan and North Bend had more suitable habitat than the reach near Louisville as a result of a flood from the Elkhorn River. Some variability is typical for breeding habitat on the Platte River under current flow conditions. In several years, suitable habitat was not predicted to occur in any reach of the river (1977, 1982, 1983, 1986, 1996, 1999, and 2004). Overall, out of 50 years, Duncan had 38, North Bend 15, and Louisville 11 years with no suitable habitat predicted.

To assess more general trends concerning suitable habitat for breeding Least Terns and Piping Plovers, the decadal average of the relative amount of suitable habitat was calculated. Several trends appear in the averaged data. First, there has been consistently more suitable habitat progressing downstream (Table 2.8 and Figure 2.17). Second, the period from 1986 – 1995 was the best period for the lower Platte River, while the decade from 1976 – 1985 was the best period near Duncan on the central Platte River. Third, suitable habitat has been decreasing near Duncan on the central Platte River and in the most recent decade little suitable habitat was predicted to have been present. Fourth, the most recent decade (1996 – 2005) had the least suitable habitat overall on the lower Platte River.

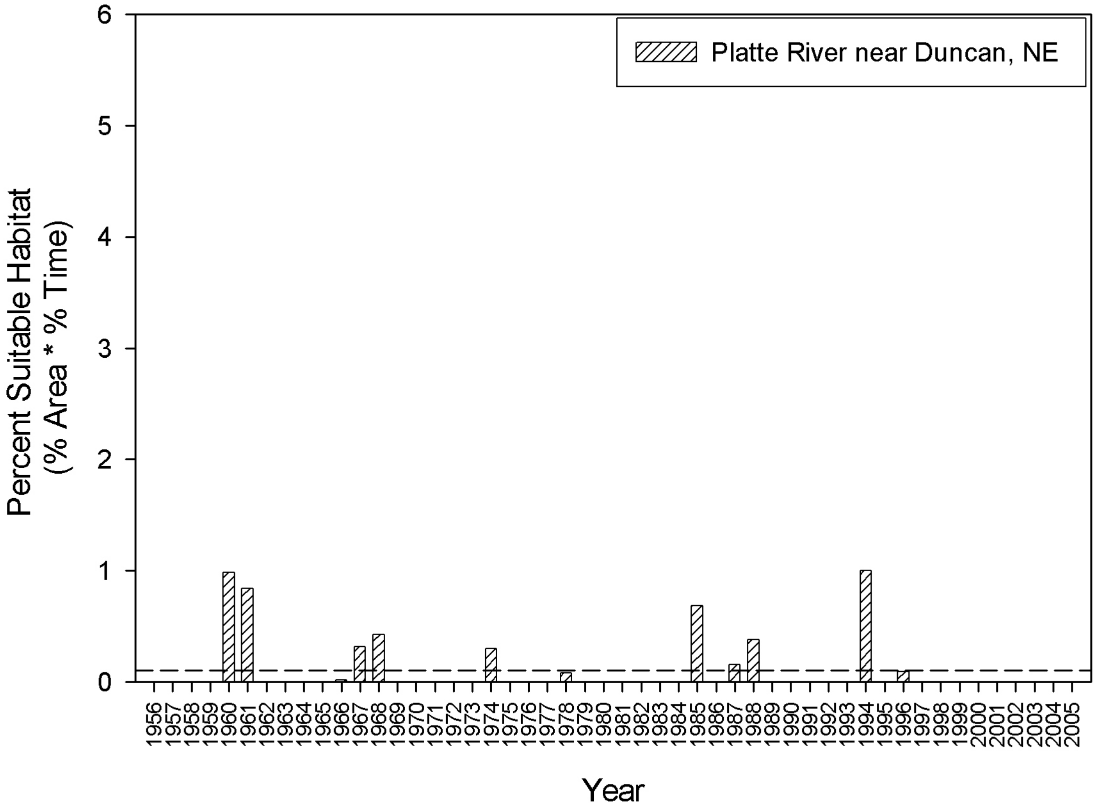

Figure 2.14. Suitable habitat estimates for the Platte River near Duncan, NE. The bars represent the average amount of suitable habitat within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005

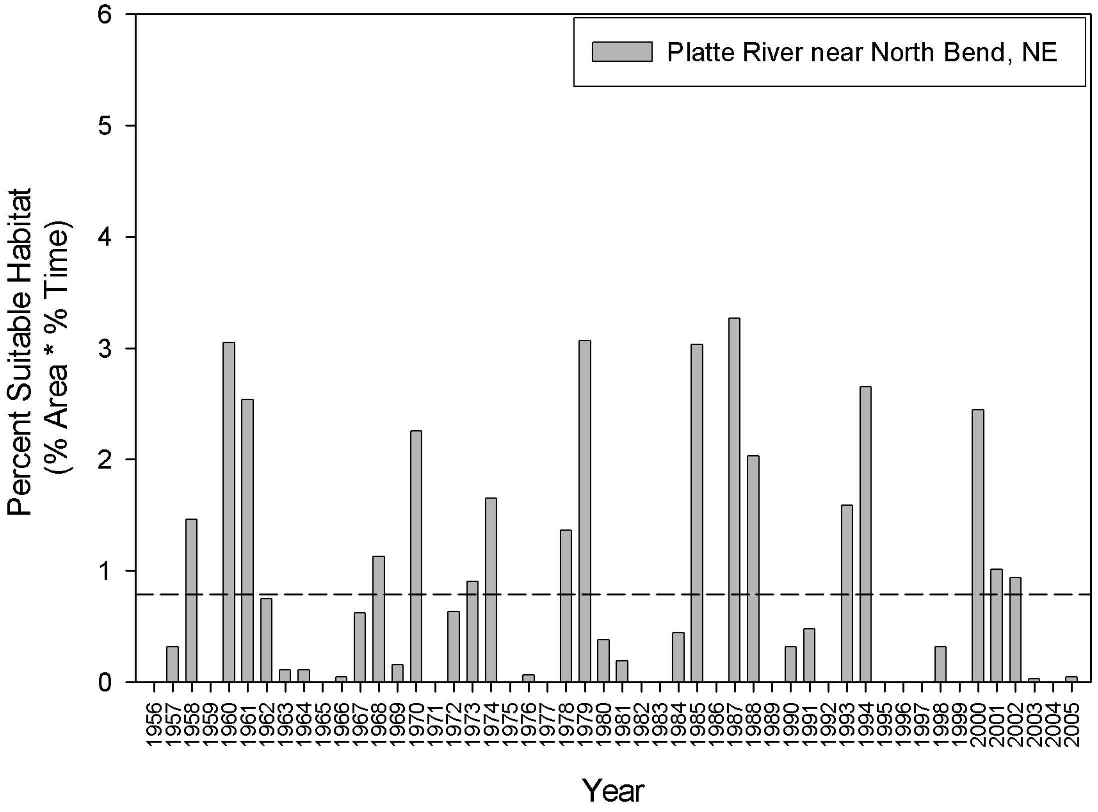

Figure 2.15. Suitable habitat estimates for the Platte River near North Bend, NE. The bars represent the average amount of suitable habitat within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

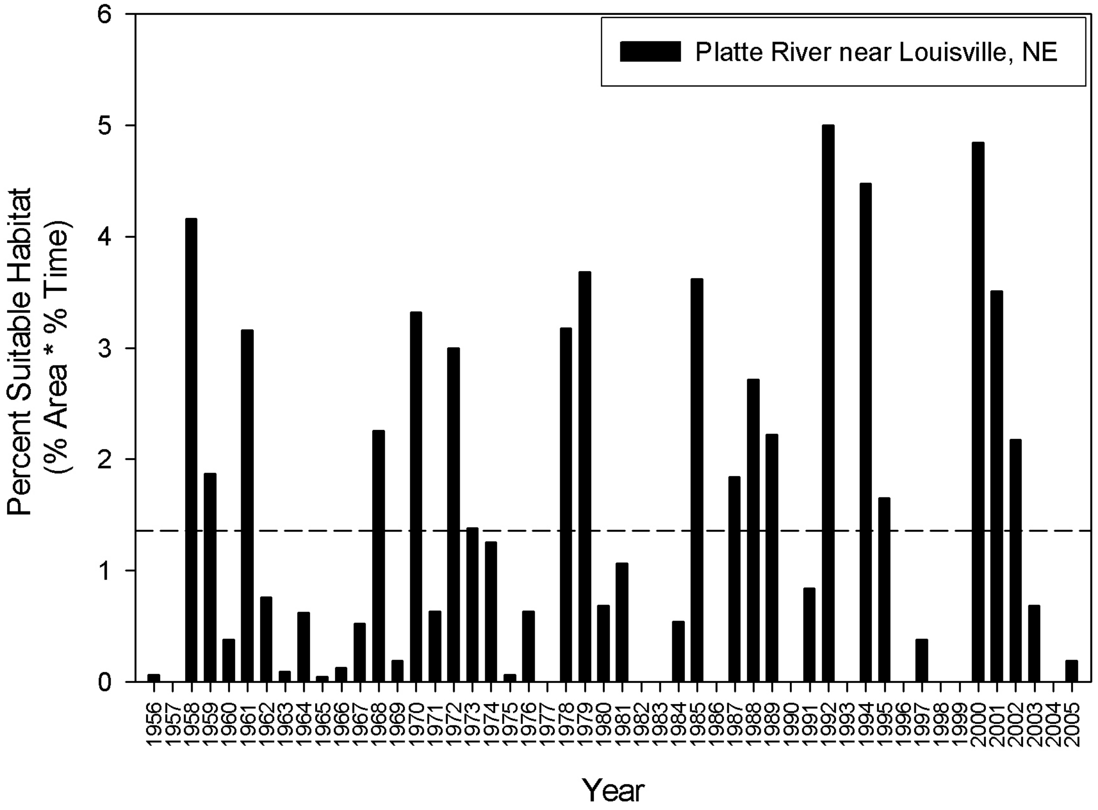

Figure 2.16. Suitable habitat estimates for the Platte River near Louisville, NE. The bars represent the average amount of suitable habitat within a single year's breeding season. The dashed line is the overall mean for the period of record from 1956 to 2005.

Table 2.7. Suitable habitat estimate comparisons for the Platte River reaches near the three gage sites for the time period from 1956 to 2005. The units are the average percent of suitable habitat for each nesting period in a given breeding season.

Year	Suitable Habitat for Platte River near Duncan, NE	Suitable Habitat for Platte River near North Bend, NE	Suitable Habitat for Platte River near Louisville, NE
1956	0.00	0.00	0.06
1957	0.00	0.32	0.00
1958	0.00	1.46	4.16
1959	0.00	0.00	1.87
1960	0.98	3.05	0.38
1961	0.84	2.54	3.16
1962	0.00	0.75	0.76
1963	0.00	0.11	0.10
1964	0.00	0.11	0.62

1965	0.00	0.00	0.05
1966	0.02	0.05	0.13
1967	0.32	0.62	0.52
1968	0.43	1.13	2.25
1969	0.00	0.16	0.19
1970	0.00	2.25	3.32
1971	0.00	0.00	0.63
1972	0.00	0.63	3.00
1973	0.00	0.90	1.38
1974	0.30	1.65	1.25
1975	0.00	0.00	0.06
1976	0.00	0.06	0.63
1977	0.00	0.00	0.00
1978	0.08	1.37	3.17
1979	0.00	3.06	3.68
1980	0.00	0.38	0.68
1981	0.00	0.19	1.06
1982	0.00	0.00	0.00
1983	0.00	0.00	0.00
1984	0.00	0.44	0.54
1985	0.68	3.03	3.62
1986	0.00	0.00	0.00
1987	0.16	3.27	1.84
1988	0.38	2.03	2.71
1989	0.00	0.00	2.22
1990	0.00	0.32	0.00
1991	0.00	0.48	0.84
1992	0.00	0.00	5.00
1993	0.00	1.59	0.00
1994	1.00	2.65	4.48
1995	0.00	0.00	1.65
1996	0.10	0.00	0.00
1997	0.00	0.00	0.38
1998	0.00	0.32	0.00
1999	0.00	0.00	0.00
2000	0.00	2.44	4.84
2001	0.00	1.02	3.51
2002	0.00	0.94	2.17
2003	0.00	0.03	0.68
2004	0.00	0.00	0.00
2005	0.00	0.05	0.19
Average	**0.11**	**0.79**	**1.36**

Table 2.8. Ten year average suitable habitat for the three Platte River gage sites.

Decade	Suitable Habitat for Platte River near Duncan, NE	Suitable Habitat for Platte River near North Bend, NE	Suitable Habitat for Platte River near Louisville, NE
1956-1965	0.18	0.83	1.12
1966-1975	0.11	0.74	1.27
1976-1985	0.08	0.85	1.34
1986-1995	0.15	1.03	1.87
1996-2005	0.01	0.48	1.18

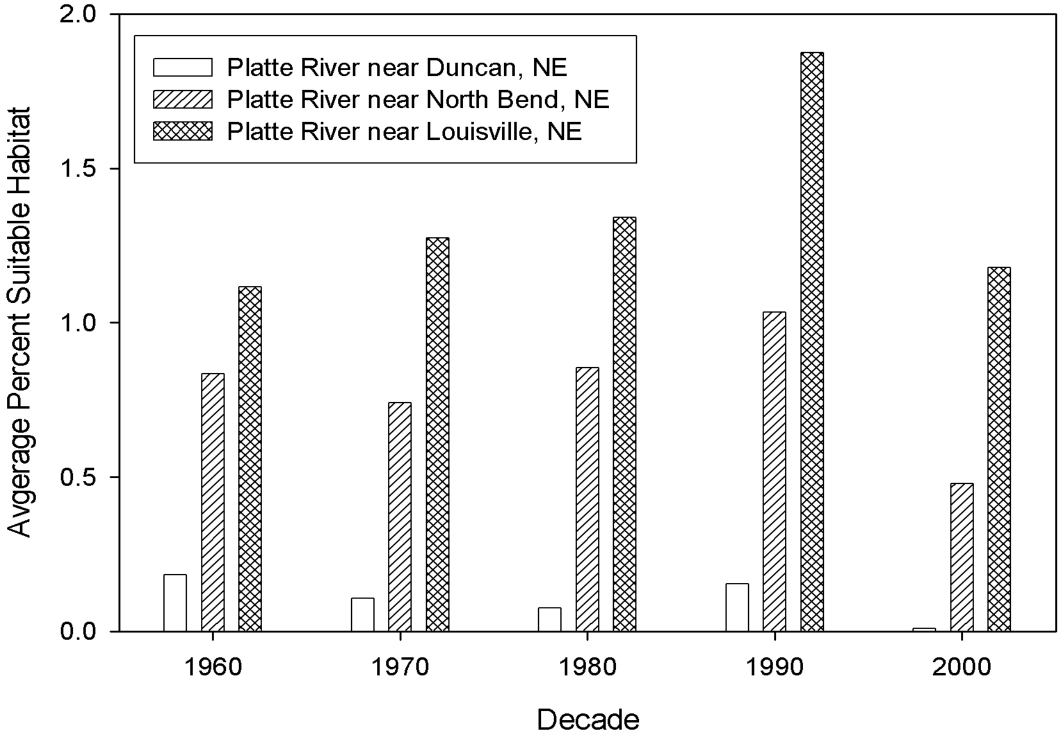

Figure 2.17. Comparison of ten year average suitable habitat for the three Platte River gage sites. The decades are 1956-1965, 1966-1975, 1976-1985, 1986-1995, and 1996-2005.

<u>Comparisons of modeling results with actual field data</u>

Historical accounts suggest that Least Terns and Piping Plovers were “a regular summer resident and breeder on the sandbars of the Platte River and its forks” (Tout 1947). At the Platte River south of Lexington, Wycoff (1960) reported finding Least Terns and Piping Plovers nesting during the 1950’s. Since that time, there has been a large decrease in the use of the central Platte River for nesting by these birds. Recent surveys find most birds associated with sand pits (Haig and Plissner 1992, Haig and Plissner 1996, Ferland and Haig 2002, NGPC database). The estimates of the amount of suitable habitat in the central Platte River near Duncan follow this pattern. Relative amounts of suitable habitat at Duncan average about 1/13 of the habitat near Louisville and 1/8 of the habitat near North Bend. Currently, little habitat exists in the central Platte River.

Biologists have been surveying the numbers of Least Terns and Piping Plovers nesting on the Platte River regularly since 1986 (Figures 2.18 and 2.19). Direct testing of the observations against the estimates of the amount of suitable habitat is not possible as the field observations do not measure nesting success (the successful fledging of chicks at the end of the season) but measure nest presence. The maximum number of nests observed during visits is presented because the fate of individual nests in unknown in many cases. The measurement of nest presence is important and is an effective gage of the relative population size and whether the habitat is actually being used by terns and plovers. Nest inundation may occur after the surveys, resulting in a season with a lot of nesting activity but little that is ultimately successful.

Against these caveats, the comparison of the field data to the modeling results is more subjective. Figures 2.18 and 2.19 approximately cover the final two decades shown in Figure 2.17. The general trends correspond with suitable habitat available in the Lower Platte River at both North Bend and Louisville from the mid 1980’s to mid 1990’s, and then a reduction of habitat at North Bend in more recent years. The amount of suitable habitat decreased near Louisville but was still present in most recent years. The years 1998 and 1999 were predicted to be poor years and that was reflected in the nest presence surveys.

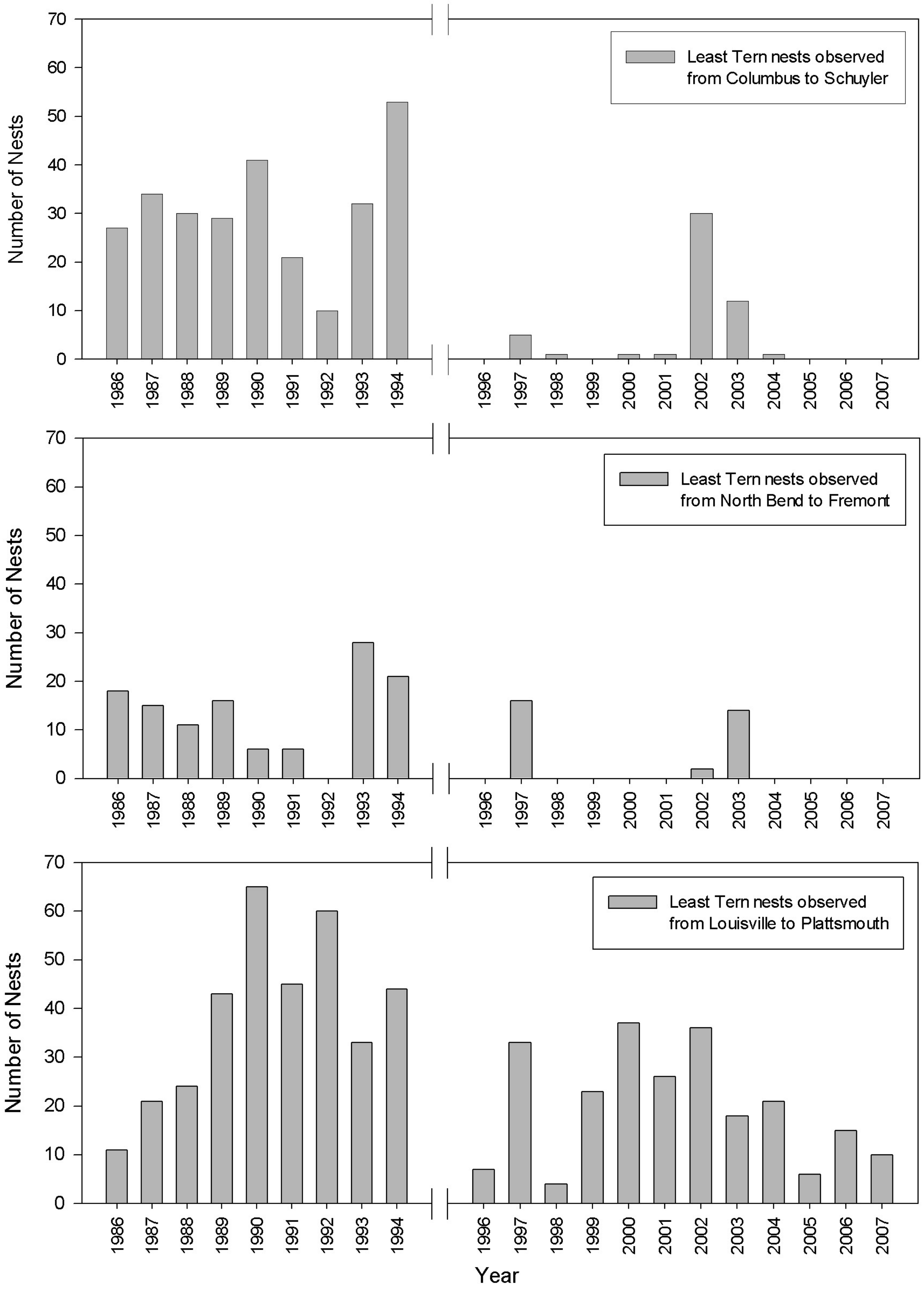

Figure 2.18. Number of least tern nests from river segments recorded during Nebraska Game and Parks Commission annual surveys. No surveys were completed in 1995.

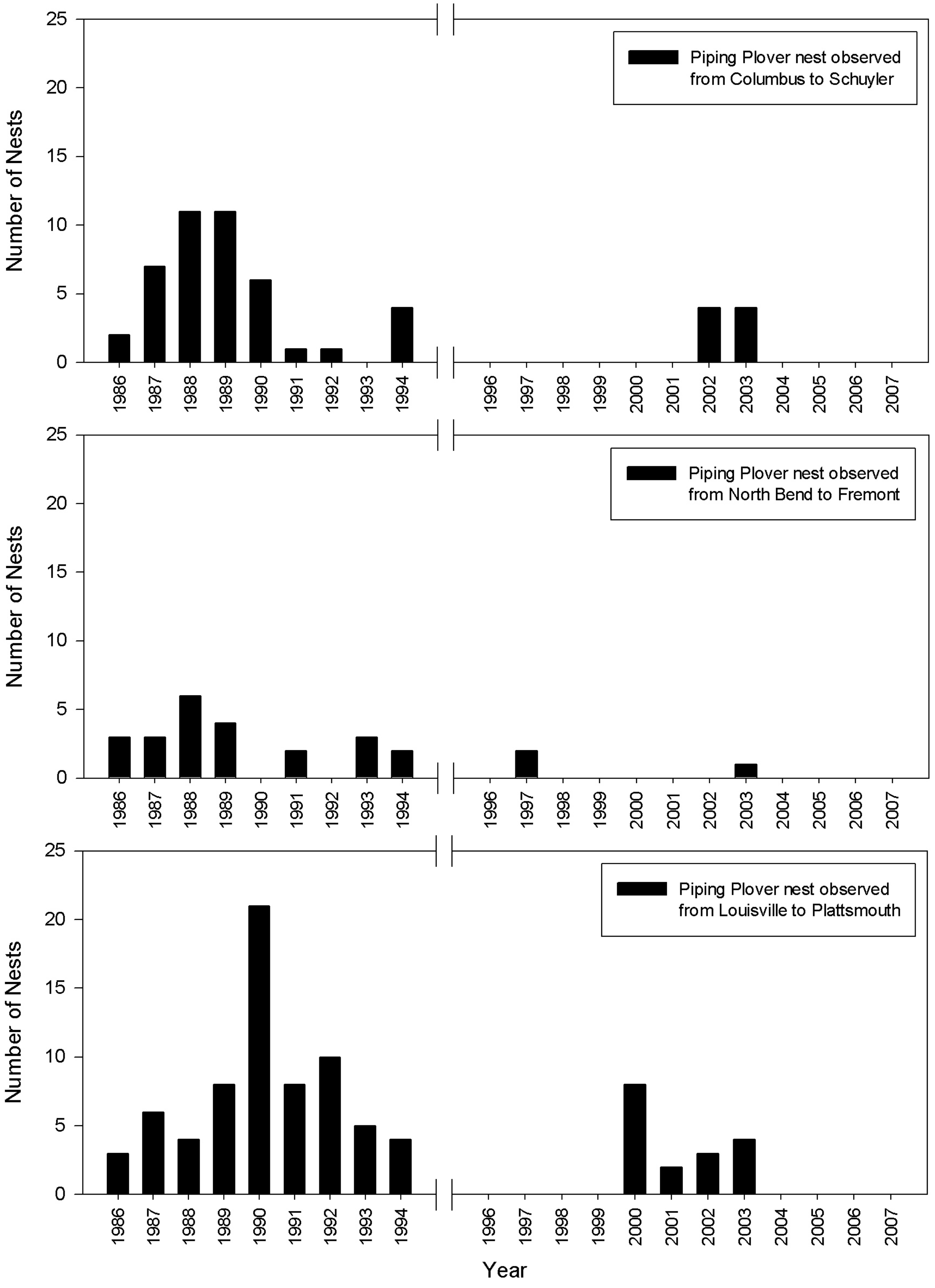

Figure 2.19. Number of Piping Plover nests from river segments recorded during Nebraska Game and Parks Commission annual surveys. No surveys were completed in 1995.

Determining Favorable Discharge Characteristics

The results of the habitat suitability index indicate which years (1956 – 2005) were *favorable years*, in that they had the appropriate sequence of flow conditions to produce sandbars where successful reproduction of least terns and piping plovers was most probable. Identifying favorable years allows characterization of the flow conditions that occurred during, and previous to, the years with the most suitable potential sandbar habitat. Each gage location was considered separately when identifying favorable years. Separation by gage location is necessary when describing flow conditions as locations used in this analysis have different flow regimes due to tributary influences. The average 1.5 year maximum discharge and average monthly flow statistics were calculated from this data set, providing an estimate of flow characteristics for favorable years.

In favorable years (top 1/3 of years with suitable habitat) higher peak flows usually resulted in higher amounts of suitable habitat (Table 2.9). Given the difference in suitable habitat among sites, the minimum suitable habitat score to be considered a favorable year was different for each site. The average suitable habitat score at Duncan was 0.88, at North Bend the average score was 2.51, and at Louisville the average score was 3.61. It is important to understand that the discharge conditions reflected by these favorable years at each of these sites are not directly comparable. The most favorable years at Duncan would be not be considered favorable years at Louisville. The results reflect the modified discharge conditions in the Platte River over the past 50 years and do not suggest that this is the natural or best possible condition (NRC 2005). The results only characterize the discharge conditions in the best years at each site.

The results reflect the need for high flows during the preceding 1.5 years to scour vegetation from sandbars and deposit new sandbars. Average peak flows were large in the Louisville (79,805 cfs) and at North Bend (54,182 cfs) reaches and much smaller in the Duncan reach (19,804 cfs). The large flow volumes at North Bend and Louisville provide substantial sediment transport capabilities. Minimum peak flows near Louisville and North Bend were larger than the maximum peak flows near Duncan. This suggests that peak flows from the central Platte River are not high enough to create suitable sandbar habitats for terns and plovers. Indeed, and not withstanding atypical occurrences or birds nesting on managed sites, these two species are now extirpated as breeding species from the central Platte River (Haig and Plissner 1992, Haig and Plissner 1996, Ferland and Haig 2002, NGPC database).

Discharge characteristics for favorable months showed that June and July were included in the favorable years more often then May and August (Table 2.10). North Bend and Louisville were the only reaches that had suitability scores over 4%. The average flow at Duncan decreased from a high of 1,710 cfs in June to a low of 572 cfs in August. The average flows for North Bend decreased each month from 5,129 cfs in May to 2,042 in August. Near the Louisville gage, the discharge decreased from 6,943 cfs in May to a low of 3,811 in August. The best overall month was May near Louisville with 6,943 cfs average discharge and an average habitat suitability score of 5.03%.

Visual inspection of the relationship between peak flows, summer flows, and suitable habitat resulted in the observation of two patterns (Figures 2.20, 2.21, and 2.22). First, in summers with mean flows substantially higher than average, little suitable habitat was observed (see year 1983 at all sites). This pattern is especially evident at Louisville, suggesting that high summer flows at Louisville were high enough to eliminate most suitable habitat, while some of the higher flows at North Bend did not preclude habitat. Summer mean flows near or slightly below 5,480 cfs resulted in the maximum amount of suitable habitat. This was a result of the maximum available habitat reaching a peak at 5,480 cfs (Figure 2.10). Second, the majority of higher suitable habitat years occurred in years with high peak flows.

The models in this chapter were based on sandbars of 1.5 feet in height above discharge levels. However, sandbars that were 2.99 ft above the water surface elevation were reported to be selected most often by terns and plovers on the lower Platte River (Ziewitz et al., 1992). Based on the maximum available habitat discharge, the peak flows necessary to create sandbars 2.99 feet in height can be calculated (threshold peak flows). At 5,480 cfs (discharge with maximum available habitat termed threshold summer flows), the water surface elevation was estimated at 1.83 ft. Adding the reported selected sandbar height of 2.99 ft to this elevation resulted in a sandbar height of 4.82 ft from the channel floor. The peak flow needed to create sandbars of 2.99 ft (4.82 ft from channel floor) was 38,170 cfs. When plotting a line at the threshold peak flow, a pattern became apparent. When comparing the threshold peak flow to years with suitable habitat greater than 2%, a peak flow of at least 38,170 cfs was observed in 7 of 9 years at North Bend and in 14 of 15 years at Louisville. Overall, 21 out of 24 (88%) of those years had a peak flow of at least 38,170 cfs. Peak flows near Duncan never reached the 38,170 cfs threshold and no years of suitable habitat greater than 2% were observed. When comparing the threshold peak flow to years with suitable habitat between 1% and 2% similar pattern exists. At all sites combined, 9 of 13 (69%) years had a peak flow greater than 38,170 cfs. Conversely, when comparing the threshold peak flow to years with 0% habitat suitability, 18 of 65 (28%) had flows greater than 38,170 cfs.

To have a successful breeding year, it is important to have high flood flows preceding falling flows during the breeding season. High flood flows or falling summer flows only, do not assure a successful breeding season.

Table 2.9. Results for 1.5 year flood discharge characteristics for top 1/3 of non-zero suitable habitat years near the three Platte River gages.

	Platte River near Duncan, NE	Platte River near North Bend, NE	Platte River near Louisville, NE
Number of non-zero years	12	34	39
Number of years in top 1/3	4	11	13
Maximum yearly suitable score	1.00	3.27	5.00
Average yearly suitable score	0.88	2.51	3.61
Minimum yearly suitable score	0.68	1.59	2.25
Maximum 1.5 year flood discharge (cfs)	22,900	82,300	138,000
Average 1.5 year flood discharge (cfs)	19,804	54,182	79,805
Minimum 1.5 year flood discharge (cfs)	15,317	30,267	39,700

Table 2.10. Monthly average discharge characteristics during breeding season for the top 1/3 of non-zero suitable habitat years near the three Platte River gages. Minimum suitable habitat score criteria for a month was from Table 2.9.

Site Name & Suitable Habitat Minimum	Month	Maximum Monthly Discharge (cfs)	Average Monthly Discharge (cfs)	Minimum Monthly Discharge (cfs)	Average Percent Suitable Habitat	Number of Months ≥ Min Score
Platte River near Duncan, NE Suitable Habitat (≥ 0.68)	May	3,990	1,535	763	0.85	2
	June	3,377	1,710	523	1.09	3
	July	1,582	662	215	1.06	3
	August	1,388	572	182	0.91	3
Platte River near North Bend, NE Suitable Habitat (≥ 1.59)	May	10,114	5,129	3,001	4.45	9
	June	10,319	4,686	2,095	4.21	11
	July	9,465	3,921	1,248	3.15	11
	August	4,559	2,042	870	2.33	7
Platte River near Louisville, NE Suitable Habitat (≥ 2.25)	May	10,174	6,943	4,879	5.03	8
	June	12,779	5,575	3,041	4.90	10
	July	13,129	5,191	2,217	3.83	12
	August	8,841	3,811	1,911	3.67	8

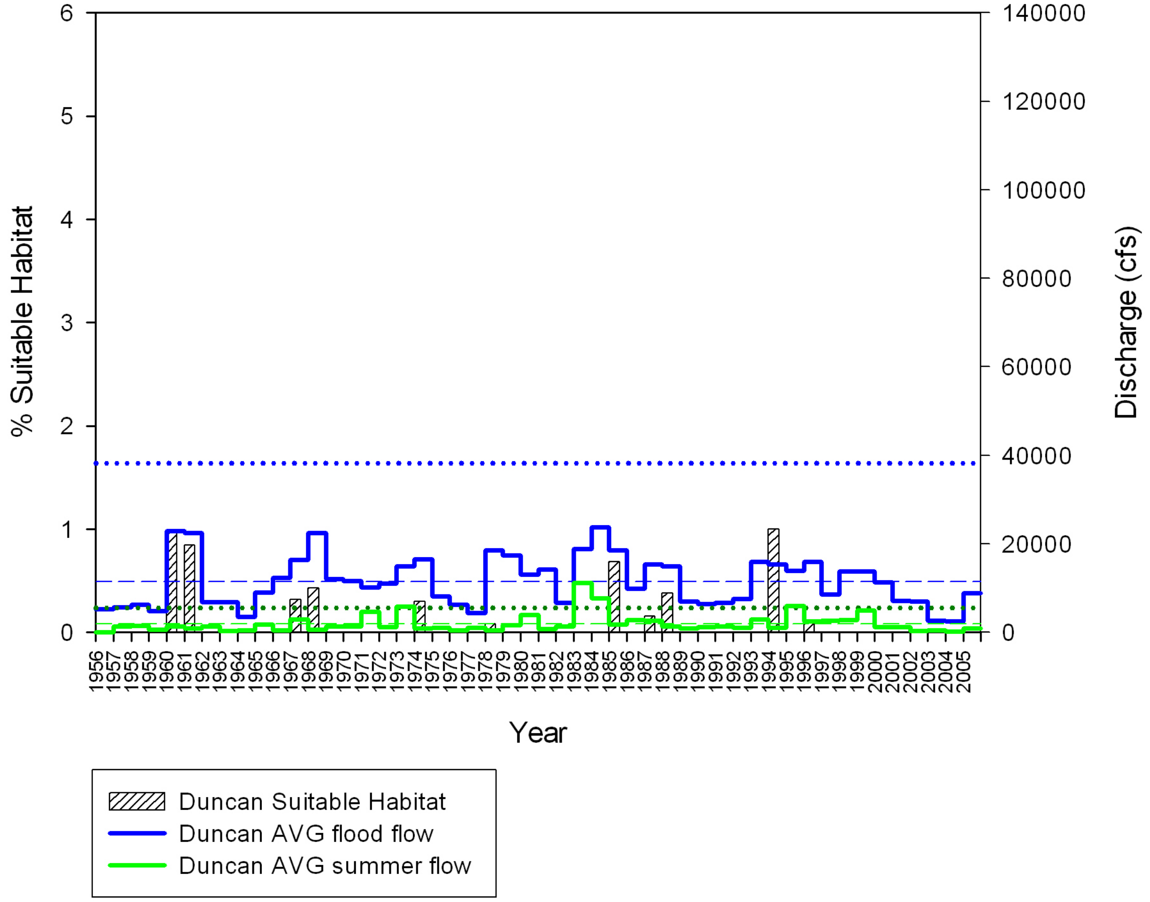

Figure 2.20. A comparison of average peak flows, average summer flows (May to August), and suitable habitat for the Platte River near Duncan, NE. The dashed lines represent the average flow for the period of record (blue for peak flows and green for summer flows). The green dotted line represents the threshold summer flow of 5,480 cfs and the blue dotted line represents the threshold peak flow of 38,170 cfs.

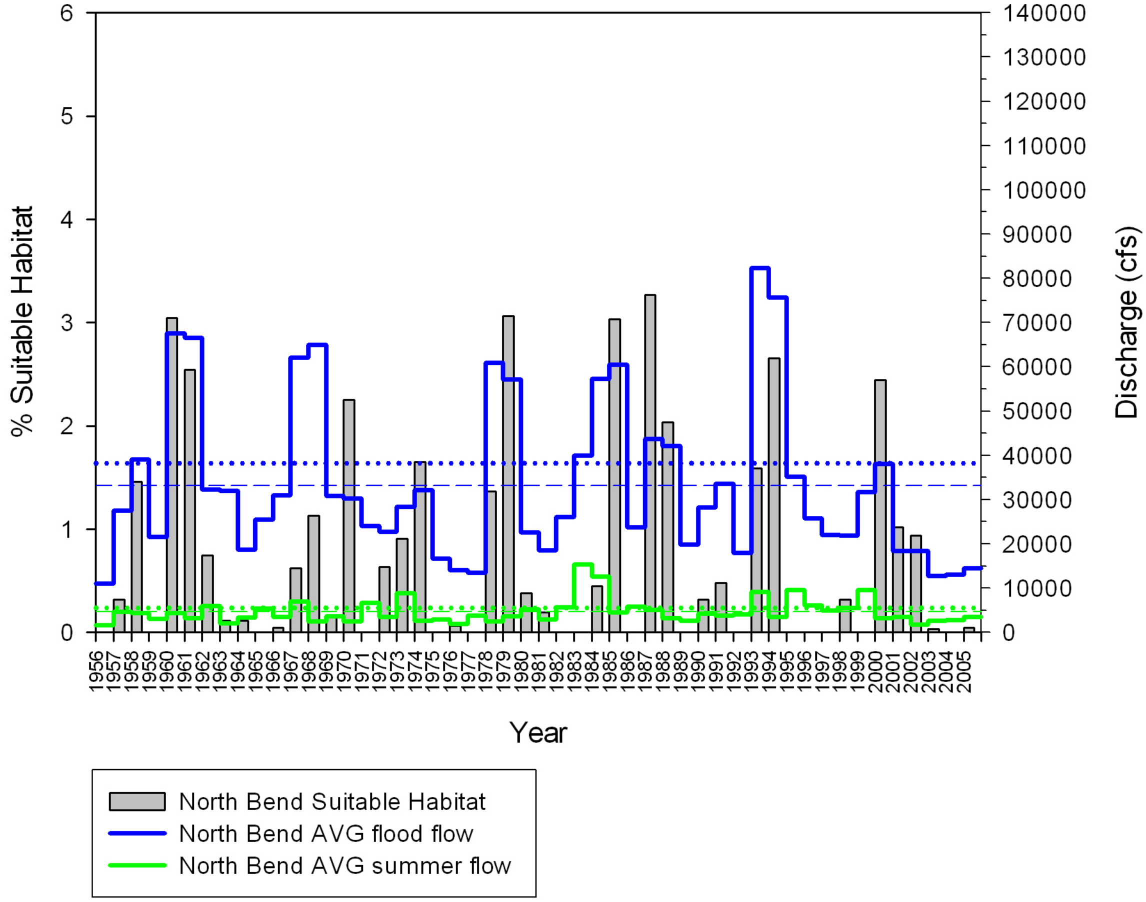

Figure 2.21. A comparison of average peak flows, average summer flows (May to August), and suitable habitat for the Platte River near North Bend, NE. The dashed lines represent the average flow for the period of record (blue for peak flows and green for summer flows). The green dotted line represents the threshold summer flow of 5,480 cfs and the blue dotted line represents the threshold peak flow of 38,170 cfs.

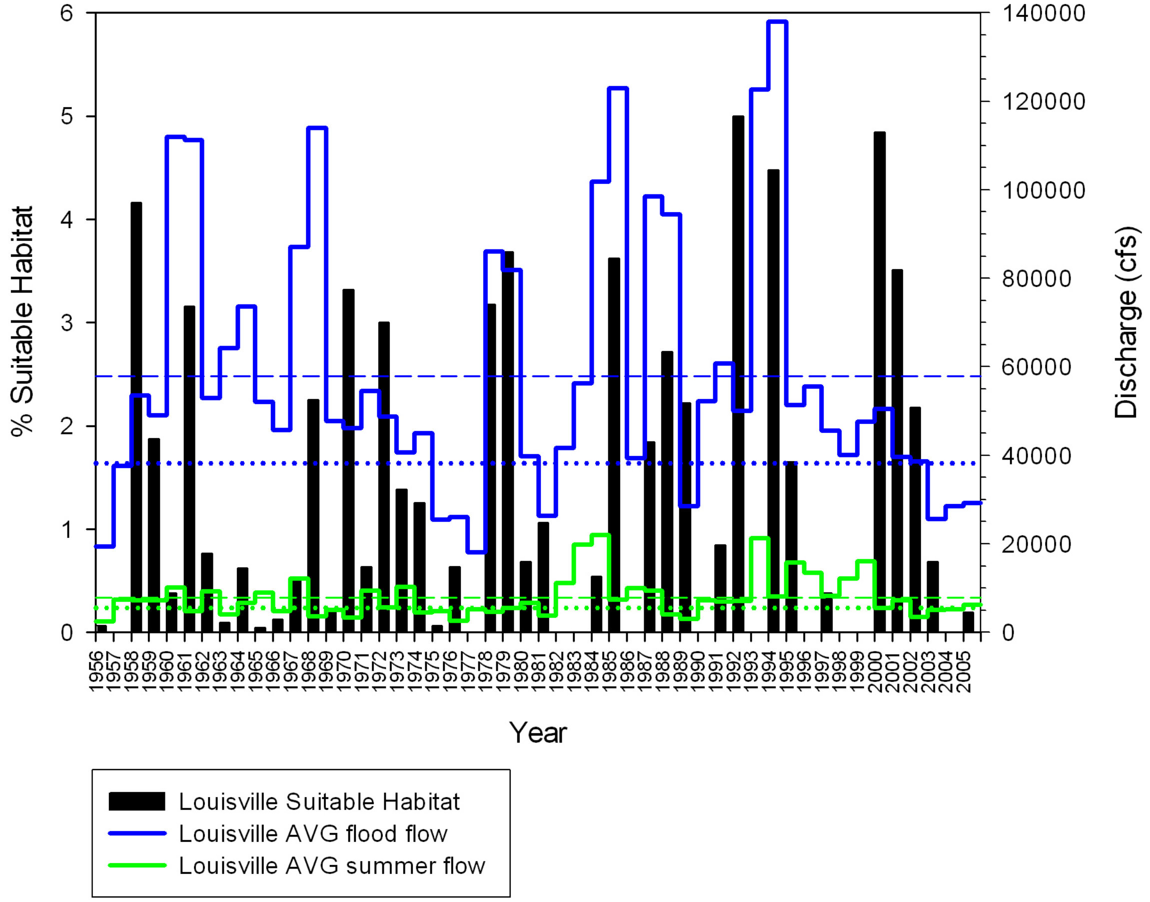

Figure 2. 22. A comparison of average peak flows, average summer flows (May to August), and suitable habitat for the Platte River near Louisville, NE. The dashed lines represent the average flow for the period of record (blue for peak flows and green for summer flows). The green dotted line represents the threshold summer flow of 5,480 cfs and the blue dotted line represents the threshold peak flow of 38,170 cfs.

Conclusions:

The model assumptions are simplifications of complex erosional and depositional processes that create and destroy sandbars on the lower Platte River. The modeling results take into account the timing, magnitude, and duration of flows observed on the lower Platte River over a 51 year period. The results are useful in understanding discharge characteristics potentially important to the creation and maintenance of suitable breeding habitat for Least Tern and Piping Plovers. It should be noted, however, that measures of suitable habitat produced here does not directly measure whether birds successfully fledged young in those years examined. There are other variables (predation rates, hail storms, human disturbance) that affect reproductive success that are not considered here. However, these other variables do not occur without nesting habitat and the presence of nesting birds.

The results illustrate the importance of high flow events in creating the large, disconnected, and unvegetated sandbars used by the Least Terns and Piping Plovers for nesting habitat. The size of the floods is not the only important characteristic, but also the frequency of the high flow events. Near Louisville, favorable years with relatively large amounts of suitable habitat were predicted in years following flows approximately 40,000 to nearly 140,000 cfs and near North Bend, these years were predicted in years following flows of approximately 30,000 cfs and 82,000 cfs. Flood flows are useful in transporting sediment during the year. Floods of these magnitudes during the breeding season most likely result in nest inundation and would be more beneficial for terns and plovers to create unvegetated sandbars if they occurred prior to nesting.

An important consideration, based on the role of the flood flows in creating suitable breeding habitat, is the protection of these larger flows from diversion. Water management actions that decrease the frequency or magnitude of flood flows will diminish the ability of the flows to create suitable sandbar habitats. Additionally, the source of sand sediment in the river and channel morphology needs to be protected, so the creation of large sandbars remains a relatively common occurrence. The interaction between the flood waters, sediment, and channel shape results in the observed sandbars on the lower Platte River. Protecting the peak discharges of a least 38,170 cfs from North Bend downstream would aid in maintaining the current levels of habitat in the lower Platte River. This minimum discharge for the 1.5 year peak flows only considers tern and plover nesting habitats and the importance of the larger less frequent flood events is not addressed.

In addition to the role of high flow in creating the suitable nesting sandbars for Least Terns and Piping Plovers, summer flows that do not rise high enough to flood nests, yet are high enough to maintain tern foraging and sandbar isolation are most favorable for increasing the likelihood that birds will successfully reproduce. Given the presence of large sandbars created by a recent flood event, the most desirable summer flows would range between 11,900 and 3,910 cfs to maximize the available amount of large sandbar habitat. The flows could be stable or falling, but rising flow would likely result in unsuitable habitat conditions. Favorable summer flow conditions ranged from approximately 5,100 cfs to 2,000 cfs at North Bend and flows from 6,900 cfs to 3,800 cfs at Louisville. Summer flows that meet the threshold of 5,480 cfs would maximize the amount of large, disconnected sandbars.

Identifying specific flow quantities the for lower Platte River that provide acceptable levels of nesting habitat for the Least Terns and Piping Plover is a difficult task. The natural, on-going process of sandbar creation, erosion, and stabilization is a function of time, discharge, sediment supply, vegetation growth, and channel morphology, not discharge alone. Estimates provided in this report only consider discharge characteristics over the past 50 years and the flows in the Platte River were highly modified prior to this time. While these habitat estimates attempt to provide targets for maximizing current habitats, historic quantities of habitat may have been substantially different from that reported here.

Improved estimates of sandbar height and nest inundation will improve the resolution of specific flow targets for maximization of habitat. The data used in creating the sandbar height estimates was from transects just up and downstream of the mouth of the Elkhorn River on the Platte River. The results were generalized and extended to characterize the lower Platte River, but local channel morphology has a large influence on the erosional and depositional processes at each site. Additionally, while the models accounted for the potential of nest inundation caused by daily fluctuations from hydropower generation, the modeling effort did not assess the role of hydropower peaking flows on the creation or maintenance of the sandbar habitats. The actual effect of hydro-peaking on Least Tern and Piping Plover habitat in the lower Platte River is currently unknown.

Nesting habitat is not the only important habitat component for terns and plovers and other wildlife on the lower Platte River. The mosaic of deep channels, shallow sandbar complexes, exposed sandbars, and woody islands provides habitat and food for a wide range of river species. Flows ranging from 4,000 to 7,000 cfs maximize the diversity of habitats in the lower Platte River (Figure 2.23). Flows in this range provide suitable habitat, as well as protect the birds from mammalian predators, by isolating the sandbars with swift, deep channels and support shallow water foraging areas. The estimate of suitable breeding conditions for Least Terns and Piping Plovers requires a balance between high flow events and the lower flows observed during nesting periods.

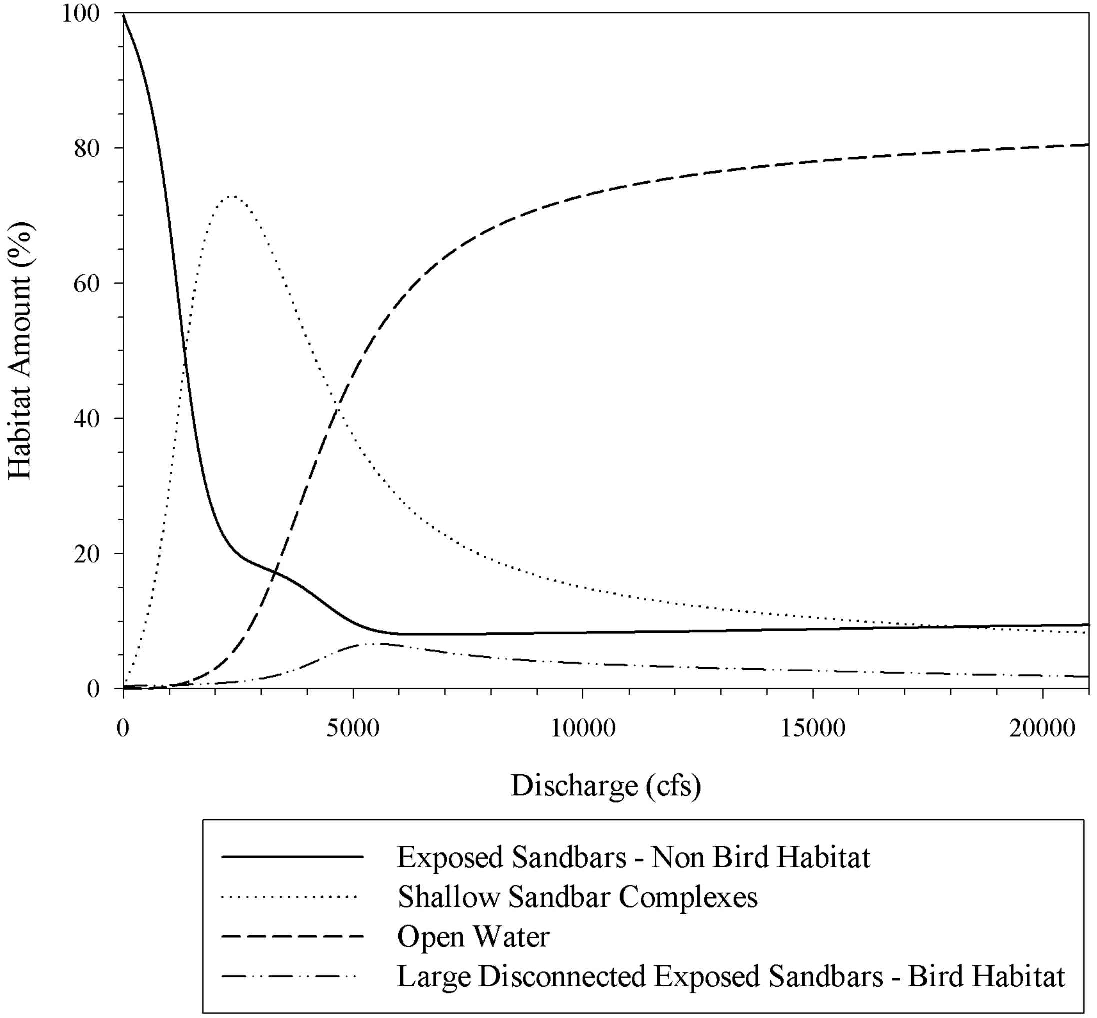

Figure 2.23. Major in channel habitat types (%) in relation to discharge (cfs) for the lower Platte River, NE. The curves for exposed sandbars, shallow sandbar complexes, and open water were reported in Peters and Parham (*in press*). The exposed sandbar category was separated into two categories, on with large disconnected exposed sandbars (bird habitat) and the other all other exposed sandbars (non bird habitat).

Chapter 3 - Estimation of Pallid Sturgeon suitable habitat and connectivity in relation to river discharge

Introduction:

Pallid sturgeon are an endangered fish that utilizes the lower Platte River. Pallid sturgeon are a large fish that is currently found in the reaches of the Platte River below the confluence with the Elkhorn River and in the lower reach of the Elkhorn River (NRC 2005). Historically, pallid sturgeon were more abundant in the main stem and major tributaries of the Missouri and Mississippi Rivers than they are currently capture data indicates (Forbes and Richardson 1905, Keenelyne 1989) In 1990, the pallid sturgeon was listed as an endangered species by the US Fish and Wildlife Service (Federal Register 55 [September 6, 1990]: 36641-36647). The decline of pallid sturgeon has been hypothesized as a result of overfishing and modification of rivers for navigation, power production, and agricultural water use (Kallemeyn 1983, USFWS 1993).

Pallid sturgeon live in the deep, swift water channels of the lower Platte River (Peters and Parham, *in press*). They have been tracked in deep channels near large sandbar complexes and in has been hypothesized that they choose current refugia on the bottoms of swift channels and feed on small fishes that are common on the nearby shallow sandbar areas (Snook et al. 2002).

In addition to using the river as habitat, pallid sturgeon have been observed moving up and back down the river in the spring months and this spring migration period has been hypothesized to be a spawning event (Peters and Parham, *in press*). The role of river connectivity to the movement of pallid sturgeon is important. The term river connectivity does not imply uninterrupted access (analogous to electricity and a wire, or a door being opened). It is better described as more like a large maze (Figure 3.1), with no "solutions"(fully connected paths) at low discharges. As discharge increases more paths are provided at the beginning of the maze starting at the confluence of the Platte River with the Missouri River and increase access upriver longitudinally. The paths through the maze increase as additional areas become connected at higher discharge until a path is "optimized" from the mouth of the Platte River to the mouth of the Elkhorn River.

Peters and Parham (*in press*) provided estimates of suitable habitat and river connectivity in relation to a range of discharges from 0 to 21,000 cfs for the lower Platte River. The goal of this chapter is to provide tables of discharge vs. suitable habitat and river connectivity based on the curves presented in Peters and Parham (*in press*). In addition, highlight values of the curves in terms of areas of maximum rate of change or changes in inflection of the curves to aid in choosing appropriate flow characteristics for maintaining habitat and river connectivity for pallid sturgeon.

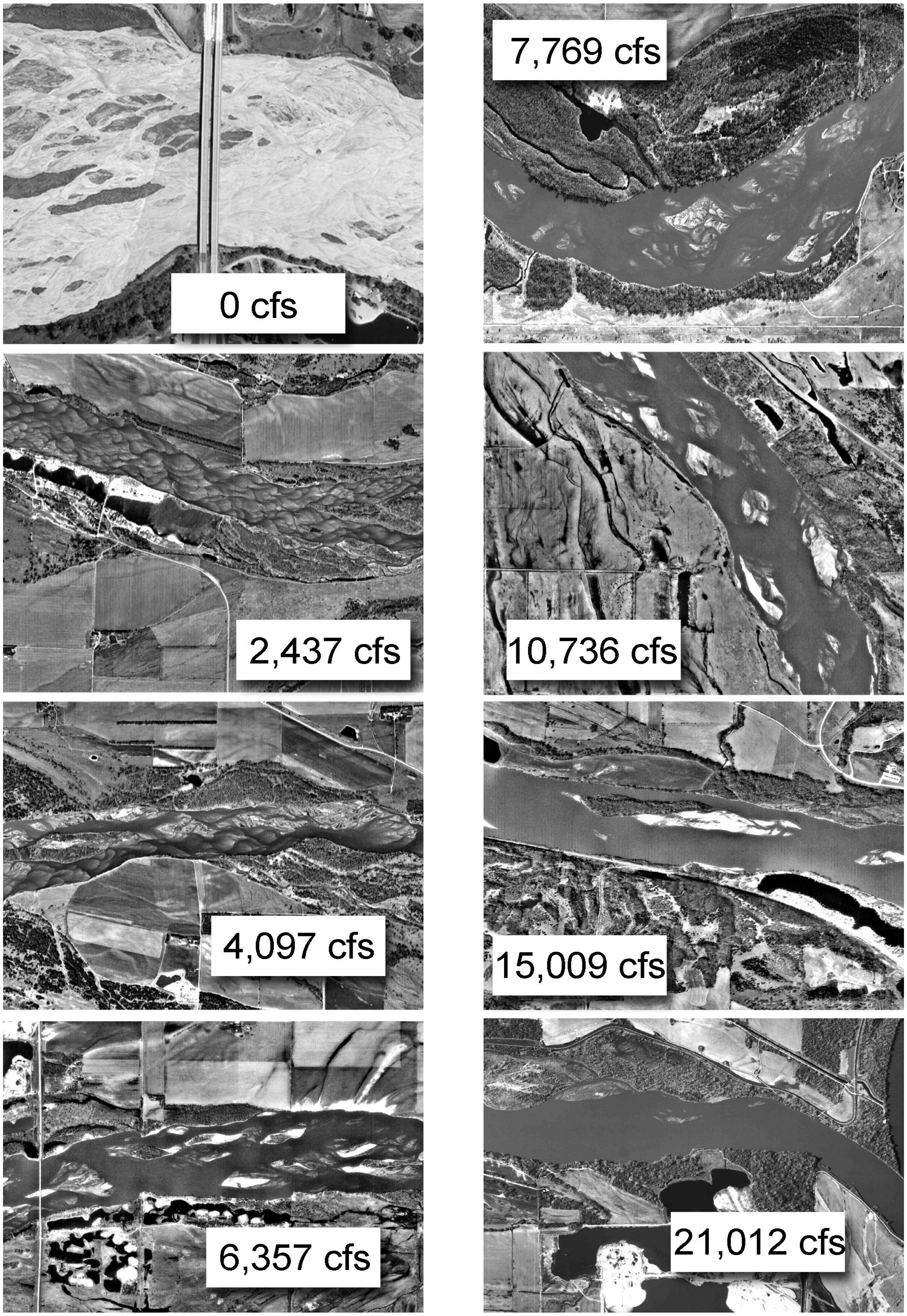

Figure 3.1. A series of aerial images from the lower Platte River showing changes in river connectivity in relation to discharge. The images were from a range of locations and a range of dates and are not all to the same scale. Note the changes in the deep channels that serve as pathways for pallid sturgeon in the series of images.

Methods:

The curves for suitable habitat for pallid sturgeon and river connectivity in Peters and Parham (*in press*) were recreated in table form providing a listing of standardized (to 100%) suitable habitat and river connectivity values from 0 to 21,000 cfs in 50 cfs steps. The relationship between suitable habitat and discharge and river connectivity and discharge are nonlinear relationships with rapid increases in habitat and connectivity before the rate of change slows as it reaches an asymptote.

Given this relationship, it is important to identify the values where small changes in discharge cause large changes in available habitat or connectivity. To determine the maximum rate of change of the curves, the first derivative was plotted and the peak of the curve was determined. Additionally, the second derivative was plotted to determine the location of the maximum rate of change for the first derivative in the upper half of the values. This was used to provide an upper critical value that would occur where the habitat or connectivity curve was beginning the almost linear drop over the middle ranges of each curve. An additional critical value was determined for each curve. For the habitat suitability curve, the point of discharge where 50% of the maximum available habitat was available was recorded. For the river connectivity curve, the point where the upper 95% confidence interval reached 100% connected was recorded.

Results:

Suitable Habitat:

Pallid sturgeon were found to select deep, swift waters of the Platte River (Peters and Parham, *in press*). These habitats are not common at low discharges on the lower Platte River and increase as river discharge increases (Figure 3.2 and Table 3.1). The location of maximum rate of change for the habitat suitability curve was located at 3,800 cfs and the upper critical point (maximum rate of change of the first derivative) was at 4,950 cfs (Figure 3.2). This suggests that discharge rates lower than 3,800 cfs are likely unsuitable for pallid sturgeon as habitats can disappear quickly below this level. The maximum amount of suitable habitat was set to equal 100% at 21,000 cfs in this analysis to determine the 50% value, but in Peter and Parham (*in press*) the total amount of suitable habitat rarely rises above 30% of total channel habitat. For pallid sturgeon 50% of the maximum available suitable habitat was observed at 4,450 cfs. When considering suitable habitat only, discharge rates near or above 5,000 cfs should provide adequate habitat for pallid sturgeon in the lower Platte River.

River Connectivity:

Pallid sturgeon are highly mobile fishes. To reach areas of suitable habitat (deep and swift habitats) they must traverse areas less suitable (shallow and/or slow habitats). In addition to general movement from area to area, pallid sturgeon potentially use the lower Platte River as spawning habitat during the spring migratory period (Peters and Parham, *in press*). For the observed upstream movements in April and May and the subsequent downstream movements during June and early July, there needs to be adequate water in the river to allow for passage for the fish to traverse the river. The river is generally unconnected at discharge rates below 4,400 cfs and rapidly becomes connected as discharges reaches 6,300 cfs (Figure 3.3 and Table 3.1). The river can be considered fully connected at a discharge of 8,100 cfs (Figure 3.4).

*Note – Table 3.1 is located at the end of the chapter due to its length.

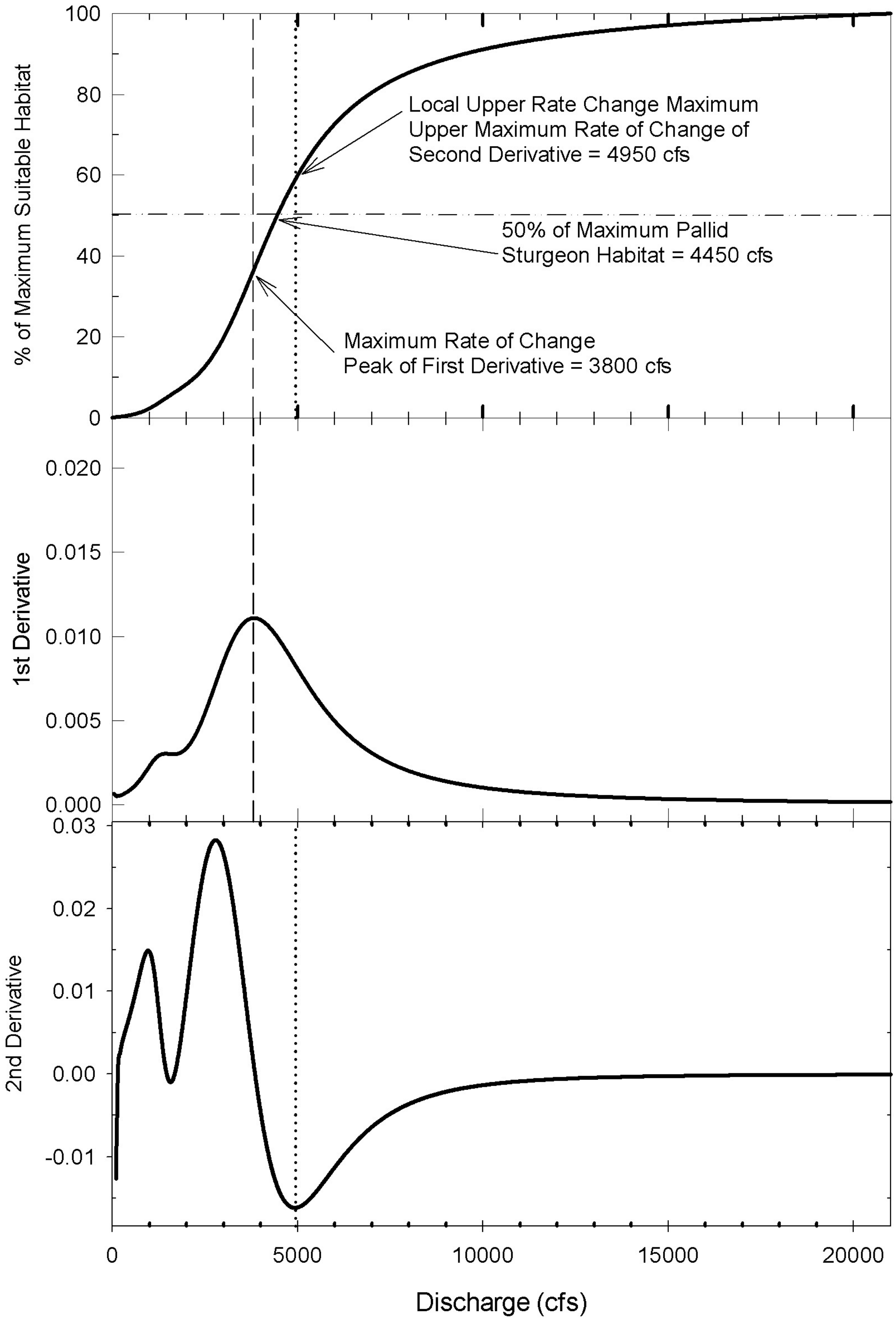

Figure 3.2. Maximum available suitable habitat, first derivative, and second derivative for pallid sturgeon in the lower Platte River, NE. Vertical dashed line is the maximum rate of change for the curve and the dotted line is the upper critical point defined as the maximum rate of change for the first derivative. The horizontal dashed line is the 50% maximum available habitat line.

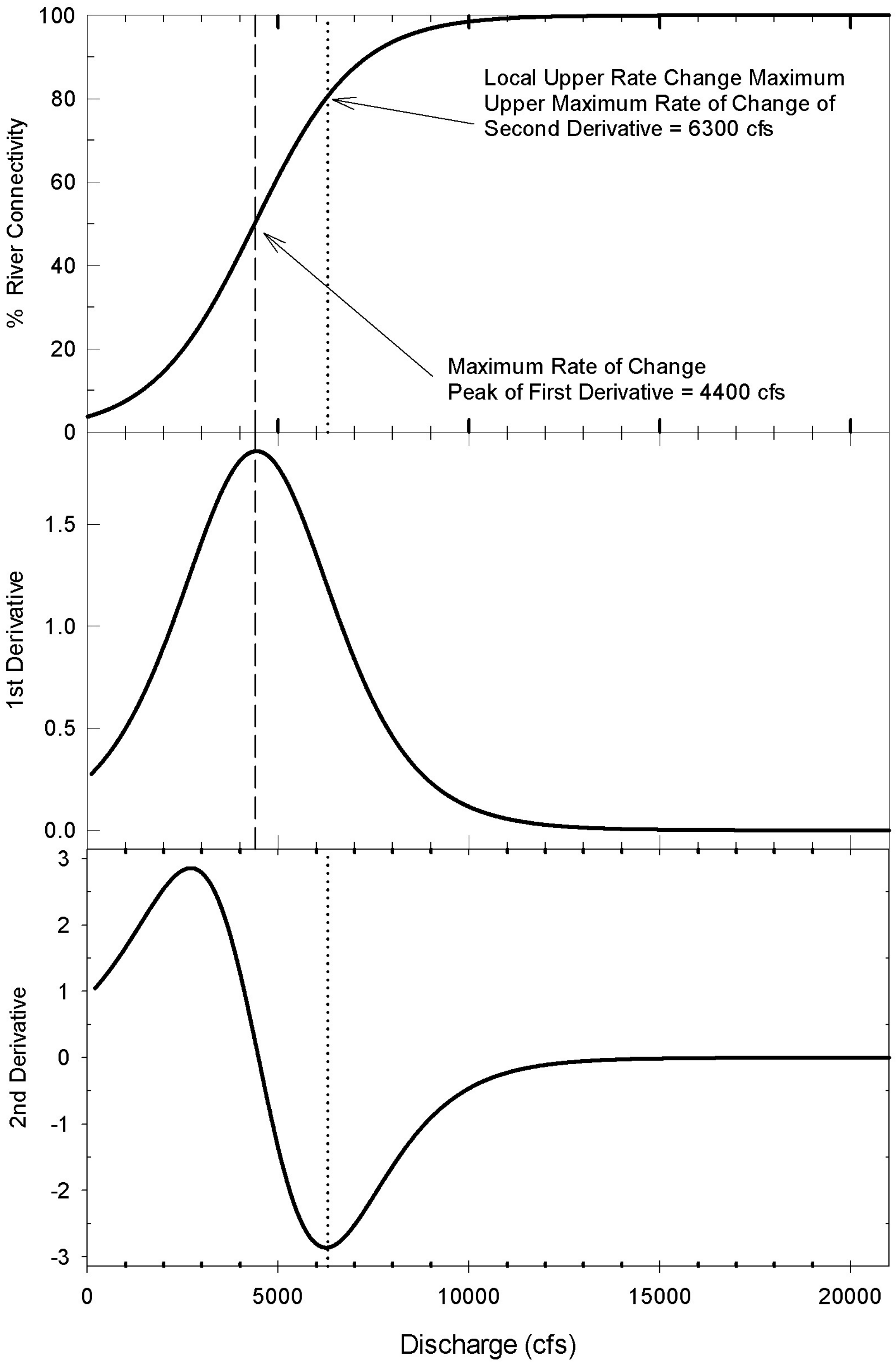

Figure 3.3. River connectivity, first derivative, and second derivative for the lower Platte River, NE. Vertical dashed line is the maximum rate of change for the curve and the dotted line is the upper critical point defined as the maximum rate of change for the first derivative.

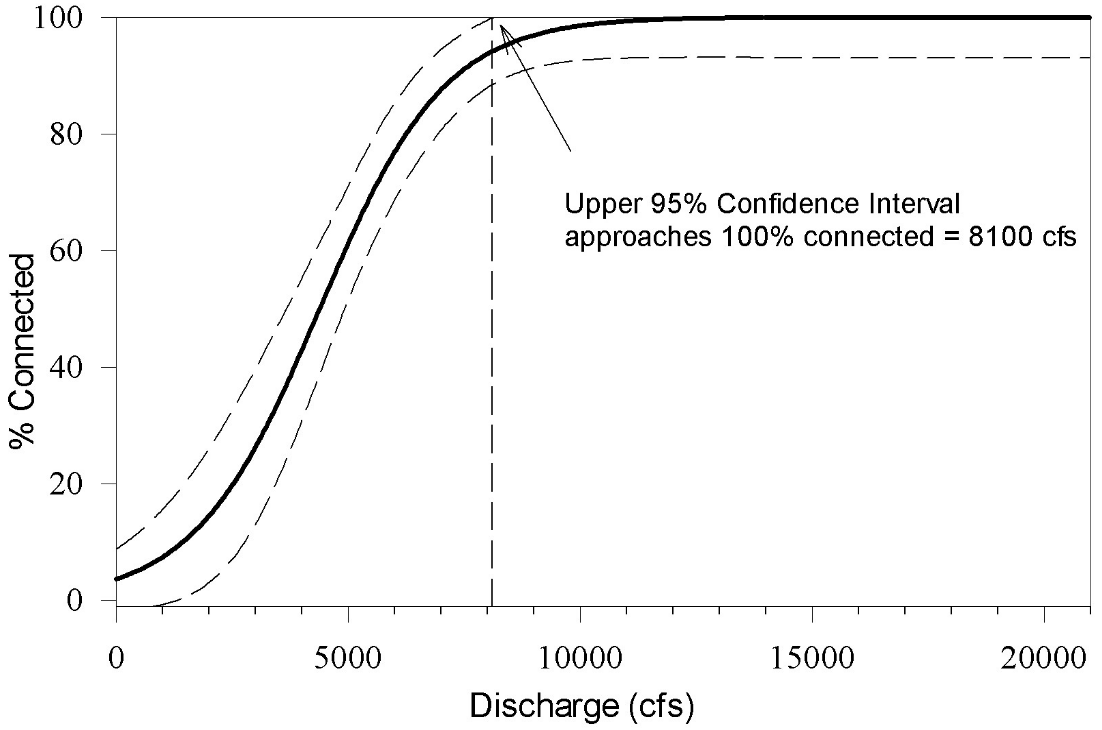

Figure 3.4. The curve for river connectivity with the upper and lower 95% confidence intervals. The vertical dashed line is the location where the upper 95% confidence interval reaches 100% connected.

Conclusions:

Pallid sturgeon select the deepest and swiftest waters in the lower Platte River and, therefore, it is highly dependent on the quantity of water in the river (Peters and Parham *in press*). During the spring migration period discharge level of 8,100 cfs would allow the sturgeon adequate movement throughout the lower Platte River, while outside of the migratory period a discharge of 4,950 cfs would maximize habitat while minimizing discharge.

When comparing these values with the exceedance values for the lower Platte River gages, more habitat was available in the downstream sections of the Platte River and the river was more highly connected in the spring than in other times of the year. Near Louisville, annual median discharge is 5,230 cfs and values greater than this are common in the spring months. More than 70% of the time during March, April and May, 5,000 cfs is available. In general, one could expect there to be suitable habitat for pallid sturgeon in the spring of the year in 7 out of 10 years on the lower Platte River from Louisville downstream. In contrast to this, at North Bend suitable habitat appears to be more limited in most years, with 5,000 cfs being exceeded 30% of the time and nearly 45% of the time during spring months. In the central Platte River near Duncan suitable habitat at 5,000 cfs occurs less than 5% of the time likely resulting in low amounts of suitable habitat west of North Bend at any time of the year. Interestingly, recreations of historical discharge for Duncan suggest that suitable habitat may have occurred in the central Platte in June of most years (Figure 3.5)

In terms of river connectivity, discharge values above 8,100 cfs would allow pallid sturgeon to move as needed among habitats and migrate up and back down the river for spring migratory purposes (e.g. spawning). Near Louisville, 8,100 cfs is equaled or exceeded nearly 45% of the time from March to June suggesting the river is connected in approximately 1 out of 2 years in this area. For North Bend, 8,000 cfs is exceed only 20 to 25% of the time in the spring months suggesting that pallid sturgeon may be able to move into this area in 1 out of 4 years on average during the spring. Near Duncan, the river is mostly unconnected for pallid sturgeon, with 8,000 cfs being exceeded in 2 to 5% of the spring months. Again, looking at the historical discharge estimates for Duncan, 8000 cfs was likely a common occurrence in this area prior to flow modifications (Figure 3.5).

Just like the least terns and piping plovers, pallid sturgeon use the mosaic of habitats in the lower Platte River and just providing deep swift channels is not likely to sustain the species. Pallid sturgeon eat small fishes that are commonly found in the shallow water of the river. Protecting the flows that scour deep channels, and create large disconnected sandbars likely will help each of these endangered species. Pallid sturgeon seem to have habitat use and movement patterns that follow the natural flow patterns of the Platte river. Most of their movement occurs from late March to early July when the river is usually high, and then they remain in deeper channels in the lower Platte River or return to the Missouri River when flows receded in the summer. Protecting or enhancing the spring rise in the lower Platte River is likely favorable to the continued use of the river by pallid sturgeon. In addition to protecting flows for river connectivity and suitable habitat, protecting high flows, sediment supply, and channel morphology will aid in protecting the natural shifting sandbars and deeper channels characteristic of the lower Platte River.

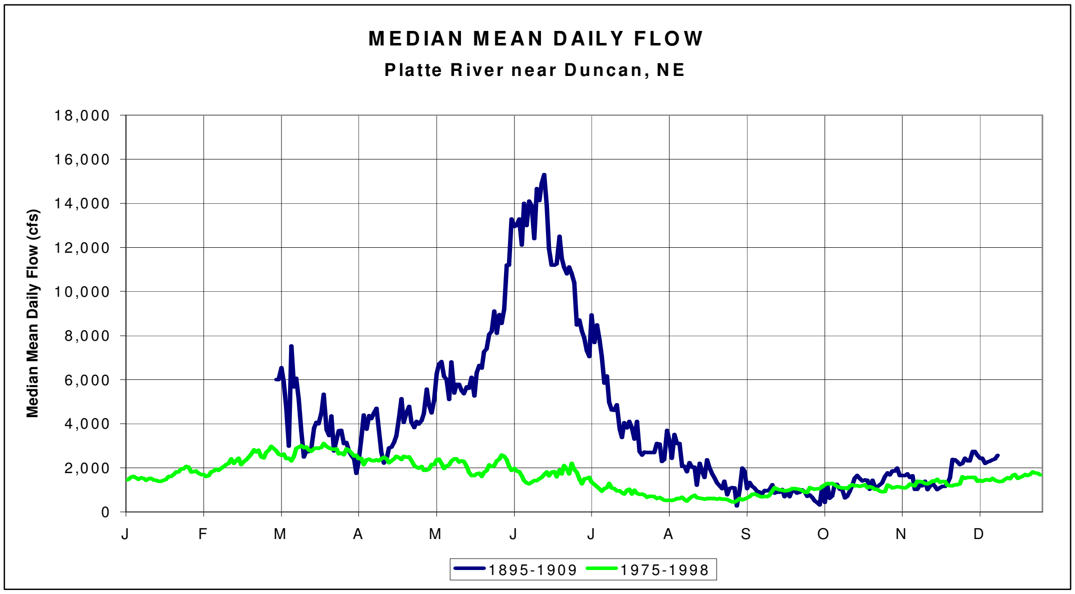

Figure 3.5. Median mean daily flow in the Platte River at Duncan, Nebraska, in 1895-1909 vs. 1975-98. (USGS gage data, as presented in Platte River FEIS, USDOI (2006)).

Table 3.1. Percent suitable habitat and river connectivity for pallid sturgeon in the lower Platte River at different discharge rates.

CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity
0	0.0%	3.7%	1,700	6.4%	12.0%	3,400	27.5%	32.5%
50	0.1%	3.8%	1,750	6.7%	12.4%	3,450	28.6%	33.3%
100	0.1%	4.0%	1,800	7.0%	12.8%	3,500	29.6%	34.2%
150	0.2%	4.1%	1,850	7.3%	13.2%	3,550	30.7%	35.0%
200	0.2%	4.3%	1,900	7.6%	13.6%	3,600	31.8%	35.9%
250	0.3%	4.4%	1,950	7.9%	14.1%	3,650	32.9%	36.7%
300	0.4%	4.6%	2,000	8.3%	14.5%	3,700	34.0%	37.6%
350	0.4%	4.8%	2,050	8.6%	15.0%	3,750	35.1%	38.5%
400	0.5%	4.9%	2,100	9.0%	15.5%	3,800	36.2%	39.3%
450	0.6%	5.1%	2,150	9.4%	16.0%	3,850	37.3%	40.2%
500	0.7%	5.3%	2,200	9.8%	16.5%	3,900	38.4%	41.1%
550	0.8%	5.5%	2,250	10.2%	17.0%	3,950	39.5%	42.0%
600	0.9%	5.7%	2,300	10.6%	17.5%	4,000	40.6%	42.9%
650	1.0%	5.9%	2,350	11.1%	18.1%	4,050	41.7%	43.9%
700	1.2%	6.1%	2,400	11.6%	18.6%	4,100	42.8%	44.8%
750	1.3%	6.3%	2,450	12.1%	19.2%	4,150	43.9%	45.7%
800	1.5%	6.5%	2,500	12.6%	19.8%	4,200	45.0%	46.6%
850	1.6%	6.8%	2,550	13.2%	20.4%	4,250	46.0%	47.5%
900	1.8%	7.0%	2,600	13.8%	21.0%	4,300	47.1%	48.5%
950	2.1%	7.2%	2,650	14.5%	21.6%	4,350	48.1%	49.4%
1,000	2.3%	7.5%	2,700	15.1%	22.3%	4,400	49.1%	50.3%
1,050	2.5%	7.7%	2,750	15.8%	22.9%	4,450	50.1%	51.3%
1,100	2.8%	8.0%	2,800	16.6%	23.6%	4,500	51.1%	52.2%
1,150	3.1%	8.3%	2,850	17.3%	24.3%	4,550	52.0%	53.1%
1,200	3.4%	8.6%	2,900	18.1%	24.9%	4,600	53.0%	54.0%
1,250	3.6%	8.9%	2,950	18.9%	25.6%	4,650	53.9%	55.0%
1,300	3.9%	9.2%	3,000	19.8%	26.4%	4,700	54.8%	55.9%
1,350	4.2%	9.5%	3,050	20.7%	27.1%	4,750	55.7%	56.8%
1,400	4.6%	9.8%	3,100	21.6%	27.8%	4,800	56.6%	57.7%
1,450	4.9%	10.2%	3,150	22.5%	28.6%	4,850	57.5%	58.6%
1,500	5.2%	10.5%	3,200	23.5%	29.3%	4,900	58.3%	59.5%
1,550	5.5%	10.9%	3,250	24.4%	30.1%	4,950	59.1%	60.4%
1,600	5.8%	11.2%	3,300	25.4%	30.9%	5,000	59.9%	61.3%
1,650	6.1%	11.6%	3,350	26.5%	31.7%	5,050	60.7%	62.2%

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CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity
5,100	61.5%	63.0%	6,800	79.2%	85.8%	8,500	87.2%	95.5%
5,150	62.3%	63.9%	6,850	79.5%	86.2%	8,550	87.4%	95.7%
5,200	63.0%	64.7%	6,900	79.8%	86.7%	8,600	87.6%	95.8%
5,250	63.7%	65.6%	6,950	80.1%	87.1%	8,650	87.7%	96.0%
5,300	64.4%	66.4%	7,000	80.5%	87.5%	8,700	87.9%	96.1%
5,350	65.1%	67.2%	7,050	80.8%	87.9%	8,750	88.0%	96.3%
5,400	65.8%	68.1%	7,100	81.1%	88.3%	8,800	88.2%	96.4%
5,450	66.4%	68.9%	7,150	81.3%	88.7%	8,850	88.3%	96.5%
5,500	67.1%	69.7%	7,200	81.6%	89.0%	8,900	88.5%	96.6%
5,550	67.7%	70.4%	7,250	81.9%	89.4%	8,950	88.6%	96.8%
5,600	68.3%	71.2%	7,300	82.2%	89.7%	9,000	88.7%	96.9%
5,650	68.9%	72.0%	7,350	82.4%	90.1%	9,050	88.9%	97.0%
5,700	69.5%	72.7%	7,400	82.7%	90.4%	9,100	89.0%	97.1%
5,750	70.0%	73.4%	7,450	82.9%	90.7%	9,150	89.2%	97.2%
5,800	70.6%	74.2%	7,500	83.2%	91.0%	9,200	89.3%	97.3%
5,850	71.1%	74.9%	7,550	83.4%	91.3%	9,250	89.4%	97.4%
5,900	71.6%	75.5%	7,600	83.7%	91.6%	9,300	89.5%	97.5%
5,950	72.2%	76.2%	7,650	83.9%	91.9%	9,350	89.7%	97.6%
6,000	72.7%	76.9%	7,700	84.1%	92.2%	9,400	89.8%	97.7%
6,050	73.1%	77.6%	7,750	84.4%	92.4%	9,450	89.9%	97.7%
6,100	73.6%	78.2%	7,800	84.6%	92.7%	9,500	90.0%	97.8%
6,150	74.1%	78.8%	7,850	84.8%	92.9%	9,550	90.1%	97.9%
6,200	74.5%	79.4%	7,900	85.0%	93.2%	9,600	90.3%	98.0%
6,250	75.0%	80.0%	7,950	85.2%	93.4%	9,650	90.4%	98.0%
6,300	75.4%	80.6%	8,000	85.4%	93.6%	9,700	90.5%	98.1%
6,350	75.8%	81.2%	8,050	85.6%	93.9%	9,750	90.6%	98.2%
6,400	76.2%	81.8%	8,100	85.8%	94.1%	9,800	90.7%	98.2%
6,450	76.6%	82.3%	8,150	86.0%	94.3%	9,850	90.8%	98.3%
6,500	77.0%	82.8%	8,200	86.2%	94.5%	9,900	90.9%	98.4%
6,550	77.4%	83.4%	8,250	86.4%	94.7%	9,950	91.0%	98.4%
6,600	77.8%	83.9%	8,300	86.5%	94.8%	10,000	91.1%	98.5%
6,650	78.1%	84.4%	8,350	86.7%	95.0%	10,050	91.2%	98.5%
6,700	78.5%	84.8%	8,400	86.9%	95.2%	10,100	91.3%	98.6%
6,750	78.8%	85.3%	8,450	87.1%	95.4%	10,150	91.4%	98.6%

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CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity
10,200	91.5%	98.7%	12,000	94.3%	99.7%	13,800	96.2%	99.9%
10,250	91.6%	98.7%	12,050	94.4%	99.7%	13,850	96.2%	99.9%
10,300	91.7%	98.8%	12,100	94.4%	99.7%	13,900	96.2%	99.9%
10,350	91.8%	98.8%	12,150	94.5%	99.7%	13,950	96.3%	99.9%
10,400	91.9%	98.9%	12,200	94.5%	99.7%	14,000	96.3%	99.9%
10,450	92.0%	98.9%	12,250	94.6%	99.7%	14,050	96.4%	99.9%
10,500	92.1%	99.0%	12,300	94.7%	99.7%	14,100	96.4%	99.9%
10,550	92.2%	99.0%	12,350	94.7%	99.7%	14,150	96.5%	99.9%
10,600	92.3%	99.0%	12,400	94.8%	99.7%	14,200	96.5%	99.9%
10,650	92.3%	99.1%	12,450	94.8%	99.8%	14,250	96.5%	99.9%
10,700	92.4%	99.1%	12,500	94.9%	99.8%	14,300	96.6%	99.9%
10,750	92.5%	99.1%	12,550	94.9%	99.8%	14,350	96.6%	99.9%
10,800	92.6%	99.2%	12,600	95.0%	99.8%	14,400	96.7%	99.9%
10,850	92.7%	99.2%	12,650	95.1%	99.8%	14,450	96.7%	99.9%
10,900	92.8%	99.2%	12,700	95.1%	99.8%	14,500	96.7%	99.9%
10,950	92.8%	99.2%	12,750	95.2%	99.8%	14,550	96.8%	99.9%
11,000	92.9%	99.3%	12,800	95.2%	99.8%	14,600	96.8%	100.0%
11,050	93.0%	99.3%	12,850	95.3%	99.8%	14,650	96.8%	100.0%
11,100	93.1%	99.3%	12,900	95.3%	99.8%	14,700	96.9%	100.0%
11,150	93.1%	99.4%	12,950	95.4%	99.8%	14,750	96.9%	100.0%
11,200	93.2%	99.4%	13,000	95.4%	99.8%	14,800	97.0%	100.0%
11,250	93.3%	99.4%	13,050	95.5%	99.8%	14,850	97.0%	100.0%
11,300	93.4%	99.4%	13,100	95.5%	99.8%	14,900	97.0%	100.0%
11,350	93.4%	99.4%	13,150	95.6%	99.9%	14,950	97.1%	100.0%
11,400	93.5%	99.5%	13,200	95.6%	99.9%	15,000	97.1%	100.0%
11,450	93.6%	99.5%	13,250	95.7%	99.9%	15,050	97.1%	100.0%
11,500	93.7%	99.5%	13,300	95.7%	99.9%	15,100	97.2%	100.0%
11,550	93.7%	99.5%	13,350	95.8%	99.9%	15,150	97.2%	100.0%
11,600	93.8%	99.5%	13,400	95.8%	99.9%	15,200	97.2%	100.0%
11,650	93.9%	99.6%	13,450	95.9%	99.9%	15,250	97.3%	100.0%
11,700	93.9%	99.6%	13,500	95.9%	99.9%	15,300	97.3%	100.0%
11,750	94.0%	99.6%	13,550	95.9%	99.9%	15,350	97.3%	100.0%
11,800	94.1%	99.6%	13,600	96.0%	99.9%	15,400	97.4%	100.0%
11,850	94.1%	99.6%	13,650	96.0%	99.9%	15,450	97.4%	100.0%
11,900	94.2%	99.6%	13,700	96.1%	99.9%	15,500	97.4%	100.0%
11,950	94.2%	99.6%	13,750	96.1%	99.9%	15,550	97.5%	100.0%

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CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity	CFS	% Pallid Sturgeon Suitable Habitat	% River Connectivity
15,600	97.5%	100.0%	17,400	98.5%	100.0%	19,200	99.3%	100.0%
15,650	97.5%	100.0%	17,450	98.6%	100.0%	19,250	99.4%	100.0%
15,700	97.6%	100.0%	17,500	98.6%	100.0%	19,300	99.4%	100.0%
15,750	97.6%	100.0%	17,550	98.6%	100.0%	19,350	99.4%	100.0%
15,800	97.6%	100.0%	17,600	98.6%	100.0%	19,400	99.4%	100.0%
15,850	97.7%	100.0%	17,650	98.7%	100.0%	19,450	99.4%	100.0%
15,900	97.7%	100.0%	17,700	98.7%	100.0%	19,500	99.5%	100.0%
15,950	97.7%	100.0%	17,750	98.7%	100.0%	19,550	99.5%	100.0%
16,000	97.8%	100.0%	17,800	98.7%	100.0%	19,600	99.5%	100.0%
16,050	97.8%	100.0%	17,850	98.8%	100.0%	19,650	99.5%	100.0%
16,100	97.8%	100.0%	17,900	98.8%	100.0%	19,700	99.5%	100.0%
16,150	97.8%	100.0%	17,950	98.8%	100.0%	19,750	99.6%	100.0%
16,200	97.9%	100.0%	18,000	98.8%	100.0%	19,800	99.6%	100.0%
16,250	97.9%	100.0%	18,050	98.8%	100.0%	19,850	99.6%	100.0%
16,300	97.9%	100.0%	18,100	98.9%	100.0%	19,900	99.6%	100.0%
16,350	98.0%	100.0%	18,150	98.9%	100.0%	19,950	99.6%	100.0%
16,400	98.0%	100.0%	18,200	98.9%	100.0%	20,000	99.6%	100.0%
16,450	98.0%	100.0%	18,250	98.9%	100.0%	20,050	99.7%	100.0%
16,500	98.1%	100.0%	18,300	99.0%	100.0%	20,100	99.7%	100.0%
16,550	98.1%	100.0%	18,350	99.0%	100.0%	20,150	99.7%	100.0%
16,600	98.1%	100.0%	18,400	99.0%	100.0%	20,200	99.7%	100.0%
16,650	98.1%	100.0%	18,450	99.0%	100.0%	20,250	99.7%	100.0%
16,700	98.2%	100.0%	18,500	99.0%	100.0%	20,300	99.8%	100.0%
16,750	98.2%	100.0%	18,550	99.1%	100.0%	20,350	99.8%	100.0%
16,800	98.2%	100.0%	18,600	99.1%	100.0%	20,400	99.8%	100.0%
16,850	98.2%	100.0%	18,650	99.1%	100.0%	20,450	99.8%	100.0%
16,900	98.3%	100.0%	18,700	99.1%	100.0%	20,500	99.8%	100.0%
16,950	98.3%	100.0%	18,750	99.2%	100.0%	20,550	99.8%	100.0%
17,000	98.3%	100.0%	18,800	99.2%	100.0%	20,600	99.9%	100.0%
17,050	98.4%	100.0%	18,850	99.2%	100.0%	20,650	99.9%	100.0%
17,100	98.4%	100.0%	18,900	99.2%	100.0%	20,700	99.9%	100.0%
17,150	98.4%	100.0%	18,950	99.2%	100.0%	20,750	99.9%	100.0%
17,200	98.4%	100.0%	19,000	99.3%	100.0%	20,800	99.9%	100.0%
17,250	98.5%	100.0%	19,050	99.3%	100.0%	20,850	99.9%	100.0%
17,300	98.5%	100.0%	19,100	99.3%	100.0%	20,900	100.0%	100.0%
17,350	98.5%	100.0%	19,150	99.3%	100.0%	21,000	100.0%	100.0%

J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

Literature Cited

Anderson D.M. and M.W. Rodney. 2006. Characterization of hydrological conditions to support Platte River species recovery efforts. Journal of the American Water Resources Association. 42(5):1391-1403.

Annable, W.K. 1994. Morphological relations of rural water courses in southeastern Ontario for use in natural channel design. Masters thesis, Univeristy of Guelph, School of Engineering, Guelph, Ontario, Canada.

Annear , T., I. Chisholm, H. Beecher, A. Locke and 12 other Authors. 2004. Instream flows for riverine resource stewardship, revised edition. Instream Flow Council, Cheyenne, WY.

Armbruster, M.J. 1986. A review of habitat criteria for least terns and piping plover using the Platte River. Unpublished report. National Ecology Research Center, US fish and Wildlife Service, Ft. Collins, CO.

Aron, C. 2005. South Dakota interior least tern (Sterna antillarum athalassos) and piping plover (*Charadrius melodus*) management plan. South Dakota Department of Game, Fish and Parks, Pierre, SD, Wildlife Division Report 2005-02.

Arthington AH, Bunn SE, Pusey BJ, Blühdorn DR, King JM, Day JA, Tharme RE, O'Keeffe JH. 1992. Development of an holistic approach for assessing environmental flow requirements of riverine ecosystems. In: Pigram JJ, Hooper BP (eds). Proceedings of an international seminar and workshop on water allocation for the environment. November 1991. The Centre for Water Policy Research, University of New England. Armidale, Australia. 282 pp.

Bauer, B.O. and J.C. Schmidt, 1993. Waves and sandbar erosion in the Grand Canyon: applying coastal theory to a fluvial system. *Annals of the Association of American Geographers*, 83(3):475-497.

Bentall, R. 1982. Nebraska's Platte River, a graphic analysis of flows. Nebraska Water Survey Paper No. 53. Conservation and Survey Division, Lincoln, Nebraska. 47pp.

Chen, A.H., Rus, D.L., and Stanton, C.P., 1999, Trends in channel gradation in Nebraska streams, 1913-95: U.S. Geological Survey Water-Resources Investigations Report 99-4103, various pagination.

Dexter, L. R.; Cluer, B. L. 1999. Cyclic Erosional Instability of Sandbars along the Colorado River, Grand Canyon, Arizona. Annals of the Association of American Geographers, 89(2): 238-266.

Dirks, B. J. 1990. Distribution and productivity of Least Terns and Piping Plovers along the Missouri and Cheyenne Rivers. M.S. thesis, S.D. State Univ.; 65p. WR 223.

Dryer, M., and P. Dryer. 1985. Investigations into the population, breeding sites, habitat characteristics, threats, and productivity of the least tern in North Dakota. U.S. Fish and Wildl. Serv. Res. Info. Pap. No. 1. 17 pp.

Dunne, T., and L.B. Leopold. 1978. Water in Environmental Planning. San Francisco: W.H. Freeman. 818 pp.

Eschner, T., R. Hadley and K. Crowley. 1981. Hydrologic and morphologic changes in the Platte River basin: a historical perspective. U.S. Geological Survey, Open-file Report 81-1125. 57pp.

Eschner, T.R., R.F. Hadley, and K.D. Crowley. 1983. Hydrologic and Morphologic Changes in the Channels of the Platte River Basin in Colorado, Wyoming, and Nebraska: A Historical Perspective. U.S. Geological Survey Professional Paper 1277-A. Washington, DC: U.S. Government Printing Office. 39 pp.

ESRI, Inc., 2004. ArcGIS 9.2. Redlands, CA

Ferland, C.L., and S.M. Haig. 2002. The 2001 International Piping Plover and Snowy Plover Census. Report to USGS Forest and Rangeland Ecosystem Science Center, Corvallis, OR. 287 pp.

Forbes, S.A., and R.E. Richardson. 1905. On a new shovelnose sturgeon from the Mississippi River. Bull. Ill. State Lab. Nat. Hist. 7:37-44.

Gordon N.D., T.A. McMahon, and B.L. Finlayson. 1992. Stream Hydrology – An introduction for ecologists. John Wiley and Sons, New York, New York.

Haig, S.M. 1992. Piping plover (Charadrius melodus). Pp. 1-18 in Birds of North America, No. 2, A.F. Poole, P.R. Stettenheim, and F. Gill, eds. Washington, DC: American Ornithologists' Union; Philadelphia, PA: Academy of Natural Sciences.

Haig, S.M., and J.H. Plissner. 1992. The 1991 International Piping Plover Census. U.S. Fish and Wildlife Service, Twin Cities, MN. 200 pp

Haig, S.M., and J.H. Plissner. 1996. Population status of the threatened/endangered Piping Plover in 1991. International Wader Studies 8: 39-41.

Ivan, J. S. and R. K. Murphy. 2005. What preys on piping plover eggs and chicks? Wildlife Society Bulletin. 33(1): 113-119.

Kallemeyn, L. 1983. Status of the pallid sturgeon, *Scaphirhynchus albus*. Fisheries 8(1):3-9.

Keenlyne, K.D. 1989. A Report on the Pallid Sturgeon. Pierre, SD: U.S. Fish and Wildlife Service.

Kirsch, E.M. 1992. Habitat selection and productivity of least terns (*Sterna antillarum*) on the Lower Platte River, Nebraska. Ph.D. Dissertation, University of Montana.

Kirsch, E.M. 1996. Habitat Selection and Productivity of Least Terns on the Lower Platte River, Nebraska. Wildlife Monographs No. 132. Bethesda, MD: Wildlife Society.

Lingle, G.R. 1988. Least tern and piping plover nesting ecology along the central Platte River Valley, Nebraska. Report to U.S. Fish and Wildlife Service, Grand Island, NE.

Lingle, G.R. 1993b. Causes of nest failure and mortality of Least Terns and Piping Plovers along the central Platte River. Pp. 130-136 in Proceedings of the Missouri River and its Tributaries: Piping Plover and Least Tern Symposium-Workshop, K.F. Higgins, and M.R. Brashier, eds. Brookings, SD: South Dakota State University, Department of Wildlife and Fisheries Sciences.

Mathews and Richter. 2007. Application of the Indicators of Hydrologic Alteration Software in Environmental Flow Setting. Journal of the American Water Resources Association 2007 43:6 140

Moriwasa, M. 1968. Streams: their dynamics and morphology. New York: McGraw Hill.

Mussetter Engineering, Inc. 2002. Analysis of proposed conservation measures, Western Sarpy and Clear Creek Levee Project, Platte River, Nebraska. Nebraska Game and Parks Commission, Lincoln, NE.

Nebraska Game and Parks Commission. 2005. Instream Flow Implementation in Nebraska. Performance Report Study 1. Federal Aid in Sport Fish and Wildlife Restoration FW-19-T-19.

NRC (National Research Council). 2005. Endangered and threatened species of the Platte River, National Academies Press, Washington, D.C.

Peters and Parham (*in press*). Ecology and management of pallid sturgeon and sturgeon chub in the Platte River, Nebraska. Nebraska Game and Parks Commission. Lincoln, NE.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime: A paradigm for river conservation and restoration. BioScience 47(11):769-784.

Putnam, John A.; Furnival, G. M.; McKnight, J.S. Management and inventory of southern hardwoods, Agric, Handb. 181. Washington, DC: U.S. Department of Agriculture; 1960. 102 p.

Richter, B.D., J.V. Baumgartner, J. Powell, and D.P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems. Conserv. Biol. 10(4):1163-1174.

Rodekor and Engelbrecht. 1988. Island and Bank Morphological Changes detected in the Platte river bounding the Papio Natural Resources District from 1949 through 1988. Center for Advanced Land Management and Information Technologies, University of Nebraska Lincoln.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs Colorado.

Rumanacik, J. 1985. Survey of the interior least tern on the Mississippi River from Cape Girardeau, Illinois, to Greenville, Mississippi. U.S. Fish and Wildl. Serv., Jackson, MS. 48 pp.

Schulenberg, J. and B. Ptacek. 1984. Status of the least tern in Kansas. Am. Birds 8(6):975-981.

Sidle, J. G., D. E. Carlson, E.M. Kirsch, and J. J. Dinan. 1992. Flooding: mortality and habitat renewal for least terns and piping plovers. Colonial Waterbirds 15:132-136.

Simons and Associates, Inc. 2000. Physical History of the Platte River in Nebraska: Focusing Upon Flow, Sediment Transport, Geomorphology, and Vegetation. Ft. Collins, CO:

Snook, V.A., E.J. Peters, and L.J. Young. 2002. Movements and habitat use by hatchery-reared pallid sturgeon in the lower Platte River, Nebraska. Pp. 161-173 in Biology, Management and Protection of North American Sturgeon, W. Van Winkle, P.J. Anders, D.H. Secor, and D.A. Dixon, eds. American Fisheries Society Symposium 28. Bethesda, MD: American Fisheries Society.

Stroup, D., M. Rodney, and D. Anderson. 2001. Flow Characterization for the Platte River Basin in Colorado, Wyoming, and Nebraska, Draft. Platte River Recovery Program EIS Office, Lakewood, CO. 21 pp plus appendices.

Systat Software Inc. 2002. Systat 10.2. Richmond, CA.

Thompson, B.C., J.A. Jackson, J. Burger, L.A. Hill, E.M. Kirsch, and J.L. Atwood. 1997. Least Tern (Sterna antillarum). The Birds of North America, No. 290, A. Poole, and F. Gill, eds. Philadelphia, PA: Academy of Natural Sciences; Washington, DC: American Ornithologists' Union.

Tout, W. 1947. Lincoln County birds. Published by author. North Platte, Nebraska. 191pp.

United States Department of the Interior. 2006. Platte River Recovery Implementation Program, Final Environmental Impact Statement.

USFWS. 1990. Recovery Pland for the interior population of the least tern (Sterna antillarum). U.S. Fish and Wildlife Service, Twin Cities, Minnesota. 90pp.

USFWS. 1993. Recovery plan for the pallid sturgeon (*Scaphirhynchus albus*). U. S. Fish and Wildlife Service, Bismark, North Dakota.

Voegel, R. M.and N.M. Fennessey. 1995. Flow duration curves II: A eview of applications in water resource planning. Water Resources Bulletin. American Water Resources Association. Vol. 31, No. 9.

Williams, G.P. 1978. The Case of the Shrinking Channels: The North Platte and Platte Rivers in Nebraska. Geological Survey Circular 781. Washington, DC: U.S. Geological Survey. 48 pp.

Wycoff, R.S. 1960. The least tern. Nebraska Bird Review 38: 39-42.

Ziewitz, J. W., J. G. Sidle, and J. J. Dinan. 1992. Habitat conservation for nesting least terns and piping plovers on the Platte River, Nebraska. Prairie Naturalist 24:1-20.

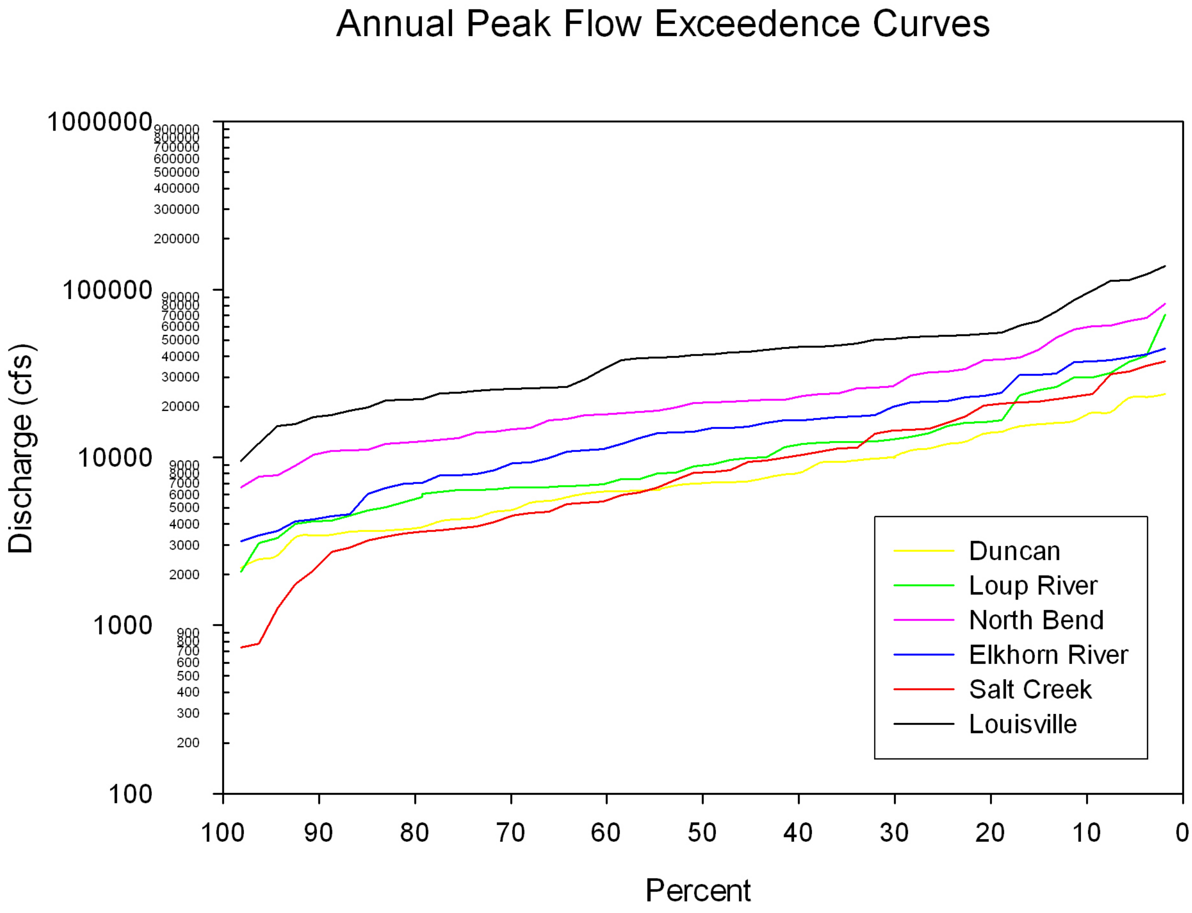
Appendix 1 – Graphs of the annual and monthly discharge characteristics for the Duncan, Loup River, Loup Power Canal, North Bend, Elkhorn River, Salt Creek, and Louisville gage sites for the period 1954 - 2005.

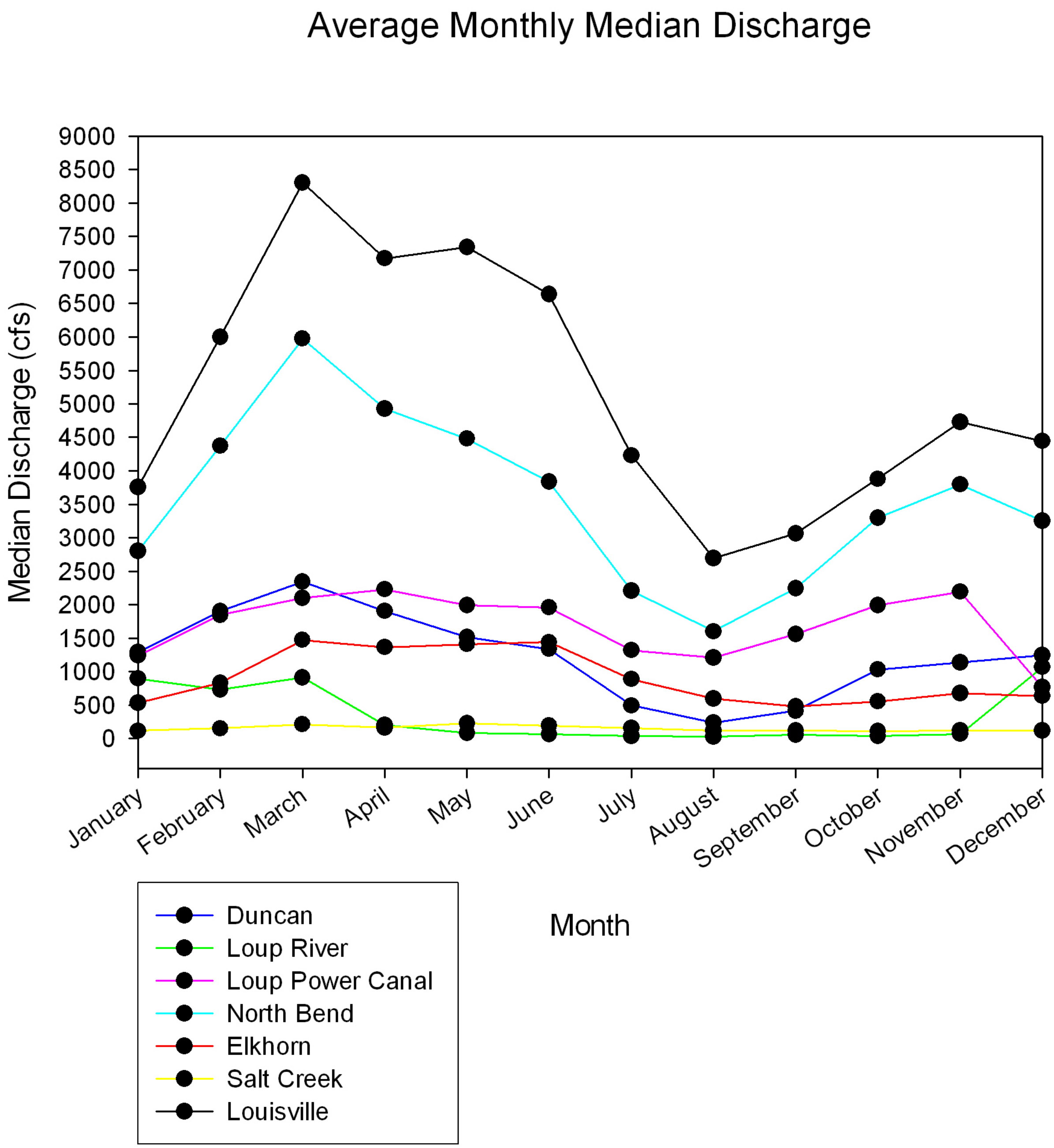
Information included for comparing sites:

- Annual Peak Flow Exceedance Curves
- Average Annual Monthly Median Discharge

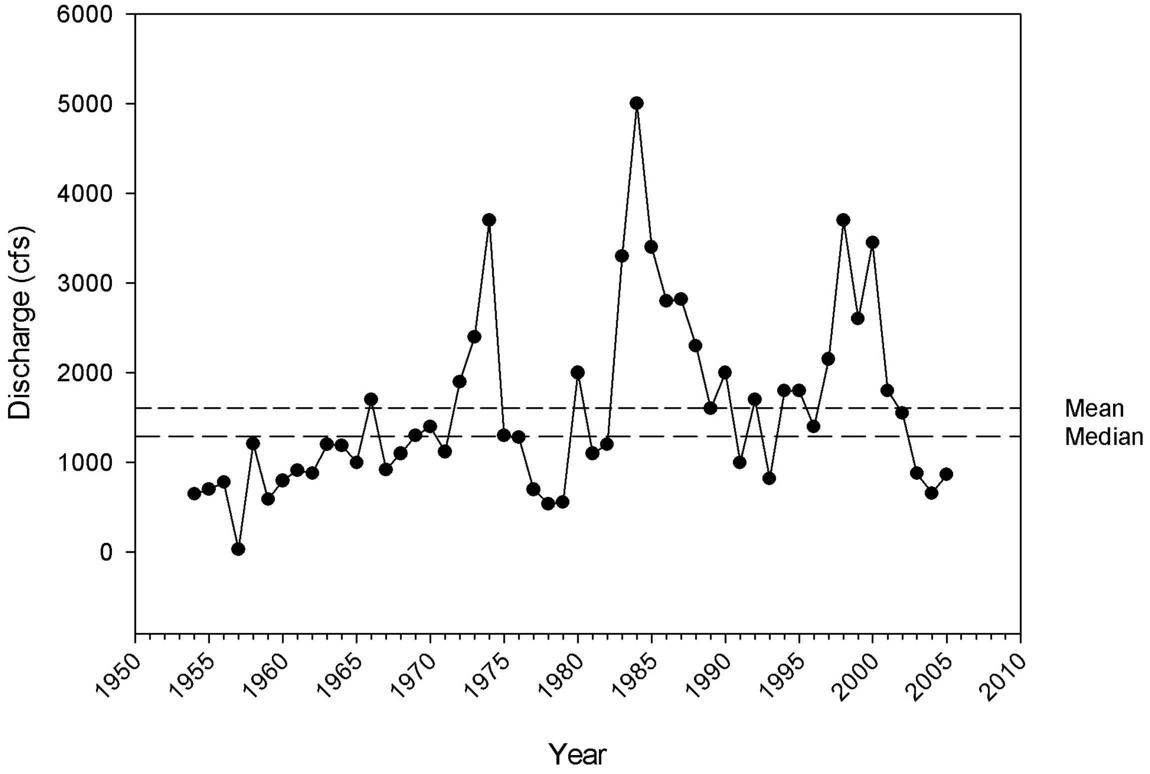
Information included for each gage site:

- Monthly Median Discharge
- 1, 7, 30, and 90-day Annual Minimum Discharge
- 1, 7, 30, and 90-day Annual Maximum Discharge
- Annual Number of Zero Flow Days
- Annual Date, Number, and Duration of Low Flows
- Annual Date, Number, and Duration of High Flows

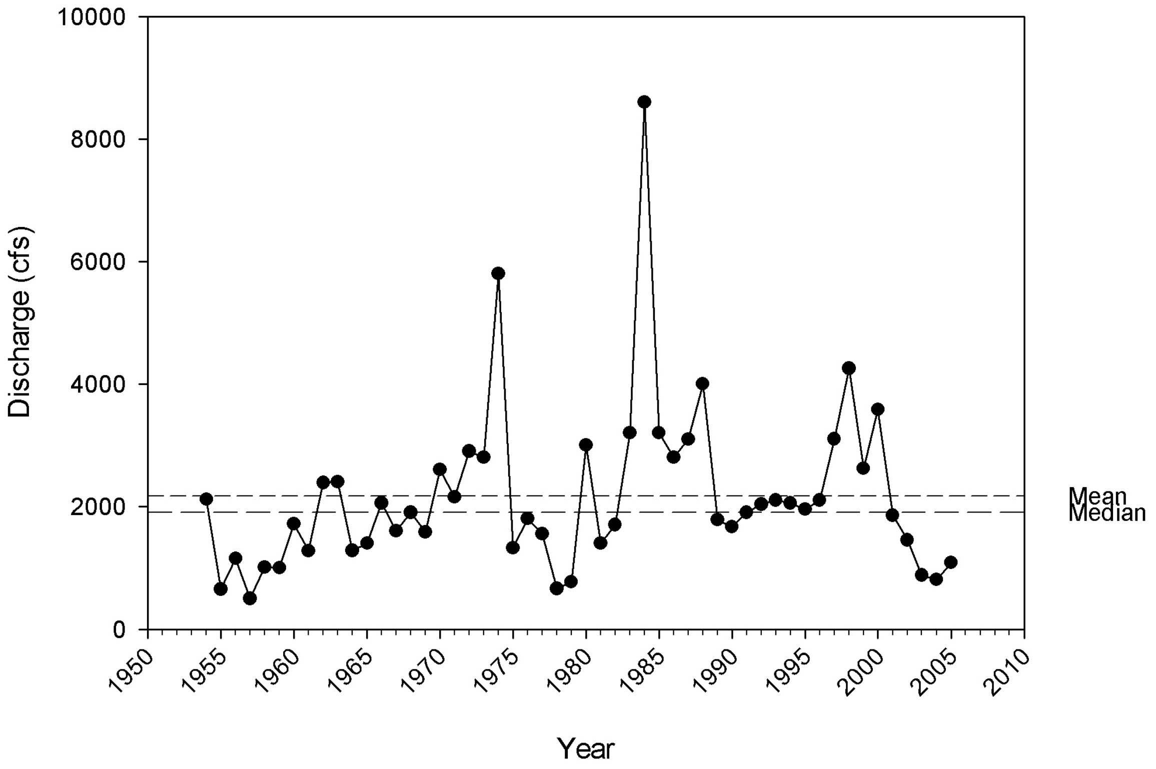

Annual Peak Flow Exceedence Curves
Discharge (cfs)
1000000
900000
800000
700000
600000
500000
400000
300000
200000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
100
90
80
70
60
50
40
30
20
10
0
Percent
Duncan
Loup River
North Bend
Elkhorn River
Salt Creek
Louisville

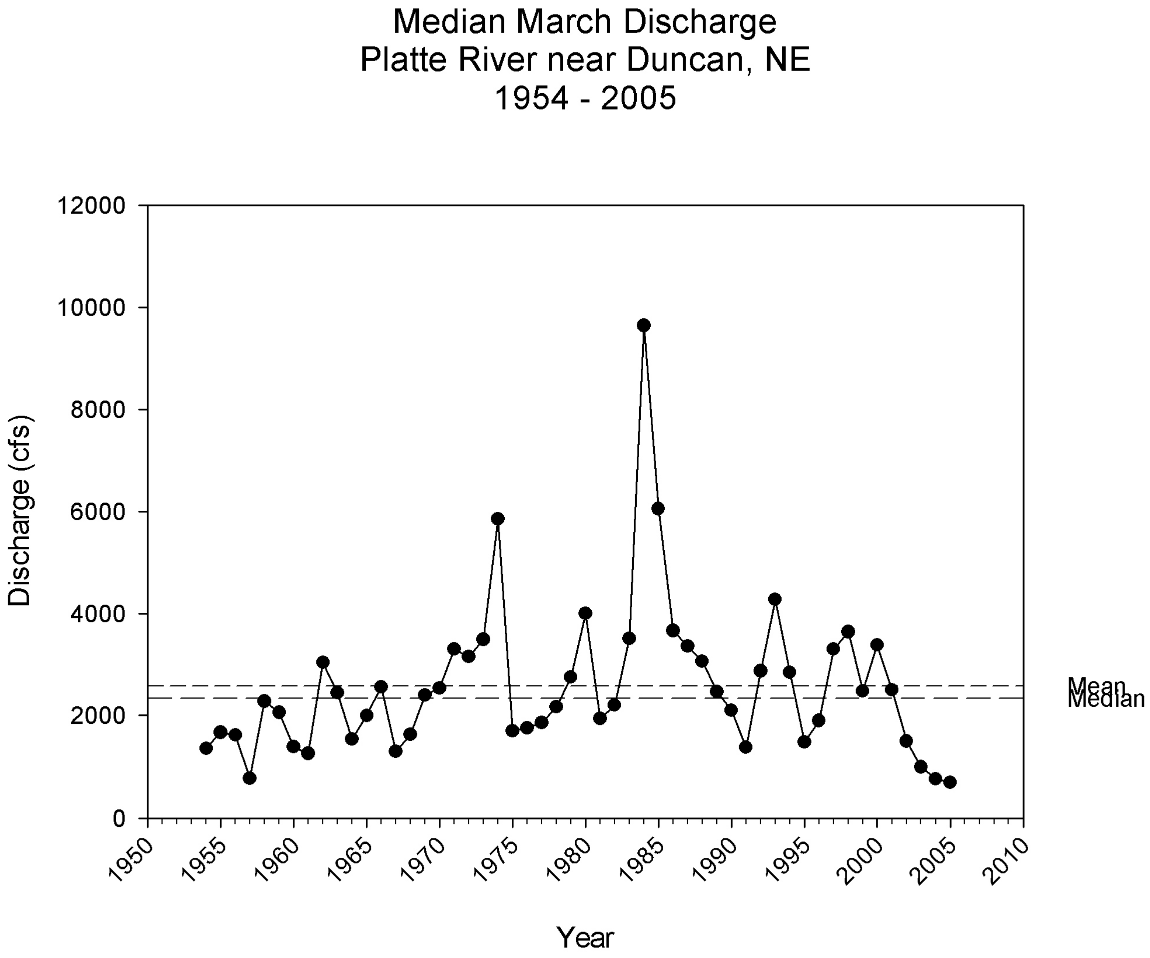

Average Monthly Median Discharge
Median Discharge (cfs)
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
January
February
March
April
May
June
July
August
September
October
November
December
Month
Duncan
Loup River
Loup Power Canal
North Bend
Elkhorn
Salt Creek
Louisville

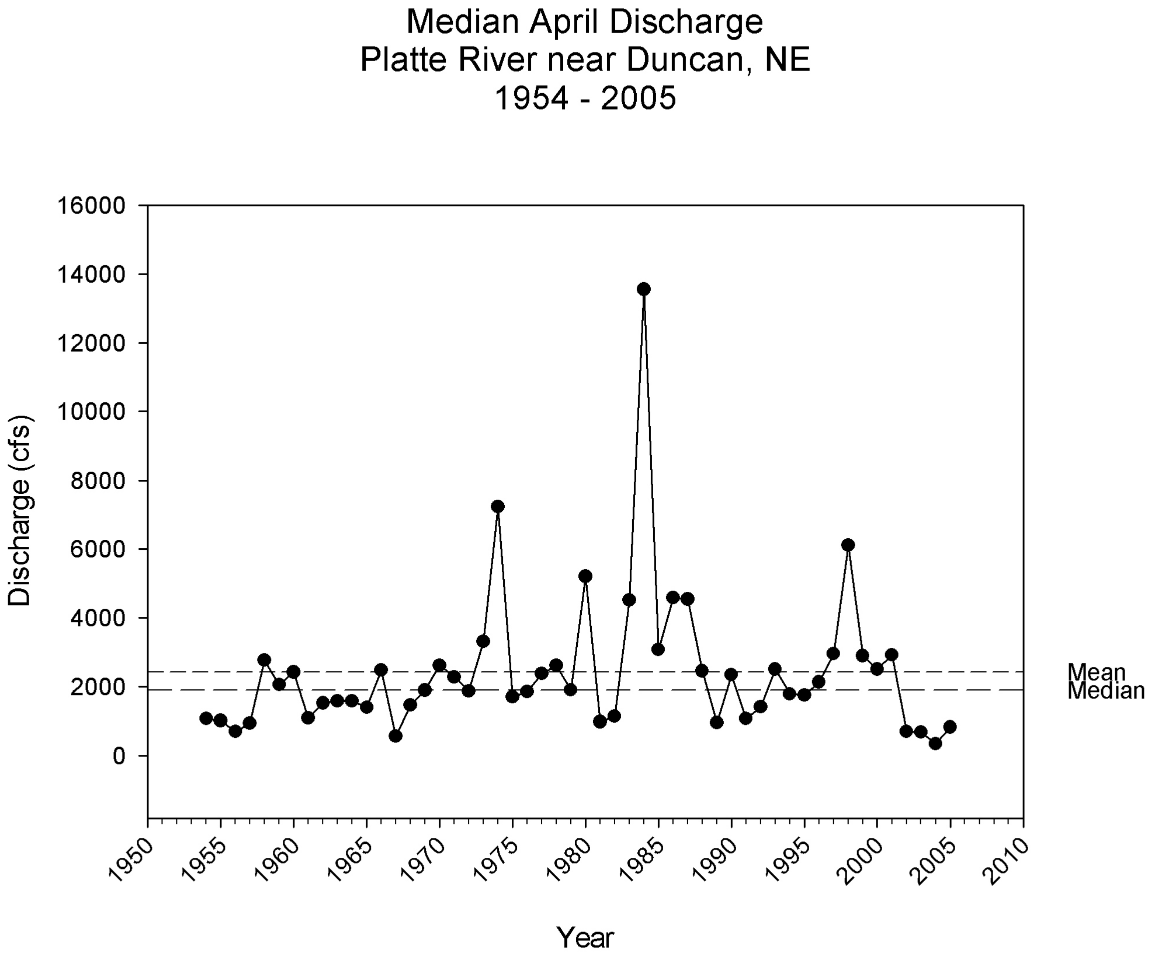
Median January Discharge
Platte River near Duncan, NE
1954 - 2005



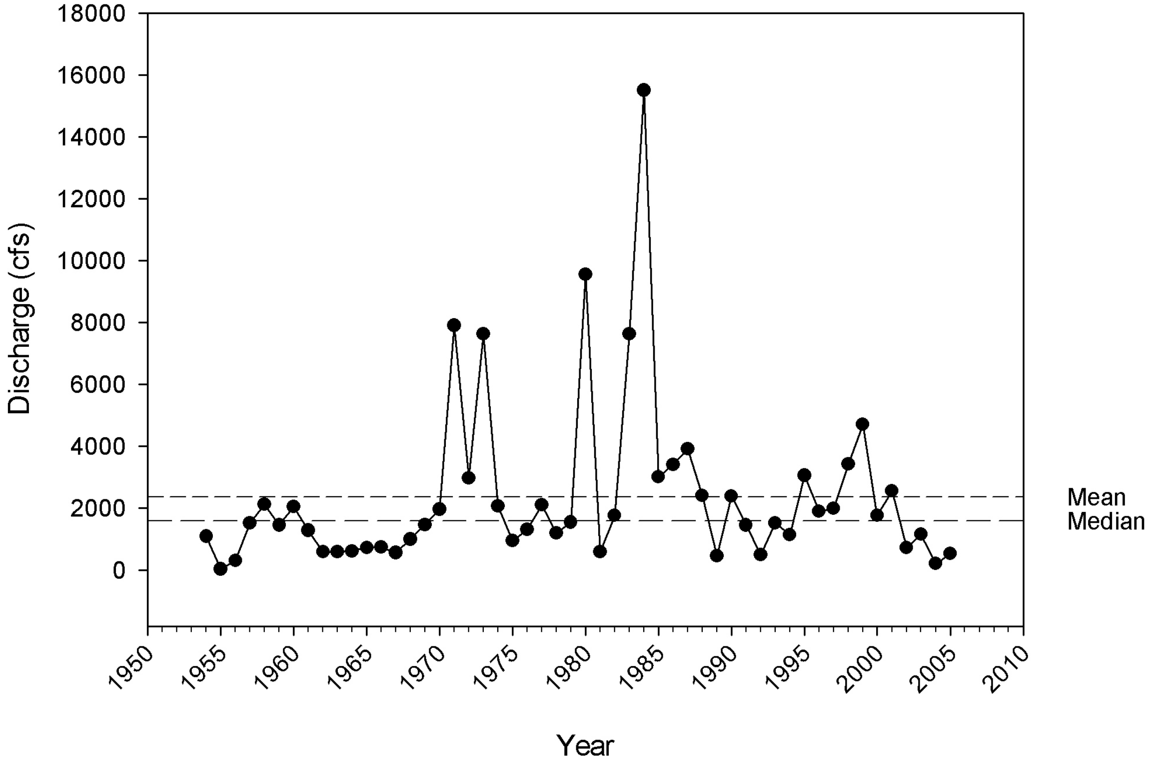
Median Feburary Discharge
Platte River near Duncan, NE
1954 - 2005



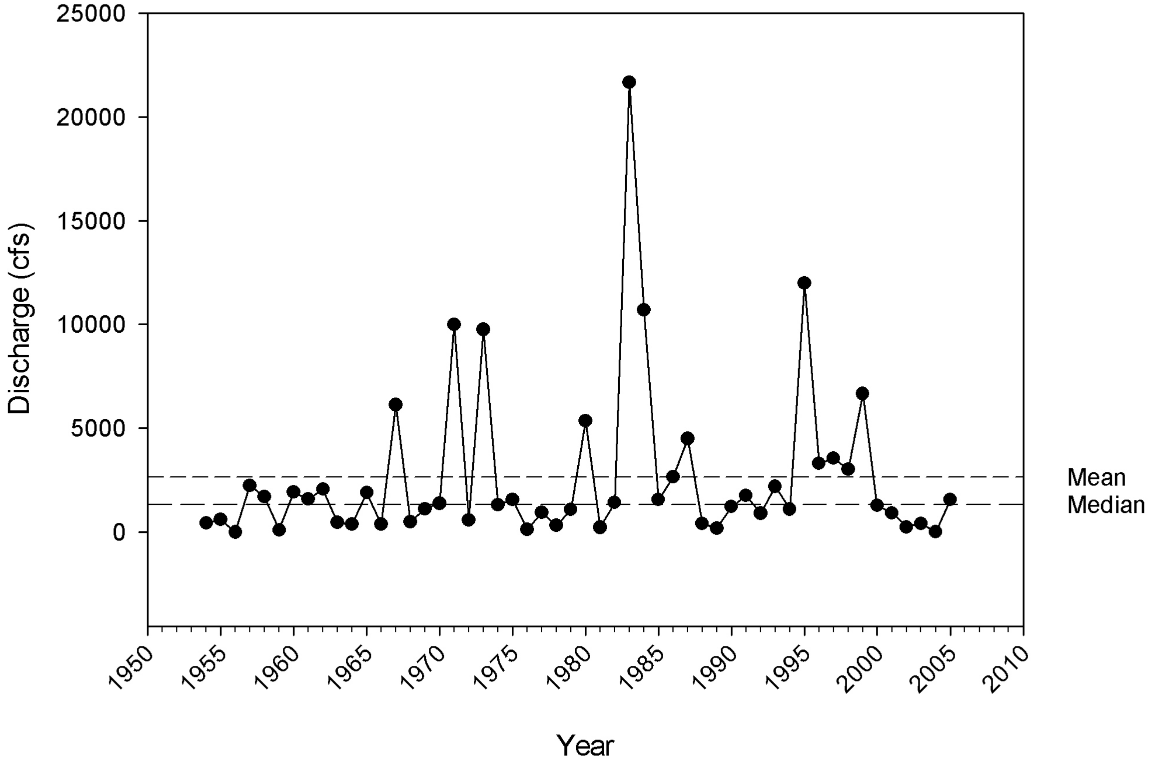

Median March Discharge
Platte River near Duncan, NE
1954 - 2005
Discharge (cfs)
12000
10000
8000
6000
4000
2000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Mean
Median

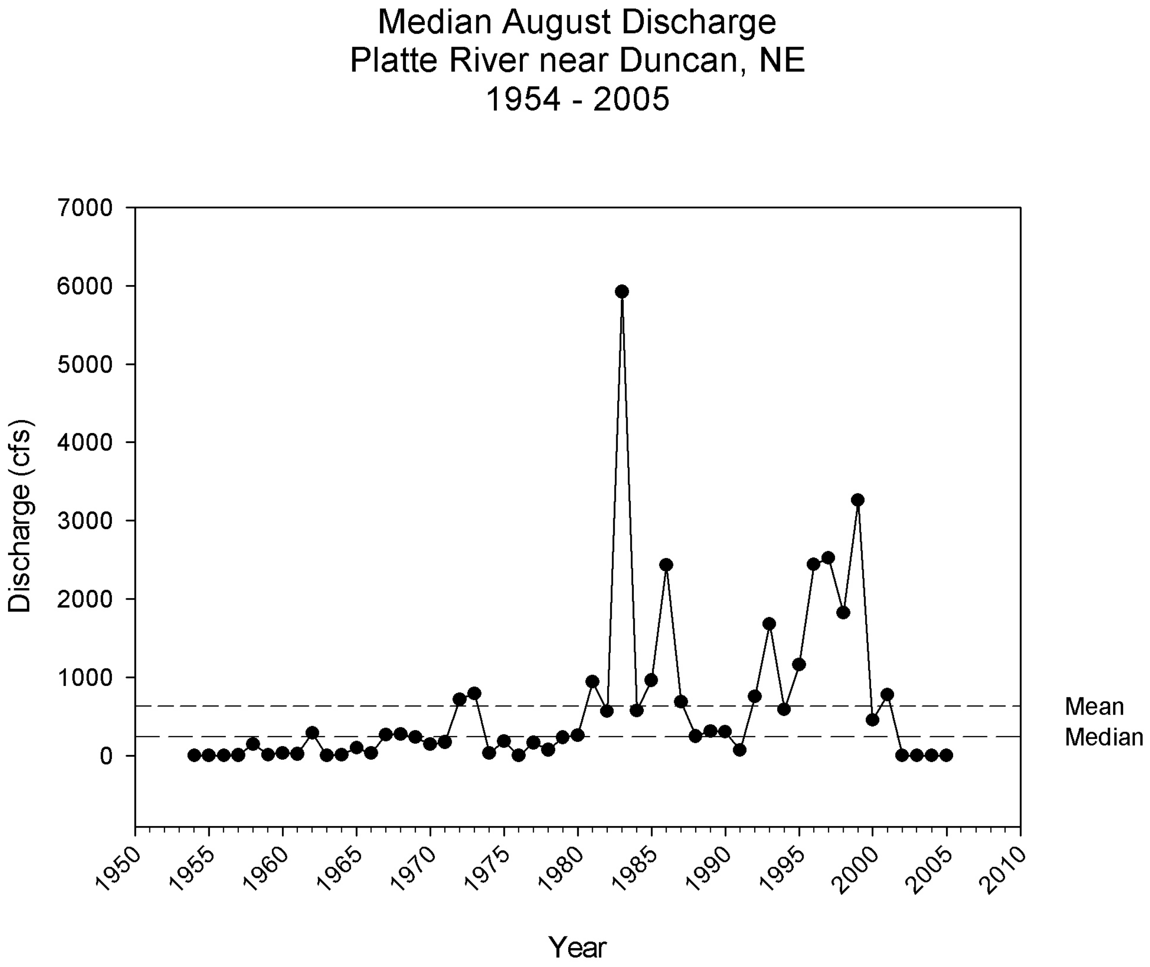

Median April Discharge
Platte River near Duncan, NE
1954 - 2005
Discharge (cfs)
16000
14000
12000
10000
8000
6000
4000
2000
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

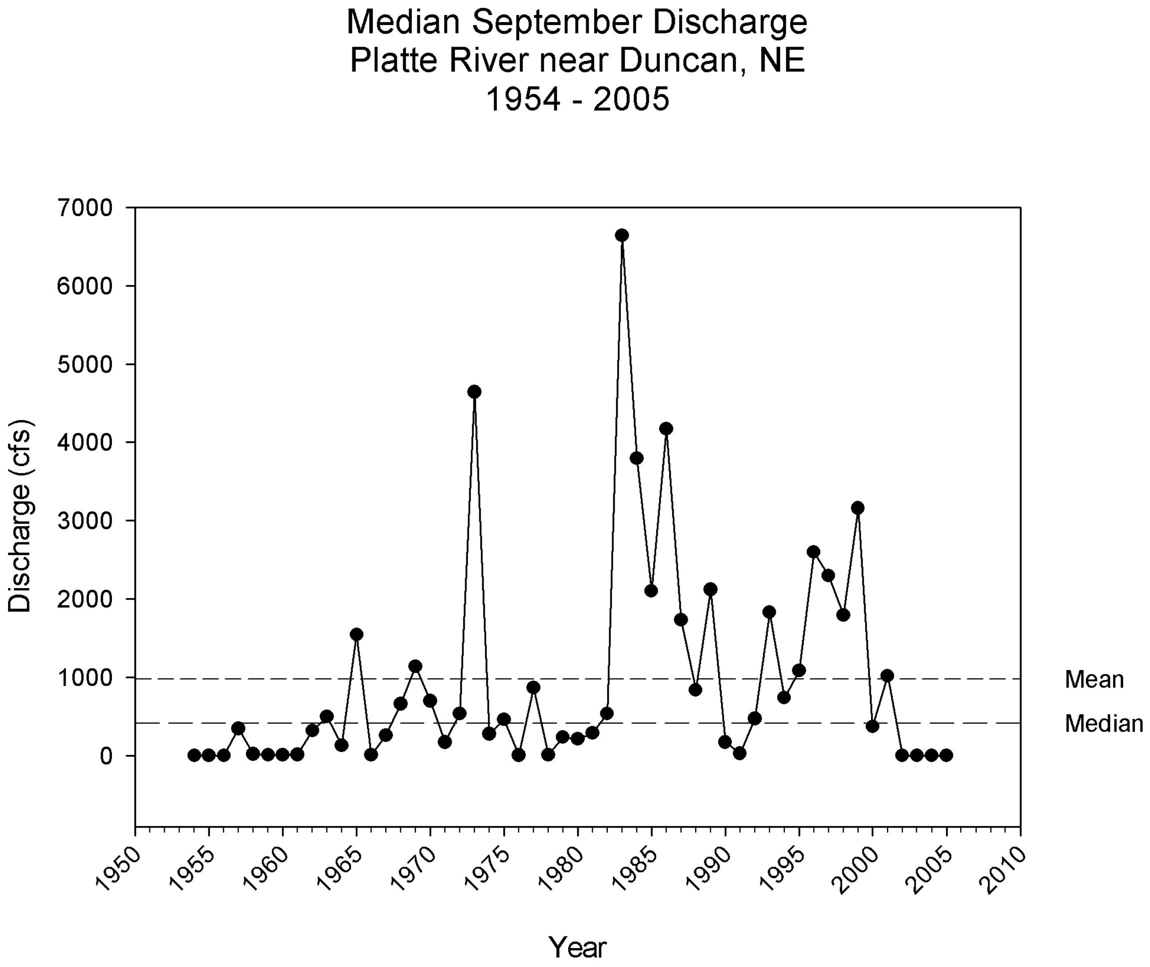
Median May Discharge
Platte River near Duncan, NE
1954 - 2005



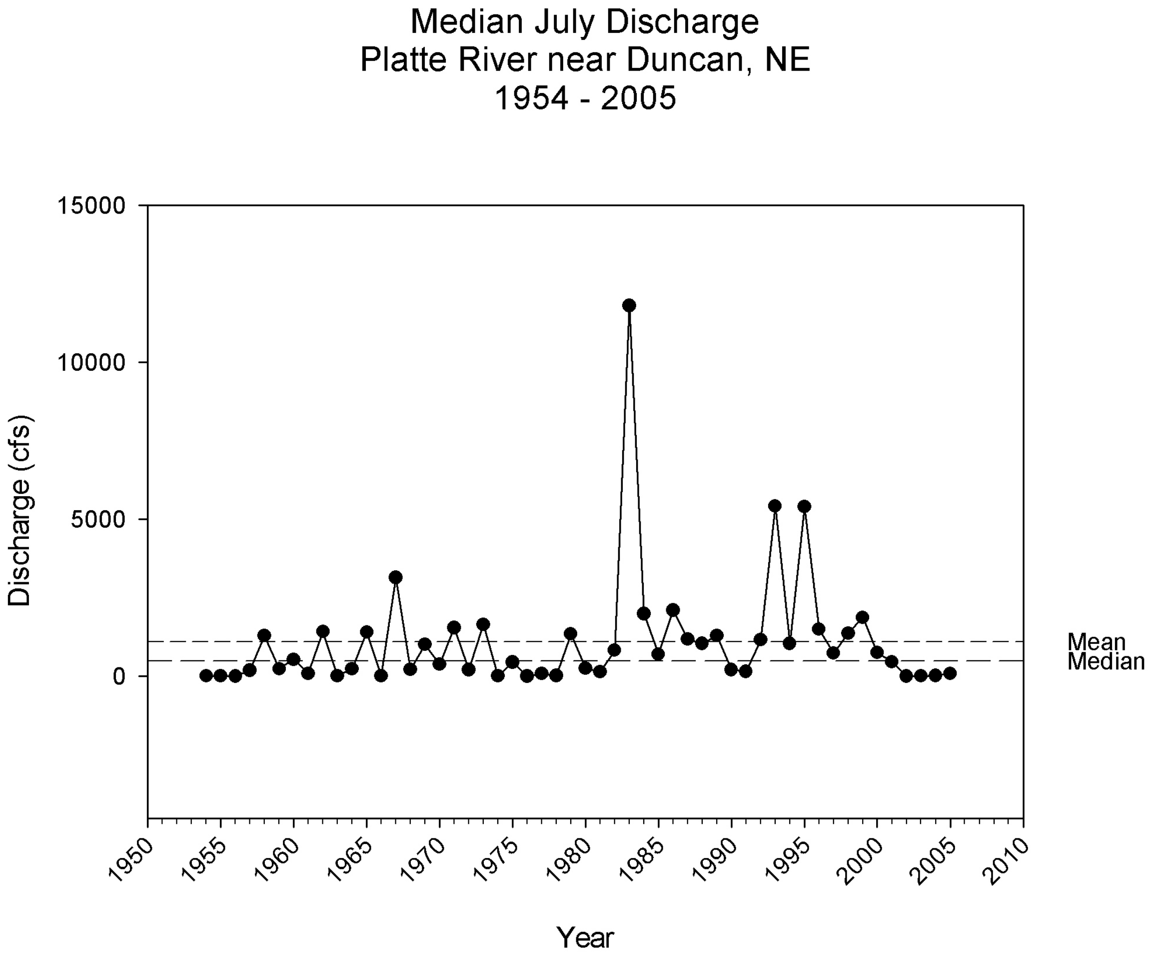
Median June Discharge
Platte River near Duncan, NE
1954 - 2005

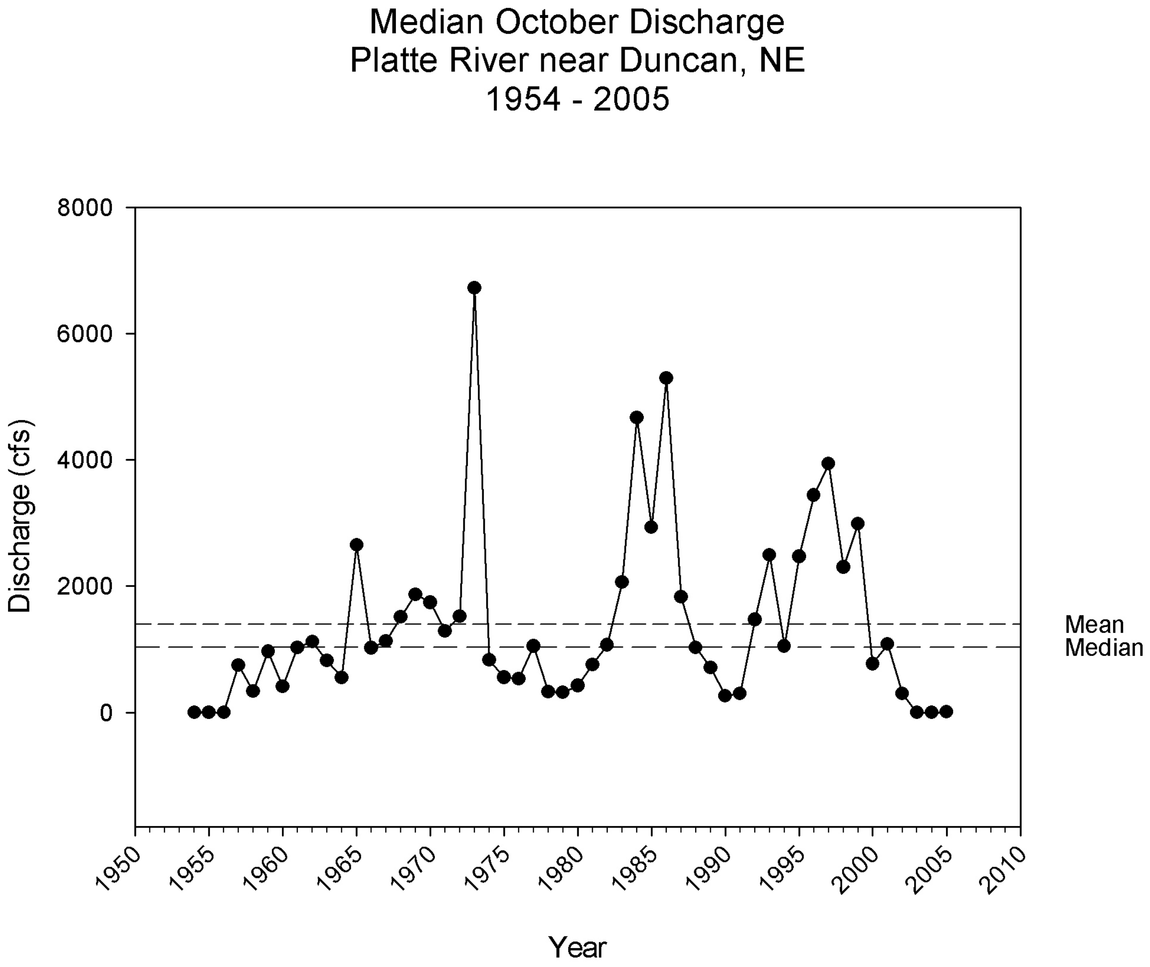



Median August Discharge
Platte River near Duncan, NE
1954 - 2005
Discharge (cfs)
7000
6000
5000
4000
3000
2000
1000
0
Year
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Mean
Median

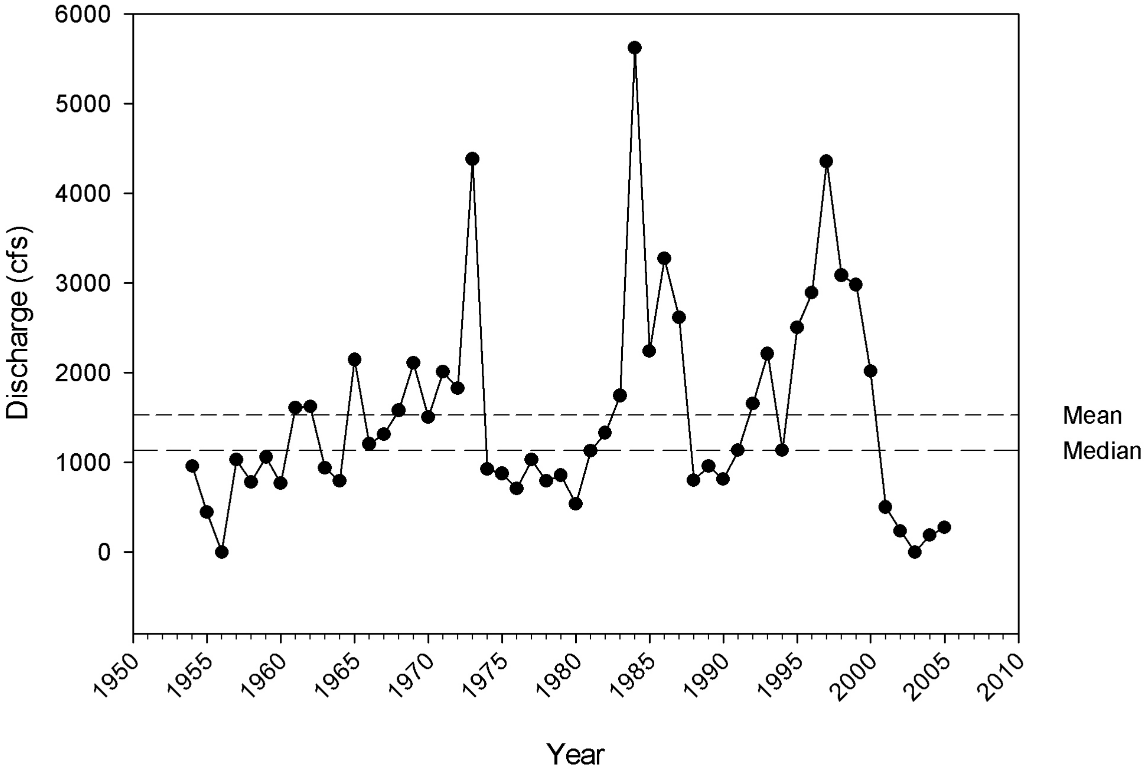


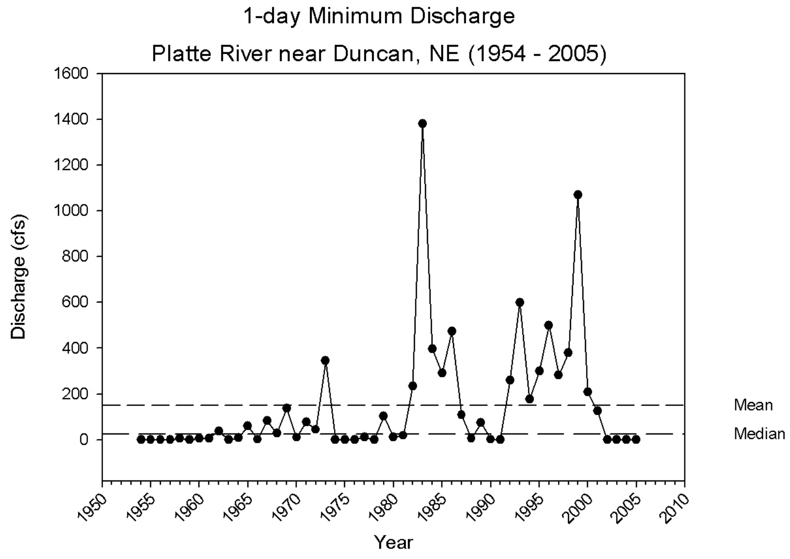
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.


Median July Discharge
Platte River near Duncan, NE
1954 - 2005
Discharge (cfs)
15000
10000
5000
0
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year
Mean
Median


Median October Discharge
Platte River near Duncan, NE
1954 - 2005
Discharge (cfs)
8000
6000
4000
2000
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

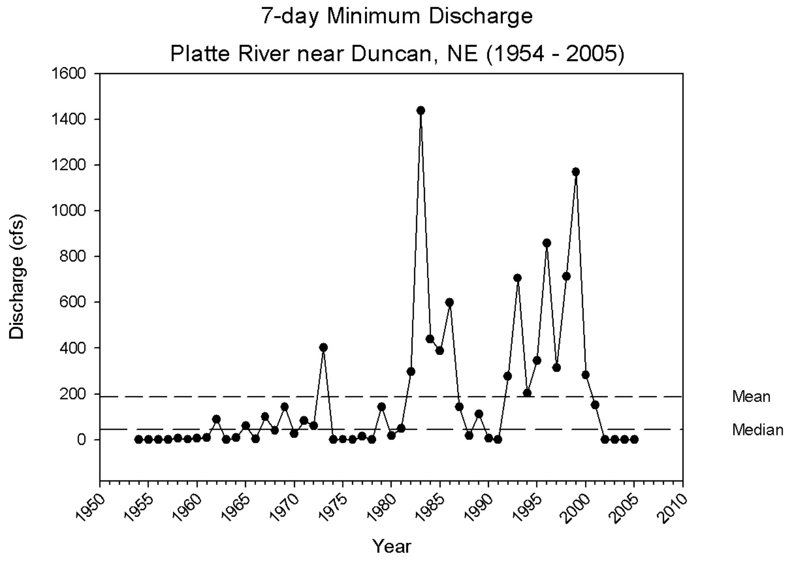
Median November Discharge
Platte River near Duncan, NE
1954 - 2005





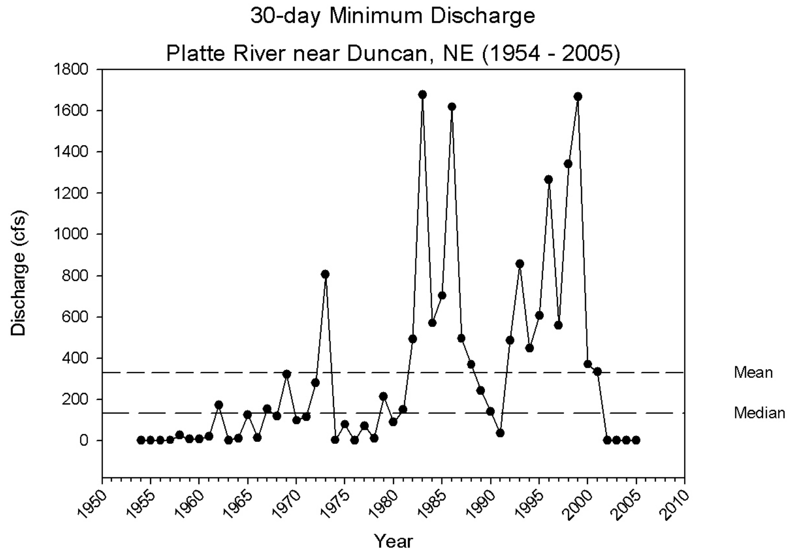
1-day Minimum Discharge

Platte River near Duncan, NE (1954 - 2005)



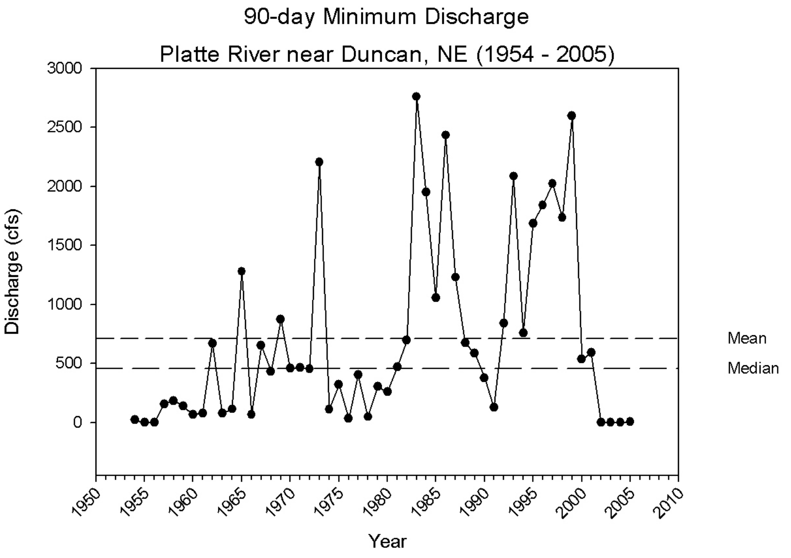
7-day Minimum Discharge

Platte River near Duncan, NE (1954 - 2005)



30-day Minimum Discharge

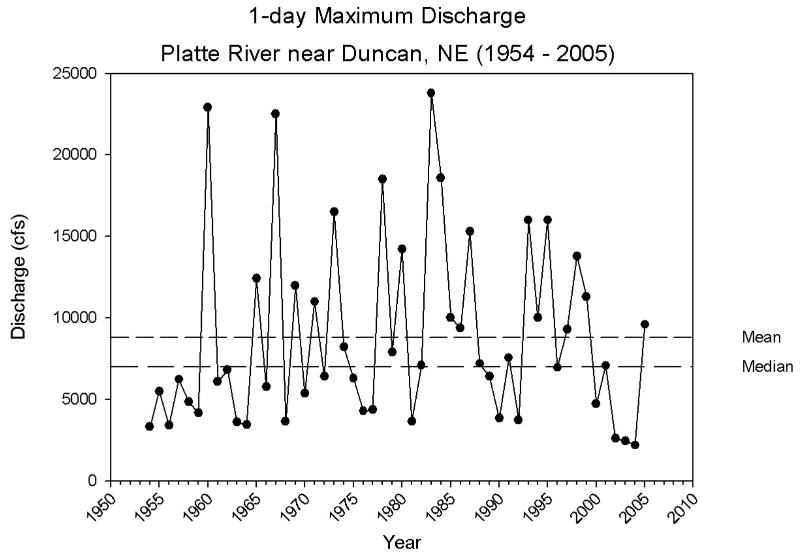
Platte River near Duncan, NE (1954 - 2005)



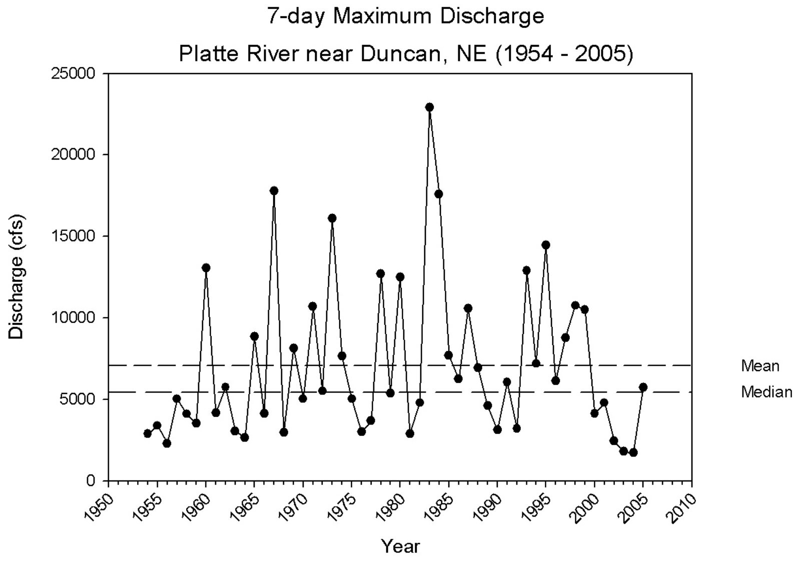
90-day Minimum Discharge

Platte River near Duncan, NE (1954 - 2005)

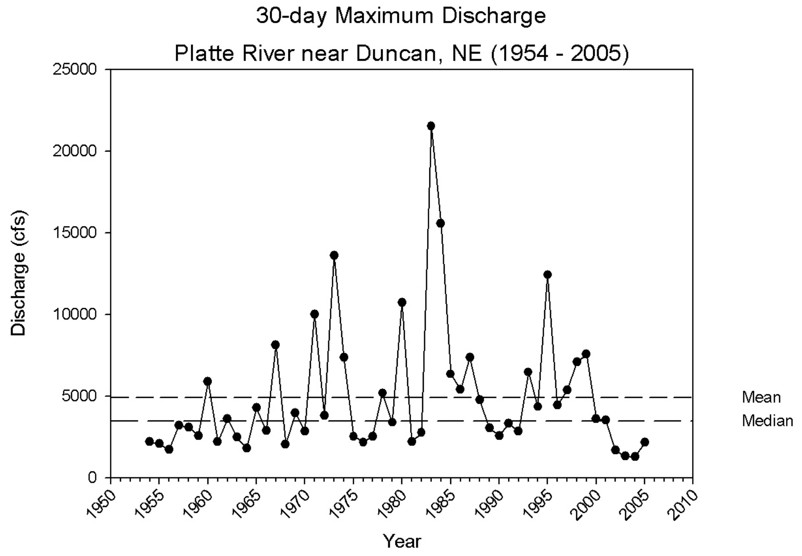
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.


1-day Maximum Discharge

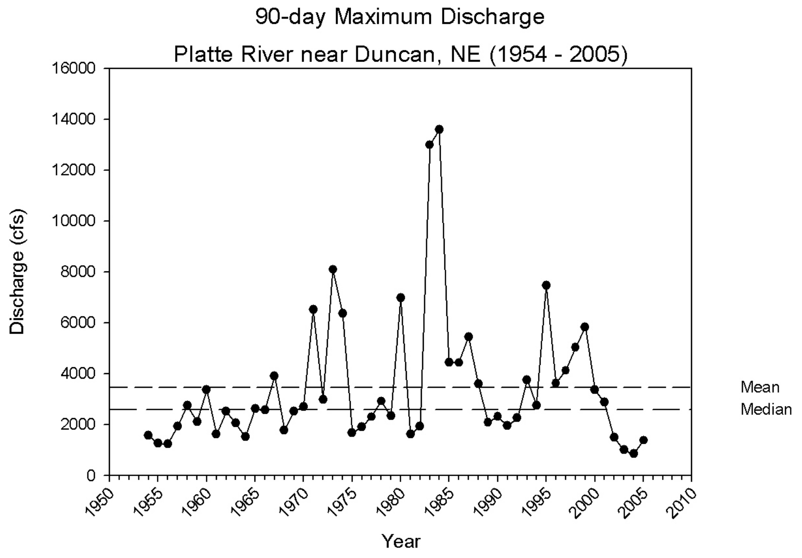
Platte River near Duncan, NE (1954 - 2005)


7-day Maximum Discharge

Platte River near Duncan, NE (1954 - 2005)


30-day Maximum Discharge

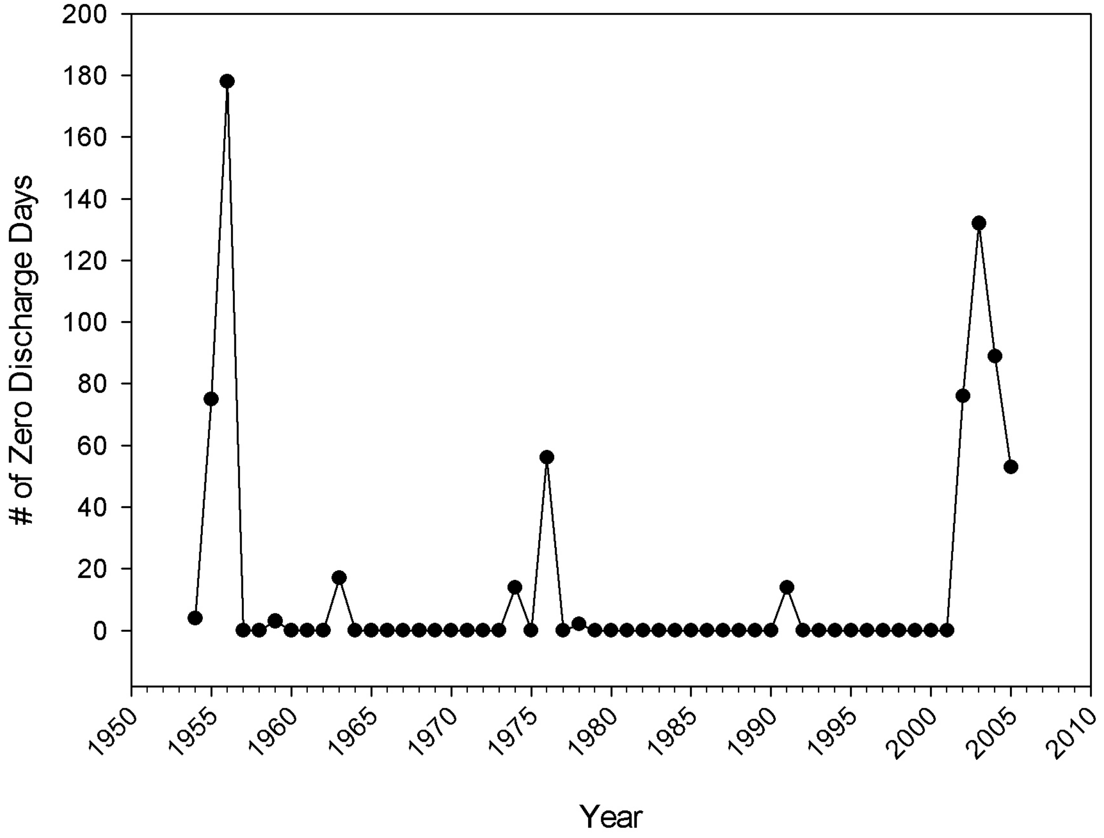
Platte River near Duncan, NE (1954 - 2005)

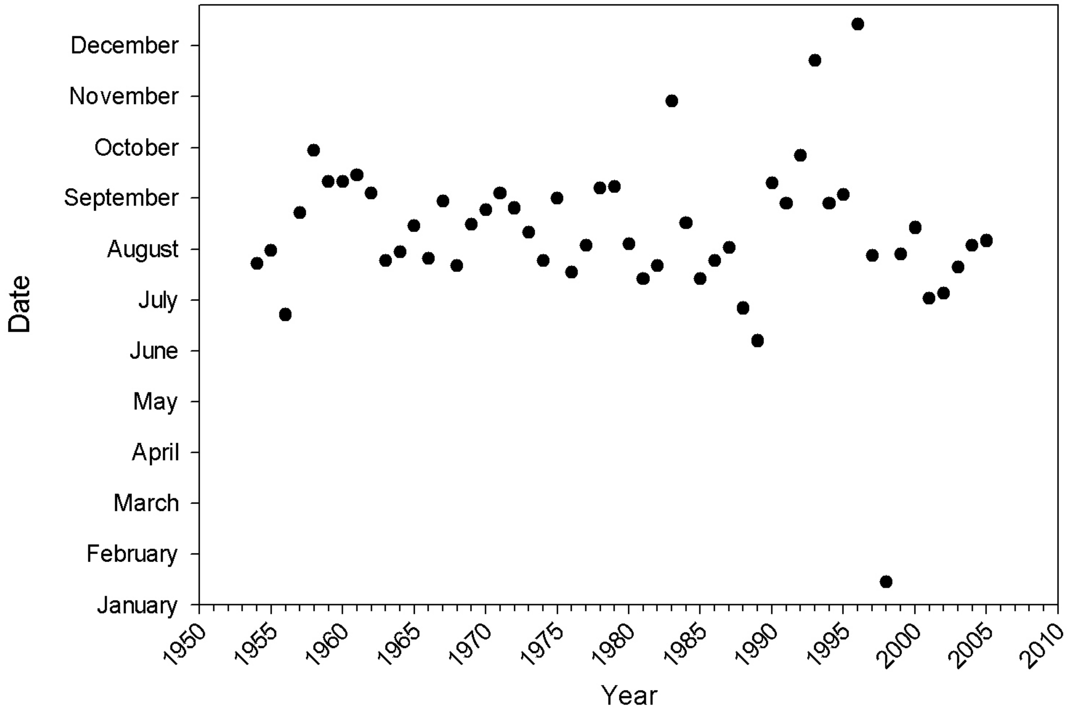

90-day Maximum Discharge

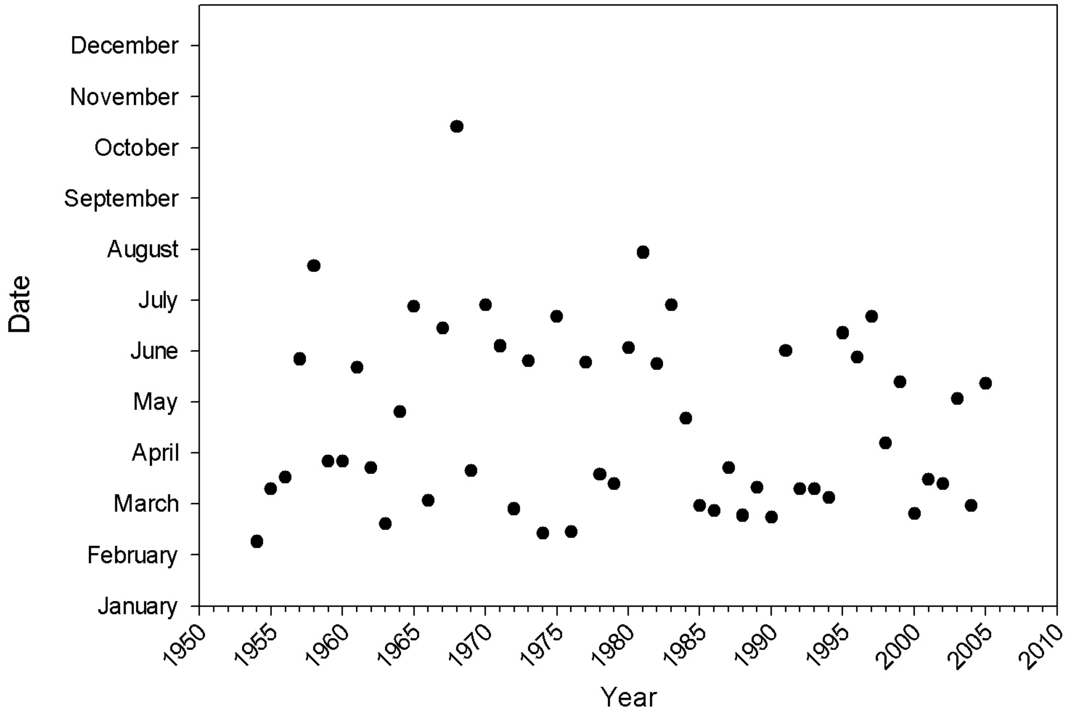
Platte River near Duncan, NE (1954 - 2005)

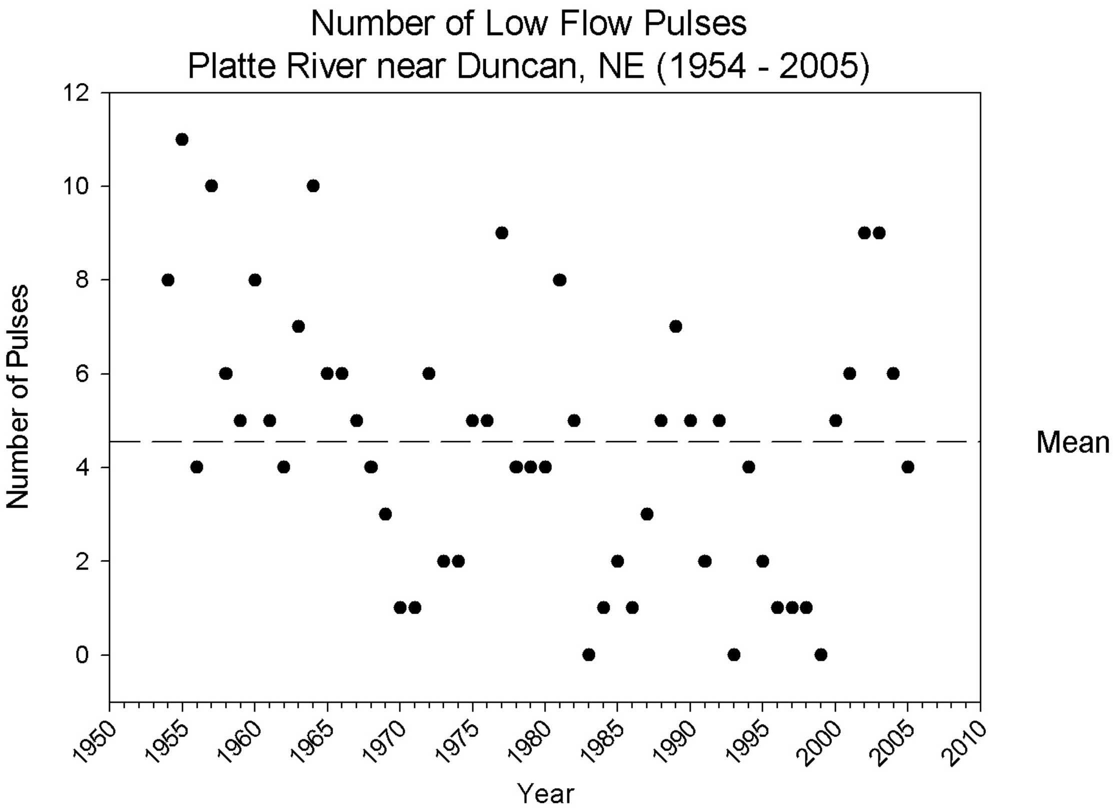
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

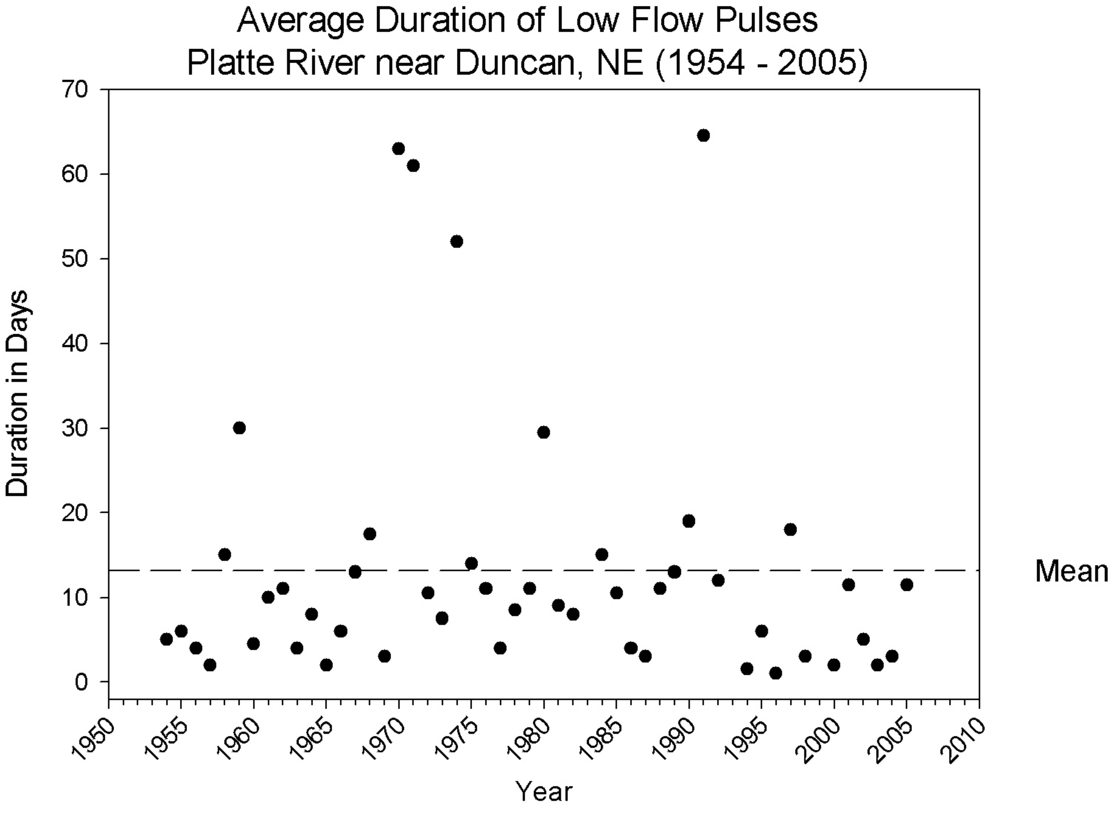
Zero Discharge Days
Platte River near Duncan, NE
1954 - 2005



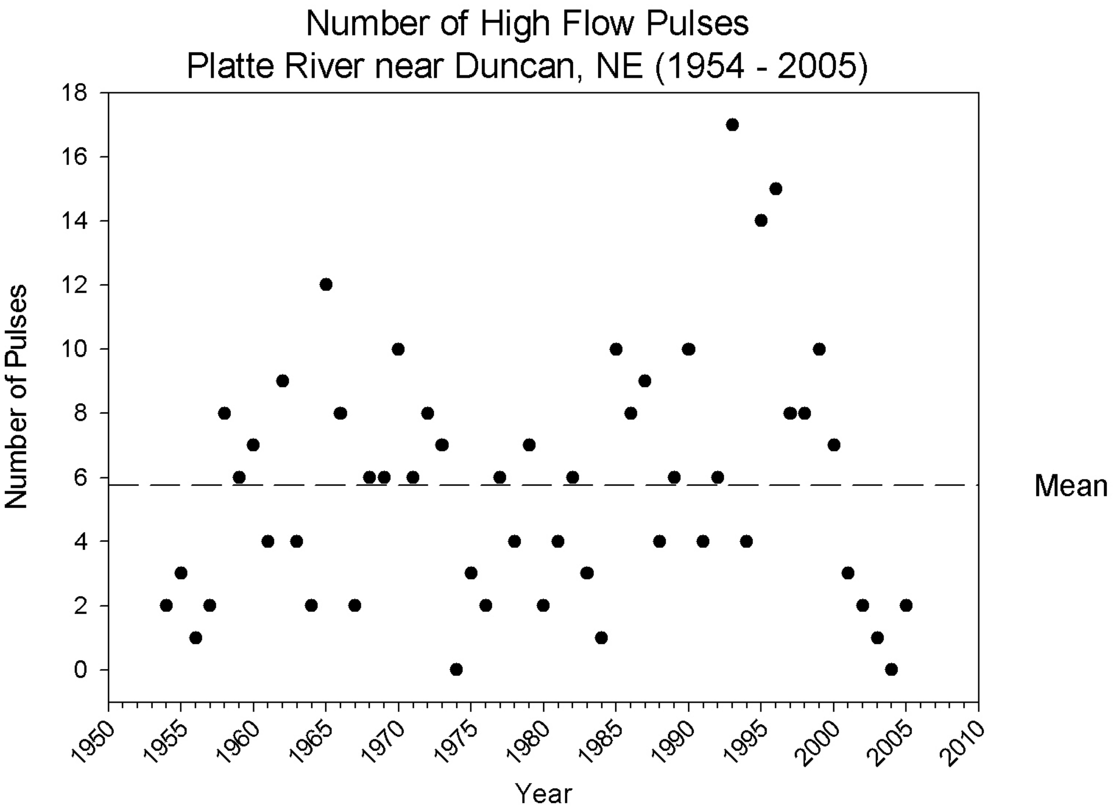

Date of Low Flow
Platte River near Duncan, NE (1954 - 2005)

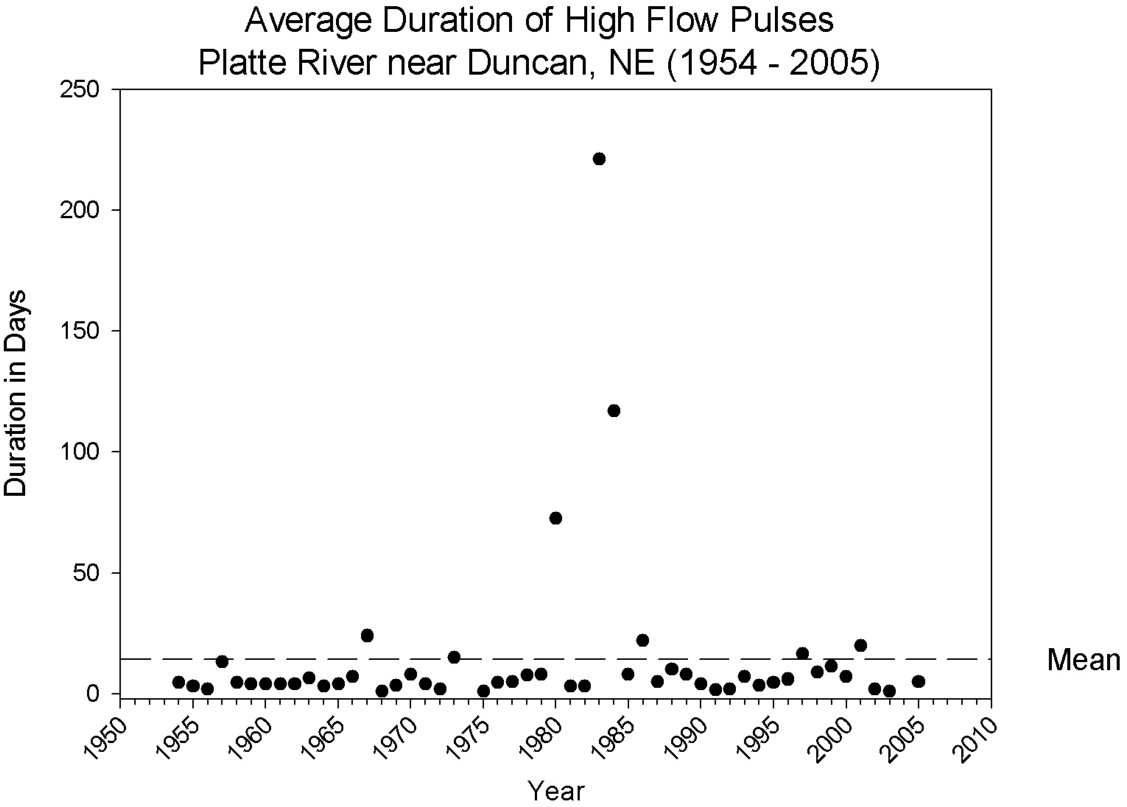

Date of Maximum Flow
Platte River near Duncan, NE (1954 - 2005)

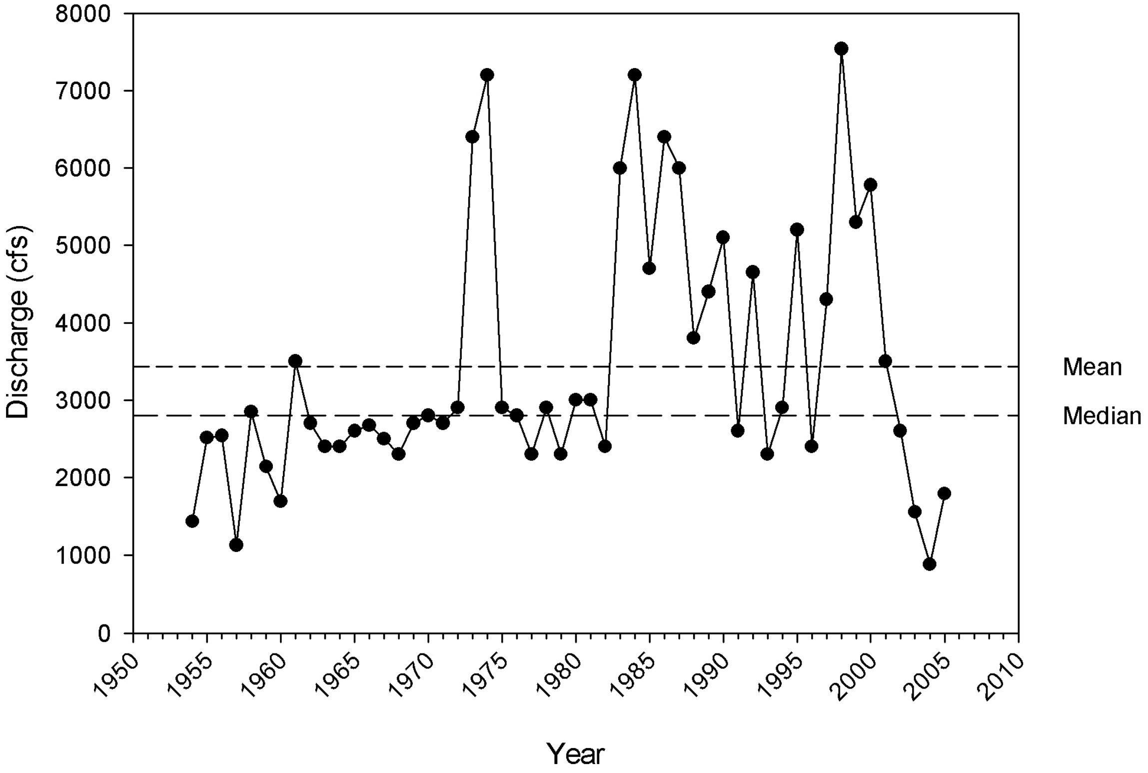




J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.


Number of High Flow Pulses
Platte River near Duncan, NE (1954 - 2005)
Number of Pulses
0
2
4
6
8
10
12
14
16
18
Year
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Mean

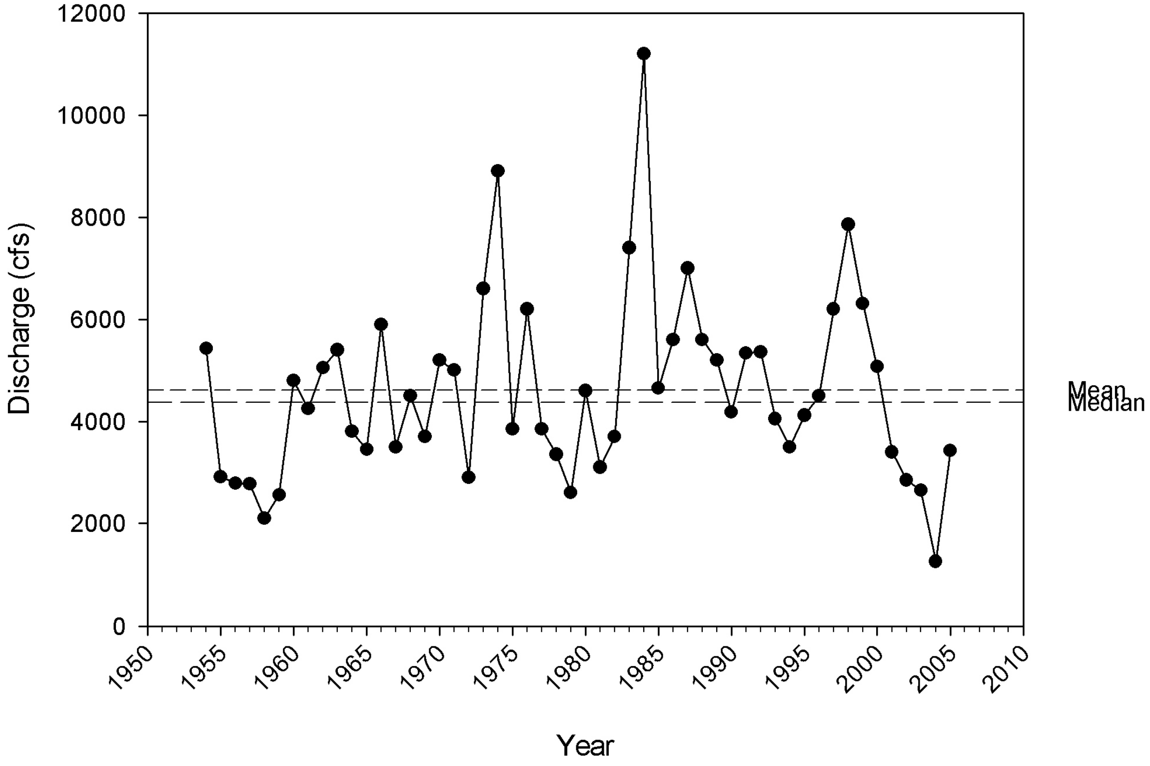

Average Duration of High Flow Pulses
Platte River near Duncan, NE (1954 - 2005)
Duration in Days
0
50
100
150
200
250
Year
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Mean

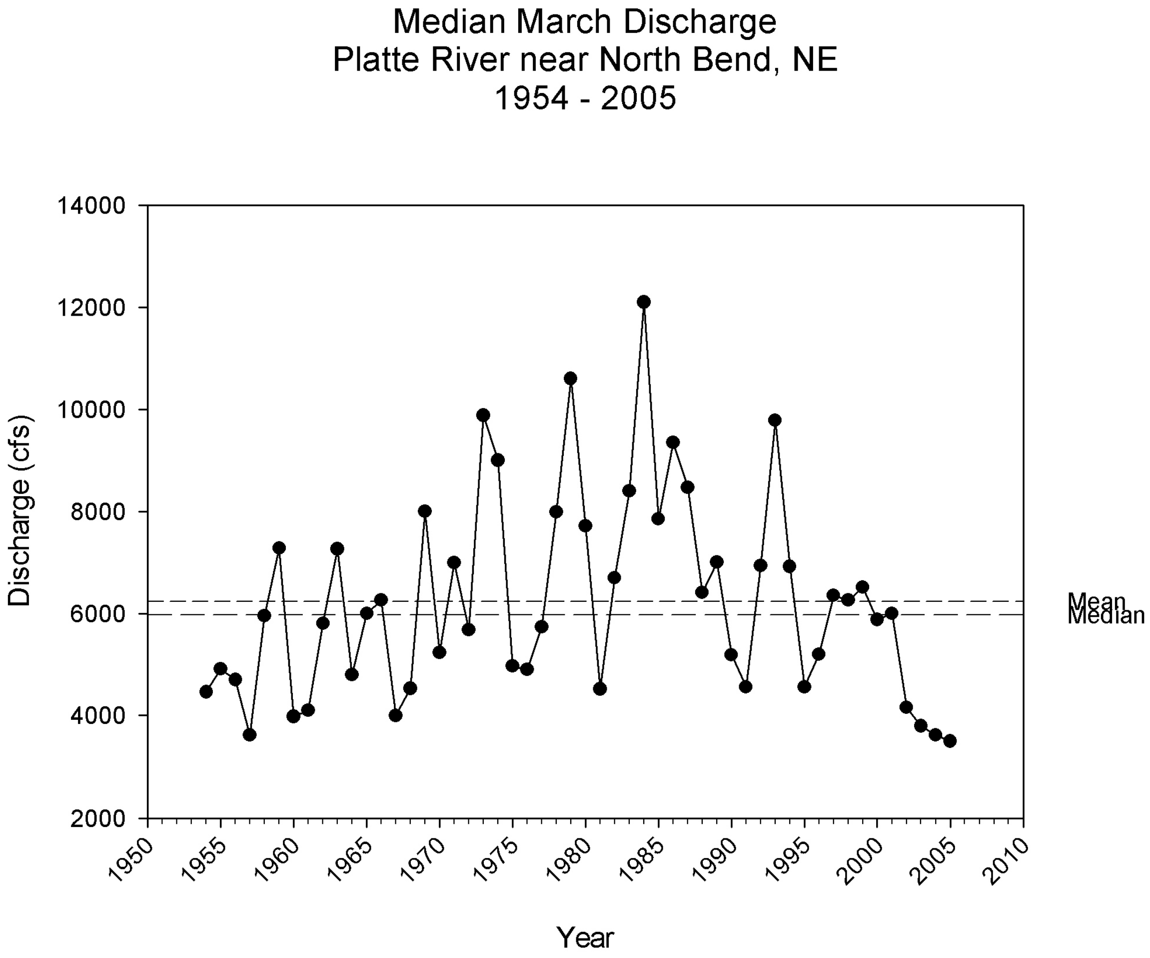


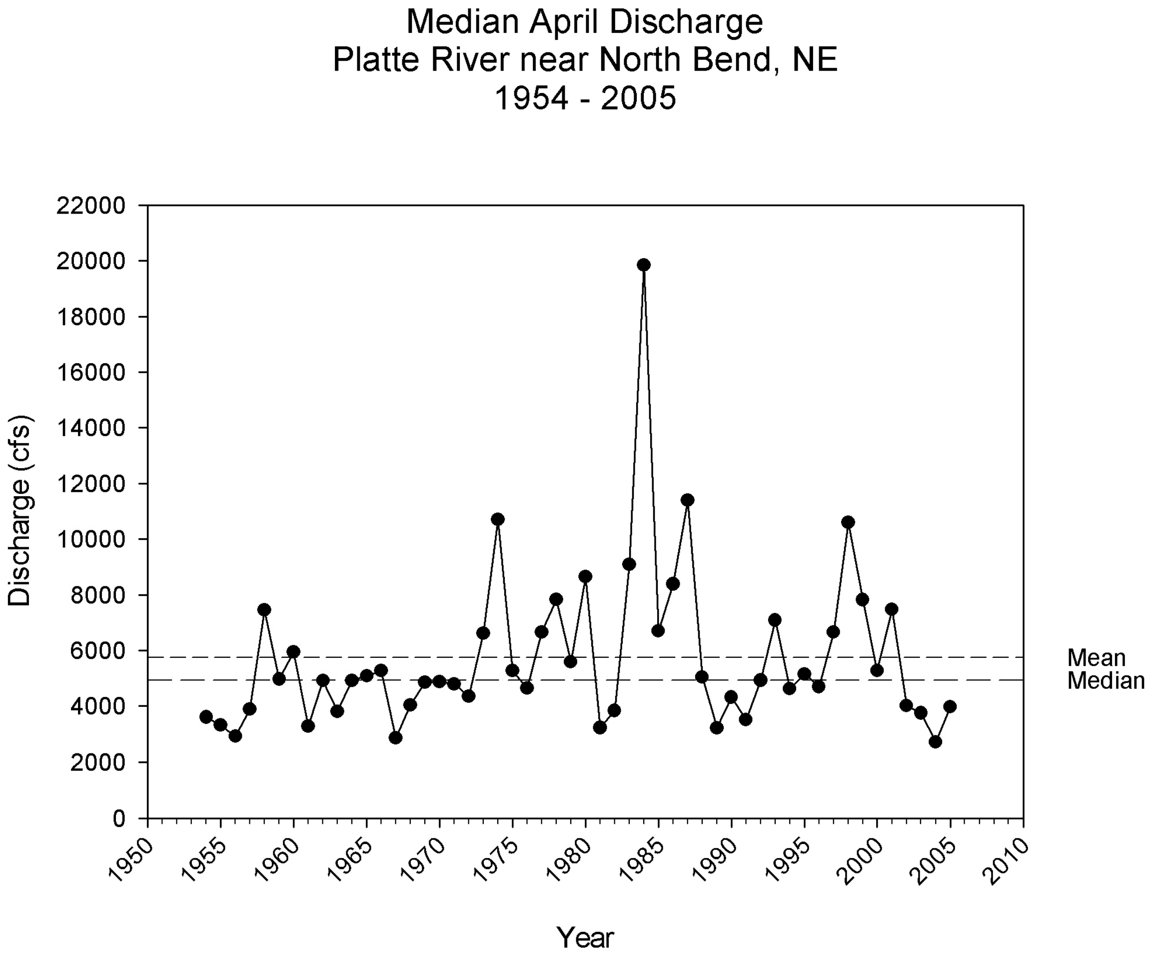
Median January Discharge
Platte River near North Bend, NE
1954 - 2005

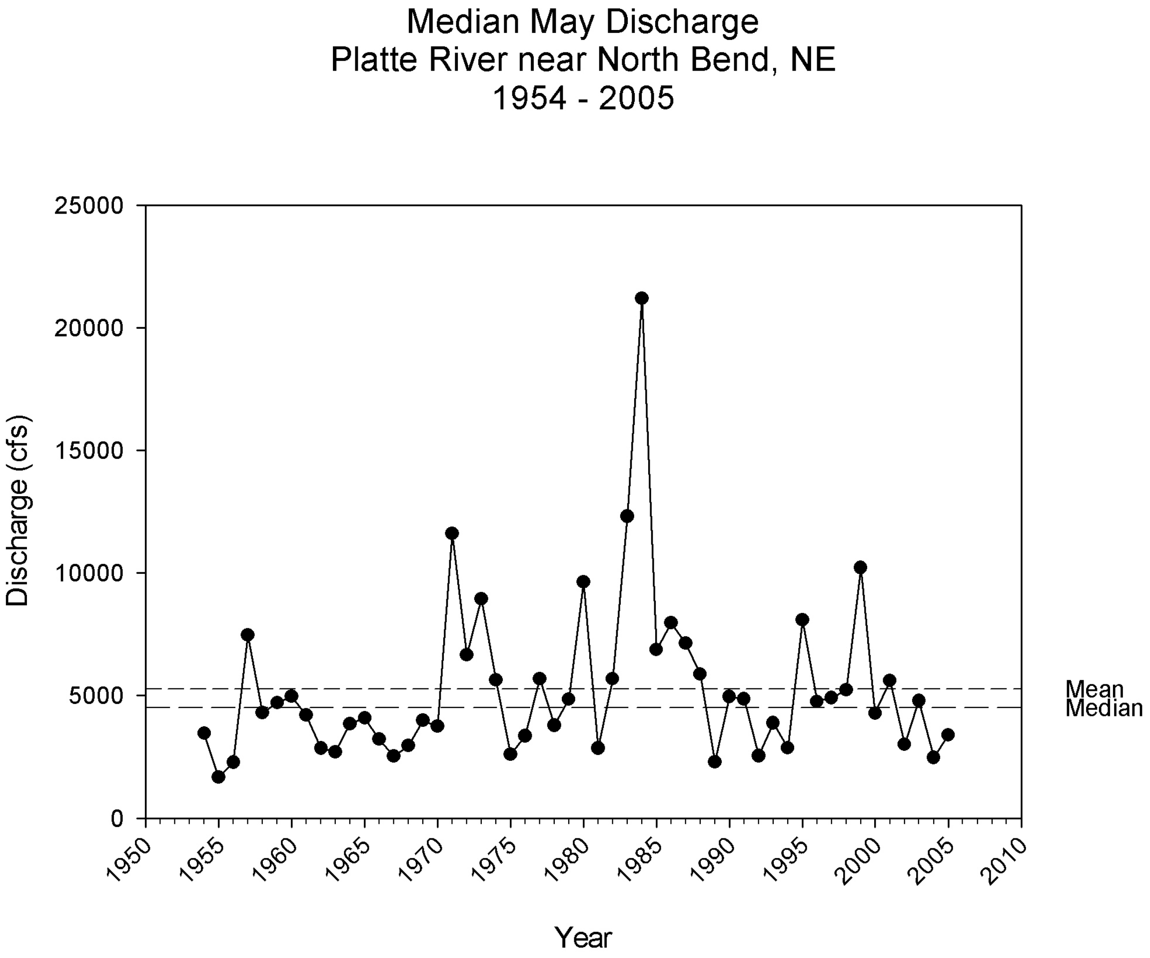
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

Median Feburary Discharge
Platte River near North Bend, NE
1954 - 2005

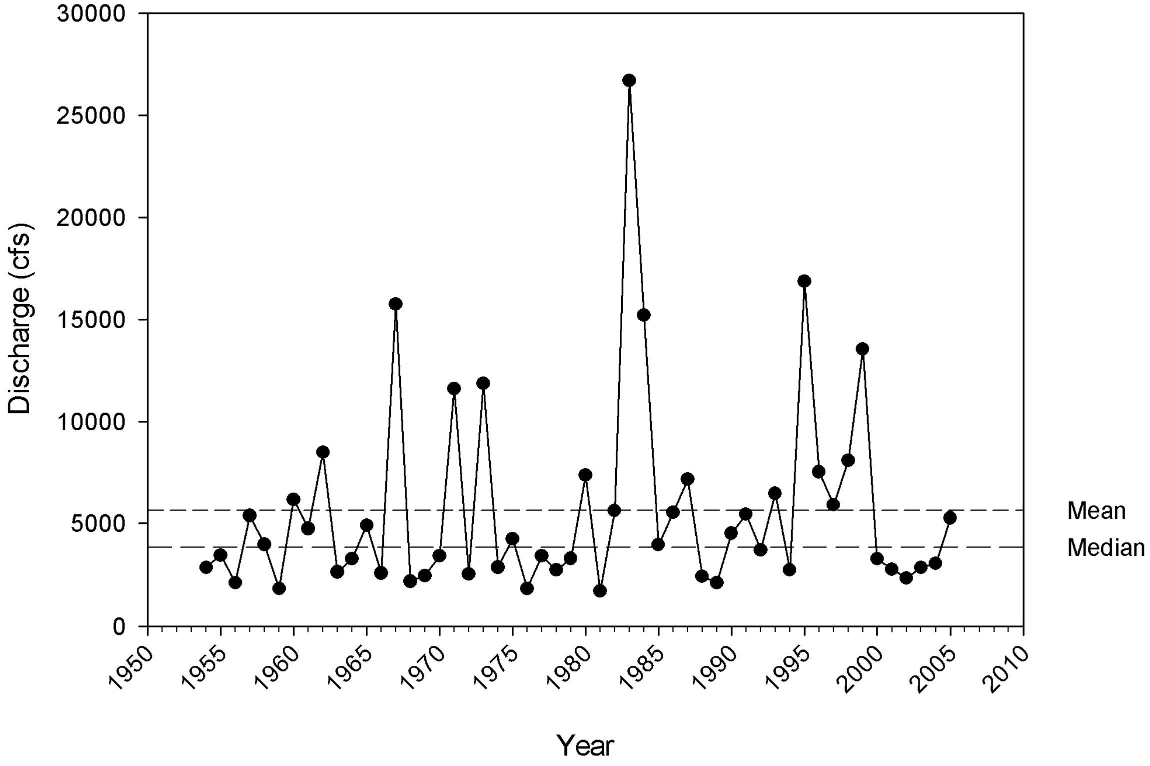


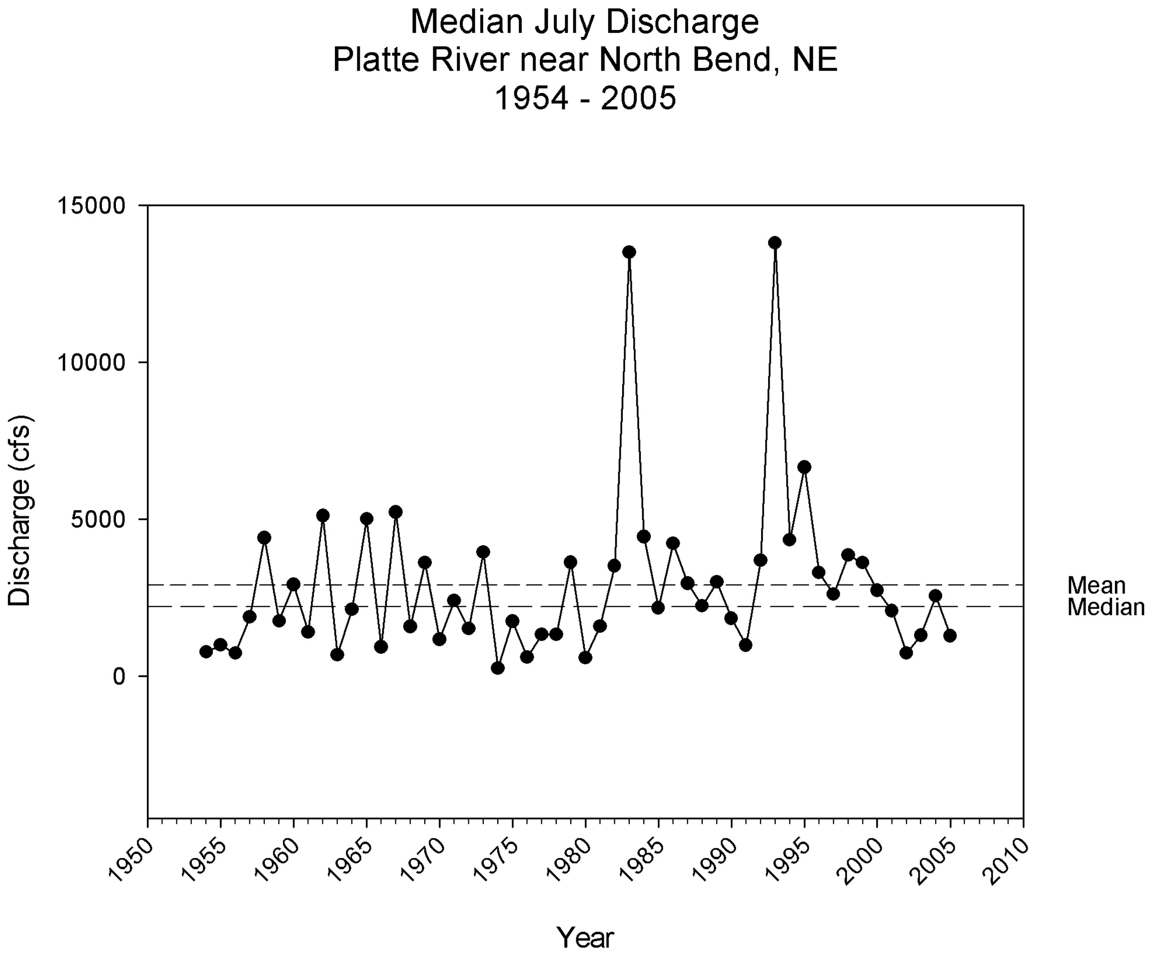

Median March Discharge
Platte River near North Bend, NE
1954 - 2005
Discharge (cfs)
14000
12000
10000
8000
6000
4000
2000
Year
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Mean
Median


Median April Discharge
Platte River near North Bend, NE
1954 - 2005
Discharge (cfs)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
Year
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Mean
Median


Median May Discharge
Platte River near North Bend, NE
1954 - 2005
Discharge (cfs)
25000
20000
15000
10000
5000
0
Mean
Median
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Year

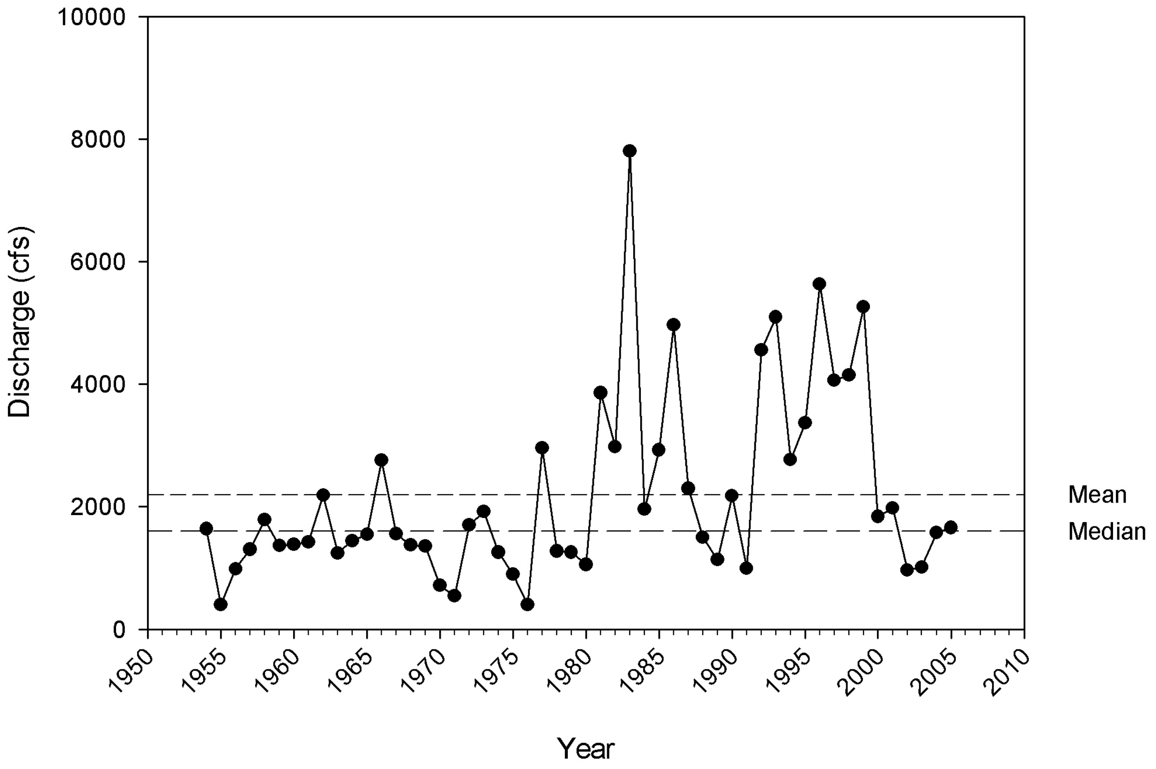
Median June Discharge
Platte River near North Bend, NE
1954 - 2005





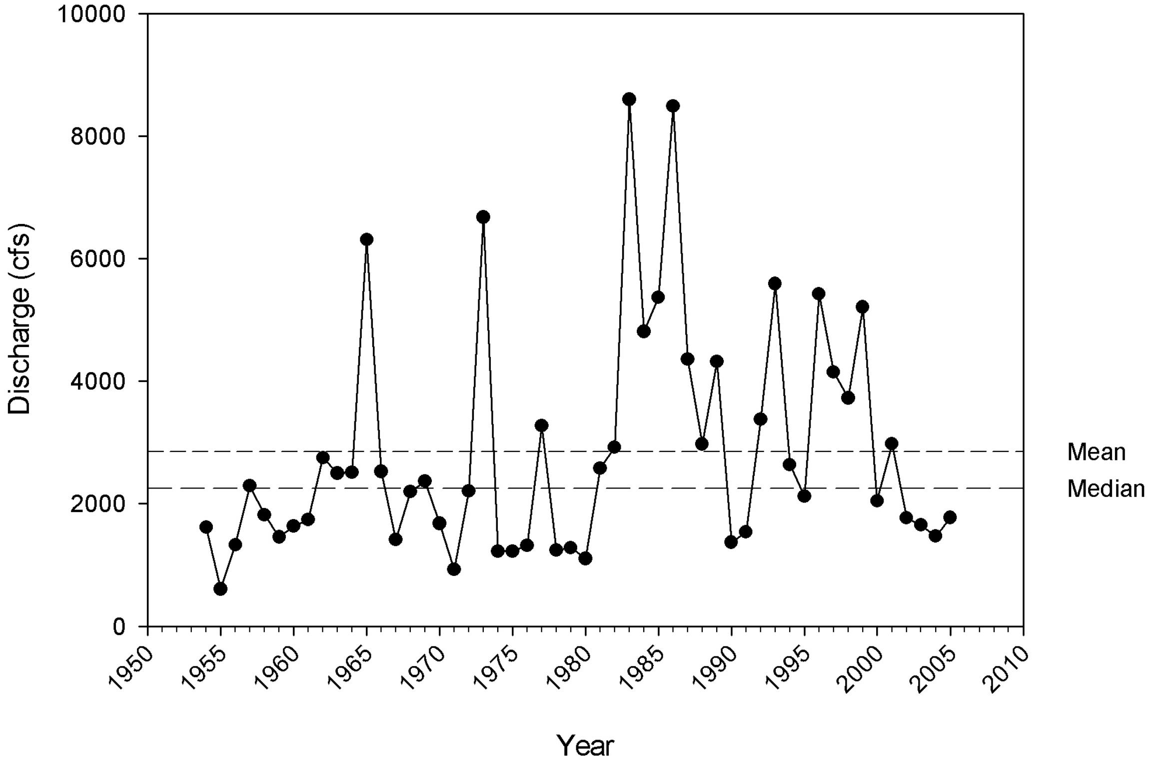
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

Median August Discharge
Platte River near North Bend, NE
1954 - 2005

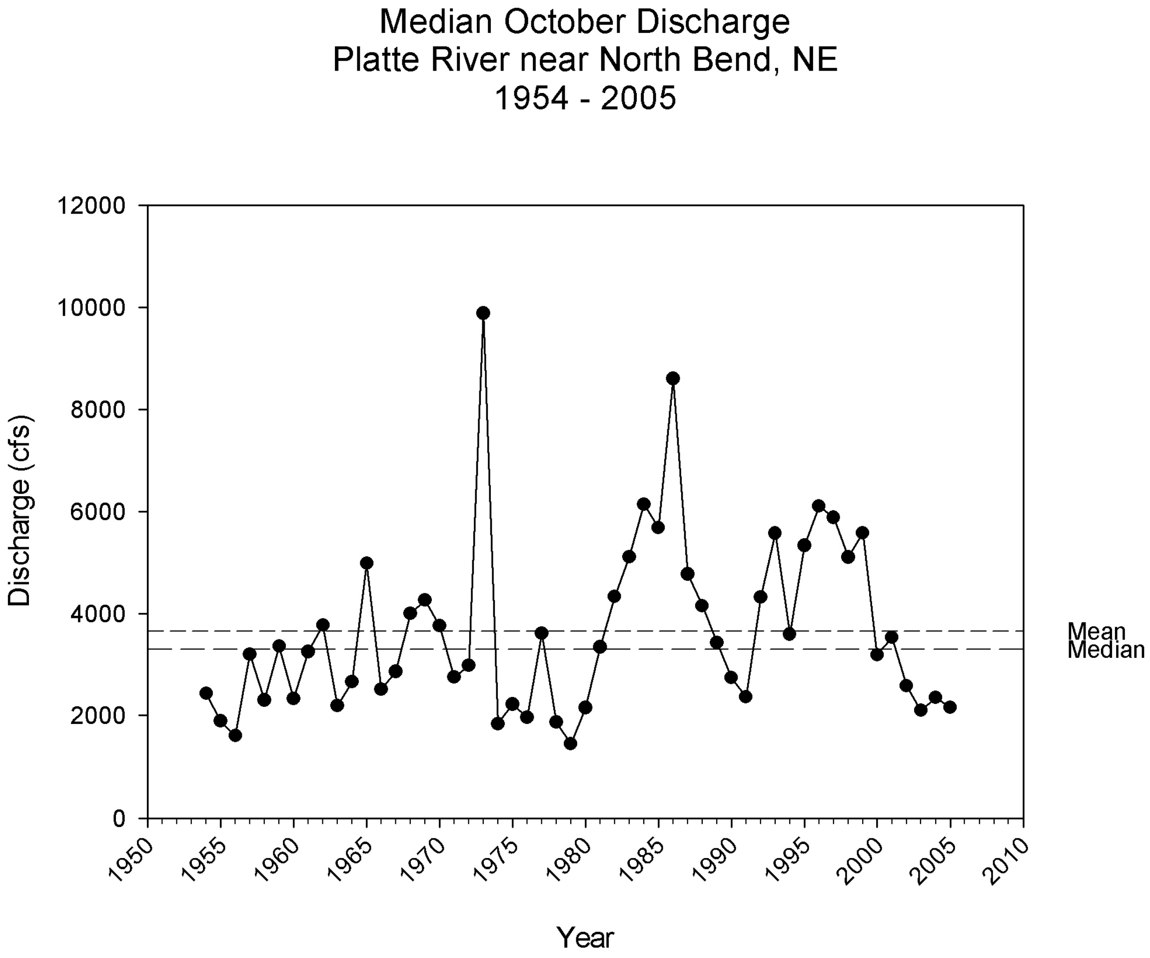


J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

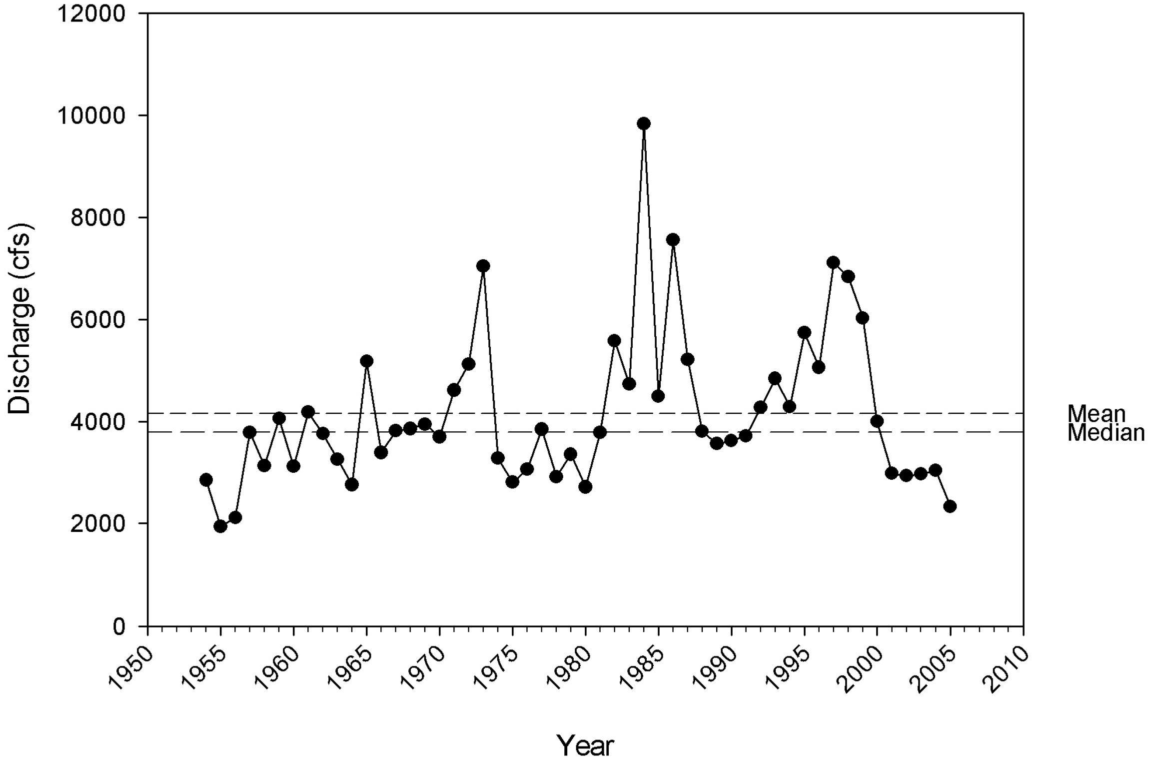
Median September Discharge
Platte River near North Bend, NE
1954 - 2005



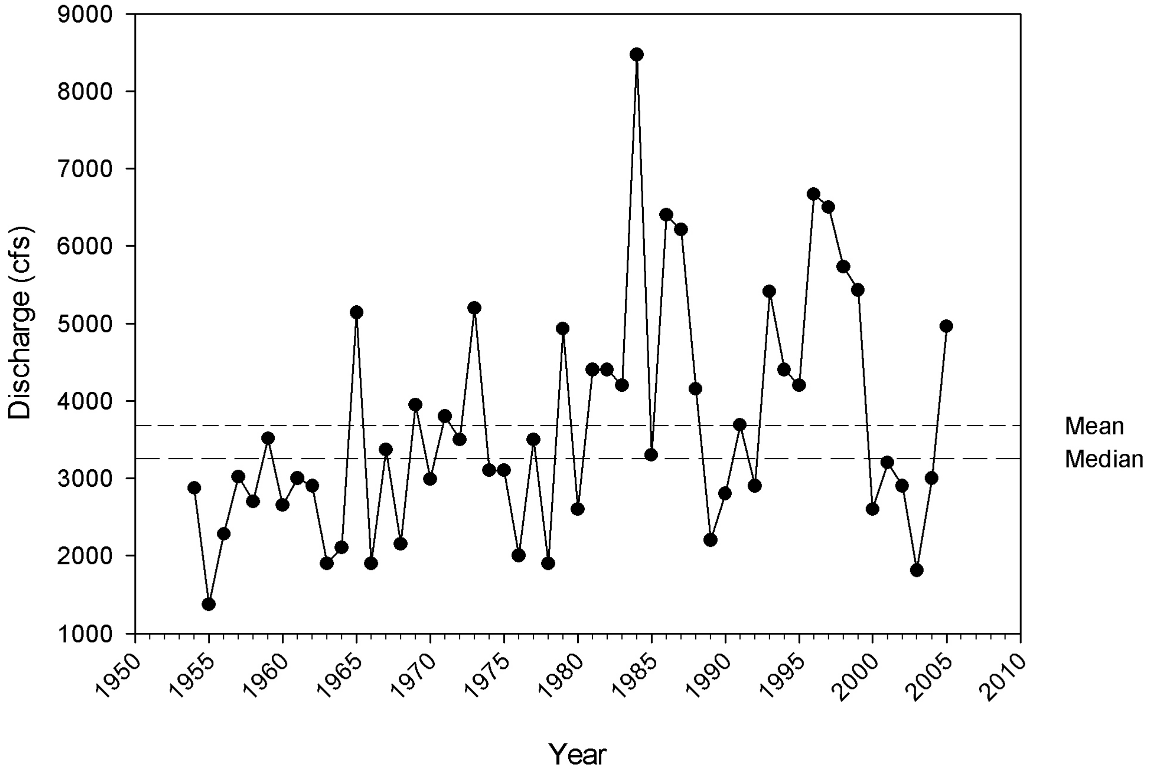
J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

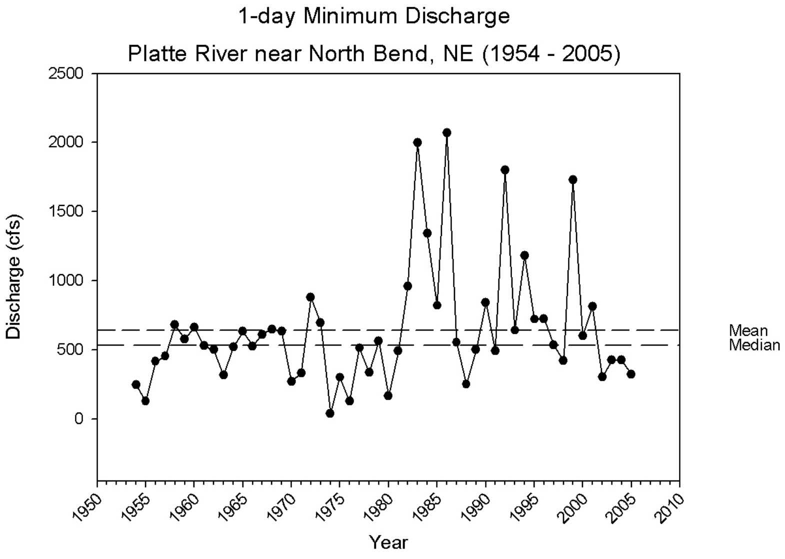

Median October Discharge
Platte River near North Bend, NE
1954 - 2005
Discharge (cfs)
0
2000
4000
6000
8000
10000
12000
Year
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Mean
Median

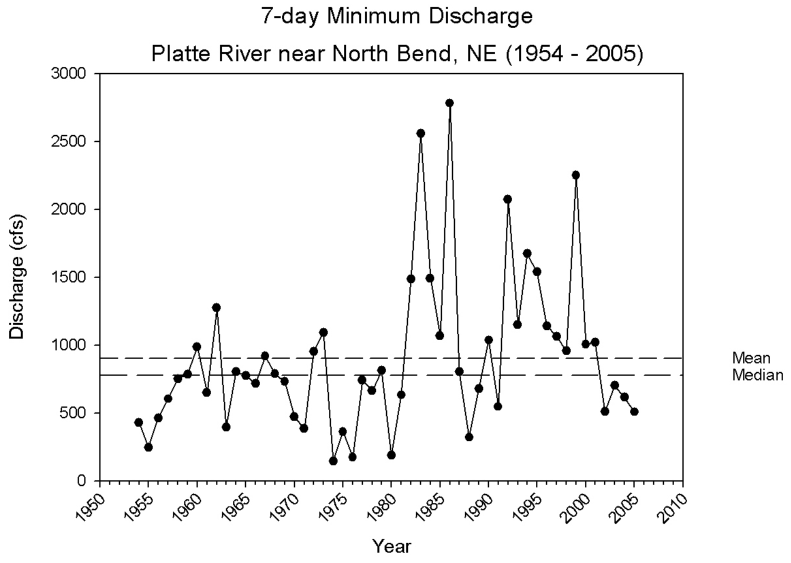
Median November Discharge
Platte River near North Bend, NE
1954 - 2005

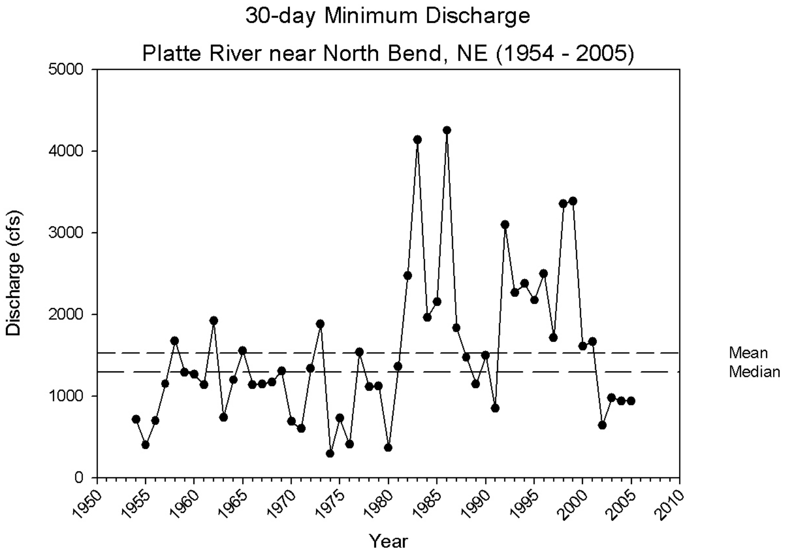


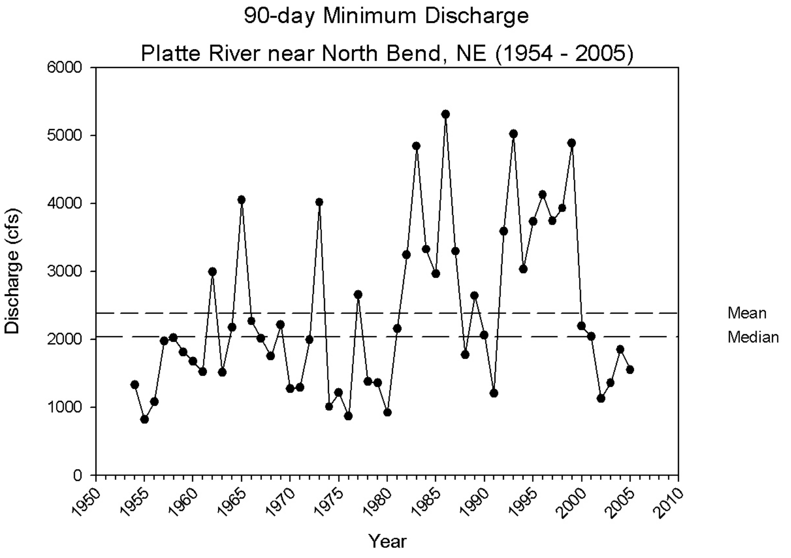
Median December Discharge
Platte River near North Bend, NE
1954 - 2005



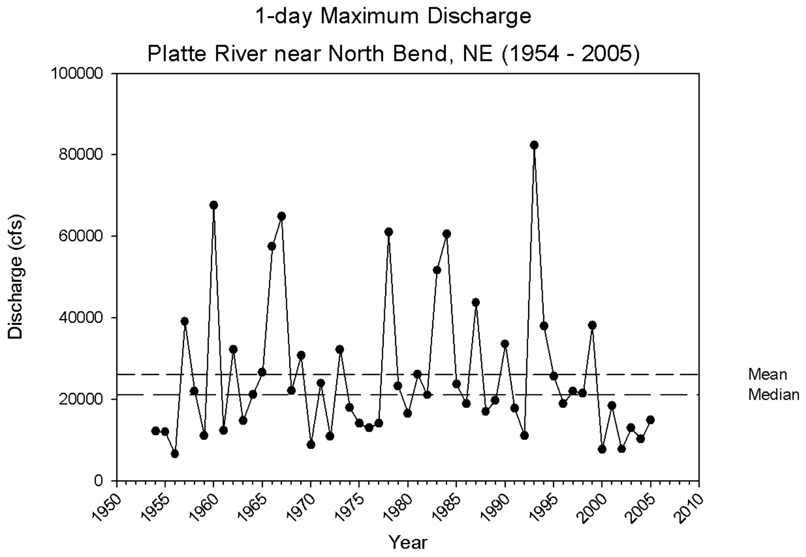

1-day Minimum Discharge
Platte River near North Bend, NE (1954 - 2005)

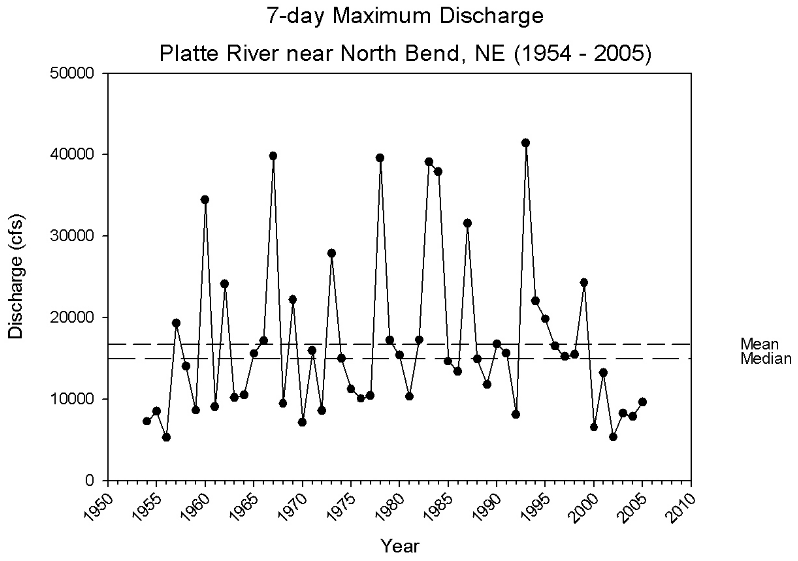

7-day Minimum Discharge
Platte River near North Bend, NE (1954 - 2005)

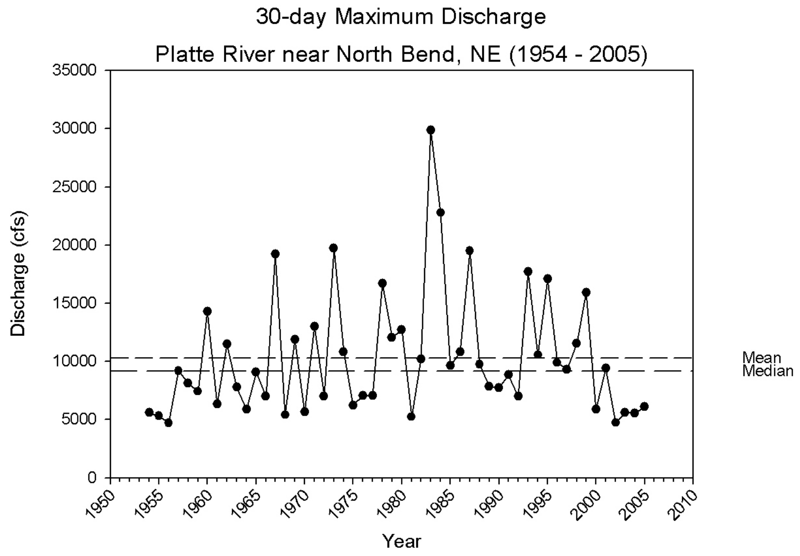

30-day Minimum Discharge
Platte River near North Bend, NE (1954 - 2005)

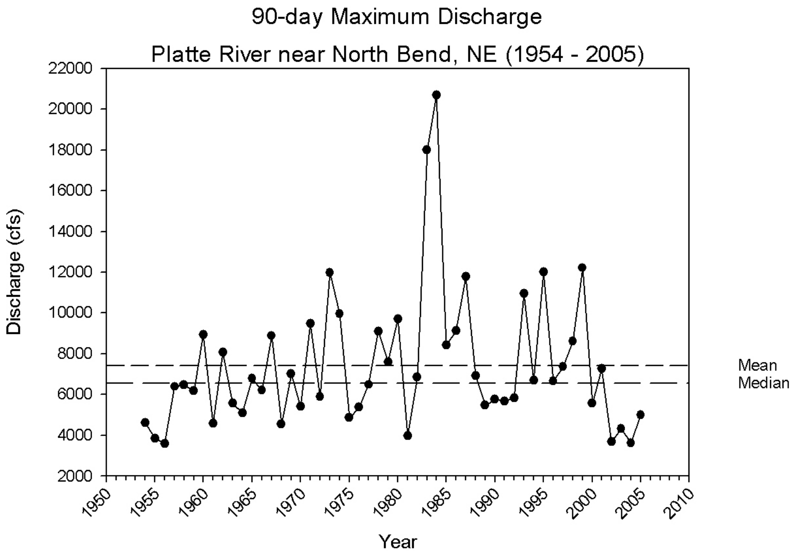

90-day Minimum Discharge
Platte River near North Bend, NE (1954 - 2005)

J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.









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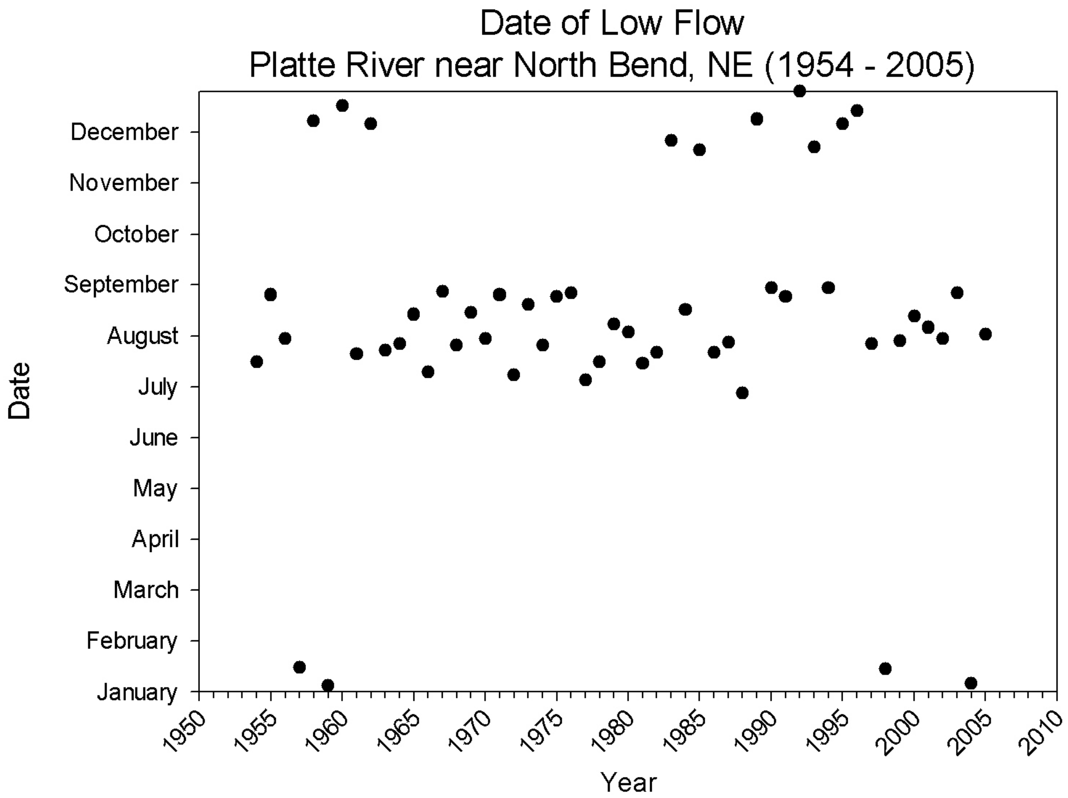
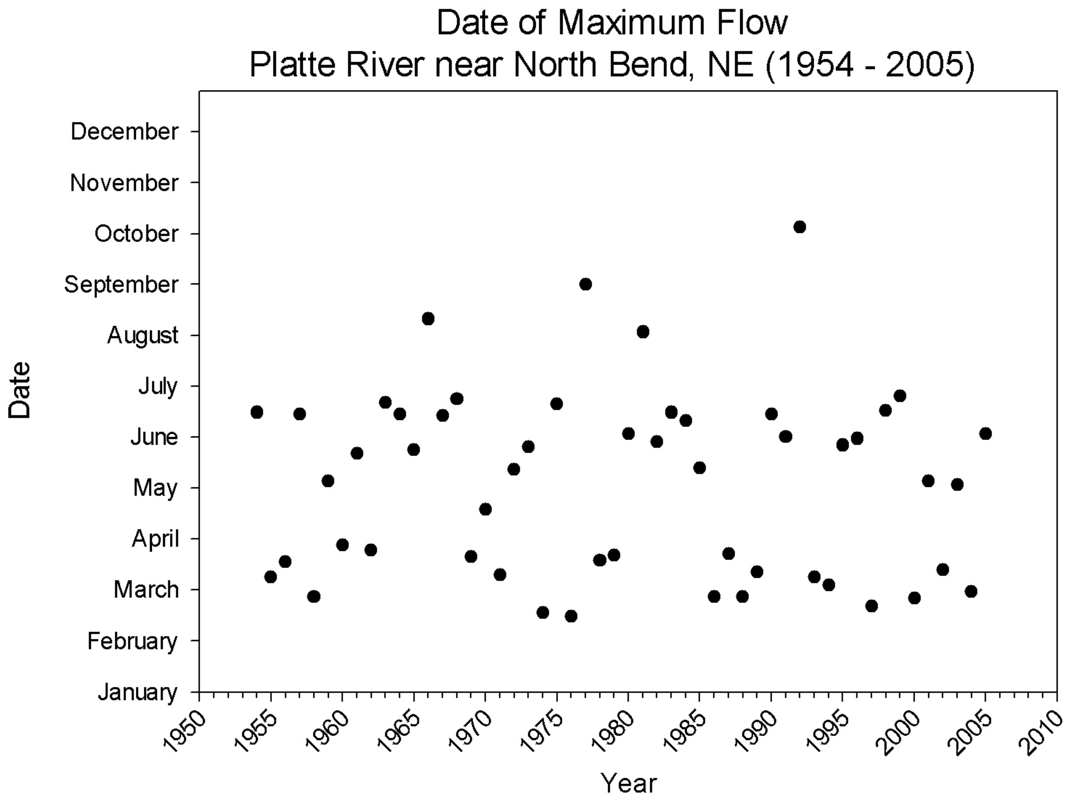
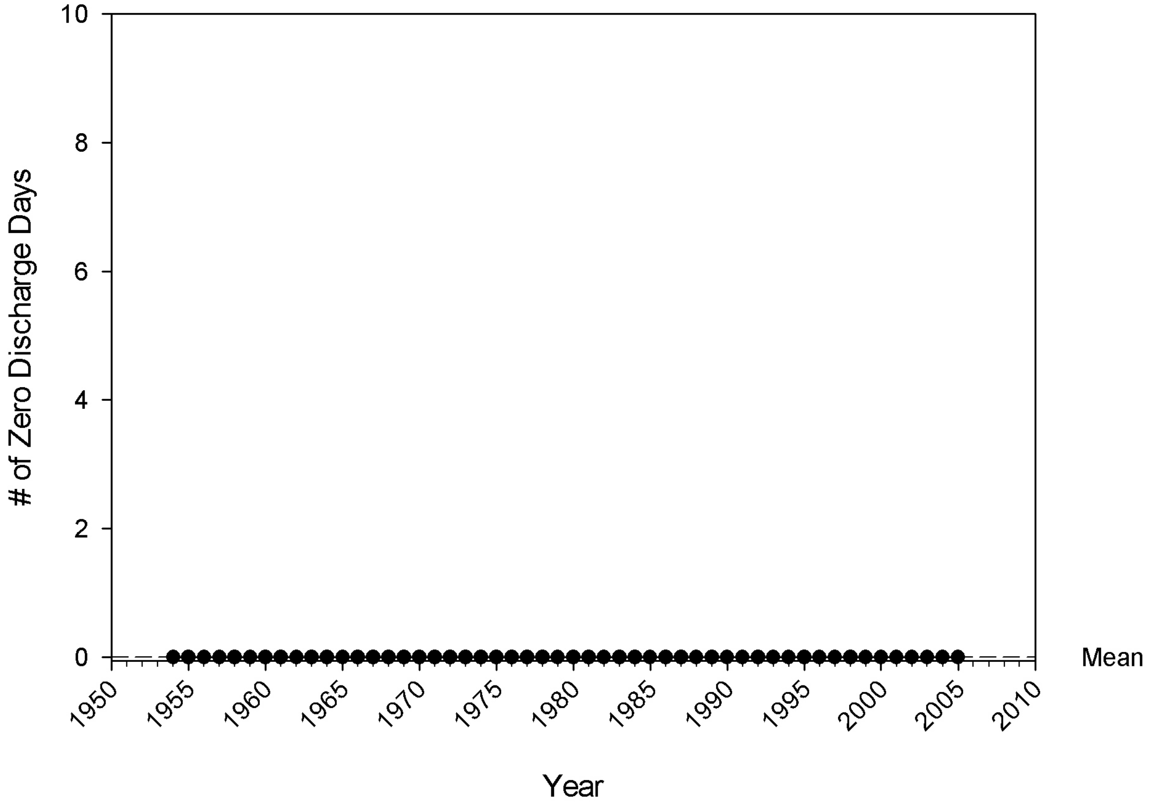
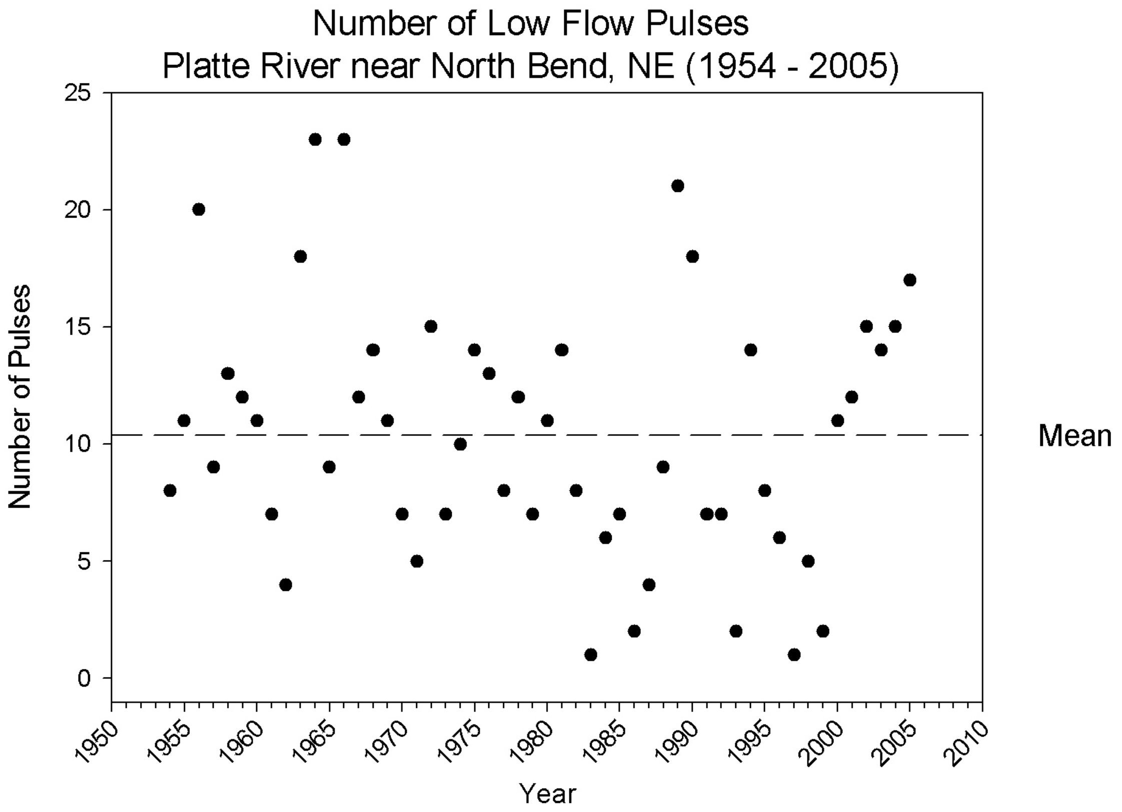
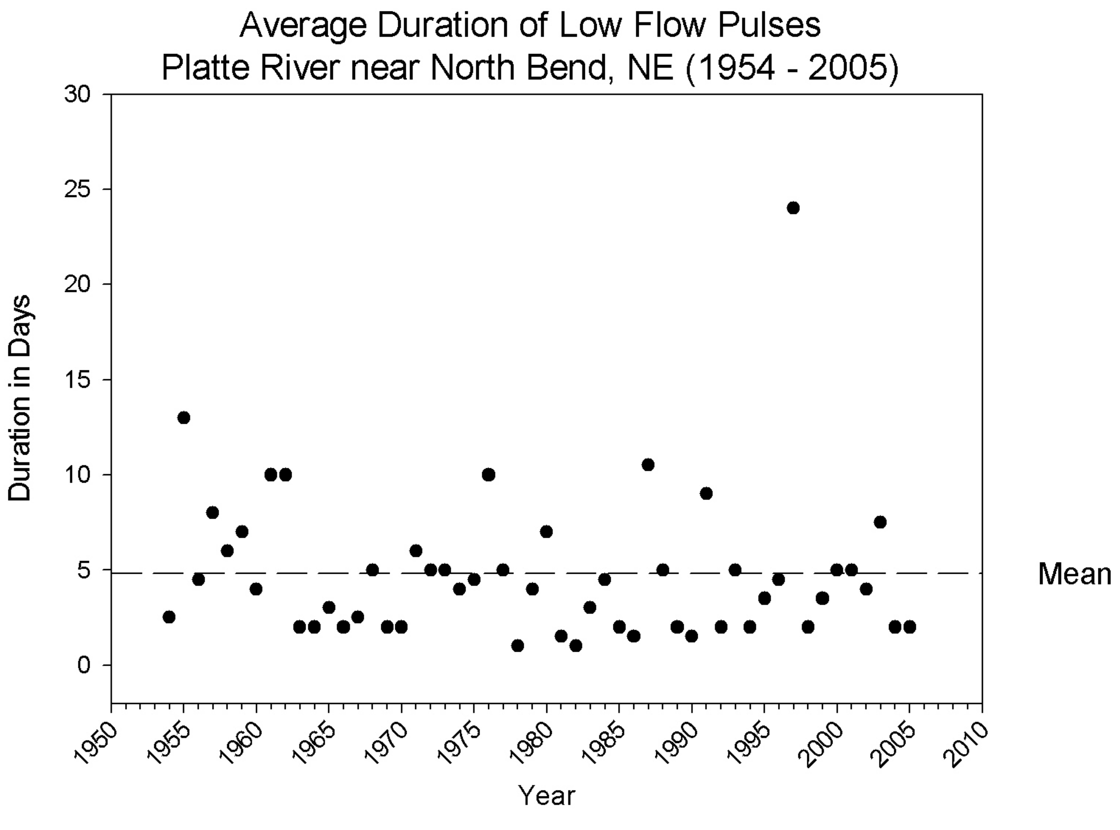

Date of Low Flow
Platte River near North Bend, NE (1954 - 2005)
Date
December
November
October
September
August
July
June
May
April
March
February
January
Year
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010


Date of Maximum Flow
Platte River near North Bend, NE (1954 - 2005)
Date
December
November
October
September
August
July
June
May
April
March
February
January
Year
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010

Zero Discharge Days
Platte River near North Bend, NE
1954 - 2005







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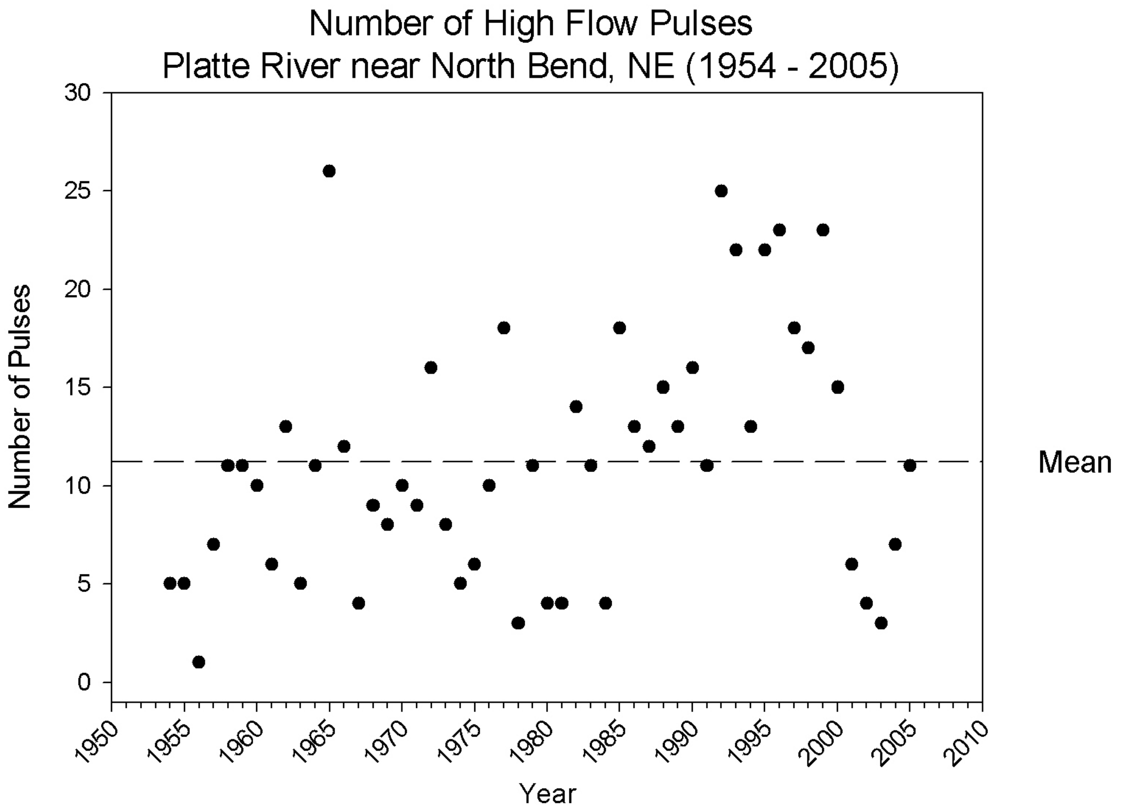
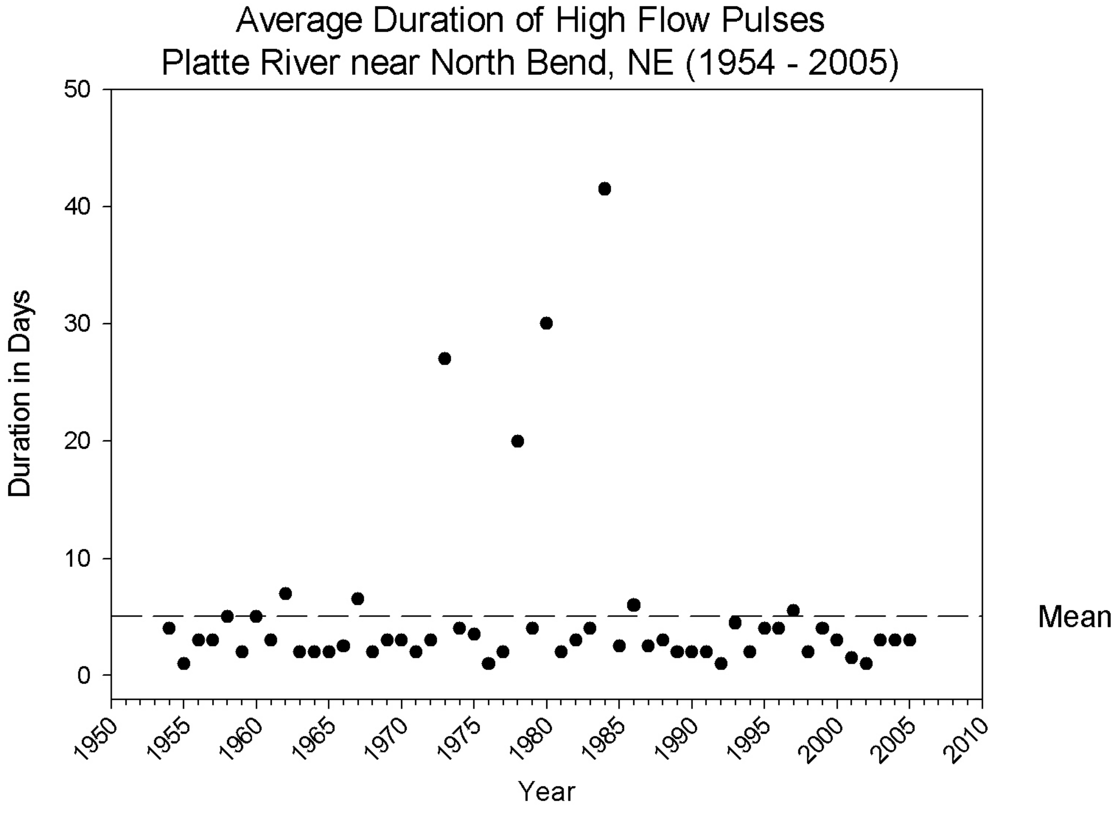
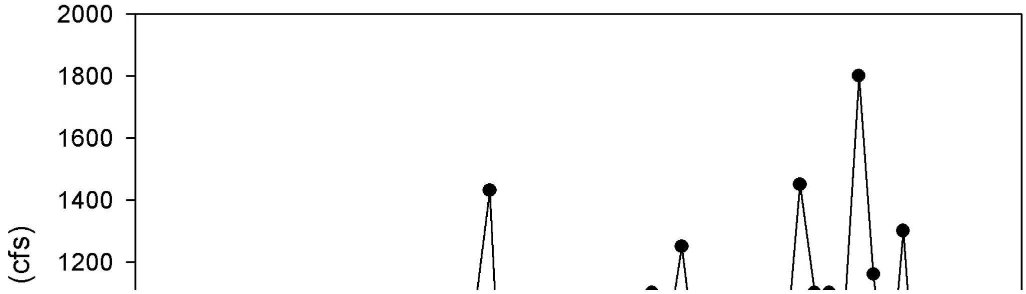




J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

Median January Discharge
Elkhorn River near Waterloo, NE
1954 - 2005



J.E.Parham, 2007. Hydrologic Analysis of the lower Platte River from 1954 -2004, with special emphasis on habitats of the Endangered Least Tern, Piping Plover, and Pallid Sturgeon.

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