APPENDIX D

FLOW DEPLETION AND FLOW DIVERSION STUDY REPORT

Loup River Hydroelectric Project
FERC Project No. 1256

Flow Depletion and Flow Diversion

Loup Power District
Hydro Project

February 11, 2011

Study 5.0 - Flow Depletion and Flow Diversion

Loup River Hydroelectric Project
FERC Project No. 1256

Study 5.0
Flow Depletion and Flow Diversion

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List of Tables

List of Figures

List of Attachments

STUDY 5.0 FLOW DEPLETION AND FLOW DIVERSION

1. INTRODUCTION

The Loup River Hydroelectric Project (Project) is located in Nance and Platte counties, Nebraska, where water is diverted from the Loup River and routed through the 35-mile-long Loup Power Canal, which empties into the Platte River near Columbus. The Project includes various hydraulic structures, two powerhouses, and two regulating reservoirs. The portion of the Loup River from the Diversion Weir to the confluence with the Platte River is referred to as the Loup River bypass reach. The Project is able to divert up to 3,500 cubic feet per second (cfs) of water. This is the capacity of the Loup Power Canal as well as the maximum allowed by the Loup River Public Power District's (Loup Power District's or the District's) water right.

1.1 Interior Least Tern and Piping Plover Use of the Loup River

Within the study area (discussed in Section 3) and directly downstream, interior least terns (*Sterna antillarum*), Federally listed as endangered, and piping plovers (*Charadrius melodus*), Federally listed as threatened, use the Loup River and adjacent sandpit lakes for nesting, breeding, and feeding. Interior least terns arrive in Nebraska in early May to mid-June and nest in colonies on open sandbars in rivers and on gravel and sand beaches on lakes. Their nests are shallow depressions with small stones, twigs, or other debris nearby. Egg-laying begins in late May with an incubation period of 17 to 28 days (U.S. Fish and Wildlife Service [USFWS], September 1990; Thompson et al., 1997). Fledging occurs 3 weeks after hatching, and departure from the colonies is usually complete by early September. The home range during breeding is limited to a reach of the river near the nest; however, this species has been known to fly up to 3.2 kilometers (Smith and Renken, 1990) and possibly farther (U.S. Geological Survey [USGS], February 23, 2009) from the nest site to forage. Interior least terns are routinely seen foraging in the Loup River. Every summer, a relatively large colony of interior least terns becomes established at the Project's North Sand Management Area (SMA), which has been included in the Tern and Plover Conservation Partnership's (TPCP's) survey of interior least terns and piping plovers since 2007[1] (Nebraska Game and Parks Commission [NGPC], November 30, 2007; TPCP, July 30, 2008).

Piping plovers arrive in Nebraska in mid-April and breed in open, sparsely vegetated habitats; on sandbars in large, open rivers; along sand and gravel shores of rivers and lakes; and in alkaline wetlands and sand flats. These migratory birds spend

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[1] Although the North SMA has been included in the TPCP survey only since 2007, interior least terns have been known to nest at the North SMA since the 1980s. This location has also been included in population counts during the International Piping Plover Census (conducted every four years starting in 1991) and the interior least tern range-wide survey (conducted in 2005).

approximately 3 to 4 months at their breeding sites, with nesting and egg-laying commencing in mid-May and an incubation period of approximately 28 days. Hatching occurs in late May to mid-June (USFWS, 1988; Haig, 1992; USFWS, November 30, 2000). During this time, the home range of the piping plover is limited to the wetland, lakeshore, sandbar, or section of beach on which its nest is located. The shallow nests, frequently lined with small pebbles or shell fragments, are located on dry salt flats, barren sandbars, or sand and gravel beaches with less than 5 to 20 percent vegetation (National Research Council, 2005). Piping plovers frequently nest in interior least tern colonies and are therefore considered nesting associates with the interior least tern. Piping plovers are also known to nest at the Project's North SMA, which has been included in the TPCP monitoring surveys of piping plovers since 2007[2] (NGPC, November 30, 2007; TPCP, July 30, 2008).

Whooping cranes (*Grus americana*), Federally listed as endangered, could also be found within the study area during migration. Currently, there have been no known recurring populations of whooping cranes within the study area; however, whooping cranes may occasionally use the Loup River system, which includes the North, Middle, and South Loup rivers and the Loup River to the confluence with the Platte River, during migration for roosting. In 2006, there was a documented sighting of an isolated family group of whooping cranes on the Loup River, approximately 8 miles upstream of the Diversion Weir (NGPC, October 2, 2008). This sighting was an isolated occurrence during the spring migration season. Additional sightings were confirmed during fall migration in 1999 near Fullerton, Nebraska, on the Loup River, and in 1996 near Belgrade, Nebraska, on the Cedar River. These birds do not typically frequent the study area and are usually found on the central Platte River, west of Grand Island, Nebraska.

Data regarding the habitat suitability of the Loup River for interior least terns, piping plovers, and whooping cranes are limited. Commercial sand pits, gravel mines, and lakeshore housing developments are common along the river and have been used by interior least terns and piping plovers for nesting, breeding, and foraging. In the last 10 years, these areas have been surveyed more regularly than the Loup River due to the cooperative efforts of TPCP and NGPC. The historic and current use of the Loup River by interior least terns and piping plovers is discussed below. Because there are very few records of use of the Loup River by whooping cranes, this species was not included in this discussion.

[2] Although the North SMA has been included in the TPCP survey only since 2007, interior least terns have been known to nest at the North SMA since the 1980s. This location has also been included in population counts during the International Piping Plover Census (conducted every four years starting in 1991) and the interior least tern range-wide survey (conducted in 2005).

1.1.1 Historic Use of the Loup River

Very limited information exists regarding the historic use of the Loup River by interior least terns and piping plovers prior to the 1980s. The little information that does exist does not describe much about the exact location of the sightings, nesting on- or off-river, or the historic density of these birds on the Loup River. Furthermore, it does not provide information on the type, density, physical aspects, or other characteristics of the sandbars and channel systems or on the "value" of the habitat during times of use.

In the 1850s, interior least terns and piping plovers were sighted near the confluence of the Loup and Platte rivers, although no count data were recorded (Ducey, 2000). On the Loup River system, very few early records exist on these species, the earliest being specimens of three interior least terns and five piping plovers that were collected during the Warren Expedition (1875, as cited in Ducey, 1985 and 2000) that were attributed to the "Loup Fork." The exact locality was not given in the expedition narrative. Approximately 100 years later, in 1965, interior least tern nesting was recorded on the Middle Loup River, 3 miles south of St. Paul, Nebraska (Short, 1966, as cited in Ducey, 1985). These records show that historically, a large number of these species did not use the Loup River.

1.1.2 Current Use of the Loup River

In the Loup River system, breeding interior least terns and piping plovers occur as far west as Valley and Howard counties, Nebraska (Sharpe et al., 2001). Currently, interior least tern and piping plover use of the Loup River in relation to use of other Nebraska rivers is minimal. Based on adult census counts and nest counts from 1983 to 2006, obtained from the NGPC Nongame Bird Program's Nebraska Least Tern and Piping Plover database, relatively few birds have been sighted and recorded nesting on the Loup River (NGPC, 2009). The largest colony of nesting interior least terns and piping plovers along the Loup River is located within the Project Boundary on the North SMA. This site is where sand dredged from the adjacent Settling Basin is stockpiled, creating a large sandy area with adjacent wetted areas. Interior least terns and piping plovers also use other sand and gravel pits and lakeshore housing developments along the Loup and North Loup rivers (NGPC, February 23, 2009). However, very little data have been gathered on interior least tern and piping plover use of the Loup and North Loup rivers themselves. Because the Loup River system has rarely had large numbers of interior least terns and piping plovers, it has not been surveyed regularly. Sand and gravel mines and housing developments adjacent to the Loup River system were last surveyed by NGPC and TPCP in 2010. The Loup River was last surveyed for interior least terns and piping plovers by Jim Jenniges of Nebraska Public Power District (NPPD) in June 2009 and by USFWS in 2010. Prior to these most recent surveys, the Loup River system was surveyed for interior least terns in 2005 during a range-wide survey (Lott, November 2006) and for piping plovers in 2006 for the International Piping Plover Census (Elliott-Smith et al., 2009).

1.1.3 Interior Least Tern and Piping Plover Numbers on the Loup River in Relation to the Entire Interior/Great Plains Populations and Nebraska Breeding Numbers

The Loup River adult census numbers for interior least terns during the 2005 range-wide survey (Lott, November 2006) are compared to the overall population total and the Platte River and tributaries group total in Table 1-1. As shown in this analysis, the significance of the Loup River system to the overall recovery of the species appears minimal. Consistent surveys on the Loup and Elkhorn rivers are conducted only in years of the International Piping Plover Census. Survey coverage of sandpits and lakeshore housing developments has improved in recent years on the Elkhorn, Loup, and North Loup rivers, with assistance from TPCP.

Table 1-1. Comparative Analysis of Interior Least Tern Range-wide Survey Data

	2005	
	Adults	Colonies
Total[1]	17,591	2,441
Nebraska Total[2]	782	36
Loup River	73	2
North Loup River	14	2
Lower Platte River	381	13
Loup River % of Total Population	0.41%	0.08%
Loup River % of Nebraska Total	18.34%	1.44%

Source: Lott, C.A., November 2006, Distribution and Abundance of the Interior Population of the Least Tern (*Sternula antillarum*), 2005. U.S. Army Corps of Engineers. EDRC/EL TR-06-13.

Notes:

1 Total bird numbers are for breeding population surveys only. For more information, see Lott, November 2006 summaries.

2 Nebraska total includes birds counted in both on- and off-river habitat throughout Nebraska, but does not include birds counted on the Missouri River within the Nebraska boundaries.

The Loup River adult census numbers for piping plovers during years of the International Piping Plover Census (1991, 1996, 2001, and 2006) are compared to the overall population total, the Northern Great Plains and Prairie Canada (NGP&PC) population total, and the State of Nebraska group total in Table 1-2. As shown in this analysis, the significance of the Loup River system to the overall recovery of the species appears minimal.

Table 1-2. Comparative Analysis of International Piping Plover Census Data

	1991		1996		2001		2006	
	Adults	Pairs	Adults	Pairs	Adults	Pairs	Adults	Pairs
Total[1]	5,482	2,441	5,913	2,668	5,945	2,747	8,092	3,516
NGP&PC Total	3,467	1,486	3,284	1,377	2,953	1,291	4,662	1,879
Nebraska Total[2]	398	139	366	155	308	133	909	341
Loup River	14	5	29	6	21	7	19	3
North Loup River	2	1	4	1	10	5	12	0
Lower Platte River	62	21	53	23	67	20	52	2
Loup River % of Total Population	0.26%	0.20%	0.49%	0.22%	0.35%	0.25%	0.23%	0.09%
Loup River % of NGP&PC Total	0.40%	0.34%	0.88%	0.44%	0.71%	0.54%	0.41%	0.16%
Loup River % of Nebraska Total	3.52%	3.60%	7.92%	3.87%	6.82%	5.26%	2.09%	0.88%

Sources: Dinan, John J., 2001, "2001 Piping Plover and Least Tern Census – Nebraska," NGPC.
Elliott-Smith, E., S.M. Haig, and B.M. Powers, 2009, Data from the 2006 International Piping Plover Census, U.S. Geological Survey Data Series 426.
Ferland, C.L., and S.M. Haig, 2002, 2001 International Piping Plover Census, USGS, Forest and Rangeland Ecosystem Science Center, Corvallis, Oregon.
Haig, S.M., and J.H. Plissner, 1993, "Distribution and Abundance of Piping Plovers: Results and Implications of the 1991 International Census," *Condor* 95:145-156.
Plissner, J.H., and S.M. Haig, 2000, Status of a Broadly-Distributed Endangered Species: Results and Implications of the Second International Piping Plover Census, *Canadian Journal of Zoology* 78:1-12.

Notes:

1 Total bird numbers are for breeding population surveys only. For more information, see Piping Plover Census summaries.

2 Nebraska total includes birds counted in both on- and off-river habitat throughout Nebraska and includes the Missouri River within the Nebraska boundaries.

1.2 Reasons for this Study

Resource management agencies have expressed concern that diminished natural flows in the Loup River bypass reach related to Project operations may affect riverine habitat distribution, including interior least tern and piping plover nesting habitat and fisheries habitat. In addition, these agencies have expressed concern that depletions attributed to the Loup Power Canal, regulating reservoirs, and irrigation activities may result in flow depletion in the lower Platte River.[3] Although whooping crane roosting habitat was not originally a concern addressed in this study, this species and associated riverine roosting habitat was an additional concern for USFWS and was added to this study by FERC in its Study Plan Determination dated August 26, 2009.

To address these issues, the District conducted this flow depletion and flow diversion study. For the purposes of this study, flow depletion is defined as Project-related water lost to consumptive use (that is, evaporation and evapotranspiration [ET]). All other water that is seeped to the groundwater is not technically lost because this area is hydraulically connected and any water that is not lost to the atmosphere will eventually return to the lower Platte River system. That is, the specific flow may be time lagged but is not lost.

This study focused on five principal questions:

- Does Loup Power Canal consumptive use under current Project operations cause depletions to the lower Platte River, and how does this compare to an alternative condition (a no diversion condition)?
- What are the Project effects of consumptive use on fisheries and habitat on the lower Platte River downstream of the Tailrace Canal?
- What effects do current Project operations have on interior least tern and piping plover nesting habitat on the Loup River, and how does this compare to a no diversion condition?
- What effects do current Project operations have on whooping crane roosting habitat on the Loup River, and how does this compare to a no diversion condition?
- What is the relative significance of the Loup River bypass reach with respect to the overall fishery habitat of the Loup River?

These questions were used to form the goals and objectives of this study, which are described in Section 2. These goals and objectives and the proposed methodology were reviewed and approved by FERC, with modifications, as outlined in its Study Plan Determination on August 26, 2009.

2. GOALS AND OBJECTIVES OF STUDY

The goals of the flow depletion and flow diversion study are to determine if Project operations result in flow depletion on the lower Platte River and to what extent the magnitude, frequency, duration, and timing of flows affect the Loup River bypass reach. The results were used to determine if Project operations (current operations) relative to flow depletion and flow diversion adversely affect the habitat used by

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[3] The lower Platte River is defined as the reach between the confluence of the Loup and Platte rivers and the confluence of the Platte and Missouri rivers.

interior least tern and piping plover populations, the fisheries, and the riverine habitat in the Loup River bypass reach and the lower Platte River compared to an alternative condition (the no diversion condition). No diversion was defined as no water being diverted into the Project but does not represent a case of Project decommissioning. Potential Project effects on whooping crane roosting habitat were an added concern of USFWS after submittal of the District's Revised Study Plan on July 27, 2009. This species and its associated roosting habitat were included in FERC's Study Plan Determination, and an additional objective was developed to address potential Project effects on this species (see Objective 7, below).

The objectives of the flow depletion and flow diversion study are as follows:

1. To determine the net consumptive losses associated with Project operations compared to the no diversion condition.
2. To use current and historic USGS gage rating curves to evaluate change in stage in the Loup River bypass reach during Project operations and compare against hydrographs of a no diversion condition.
3. To evaluate historic flow trends on the Loup and Platte rivers since Project inception.
4. To determine the extent of interior least tern and piping plover nesting on the Loup River above and below the Diversion Weir.
5. To determine Project effects, if any, of consumptive use on fisheries and habitat on the lower Platte River downstream of the Tailrace Canal.
6. To determine the relative significance of the Loup River bypass reach to the overall fishery habitat for the Loup River.
7. To determine the availability of potential whooping crane roosting habitat above and below the Diversion Weir under Project operations compared to the no diversion condition.

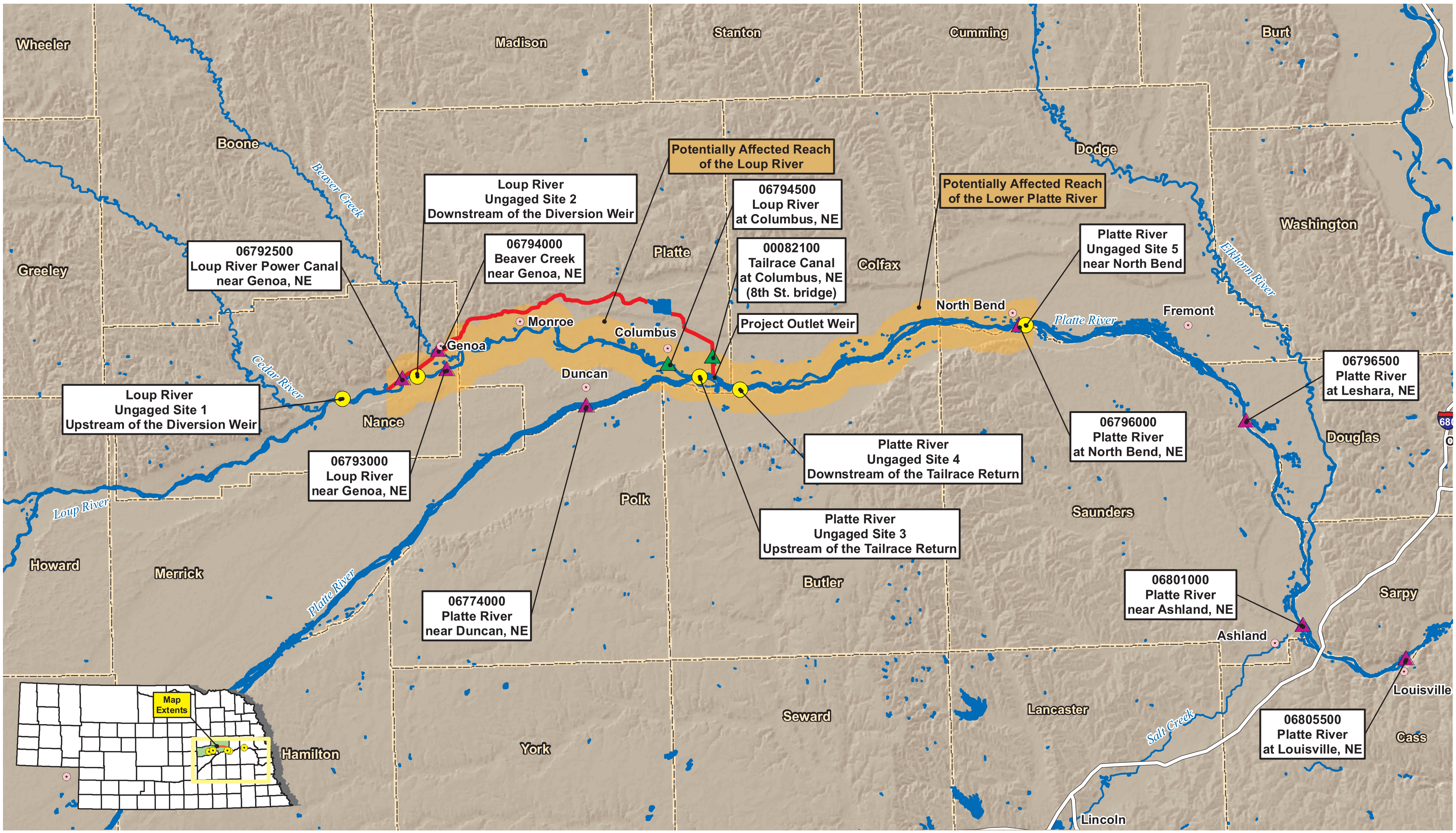
3. STUDY AREA

The study area includes the Loup Power Canal and associated regulating reservoirs; the Loup River bypass reach, which begins at the Diversion Weir, located west of Genoa, and ends at the confluence with the Platte River at Columbus; and the lower Platte River from the confluence with the Loup River to the USGS gage at North Bend, shown in Figure 3-1. Stream gage information from locations on the Loup River, the Loup Power Canal, and the lower Platte River were used, as discussed in Section 4.1. The following existing stream gage locations in the study area served as study sites for analyses:

- USGS Gage 06793000, Loup River near Genoa, NE
- USGS Gage 06794500, Loup River at Columbus, NE

In addition to these study sites, FERC, in its Study Plan Determination dated August 26, 2009, required that "ungaged" sites also be evaluated. The approved methodology for the flow depletion and flow diversion study included a provision that cross-section surveys and calculations of sediment transport indicators be conducted at three ungaged sites. The approved methodology for the sedimentation and the hydrocycling studies included a provision that cross-section surveys and calculations of sediment transport indicators be conducted at two additional ungaged sites. The ungaged sites were chosen in consultation with USFWS and NGPC through the use of aerial photographs. The five ungaged sites and the studies with which they are associated are listed below and are shown in Figure 3-1; the three ungaged sites relevant to this flow depletion and flow diversion study are Sites 1, 2, and 3:

1. Loup River upstream of the Diversion Weir (Site 1) – Sedimentation and flow depletion and flow diversion
2. Loup River immediately downstream of the Diversion Weir (Site 2) – Flow depletion and flow diversion
3. Lower Platte River downstream of the Loup River confluence and upstream of the Tailrace Return confluence (Site 3) – Sedimentation, hydrocycling, and flow depletion and flow diversion
4. Lower Platte River within 5 miles downstream of the Tailrace Return confluence (Site 4) – Sedimentation and hydrocycling
5. Lower Platte River near the USGS North Bend gage (Site 5) – Hydrocycling



Legend
- City
- NDNR Gaging Station
- USGS Gaging Station and/or Study Site
- Ungaged Study Sites
- Interstate
- Stream/River
- Loup Power Canal
- Waterbody
- County
- Potentially Affected Reach

Source: Stream Gage, Nebraska Department of Natural Resources; Streams/Waterbodies, 2000 Tiger Files

Flow Depletion and Flow Diversion Study Sites

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DATE
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FIGURE
3-1

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4. METHODOLOGY

The methodology used to complete the flow depletion and flow diversion analysis is described below. The results of the flow depletion and flow diversion study are discussed in Section 5, and supporting graphs and tables are included in Attachments A through L. The methodology for the flow depletion and flow diversion study includes nine tasks designed to meet the seven objectives presented in Section 2, Goals and Objectives of Study. These objectives and the tasks that were conducted to meet each objective are as follows:

- All seven objectives
  - Task 1: Data Collection
- Objective 1: To determine the net consumptive losses associated with Project operations compared to the no diversion condition.
  - Task 2: Net Consumptive Use
- Objective 2: To use current and historic USGS gage rating curves to evaluate change in stage in the Loup River bypass reach during Project operations and compare against hydrographs of a no diversion condition.
  - Task 3: Flow Duration, Volume Duration, and Flood Flow Frequency Relationships
  - Task 4: Stage
- Objective 3: To evaluate historic flow trends on the Loup and Platte rivers since Project inception.
  - Task 5: Loup River and Platte River Depletions
- Objective 4: To determine the extent of interior least tern and piping plover nesting on the Loup River above and below the Diversion Weir.
  - Task 6: Interior Least Tern and Piping Plover Nesting on the Loup River Bypass Reach
- Objective 5: To determine Project effects, if any, of consumptive use on fisheries and habitat on the lower Platte River downstream of the Tailrace Canal.
  - Task 2: Net Consumptive Use
- Objective 6: To determine the relative significance of the Loup River bypass reach to the overall fishery habitat for the Loup River.
  - Task 7: Fishery Populations Above and Below the Diversion Weir
  - Task 8: Montana Method

- Objective 7: To determine the availability of potential whooping crane roosting habitat above and below the Diversion Weir under Project operations compared to the no diversion condition.
  - Task 9: Whooping Crane Roosting Habitat Evaluation on the Loup River Bypass Reach

4.1 Task 1: Data Collection

Flow and stage data were collected at the study sites as well as at additional USGS and Nebraska Department of Natural Resources (NDNR) gages in and near the study area, as listed in Table 4-1 and shown in Figure 3-1. The data included daily and sub-daily discharge data, summaries of streamflow measurements, and current and historical rating curves.

Evaporation and ET data, including daily, monthly, and annual evaporation and ET data, were collected at the following stations:

- National Weather Service (NWS) station at Grand Island Airport – Cooperative Observer ID 253395
- NWS station at Valley, Nebraska – Cooperative Observer ID 258795

In addition to the stream and atmospheric data, the following data were collected to aid in evaluation and analysis of flow depletions:

- U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) soil surveys for Nance and Platte counties
- District irrigation metering records
- NDNR and/or USDA Farm Service Agency records for irrigated crop types
- USDA Farm Service Agency's National Agricultural Imagery Program (NAIP) aerial satellite imagery for 2003, 2004, 2005, 2006, and 2009
- District plans and operations and maintenance (O&M) manuals for regulating reservoir specifications (stage-surface area relationship)
- District information on Lost Creek Siphon to estimate discharges

Table 4-1. Study Sites and Other Gaged Sites

USGS Gage Number	Gage Name and Location	Drainage Area (sq. mi.)	Mean Daily Discharge (cfs)	Period of Record	Comments
06793000[1]	Loup River near Genoa, NE	14,320	989	1929 - 2009	Available discharge and gage height data from April 1, 1929, to 2009 include daily and sub-daily data.
06792500	Loup River Power Canal near Genoa, NE	NA	1,610	1937 - 2009	Available discharge data from January 1, 1937, to 2009 include daily and sub-daily data.
06794000	Beaver Creek at Genoa, NE	677	131	1940 - 2009	Available discharge data from October 1, 1940, to 2009 include daily and sub-daily data.
00082100	Loup River Power Canal Return [Tailrace Canal] at Columbus, NE (8th Street bridge)	NA	1,610	2002 - 2009	Available discharge data from October 1, 2002, to 2009 include daily and sub-daily data.
06794500[1,2]	Loup River at Columbus, NE	15,200	1,197	1934 - 1978	Available daily discharge and gage height data from April 1, 1934, to October 10, 1978. This gage was restarted by NDNR on September 23, 2008.
06774000	Platte River near Duncan, NE	59,300	2,078	1929 - 2009	Available discharge and gage height data from May 3, 1895, to 2009 include daily and sub-daily data. Data between 1895 and 1928 are incomplete. The period of record for continuous approved data is 1929 to 2009.
06796000	Platte River at North Bend, NE	70,400	4,938	1949 - 2009	Available discharge and gage height data from April 1, 1949, to 2009 include daily and sub-daily data.

Notes:

NA = Not available.

1 Designated as a study site.

2 Formerly a USGS gage, but currently maintained by NDNR.

Field surveys were conducted at each of the ungaged sites to measure the topography using 9 closely spaced cross sections and flow parameters of top width and depth. Velocity measurements were not taken during high flows, as described below. Data collection for the ungaged sites was scheduled during typical high-flow conditions, which are typically around the first week of May, and during low-flow conditions, which are typically in late July and August. The low-flow condition was identified in FERC's Study Plan Determination as being 50 to 75 cfs; however, during subsequent discussions with FERC regarding the difficulty of surveying such a low flow, a discharge of approximately 300 to 500 cfs was selected as a target low flow.

High water experienced in early May and extending through June 2010 (see Figures 4-1 and 4-2) postponed a portion of the data collection effort until mid- to late June. It was concluded that the sustained high flows observed in May and June were in some respects reflective of the typical annual spring runoff and that the consistent lower flows experienced in July and August were reflective of the typical summer low flows. Velocity measurements were not taken during the high flows experienced in 2010 because a significant portion of the river was not wadeable. Although the District was directed in FERC's Study Plan Determination to collect the data as close in time as possible to when USGS collects data at its gaged sites, the data were collected when flows were conducive to this activity. No attempt was made to coordinate with USGS. Data were collected at the ungaged sites for the following months:

- Site 1, Upstream of the Diversion Weir – June and October 2010
- Site 2, Downstream of the Diversion Weir – April, August, and September 2010
- Site 3, Upstream of the Tailrace Return – May, August, and September 2010

During the field surveys, photographs were taken to document the survey effort. The cross-section locations and photographs are provided in Attachment A. The dates when data collection occurred at each cross section are provided in Table 4-2. The times when data collection occurred are not included; multiple rovers and site conditions caused many cross sections to be surveyed in portions at varying times of day. Graphs of the cross sections comparing the spring and fall measurements at each location are included in Attachment A.

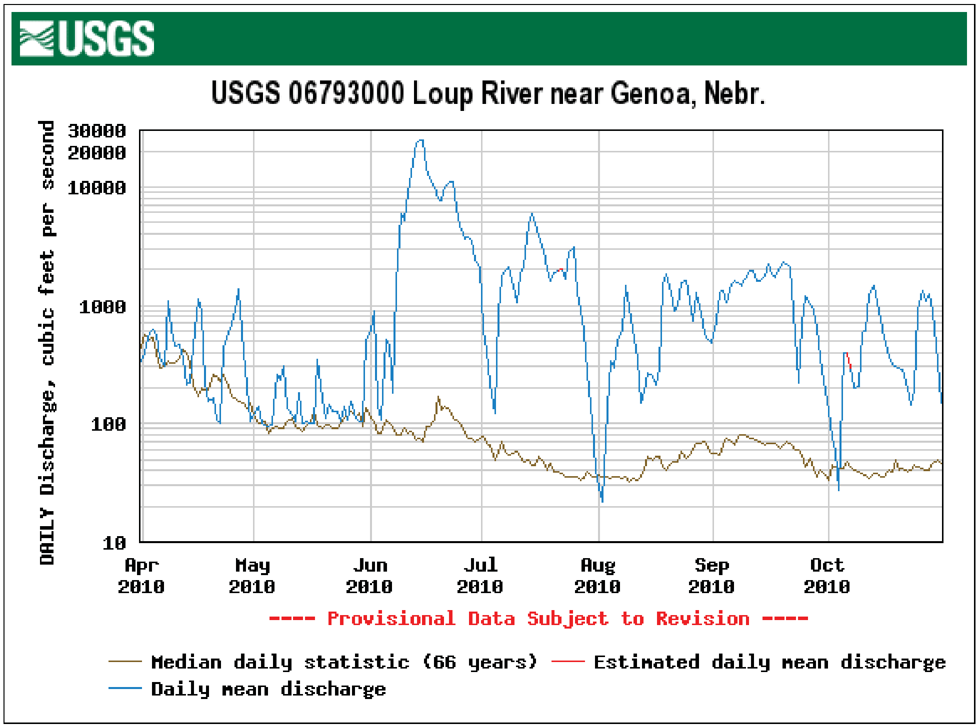


Figure 4-1. Flow on the Loup River near Genoa, Spring, Summer, and Fall 2010

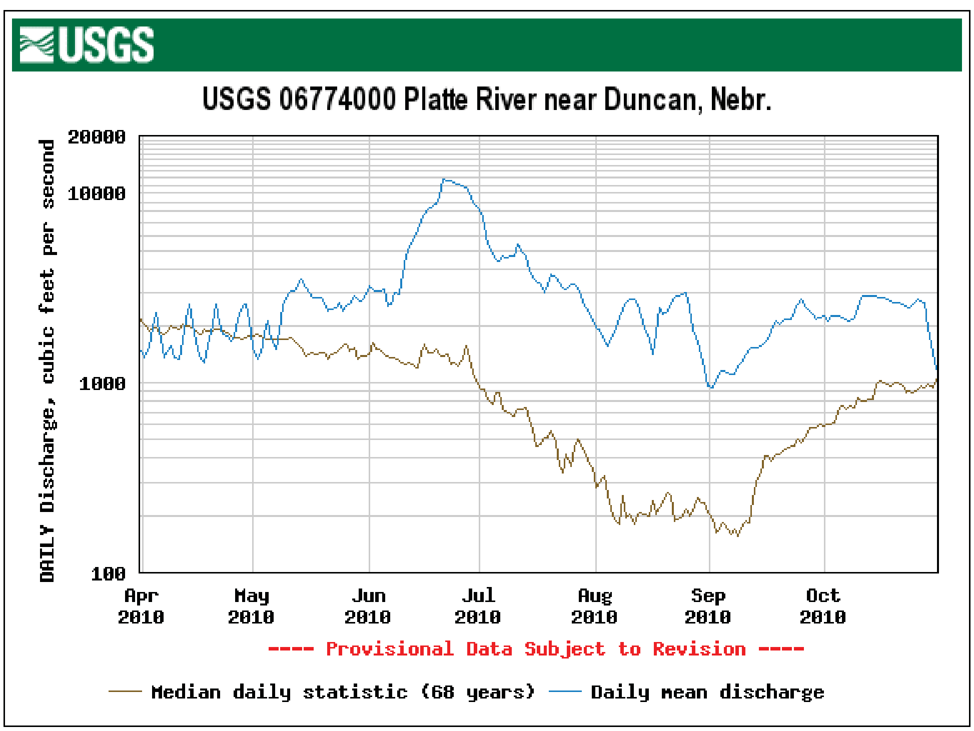


Figure 4-2. Flow on the Platte River near Duncan, Spring, Summer, and Fall 2010

Table 4-2. Cross-Section Data Collection

Location	Data Collection Effort	Cross Section 1	Cross Section 2	Cross Section 3	Cross Section 4	Cross Section 5	Cross Section 6	Cross Section 7	Cross Section 8	Cross Section 9
Site 1 – Upstream of the Diversion Weir	Spring	6/3/2010	6/3/2010	6/3/2010	6/3/2010	6/3/2010	6/3/2010	6/2/2010	6/2/2010	6/2/2010
	Fall	10/5/2010	10/5/2010	10/5/2010	10/5/2010	10/5/2010	10/5/2010	10/5/2010	10/5/2010	10/5/2010
Site 2 – Downstream of the Diversion Weir	Spring	4/15/2010	4/15/2010	4/15/2010	4/15/2010	4/15/2010	4/15/2010	4/15/2010	4/15/2010	4/15/2010
	Summer	8/5/2010	8/5/2010	8/5/2010	8/5/2010	8/5/2010	8/5/2010	8/5/2010	8/5/2010	8/5/2010
	Fall	9/28/2010	9/28/2010	9/28/2010	9/28/2010	9/28/2010	9/28/2010	9/28/2010	9/28/2010	9/28/2010
Site 3 – Upstream of the Tailrace Return	Spring[1]	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010	5/2/2010 or 5/3/2010
	Summer	8/11/2010	8/11/2010	8/11/2010	8/11/2010	8/11/2010	8/11/2010	8/11/2010	8/11/2010	8/11/2010
	Fall	9/29/2010	9/29/2010	9/29/2010	9/29/2010	9/29/2010	9/29/2010	9/29/2010	9/29/2010	9/29/2010

Note:
1 Data were collected on May 2 and May 3, but the exact date when data was collected at each cross-section location is unknown.

Objective 1: To determine the net consumptive losses associated with Project operations compared to the no diversion condition.

4.2 Task 2: Net Consumptive Use

Net consumptive use was evaluated using USGS and NDNR flow and stage data listed in Table 4-1. The following were developed:

- Classification of flow records as wet, dry, and normal years
- Synthetic hydrographs for current operations and the no diversion condition at the gaged and ungaged sites
- Flow duration, volume duration, and flood flow frequency relationships

4.2.1 Classification of Flow Records as Wet, Dry, and Normal Years

During preparation of the District's Pre-Application Document (PAD), dated October 16, 2008, flow depletions on the lower Platte River associated with the Loup Power Canal were estimated through development of an annual water budget. Incremental and cumulative water budgets were developed for the Loup Power Canal using the Loup Power Canal near Genoa gage, power generation records at the Columbus Powerhouse, and the Tailrace Canal at Columbus gage (8th Street bridge). This task of the flow depletion and flow diversion study built on the flow depletion calculations described in the PAD by calculating daily, monthly, seasonal, and annual net consumptive use for a typical wet year, dry year, and normal year. The District's Revised Study Plan, dated July 27, 2009, indicated that the consumptive use analysis would be calculated for years 1980 through 2009. Those years were initially selected to ensure that wet, dry, and normal cycles were included. However, a review of the available atmospheric data showed inconsistencies between the gages for that time period (such as monthly versus daily data). In addition, as directed in FERC's Study Plan Determination, sedimentation and habitat evaluations were conducted for a typical wet, dry, and normal year. There were consistent daily atmospheric data between gages for the typical wet, dry, and normal years used for this study, which are listed in the following paragraph. Therefore, due to data availability, data consistency, and comparison with other studies (such as habitat), evaluating for a typical wet, dry, and normal year was considered representative and reasonable for this analysis.

Each year for the period of record was classified as wet, dry, or normal for both the gaged and ungaged sites based on an approach developed by Anderson and Rodney (October 2006). This included the study period from 2003 to 2009, which was the period during which the Tailrace Canal at Columbus gage (8th Street bridge) has been in operation. This gage measures Loup Power Canal return flows. This approach ranks the mean annual discharge in descending order. The highest 33 percent of the mean annual flows recorded during the study period were classified as wet years. The lowest 25 percent of the mean annual flows recorded during the study period were classified as dry years. The remaining flows were classified as normal years.

The mean annual discharge at each gaged site for the gage's period of record was obtained from USGS and NDNR. The mean annual discharge at each ungaged site was calculated by adding the mean annual discharges from the closest gaged sites. For example, the mean annual discharge for Site 3, upstream of the Tailrace Return, was computed by adding the mean annual discharge for the Platte River near Duncan, Beaver Creek at Genoa, and the Loup River near Genoa. Because this is a mean annual discharge, no adjustments were made for travel time or reach gain/loss (RGL). Additionally, the wet, dry, and normal year analysis is the same for current operations and for the no diversion condition. This allowed for relative assessments of current operations and the no diversion condition for years representing all three flow classifications.

The results of the wet, dry, and normal year analysis at each gaged site for the period of record are shown in Attachment B. The results of the wet, dry, and normal year analysis at each gaged and ungaged site for the years 2003 to 2009 are shown in Table 4-3. In some instances, a year was very near the threshold between classifications. In order to have each classification represented between 2003 and 2009, that year may have been placed in the next classification. For example, year 2005 at Site 2, downstream of the Diversion Weir, had a ranking of 32.8, which is one position from being classified as normal. Similarly, year 2006 at Site 2 had a ranking of 71.64, which is two positions from being classified as dry. For the Loup River basin (Loup River near Genoa and Loup Power Canal near Genoa flows), years 2005 and 2006 were well-seated in the normal and dry classification, respectively Therefore, years 2005 and 2006 at Site 2 were considered normal and dry, respectively, for purposes of this analysis.

Net consumptive use was calculated for the Loup Power Canal and the Loup River bypass reach for current operations and for the no diversion condition. No diversion was defined as no water being diverted into the Project but does not represent a case of Project decommissioning. Consumptive use losses were calculated by adding open-water evaporative losses and ET losses from riparian vegetation, consistent with methodology outlined in USFWS (May 15, 2002) for calculating evaporation and ET. As stated in Section 1, Introduction, groundwater seepage eventually returns to the Loup River or the lower Platte River; though slightly time lagged, these flows are not removed from the system and therefore are not considered consumptive losses. This assumption is supported by the 10/50 line analysis conducted by NDNR (December 18, 2009) for hydraulically connected areas in the lower Platte River Basin. NDNR considers the area within which groundwater is hydrologically connected to a stream to be that area in which the 10/50 line shows the boundary that results when "pumping of a well for 50 years will deplete a river or base flow tributary thereof by at least 10% of the amount pumped in that time" (that is, the10/50 area) (NDNR, December 18, 2009).

Table 4-3. Calendar Year Flow Classification and Ranking at Each Gaged and Ungaged Site, 2003 through 2009

Calendar Year	Platte River near Duncan		Site 2 – Downstream of the Diversion Weir; Loup River near Genoa		Loup Power Canal near Genoa		Site 1 – Upstream of the Diversion Weir; Loup River near Genoa + Loup Power Canal near Genoa		Site 3 – Platte River Upstream of the Tailrace Return	
	Flow Classification	Ranking	Flow Classification	Ranking	Flow Classification	Ranking	Flow Classification	Ranking	Flow Classification	Ranking
2003	Dry	94.20	Normal	73.13	Dry	78.08	Dry	82.09	Dry	94.03
2004	Dry	98.55	Normal	41.79	Dry	91.78	Dry	74.63	Dry	91.04
2005	Dry	89.86	Wet[1]	32.84	Normal	68.49	Normal	50.75	Dry	76.12
2006	Dry	97.10	Normal[2]	71.64	Dry	84.93	Dry	83.58	Dry	95.52
2007	Normal	49.28	Wet	16.42	Wet	27.40	Wet	14.93	Normal	34.33
2008	Normal	37.68	Wet	5.97	Wet	28.77	Wet	8.96	Wet	22.39
2009	Normal	50.72	Wet	28.36	Wet	1.37	Wet	11.94	Normal	44.78

Notes:

1 The flow classification for 2005 is one position away from being classified as normal, which is consistent with the Loup River basin for 2005. Therefore, for purposes of this analysis, 2005 was considered as a normal year.

2 The flow classification for 2006 is two positions away from being classified as dry, which is consistent with the Loup River basin for 2006. Therefore, for purposes of this analysis, 2006 was considered as a dry year.

4.2.2 Synthetic Hydrographs

Synthetic hydrographs for the gaged and ungaged sites were developed and plotted for current operations and the no diversion condition for wet, dry, and normal flow years from 2003 to 2009. Reach gain/loss (RGL) (evaporation, ET, and seepage) from the nearest gage or gages to each ungaged site was estimated based on monthly averages from 1985 to 2009. The methodology used to develop and validate the synthetic hydrographs at the ungaged sites for current operations, and at the gaged and ungaged sites for the no diversion condition, followed the same process as outlined in the Second Initial Study Report, Appendix B, Hydrocycling Study Report, Section 4.2.

The methodology applied in the Loup River bypass reach was verified for water year 2009 by comparing the calculated daily synthetic hydrograph at Columbus with the NDNR 2009 gage data for the Loup River at Columbus. In addition, the synthetic hydrograph was compared with the values provided by USFWS regression equations. The USFWS equations are linear regression equations (by month) that estimate Columbus flows based on measured Genoa data.

It was found that the synthetic hydrograph was consistent with both the USFWS regression equations and the NDNR gage at Columbus. Some discrepancies were noted between the synthetic and NDNR gage data during ice-affected flows when the NDNR gage record indicated that the flow was "estimated." Synthesized versus gaged annual (water year) volumes were also used as verification at the various locations on both the Loup River bypass reach and the lower Platte River.

Figure 4-3, located at the end of this section, illustrates the comparison of the synthetic hydrograph, NDNR gage data, and USFWS regression equations at Columbus for water year 2009. The following were revealed:

- The synthetic hydrograph predicted the annual volume for water year 2009 within 5 percent (±) of the USFWS regression equations.
- The synthetic hydrograph and the USFWS regression equations were 20 and 15 percent higher, respectively, than the annual volumes for the 2009 historic gage data. This is likely attributed to the fact that the Columbus gage record for water year 2009 contains 81 days (approximately 22 percent) of "estimated" flow values.

A root mean square error (RMSE) analysis was performed to compare the daily flows from the synthetic hydrograph using the calculated RGL to the corresponding values using the USFWS regression equations. The RMSE for the RGL analysis compared favorably with the RMSE for the USFWS regression when comparing both methodologies with the 2009 historical NDNR gage data.

A similar verification of the method's ability to predict downstream flows by combining upstream gage data with RGL data was used for the Platte River synthetic hydrographs at North Bend. Figure 4-4 illustrates a comparison of the historic gage and calculated synthetic hydrographs at North Bend for water years 2003 to 2009. The following were noted:

- On average, for water years 2003 to 2009, the RGL analysis was within 2 percent of the historically gaged volumes at North Bend.
- The RGL analysis varied from -5 percent in water year 2008 to +11 percent in water year 2009 when compared to the historical gaged volume at North Bend.

The verification process incorporated for this flow depletion and flow diversion study revealed good agreement between synthetic and measured hydrographs. Therefore, the synthetic hydrographs at the ungaged sites for current operations were adopted for this study. In addition, based on the verification of the synthetic hydrographs at the gaged sites, the synthetic hydrographs for the no diversion condition at the gaged and ungaged sites were adopted. The synthetic hydrographs for the gaged and ungaged sites are shown in Attachment C.

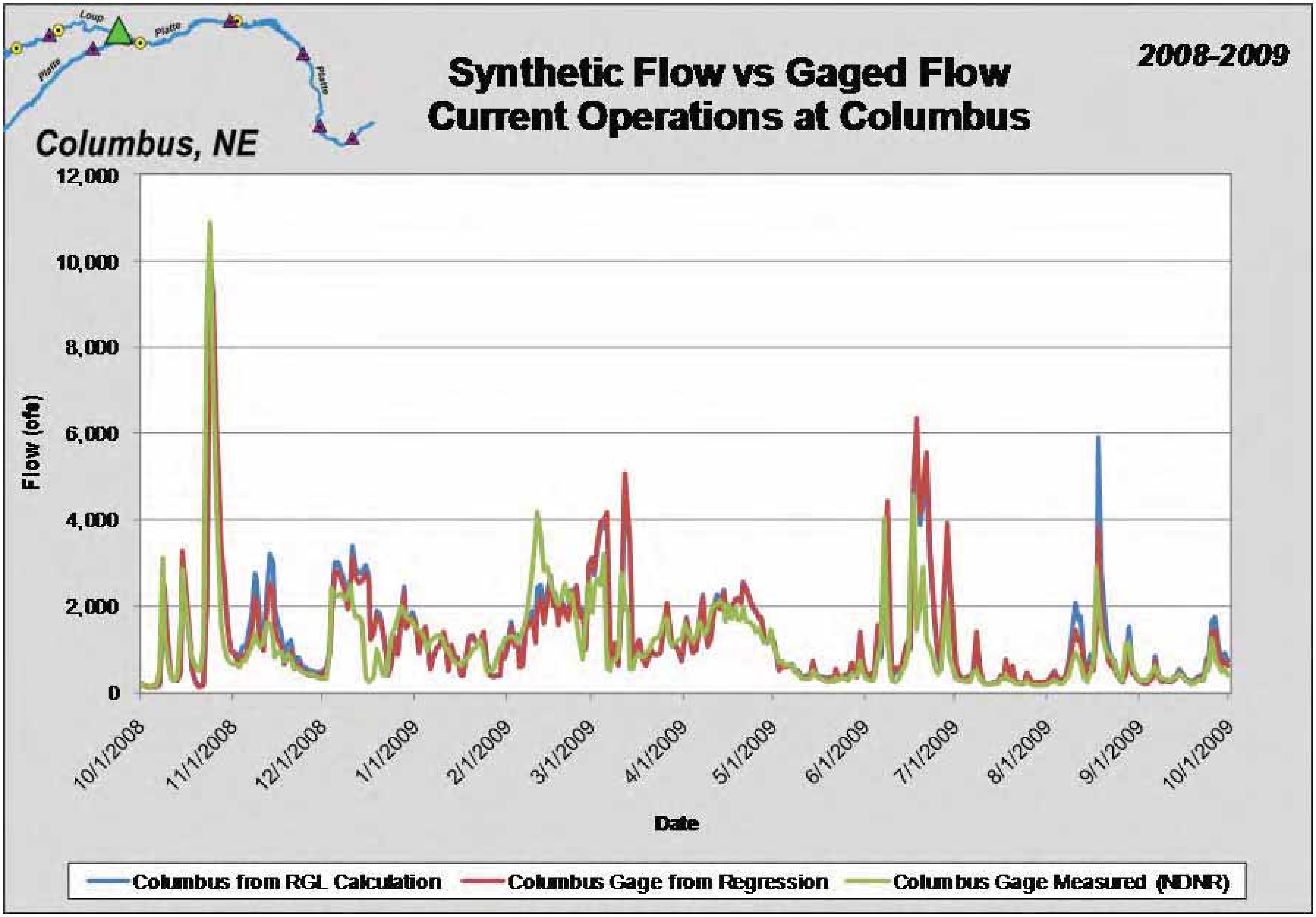


Figure 4-3. Comparison of Synthetic Hydrographs, NDNR Gage Data, and USFWS Regression Equations at Columbus, Water Year 2009

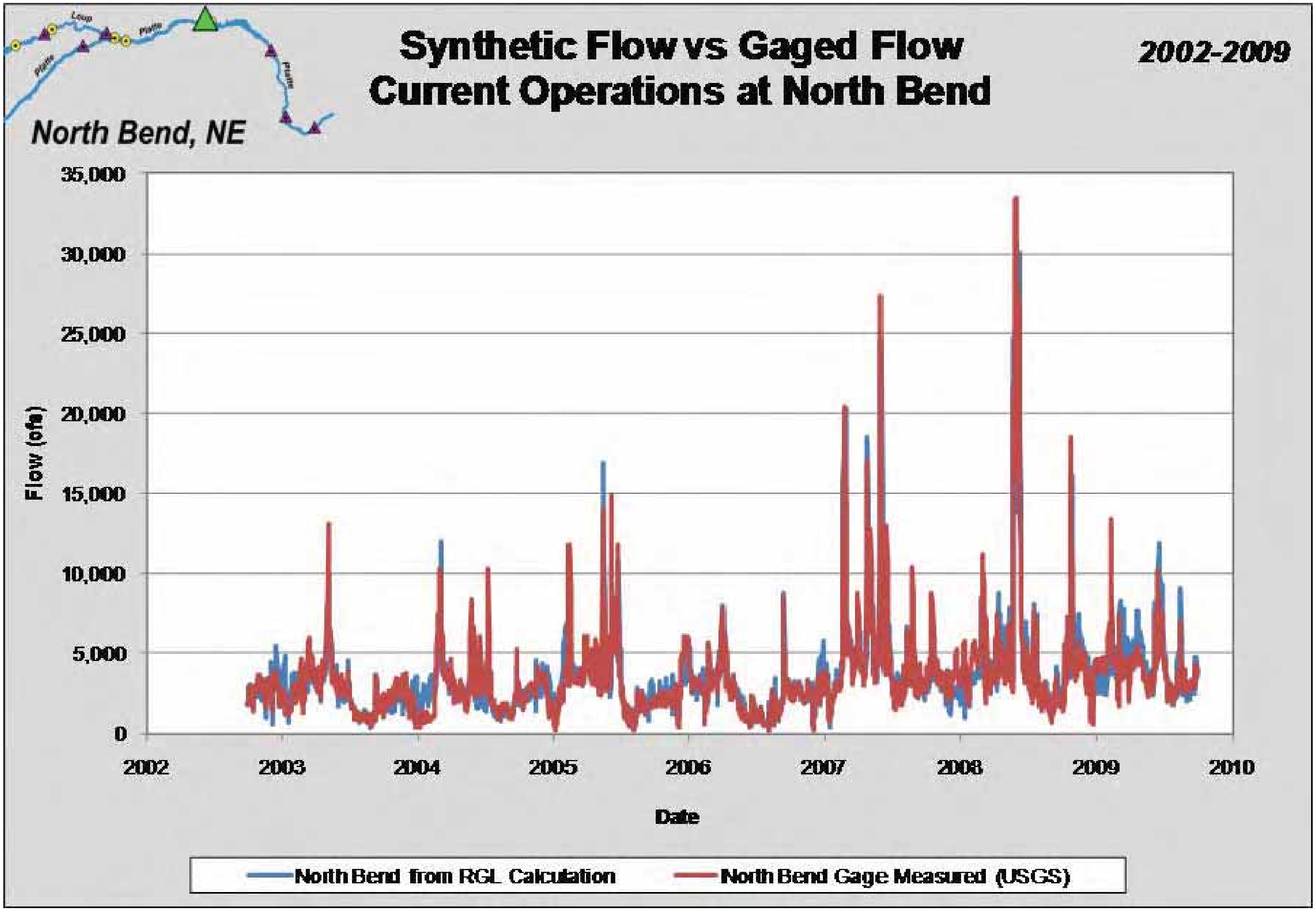


Figure 4-4. Comparison of the Historic Gage and Calculated Synthetic Hydrographs at North Bend, Water Years 2003 to 2009

4.2.3 Consumptive Use in the Loup Power Canal and Associated Regulating Reservoirs

Consumptive use in the Loup Power Canal and associated regulating reservoirs was calculated on a monthly, seasonal, and annual basis by adding the evaporation and ET consumptive use losses. This was completed for both current operations and the no diversion condition.

Open-water evaporative losses for the Loup Power Canal and regulating reservoirs were estimated by using the total surface area exposed to the atmosphere and a relationship of lake to pan evaporation data collected from the NWS stations. Surface area was calculated from the canal channel width, normal maximum operating depth, and canal length based on District design drawings. The regulating reservoir areas were based on District design drawings and O&M manuals.

Daily pan evaporation values for 2005 (a normal year), 2006 (a dry year), and 2008 (a wet year) were obtained from the NWS Class A Pan stations at the Grand Island Airport and at Valley for the summer months of May, June, July, August, and September. If no data were collected on a particular day during these summer months, the daily evaporation value was calculated as the average of the surrounding days. The NWS stations at the Grand Island Airport and at Valley do not collect winter evaporation data. Daily evaporation values for the winter months (January, February, March, April, October, November, and December) were determined using the historic monthly average evaporation divided by days per month. The historic monthly evaporation data is the average evaporation per month based on monthly evaporation for the period of 1954 to 2000, obtained from USFWS (May 15, 2002).

Because the Loup Power Canal and regulating reservoirs are relatively deep, use of the standard 0.7 pan coefficient for lake evaporation was adopted, which was also used by USFWS (May 15, 2002) for the Platte River. The relationship approximates lake evaporation as 70 percent of measured pan evaporation. Because of variability of pan coefficients during any calendar year, they are normally applied seasonally, generally by month, to estimate evaporation from any lake or stream. Lake evaporation coefficients tend to range in value from 0.65 to 0.85 (U.S. Department of Commerce, 1968). The coefficient is higher under humid conditions and lower under arid or dry conditions. A coefficient of 0.7 is considered most applicable when water and air temperatures are approximately equal. For the Loup Power Canal and Lake North, a lake coefficient of 0.7 was applied to the pan evaporation rates. Due to the shallow nature of Lake Babcock, no lake coefficient was applied, as discussed in Section 4.2.4.

Daily ET was determined based on the relationship between lake evaporation and ET used by USFWS (May 15, 2002). For estimates of ET loss rates from vegetated areas, an additional factor of 0.5 was applied to estimate ET rates during the winter season (October through April) and 0.8 was applied to estimate ET rates during the growing season (May through September). The relationship was weighted seasonally, as shown in Table 4-4.

Table 4-4. Seasonal Lake Evaporation to ET Relationships

Season (Months)	ET to Lake Evaporation Ratio
Winter Season (October through April)	0.5
Growing Season (May through September)	0.8

The area contributing to ET was determined using the methodology detailed by USFWS (May 15, 2002). This approach assumes that the effective ET area is the riparian vegetative area within 100 feet of the source, in this case the Loup Power Canal or regulating reservoirs. For this flow depletion and flow diversion study, aerial photographs (USDA Farm Service Agency, Aerial Photography Field Office, 2006) were used to calculate the vegetated riparian area within 100 feet of the canal. Figure 4-5 shows a representative area of the 100-foot riparian vegetated buffer along a section of the Loup Power Canal.

4.2.4 Consumptive Use in the Loup River Bypass Reach

Consumptive use in the Loup River bypass reach was calculated on a daily, monthly, seasonal, and annual basis by adding the evaporation and ET consumptive use losses. This was completed for both current operations and the no diversion condition. Only two entities hold small surface water rights along the Loup River bypass reach. The impacts from these diversions are considered negligible and were not incorporated.

Monthly open-water evaporative losses for the Loup River bypass reach were estimated by using the surface area and evaporation data collected from the NWS Class A Pan stations. Evaporation pans and associated pan coefficients were developed for use in estimating deep lake or reservoir evaporation, and pan coefficients used for deep lakes should not be assumed to apply in estimating evaporation from open water areas of shallow lakes or flowing streams. Flowing rivers, especially braided rivers, have relatively shallow depths, so transferring pan coefficients for estimating lake evaporation into river settings does not recognize the differences in physical processes governing evaporation from the two sources.

When evaporation pan data is used for estimating river evaporation, the literature supports estimates of flowing river evaporation rates as high as the magnitudes of the Class A pan values (for example, McKenzie and Craig, 2001). Jensen (2010) provides detailed descriptions of methods for estimating evaporation from shallow water bodies. The method used by USFWS (May 15, 2002) for the Platte River was to treat flowing river evaporation the same as lake evaporation. Lake evaporation provides reasonable estimates of evaporation from the Loup Power Canal, but water depth in the Loup River bypass reach is considerably shallower and is not physically similar to a lake. Pan evaporation rates were used to determine the open-water evaporation of the Loup River bypass reach. As stated above, the literature would suggest applying no pan coefficient for shallow-water rivers. However, for purposes of this flow depletion and flow diversion study, a coefficient of 0.9 was applied to the pan evaporation rate to determine Loup River bypass reach evaporation. This value seemed reasonable in that it was lower than the pan evaporation rate, yet higher than the lake coefficient of 0.7. Consistent with USFWS methodology (May 15, 2002), ET rates for the Loup River bypass reach were developed using a seasonal factor and lake coefficient applied to the pan evaporation rates.

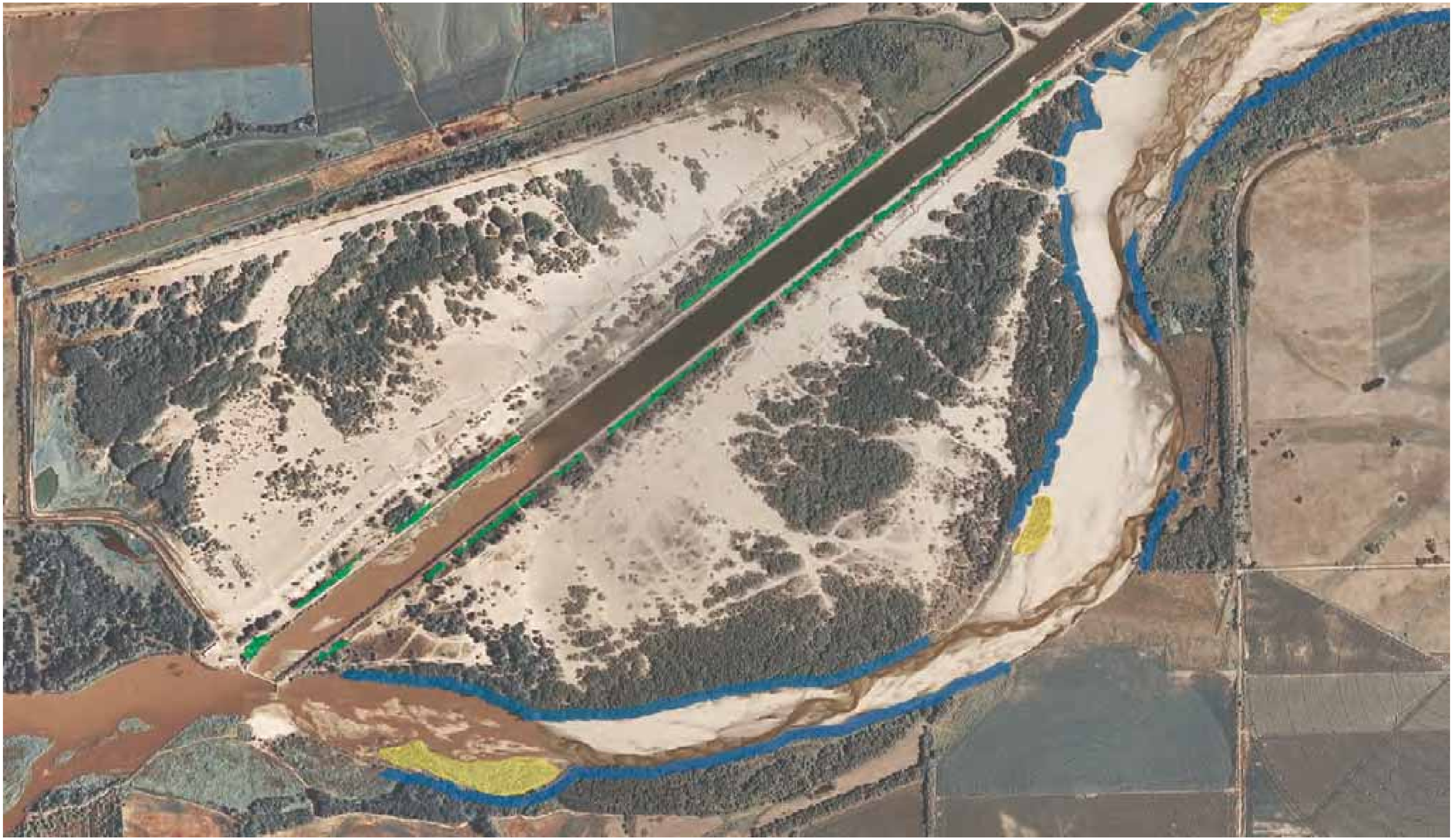
Surface area for calculation of open-water evaporation was obtained from the results of the steady-state one-dimensional (1-D) HEC-RAS computer model of the Loup River bypass reach developed and calibrated by the U.S. Army Corps of Engineers (USACE) Omaha District. The Loup River bypass reach model was executed using the daily discharges for the selected wet, dry, and normal years. Once executed, the resulting surface area between cross sections was summed to establish the surface area for the selected wet, dry, and normal years.

Consumptive losses due to both open-water evaporation and ET were evaluated using the same methodology as for the Loup Power Canal and associated regulating reservoirs, discussed in Section 4.2.1. Figure 4-5 shows a representative area of the 100-foot riparian vegetated buffer along a section of the Loup River bypass reach.

4.2.5 Calculation of Net Consumptive Use

The net consumptive use was estimated by calculating the difference between the consumptive use losses in the Loup Power Canal and regulating reservoirs plus the consumptive use losses in the Loup River bypass reach for current operations, and then compared to loss estimates in the Loup River bypass reach under the no diversion condition. Values were estimated on a monthly, seasonal, and annual basis for the selected wet, dry, and normal years.

As noted in the District's Revised Study Plan, if Project operations result in less flow depletion in the lower Platte River than the no diversion condition, it can be concluded that Project operations do not adversely impact, and may benefit, fisheries and aquatic habitat relative to flow depletions. If Project operations result in an increase in flow depletions as compared to the no diversion condition, then the District will assess implications of the depletions on lower Platte River morphology and will coordinate with the agencies as needed to determine reasonable and prudent alternatives or mitigation.



Aerial Imagery: 2006 National Agriculture Imagery Program (NAIP)

Legend

- Loup Bypass 100 ft Riparian Vegetation
- Loup Power Canal 100 ft Riparian Vegetation
- Island Vegetation

Flow Depletion Study - Riparian Vegetation

Loup River Hydroelectric Project
FERC Project No. 1256
Study 5.0 - Flow Depletion and Flow Diversion

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DATE
Feb. 11, 2011

FIGURE
4-5

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4.2.6 Consumptive Use of Irrigation Water

Consumptive use associated with irrigation water taken out of the Loup Power Canal was also evaluated for current operations as directed by FERC in its Study Plan Determination. The average annual amount of water taken out of the canal was based on the District's meter records. The consumptive use was estimated based on crop irrigation demands versus the amount of water applied. This procedure is standard methodology used by NDNR, detailed in Attachment D. As stated in FERC's Study Plan Determination, irrigation diversions will be allowed to continue as they have historically. Therefore, consumptive irrigation losses were assumed to be the same for both current operations and the no diversion condition.

4.2.7 Consumptive Use of Lost Creek

There are two structures associated with the Tailrace Canal that convey Lost Creek flows (Loup Power District, October 16, 2008). The USACE Lost Creek Flood Control Channel discharges flow into the Tailrace Canal just downstream of the Columbus Powerhouse. Approximately 4.8 miles further downstream, some flow from the Tailrace Canal is discharged into the Lost Creek Siphon to prevent sediment and debris build-up. In effect, the Tailrace Canal acts as a conduit, conveying Lost Creek flows from the Lost Creek Flood Control Channel to the Lost Creek Siphon, where flows are allowed to continue downstream in the natural Lost Creek channel.

As directed in FERC's Study Plan Determination, the consumptive use associated with flows discharged to maintain the Lost Creek Siphon were evaluated. This was done by quantifying and comparing the flows being discharged into and out of the Tailrace Canal by the Lost Creek Flood Control Channel and Lost Creek Siphon, respectively.

Magnitudes of flows entering the Tailrace Canal were estimated using a weir equation for the rectangular, slotted low-flow channel of the Lost Creek Flood Control Channel spillway. The width and depth of the low-flow channel were based on design drawings and field measurements. The typical or normal daily flow depth was based on water markings on the walls of the low-flow channel of the spillway. Storm event runoff would clearly exceed the low-flow channel, passing through the slot as well as over the top of the weir. However, there is no data from which to estimate storm event flows. Therefore, average annual runoff for the Lost Creek basin conveyed by the Lost Creek Flood Control Channel to the Tailrace Canal was estimated using standard Nebraska Soil Conservation Service (now NRCS) engineering manual runoff curves.

The Lost Creek Siphon was constructed with the original Project to convey Lost Creek flows under the Tailrace Canal. Flow is discharged into the Lost Creek Siphon from the Tailrace Canal through a sloping, 24-inch-tall by 45-inch-wide adjustable sluice gate. Flow is conveyed to an open ditch at the upstream end of the Lost Creek Siphon through a 42-foot-long, 24-inch corrugated metal pipe. The flow discharged out of the Tailrace Canal through the sluice gate and 24-inch pipe was estimated for a range of gate openings using HY-8, an industry standard software package used to evaluate culvert pipe flow. The depth of flow in the downstream open ditch entering the Tailrace Canal was based on normal operating depth. The gate openings were based on District records.

Objective 2: To use current and historic USGS gage rating curves to evaluate change in stage in the Loup River bypass reach during Project operations and compare against hydrographs of a no diversion condition.

4.3 Task 3: Flow Duration, Volume Duration, and Flood Flow Frequency Relationships

Flow duration, volume duration, and flood flow frequency analyses for current operations and the no diversion condition were performed for the gaged and ungaged sites using the USACE HEC-SSP software package. Model inputs, including the period of record analyzed, mean skew, station skew, and adopted skew for each gage, are provided in Attachment E. Computed model results are also listed by gage in Attachment E. Flow duration analyses were performed using spreadsheets for the wet, dry, and normal years for the ungaged sites, with results also included in Attachment E.

4.4 Task 4: Stage

The stage in the Loup River bypass reach at Genoa and Columbus was evaluated using current and historic USGS rating curves and the results from Task 3, Flow Duration, Volume Duration, and Flood Flow Frequency Relationships. The stage for current operations was compared with the stage for the no diversion condition to obtain change in stage for the 25 (high-flow), 50 (medium-flow), and 75 (low-flow) percent exceedance flows for a typical wet, dry, and normal year. The District's Revised Study Plan, dated July 27, 2009, stated that the period from 1980 to 2009 would be used for the analysis. Those years were initially selected to ensure that wet, dry, and normal cycles were included. However, for comparison with other studies (such as habitat), evaluating for any wet, dry, and normal year was considered representative and reasonable for this analysis. If the stages for current operations are not materially different from stages under the no diversion condition, then it can be concluded that Project operations do not impact stage in the Loup River bypass reach. If the current operations stage is materially different from the no diversion condition stage, then the District will assess implications to the species of the magnitudes and frequencies of the stage changes on the Loup River bypass reach and will coordinate with the agencies as needed to determine reasonable and prudent alternatives or mitigation.

Objective 3: To evaluate historic flow trends on the Loup and Platte rivers since Project inception.

4.5 Task 5: Loup River and Platte River Depletions

Historic flow records and long-term streamflow studies by other investigators as well as additional analyses by the District were combined to determine the general flow trend (increasing, decreasing, or relatively constant) in the Loup and Platte rivers.

USGS gages on the Loup River near Genoa and at Columbus and USGS gages on the Platte River near Duncan, at North Bend, and at Louisville were evaluated. In addition to the 25-year analyses of 1985 to 2009 flow trends reported in the Initial Study Report, Appendix A, Sedimentation Study Report, two USGS reports (Ginting, Zelt, and Linard, 2008; Dietsch, Godberson, and Steele, 2009) were used to assess longer-term flow changes in the Platte River. This information was used as the baseline to evaluate Project-related effects.

Objective 4: To determine the extent of interior least tern and piping plover nesting on the Loup River above and below the Diversion Weir.

4.6 Task 6: Interior Least Tern and Piping Plover Nesting on the Loup River Bypass Reach

4.6.1 Nesting Data Comparison

Existing information on interior least tern and piping plover nesting on the Loup River both above and below the Diversion Weir was collected from the NGPC Nongame Bird Program's Nebraska Least Tern and Piping Plover database. Both on- and off-river nest count data were received for the years 1983 to 2006.[4] Recorded nest occurrences on the Loup River, based on Public Land Survey System (PLSS) and latitude and longitude locations, were plotted using ArcGIS. Highest nest counts (from a single visit) above the Diversion Weir were compared to highest nest counts (from a single visit) below the Diversion Weir to the confluence of the Tailrace Return to determine if significant differences exist. If there is no significant difference in nesting occurrence numbers above and below the Diversion Weir, then the assumption could be made that the natural nesting conditions above and below the Diversion Weir are similar and that Project operations are not affecting habitat availability in the Loup River bypass reach. However, the comparison of nesting occurrences of interior least terns and piping plovers above and below the Diversion Weir yielded inconclusive results (see Section 5.5.1 for more information). Therefore, an aerial imagery review and a habitat evaluation consisting of a review of

[4] Data were received for this range of years; however, some years within this range did not have survey information for on-river sites because the Loup River was not surveyed.

potential habitat parameters using HEC-RAS modeling were conducted to determine if Project operations have an effect on potential habitat in the Loup River bypass reach, as described in Sections 4.6.2 and 4.6.3, respectively.

4.6.2 Aerial Imagery Review

When significant differences in nesting occurrences above and below the Diversion Weir existed (or when the analysis was inconclusive), an aerial imagery review of the Loup River above and below the Diversion Weir was conducted. Prior to the aerial imagery review, a literature review was conducted to identify potential habitat parameters for interior least terns and piping plovers. The parameters listed in Table 4-5 are habitat measurements identified at interior least tern and piping plover nesting sites on Nebraska rivers.

Table 4-5. Habitat Characteristics Noted at Nebraska Riverine Nest Sites for Interior Least Tern and Piping Plover

Habitat Parameter	Observed Measurements of Habitat Parameters	References
Channel width (bank to bank)	975 to 1,554 feet	Ziewitz et al., 1992; Kirsch, 1996; Brown and Jorgensen, 2009
Dry sand area	0.03 to 3.58 acres	Ziewitz et al., 1992; Kirsch, 1996; Brown and Jorgensen, 2009
Vegetation cover on dry sand area (percent)	0 to 25%	Ducey, 1988; Faanes, 1983; Ziewitz et al., 1992
Average location of sandbars (point or mid-channel)	Mid-channel	Kirsch, 1996
Valley width	0.68 to 4.72 miles	Elliott et al., 2009

NAIP color aerial imagery of five randomly selected river miles in the Loup River within approximately 35 river miles upstream of the Diversion Weir as well as five randomly selected river miles in the Loup River bypass reach within approximately 35 river miles downstream of the Diversion Weir was examined to identify and compare the following potential habitat parameters:

- Number of sandbars per river mile
- Average area of sandbars per river mile
- Average wetted width per river mile
- Average channel width per river mile
- Average valley width per river mile

- Percentage of vegetation on sandbars
- Percentage of mid-channel sandbars per river mile
- Percentage of point sandbars per river mile
- Percentage of bare sand per river mile
- Average area of bare sand per river mile
- Average area of shallow water/wet sand[5] per river mile
- Percentage of shallow water/wet sand areas

To calculate the average channel width, transects were established at intervals of 100 feet throughout the river mile, and measurements were taken from primary bank to primary bank (using permanent vegetation as an indicator of primary bank lines). Sandbars and islands that are located within the primary banks were included in the channel width calculation. Average wetted width was calculated using the same transects as the channel width calculations and extracting the pixels classified as water. This area was then measured in linear feet from edge of water to edge of water to gain wetted widths. Wetted width lengths were then averaged for each river mile.

In addition, the valley width was calculated. USGS conducted a study on the Platte River that included a measurement of valley width (Elliott et al., 2009). Therefore, USGS shapefiles were obtained. These files calculated valley width on the lower Platte River from the Missouri River confluence upstream to river mile (RM) 138.5. According to the USGS files, the Loup River from its confluence with the Platte River and upstream to the Diversion Weir is located within the Platte River valley. Using the USGS shapefiles as a baseline, the walls of the Platte River valley upstream of RM 138.5 to RM 187 on the Platte River were digitized using regional geologic maps, digital elevation models, and 1:24,000 USGS topographic maps to identify consistent slope break. The Loup River upstream of the Diversion Weir to the confluence of the North Loup River was identified within the Platte River valley. Upstream of the North Loup River, the Loup River begins to form its own valley and is no longer part of the Platte River valley. Therefore, because the Loup River within the study area is located within the Platte River valley, transects along the Platte River channel were established at intervals of 0.25 mile (1,320 feet) to calculate valley width. These transects were then compared to the selected river miles on the Loup River to calculate an average valley width for the selected study sites.

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5 The classifications of shallow water and wet sand could not be separated because pixel coloration for these two features was very similar and difficult to classify. Depth of the water could not be determined from the aerial interpretation; therefore, water with a darker pixel shade was classified as deep water, and water or sand with a lighter pixel shade was classified as shallow water/wet sand.

Method for Selecting River Miles

The 10 river miles of the Loup River (five locations upstream and five locations downstream of the Diversion Weir) to be investigated as part of this flow depletion and flow diversion study were randomly selected from the Loup River reach extending from RM 1 near Columbus to RM 69 near Cushing, Nebraska. In particular, locations within 5 miles upstream and downstream of the Diversion Weir were desired. In order to have a representation of the Loup River in close proximity to the Diversion Weir, one location was selected randomly from RMs 31 to 35 (downstream of the Diversion Weir) and one was randomly selected from RMs 36 to 40 (upstream of the Diversion Weir). The other river miles for study were then randomly selected from RMs 1 to 30 and 41to 69, for downstream and upstream of the Diversion Weir, respectively. River miles were randomly selected to avoid bias in the analysis. Although locations of revetment (bank protection), tributaries, and adjacent land use may affect river morphology and riverine habitat, the intent was to have unbiased representation of the river characteristics.

Random numbers were derived from a random integer generator (Haahr, 2011). The following river miles were randomly selected:

- Loup River downstream of the Diversion Weir (that is, the Loup River bypass reach) (RMs 1 to 35) – 5 to 6, 7 to 8, 13 to 14, 26 to 27, and 32 to 33
- Loup River upstream of the Diversion Weir (RMs 36 to 69) – 38 to 39, 49 to 50, 54 to 55, 60 to 61, and 65 to 66

Method for Selecting Years of Aerial Imagery

Potential parameters for interior least tern and piping plover nesting habitat were quantified using NAIP color aerial imagery. The imagery for Nance and Platte counties for 2003 through 2010 is available from NRCS. All data derived from orthophotography have the horizontal datum North American Datum, 1983 (NAD83). The projection used for all data associated with this flow depletion and flow diversion study report is Universal Transverse Mercator Zone 14, Meters (UTM 14). Because NAIP imagery was used, the aerial photographs were not captured on the same date each year; however, all photographs for each year were taken within 30 days of the other photographs in that dataset. Most photographs were recorded during late June and July, with a few outliers in August; however, most photographs were taken within the accepted nesting season for interior least terns and piping plovers (late April to early August).

Mean annual discharge on the Loup River near Genoa was evaluated using the methodology discussed in Section 4.2 to classify each year of the study period (2003 to 2009) as wet, dry, or normal. Based on the evaluation for the Loup River bypass reach at Genoa alone, 2003 fell near the lowest 25 percent of flows (dry) but was classified as normal, 2004 was classified as normal, 2005 fell just within the highest 33 percent of flows and was classified as wet, 2006 was classified as normal, and

2007 through 2009 fell within the highest 33 percent of flows and were classified as wet. For the Loup River upstream of the Diversion Weir, the classification of wet, dry, and normal years varied slightly from conditions in the Loup River bypass reach. Upstream of the Diversion Weir, the years 2003, 2004, and 2006 were considered dry, 2005 was considered normal, and 2007 through 2009 were considered wet.

As discussed in a data gathering meeting with USFWS and NGPC on January 5, 2010, this evaluation was to include 5 years of aerial photography with a representative sample of wet, dry, and normal years. A representative sample for evaluation was determined to be one wet year, one dry year, and three normal years based on the 1985 Food Security Act and Section 404 of the Clean Water Act methodology for determining a representative sample when mapping wetlands (Iowa Department of Natural Resources et al., January 20, 1995). The years classified as wet were 2007, 2008, and 2009 for both upstream and downstream of the Diversion Weir. Because only one wet year was needed for review and three were available, the wet year was chosen randomly from the available years through use of a random number generator (Haahr, 2011). Based on the random number generation, 2009 was chosen as the evaluated wet year.

For the purposes of this analysis, within the remaining four years, three of the years needed to be classified as normal and one needed to be classified as dry. Based on the evaluation for the Loup River bypass reach at Genoa alone, no year was classified as dry. Years 2003 and 2006, while both classified as normal, were ranked two and three positions away from the dry classification, respectively. Because 2003 was one position closer to being classified as a dry year than 2006, 2003 was classified as a dry year for the purposes of this analysis.

Of the three remaining years, 2004, 2005, and 2006, all were classified as normal years for the purposes of this analysis. 2004 is classified as normal in the Loup River bypass reach at Genoa and is one position away from being classified as normal upstream of the Diversion Weir; therefore, it was determined that using 2004 as a normal year was appropriate for this analysis. 2005 is the last ranked wet year Loup River bypass reach at Genoa and is well seated in the normal classification upstream of the Diversion Weir; therefore, it was determined that using 2005 as a normal year was appropriate for this analysis. Though 2006 is classified as a normal year in the Loup River bypass reach at Genoa, it is classified as a dry year upstream of the Diversion Weir. However, since the methodology required the use of three normal years, and 2006 at the Loup River bypass reach at Genoa is classified as normal, it was determined that using 2006 as a normal year was acceptable for this analysis.

Therefore, the following years of NAIP color aerial imagery were analyzed for the associated habitat characteristics: 2003 (dry), 2004 (normal), 2005 (normal), 2006 (normal), and 2009 (wet).

Method for Identifying Habitat Parameters on Aerial Images

Prior to conducting the aerial imagery analysis, a field visit was conducted for all river miles selected. River miles upstream of the Diversion Weir were visited on June 28, 2010, and river miles downstream of the Diversion Weir were visited on June 29, 2010. Using 2009 aerial imagery, color signatures were verified as certain features, such as dry sand, rock riprap, trees, shrubs, and emergent vegetation.

All reviewed aerial images included areas within the normal high banks of the river, as determined through associated bank vegetation. The area of interpretation for each river mile was derived by using the National Hydrography Dataset (NHD) area polygon for the Loup River (USGS, November 17, 2006), which was then buffered by a distance of 100 feet to capture land forms adjacent to the river.

To help conduct an unbiased aerial interpretation of features within the river banks, a hybrid method consisting of unsupervised classification with visual interpretation for each river mile was used. The NAIP imagery selected for each of the river miles previously discussed was first cropped to reduce the file size and area of interpretation using GeoExpress V6.1 image processing software. The cropped NAIP imagery was then converted from the native compressed Mr. Sid file format (.sid) to an uncompressed ERDAS Imagine file format (.img) to make it compatible with the ERDAS Imagine software. The new image files (.img) were then imported into ERDAS Imagine, where an unsupervised classification using an isodata algorithm was performed. Unsupervised classification creates natural groupings or clusters of pixels based on the image pixel values. Using this method, it is assumed that pixels of similar value represent the same cover type. Each image file was classified into 15 classes. The reclassified images (raster files) were then cropped to the area of interpretation boundaries and converted to polygons (vector files) using ArcGIS software. The results of the image classification were mixed. Flat and somewhat smooth features such as areas of bare sand, wet sand, and in some cases water, were accurately defined based on pixel cluster location and visual inspection of the imagery. Rough features such as vegetation and choppy water were poorly defined and difficult to classify based on pixel cluster location and visual inspection of the imagery. As a result of the image processing, only pixel clusters representing bare sand and shallow water/wet sand cover types were carried forward in the aerial interpretation process. Therefore, visual interpretation was necessary to classify other land features.

The second part of the aerial interpretation process consisted of visually identifying and digitizing areas of emergent, scrub shrub, and forested vegetation strata, and water features. The majority of this process was aided by previous field verification of land cover types throughout all of the areas of interpretation. The visual aerial interpretation and image processing results were combined to form the final aerial interpretation. Areas of bare sand and shallow water/wet sand were further classified based on location.

Potentially usable nesting substrate, specifically areas of bare sand with less than 25 percent vegetative cover within the typical high banks of the river (Ziewitz et al., 1992), was identified and quantified using the image classification process. Polygons were created around areas that would typically be considered macroforms with large areas of bare sand and, for the purposes of this study, were classified as sandbars. The numbers and average size of these sandbars, total area of sand in the image, channel width, percentage of the sandbar covered by vegetation, and location of the sandbars in relation to the river banks were quantified from the aerial images. Channel banks were digitized using the permanent vegetation boundary and/or rock riprap areas. Digitized bank lines were used to calculate channel width between high banks.

Although determining which pixel shades would represent bare sand is fairly subjective, interpretations are likely consistent because all selected river miles and transects were visited by airboat and pixel shades were verified on current aerial imagery. The locations of the bare sand areas were classified as either point bar or mid-channel. Point bar classification was assigned to images where greater than 75 percent of the sand in the image was connected to the river bank. Mid-channel classification was assigned to images where greater than 75 percent of the sand in the image was completely surrounded by water. No attempt was made to define a "sandbar" because size and connectivity of sand areas change greatly with different river flows (Kirsch, 1996). Areas of bare sand are not necessarily sandbars but are areas of sandbars that are relatively bare and dry. No attempt was made to define the suitability of the identified sandbars for interior least tern and piping plover habitat because habitat is not constant for these species and the species respond to what is available, thus making the habitat for these species a changing entity and difficult to define.

Polygons were created around areas of perennial vegetation, and the average percentage of each river mile covered by perennial vegetation was calculated. All unclassified areas in the images were classified as either shallow water/wet sand or deeper water, depending on pixel shades. Areas of shallow water/wet sand were also quantified in relation to potential roosting habitat parameters for whooping cranes.

4.6.3 Habitat Evaluation Using HEC-RAS Model

In addition to the aerial interpretation, a steady-state 1-D HEC-RAS model was developed to evaluate habitat as directed in FERC's Study Plan Determination. Separate models for each data-collection period were developed for Sites 1 and 2, upstream and downstream of the Diversion Weir, respectively. Topographic and water surface elevation data collected in Task 1 were used to develop and calibrate the hydraulic models. The cross-section locations for each of the modeled sites are shown in Attachment A. Water surface elevations were obtained at the left and right banks as well as at any mid-channel island or sandbar. Hydraulic models were developed for each site for each survey period; for example, two models were developed for Site 1: one based on data obtained in June and one based on data obtained in October.

Once developed, the models were executed using the location-specific synthetic flow rates for the day or days on which the survey occurred. Table 4-6 lists the discharges for the survey dates at each modeled location. For example, the Site 1 cross sections were surveyed between June 2 and 3, 2010, when minimum flows ranged from 1,980 to 3,235 cfs. A synthetic hydrograph was developed for the same two days based on sub-daily gage data at the gaged sites. The water surface profiles for the synthetic minimum, mean, and maximum discharge computed results were compared to the measured profiles for those days. The Manning's "n" value was adjusted until a "best fit" to the measured water surface profile in each reach was obtained. An exact fit to the observed data using a 1-D model for a braided system using a synthetic hydrograph is unlikely. However, a reasonable fit was obtained for each modeled location using a Manning's "n" value of 0.027. This value is consistent with other studies on the lower Platte River, including the Lower Platte River Stage Change Study (HDR et al., December 2009). The computed and measured water surface profiles at each location detailing these results are shown in Attachment F.

Table 4-6. Discharges at the Ungaged Sites on the Loup River

Site	Survey Date	Flow		
		Minimum	Mean	Maximum
Site 1	6/2/10	3,235	3,918	4,370
	6/3/10	2,775	3,030	3,218
	10/5/10	1,980	2,262	3,330
Site 2	4/15/10	--	432	--
	8/5/10	187	289	480
	9/28/10	390	580	855

The model results were used to study the effects of flow diversion on potential interior least tern and piping plover nesting habitat. A meeting was held with USFWS and NGPC on January 5, 2010, to consult with these agencies on what model parameters may be considered important for determining effects on interior least tern and piping plover nesting habitat. USFWS further consulted with NGPC and responded that "understanding the relationship among various discharge alternatives and the number, size, bar height, bar position (mid-channel or point), and channel depths which isolate these bars" would be important information for the model to produce (USFWS, January 22, 2010). Because the model is a steady-state 1-D model with a rigid bed and is limited in the amount of information that could be obtained regarding the above parameters, only the percentage of channel width exposed (above the water surface between high banks) as it relates to interior least tern and piping plover nesting habitat (exposed sandbars within the channel) could be identified through the use of the model.

The percentage of channel width exposed was evaluated at 25 (high-flow), 50 (medium-flow), and 75 (low-flow) percent exceedance daily discharges to determine the effects based on a variety of discharge rates. Additionally, synthesized mean daily flows representative of wet, dry, and normal years, as described in Section 4.2, were evaluated to determine the percentage of channel width exposed for each.

Sets of cross sections were taken at each study site in either late spring or early summer and in either late summer or early fall. As shown in Attachment A and discussed in the Second Initial Study Report, Appendix B, Section 5.5.5, individual and collective cross sections experienced significant changes even in these short intervals. The hydraulic (and morphologic) changes in cross sections during these intervals were compared to evaluate how these measured changes in the cross sections (morphology) throughout the nesting season affected the hydraulics and the resultant effect on the percentage of channel width exposed associated with interior least tern and piping plover nesting habitat.

The calibrated models were executed for both current operations and the no diversion condition. For each cross section within a study site, the amount of exposed channel width that exists above the water surface was determined. A percentage of this amount was calculated based on the channel width at that cross section. These percentages were summed, and then the average for the study site was determined. This process was conducted for each flow scenario for both current operations and the no diversion condition.

4.6.4 Comparison of Sedimentation Indicators for Current Operations and the No Diversion Condition

The District's Revised Study Plan for the flow depletion and flow diversion study involved comparisons of flow depletions for both current operations and alternative conditions (the no diversion condition). The study plan also called for calculations of the sediment transport indicators for both current operations and alternative conditions (the no diversion condition) to further assess impacts of the Project.

The same methodologies used in the Initial Study Report, Appendix A, Sedimentation Study Report, dated August 26, 2010, were used for this assessment. This involved development of hydraulic geometry relationships for the ungaged sites that could be used to provide parameters required by Yang's sediment transport capacity equation.

Once the HEC-RAS model was developed and calibrated at each ungaged site, it was used to develop hydraulic geometry relationships of the discharge rate versus the channel width, depth, and velocity at each. It was assumed that the cross sections would have rigid boundaries for all flow rates, which is not physically the case.

When flows increase, part of the material in the bed mobilizes (that is, becomes part of the flow), increasing the flow area, depth, velocity, and possibly even the width. In addition, the cross-sectional measurements taken at the sites were not the result of the flow on that day but were the end product of a series of flows leading up to the dates of the measurements. The hydraulic widths and depths measured each day should not be interpreted as being the parameters that formed the channel's shape each day. As demonstrated in the Initial Study Report, Appendix A, Sedimentation Study Report, a wide range of velocities and depths can exist for the same discharge rate.

Because each site contained several cross sections, individual values of width, depth, and velocity were developed and compared using the HEC-RAS models at each cross section for the same discharge rate. The relationships for calculation of sediment transport indicators needed to cover the full range of discharges in each river, so discharge versus width, depth, and velocity relationships were developed throughout the full range of flows. The relationships are included in Attachment G.

The range of each parameter (width, depth, and velocity) for any given discharge rate is moderately large. Each point plotted for the same discharge represents hydraulic conditions at the individual cross section within the set of cross sections. The width, depth, and velocity graphs in Attachment G reveal how widely variable these values are within a few hundred feet of each other in a braided river. They also reveal why it would be very difficult using any kind of rigid-bed model, or even a mobile-bed model, to replicate even the average values of width, depth, and velocity measured over a few hundred feet of a braided stream.

Objective 5: To determine Project effects, if any, of consumptive use on fisheries and habitat on the lower Platte River downstream of the Tailrace Canal.

This objective was completed under Task 2, Net Consumptive Use. The methodology for Task 2 is discussed in Section 4.2.

Objective 6: To determine the relative significance of the Loup River bypass reach to the overall fishery habitat for the Loup River.

4.7 Task 7: Fishery Populations Above and Below the Diversion Weir

Data collected during 1996 and 1997 NGPC fish sampling efforts on the Loup River were used to analyze fish populations above and below the Diversion Weir (NGPC, June 1997 and April 1998).

The District's Revised Study Plan indicated that flow information from Task 3 would be used to calculate the opportunity for fish species to migrate upstream of the Diversion Weir during high flows when the Diversion Weir is submerged or the Sluice Gates are opened. Specific analysis of the flows from Task 3 was not conducted. Instead, the results from Study 7.0, Fish Passage, which were presented in the District's Initial Study Report, Appendix E, are summarized.

4.8 Task 8: Montana Method

The suitability of aquatic habitat was determined using the "Montana method." The Montana method (Tennant, 1976), also known as the Tennant method, provides an efficient way to assess flow requirements for ecologically suitable fisheries habitat. The method bases its flow requirements on the observation that fisheries habitat conditions are closely correlated to flow, and it assumes that a percentage of the mean annual flow is needed to maintain a healthy stream environment. This analysis was used to determine whether a sufficient amount of water could be expected within the Loup River bypass reach during various periods of the year.

While field observations are recommended, the Montana method is often used without them, and minimum instream flow determinations are based on Tennant's brief description of flows and associated percentage of average flows, as shown in Table 4-7. The Montana method has been adopted by many states and is one of the most-used methods in the world for evaluating fisheries habitat based on streamflow conditions. However, the Montana method does not explicitly consider flows for specific requirements or activities of species, such as fish passage and spawning, or for ecosystem components. Furthermore, there may be some doubt as to the accuracy of using a method based on average flows because average flows are influenced by extreme flow events. The Montana method also does not consider ecologically relevant flow variability (daily, seasonal, annual, or interannual) timing in terms of flow targets.

The first step of the Montana method was to calculate the average annual flow for selected reaches of the Loup River. Average annual flow was calculated using daily flows from 1954 to 2009. The year 1954 was used as a starting date because all gages were in operation at this point in time. Flow information was used from the following locations on the Loup River:

- Site 1, upstream of the Diversion Weir
- Loup River near Genoa gage

Synthetic hydrographs were developed for Site 2, downstream of the Diversion Weir. However, only the Loup River near Genoa gage, which is also downstream of the Diversion Weir, was evaluated because the flows at this location and Site 2 are nearly identical in hydrograph shape and magnitude.

The same methodology was used to evaluate habitat on the Platte River above and below the confluence of the Loup River bypass reach. Flow information was used from the following locations on the Platte River:

- Platte River near Duncan gage
- Site 3, downstream of the Tailrace Return

From those results, each average annual flow was multiplied by Tennant's (1976) stream condition categories, shown in Table 4-7. For this flow depletion and flow diversion study, each rating was broken down as shown in Table 4-8. Next, baseline flow conditions were estimated for each reach. This involved calculating mean monthly flows for each reach. Each monthly flow was compared to the requirements for "Satisfactory," "Fair," "Poor," and "Severe Degradation," as shown in Table 4-8. This analysis provides some indication as to whether each reach of the Loup and Platte rivers has poor or degraded flows and during which months those ratings primarily occur.

Table 4-7. Stream Condition Categories as Described by Tennant (1976)

Category	April to September	October to March
Optimum	60 to 100% of annual mean	60 to 100% of annual mean
Outstanding	60% of annual mean	40 to 59% of annual mean
Excellent	50 to 59% of annual mean	30 to 39% of annual mean
Good	40 to 49% of annual mean	20 to 29% of annual mean
Fair	30 to 39% of annual mean	10 to 19% of annual mean
Poor	10 to 29% of annual mean	10% of annual mean
Severe Degradation	Less than 10% of annual mean	Less than 10% of annual mean

Table 4-8. Modified Montana Method Categories for Use on the Loup and Platte Rivers

Category	April to September	October to March
Satisfactory[1]	>40% of annual mean	>20% of annual mean
Fair	30 to 39% of annual mean	10 to 19% of annual mean
Poor	10 to 29% of annual mean	10% of annual mean
Severe Degradation	Less than 10% of annual mean	Less than 10% of annual mean

Note:

1 It was assumed that any category above "Good" based on the Montana method would be "Satisfactory" for fisheries within the reach.

The flow requirements for each reach of the Loup and Platte rivers are summarized in Table 4-9. Though flows in the Loup River upstream of the Diversion Weir may be considered ideal, percentages were based on the average annual flow for each location. For example, each month's average flow at the Loup River near Genoa gage was compared to the annual average flow for the entire period of record (1954 to 2009) at the Loup River near Genoa gage. Tennant bases his method on the theory that flow velocity is closely correlated with stream morphology and ecological processes within the reach in question. Because the stream morphology changes significantly below the Diversion Weir, it is appropriate to use average annual flows from this point rather than from upstream of the Diversion Weir.

Table 4-9. Minimum Streamflow Requirements for Each Stream Condition Category as Calculated Using the Montana Method

Reach	Average Annual Flow (cfs)	Satisfactory 40% (cfs)	Fair 30% (cfs)	Poor 10% (cfs)[1]
Site 1 – Upstream of the Diversion Weir (Loup River)	2,379	952	714	238
Loup River near Genoa gage	743	297	223	75
Platte River near Duncan gage	1,821	728	546	182
Site 3 – Downstream of the Tailrace Return	2,828	1,131	848	283

Note:

1 Any flows below 10 percent of the mean annual flow are considered to be in the "Degraded" category.

Objective 7: To determine the availability of potential whooping crane roosting habitat above and below the Diversion Weir under Project operations compared to the no diversion condition.

4.9 Task 9: Whooping Crane Roosting Habitat Evaluation on the Loup River Bypass Reach

4.9.1 Aerial Imagery Review

The same methods detailed in Section 4.6.2 were used to identify potentially available whooping crane roosting habitat above and below the Diversion Weir.

Prior to conducting an aerial imagery review of the Loup River above and below the Diversion Weir, a literature review was conducted to identify potential roosting habitat parameters for whooping cranes. The parameters listed in Table 4-10 are habitat measurements identified at whooping crane roosting sites on Nebraska rivers.

Table 4-10. Habitat Characteristics Noted at Nebraska Riverine Roost Sites for Whooping Crane

Habitat Parameter	Observed Measurements of Habitat Parameters[1]	References
Channel width (bank to bank)	≥180 feet, usually >508 feet; average 764±276 feet	Johnson, 1982; Austin and Richert, May 2001
Channel inundated (percent)	>80%	Faanes et al., 1992
Unobstructed channel width (feet)	≥1,165 feet, <2,625 feet	Faanes, 1992; Austin and Richert, May 2001
Depth of water for roosting	0 to 0.82 foot, approximately 40% of channel area <0.7 foot	Johnson, 1982; Faanes, 1992; Farmer et al., 2005; Austin and Richert, May 2001; PRRIP, October 24, 2006

Note:
1 Values were converted from centimeters and meters to feet.

Habitat parameters evaluated in the aerial imagery review (described in Section 4.6.2) relating to whooping crane roosting habitat were as follows:

- Channel width
- Average area of shallow water/wet sand[6] per river mile
- Percentage of shallow water/wet sand areas
- Unobstructed channel width

Unobstructed channel width, as a measure of horizontal visibility, was calculated as the distance across a channel between visual obstructions. For the purposes of this flow depletion and flow diversion study, visual obstructions are defined as either a bank and/or perennial vegetation whose combined height is greater than 3 feet (Farmer et al., 2005).

6 The classifications of shallow water and wet sand could not be separated because pixel coloration for these two features was very similar and difficult to classify. Depth of the water could not be determined from the aerial interpretation; therefore, water with a darker pixel shade was classified as deep water, and water or sand with a lighter pixel shade was classified as shallow water/wet sand.

4.9.2 Habitat Evaluation Using HEC-RAS Model

In addition to the aerial interpretation, the steady-state 1-D HEC-RAS model described in Section 4.6.3 was used to evaluate whooping crane roosting habitat as directed in FERC's Study Plan Determination. Additional description of the model development is provided in Section 4.6.3.

The model results were used to study the effects of diverted flows on potential whooping crane roosting habitat. During the January 5, 2010, meeting with USFWS and NGPC described in Section 4.6.3, the agencies identified the same model parameters (relationship among discharge and unobstructed channel width, total wetted width, distance to visual obstructions, and cumulative depth) as being important for determining effects on whooping crane roosting habitat. For the same reasons identified in Section 4.6.3, the model is limited in the amount of information that could be obtained. However, the model is able to provide estimates of the percentage of channel width (calculated as high bank to high bank) with water depths of 0.8 foot or less as it relates to whooping crane roosting habitat (wetted sand areas within the channel banks with water depths of 0.8 foot or less), so this was identified as an indicator of whooping crane habitat. In this case, high bank to high bank channel width (referred to hereafter as channel width) was used instead of wetted width because the channel width metric does not change with the different flow conditions and made it easier to compare the identified habitat parameter from year to year and under different flow conditions.

The percentage of channel width with a depth of 0.8 foot or less was evaluated at 25 (high-flow), 50 (medium-flow), and 75 (low-flow) percent exceedance flows to determine the effects on this indicator based on a variety of flow levels. Additionally, representative wet, dry, and normal years, as described in Section 4.2, and mean daily flows were evaluated against the percentage of channel width with a depth of 0.8 foot or less. Cross sections were taken in either late spring or early summer and in either late summer or early fall.

Once calibrated, the model was executed for both current operations and the no diversion condition. For each cross section within a study site, the amount of channel width (bank to bank) that had depths of 0.8 foot or less was determined. A percentage of this amount was calculated based on the total channel width at that cross section. These percentages were summed, and then the average for the study site was determined. This process was conducted for each flow scenario for both current operations and the no diversion condition. This analysis was conducted for only the early summer (June) cross section because this time frame relates best to conditions during a period when the whooping crane is migrating through the region; however, whooping cranes also migrate through Nebraska in the fall.

5. RESULTS AND DISCUSSION

As stated in Section 2, the goals of this flow depletion and flow diversion study are to determine if Project operations result in a flow depletion on the lower Platte River and to what extent the magnitude, frequency, duration, and timing of flows affect the morphology and habitat in the Loup River bypass reach. This study also evaluated the extent of interior least tern and piping plover nesting and whooping crane roosting habitat on the Loup River above and below the Diversion Weir, quantified the effects of the Project on fisheries and habitat in the Lower Platte River below the Tailrace Canal, and determined the relative significance of the Loup River bypass reach to the Loup River fisheries.

The results of this study, which quantify the consumptive losses and the effects of these losses on the river stage, are summarized below, and a full discussion of the analyses related to each study objective follows. The discussion provides representative tabular and graphical data that support this study's conclusions. A complete presentation of these data is included in Attachments A through L.

5.1 Summary of Results

Objective 1: To determine the net consumptive losses associated with Project operations compared to the no diversion condition.

The consumptive loss analysis shows that flow depletions under current operations are less than would occur under the no diversion condition. Therefore, it is concluded that Project operations do not adversely impact fisheries and aquatic habitat relative to flow depletions.

Objective 2: To use current and historic USGS gage rating curves to evaluate change in stage in the Loup River bypass reach during Project operations and compare against hydrographs of a no diversion condition.

The increase in flow in the Loup River bypass reach between current operations and the no diversion condition results in an increase in stage, which is to be expected. In general, the magnitude of the stage change decreases for higher flows. In addition, both the flow and associated stage change are greater under a dry year classification than a wet year classification.

Objective 3: To evaluate historic flow trends on the Loup and Platte rivers since Project inception.

The long-term historic trends indicate that annual Platte River flows upstream (at Duncan) and downstream (at North Bend and Louisville) of the Loup River confluence have been well-documented as increasing throughout the period that the Project has been in operation. As shown in two USGS reports (Ginting, Zelt, and Linard, 2008; Dietsch, Godberson, and Steele, 2009) and additional analyses by the District, no adverse flow impacts of Project operations are evident. Although flows are highly fluctuating and cyclic, this natural positive long-term trend in flows is statistically significant and, according to USGS, is attributed largely to natural climatic cycling. The positive trend should be neither credited to nor charged against the Project because the Project does not impact flows at Duncan, yet the same trends identified at Duncan also occur downstream.

Objective 4: To determine the extent of interior least tern and piping plover nesting on the Loup River above and below the Diversion Weir.

The comparison of nesting occurrences of interior least terns and piping plovers above and below the Diversion Weir yielded inconclusive results. Because of the small sample size and limited dataset, it was concluded that data were insufficient to accurately determine if there is a significant difference between nesting occurrences above and below the Diversion Weir.

However, the aerial imagery review of interior least tern and piping plover habitat parameters above and below the Diversion Weir yielded detectable differences in the measured parameters (number of sandbars, channel widths, average size of the sandbars, and location of sandbars). On average, there are more sandbars per river mile above the Diversion Weir, but these sandbars are smaller than sandbars below the Diversion Weir. The channel widths (high bank to high bank) are wider above the Diversion Weir and become approximately 400 feet narrower below the Diversion Weir. In general, there is a higher percentage of vegetation on sandbars located below the Diversion Weir, although all average vegetation percentages were less than 21 percent and within the range of acceptable vegetation percentages for nesting interior least terns and piping plovers.

Sandbars below the Diversion Weir, likely due to their larger size, also had a higher percentage of bare sand and a larger bare sand area than sandbars above the Diversion Weir. Most sandbars located below the Diversion Weir are point bars and located along the riverbanks, while, on average, a greater percentage of mid-channel bars exist above the Diversion Weir.

The comparison above and below the Diversion Weir under current operations and the no diversion condition using the 1-D HEC-RAS model determined that, on average and as expected, the percentage of exposed channel width was generally greater under current operations below the Diversion Weir during all flows and all years. The percentage of exposed channel width above the Diversion Weir ranged from 38 percent of the channel width under low flows in a dry year to 2 percent of the channel width under high flows in a wet year. The percentage of exposed channel width below the Diversion Weir under current operations ranged from 87 percent of the channel width under low flows in a dry year to 10 percent of the channel width under high flows in a wet year. Below the Diversion Weir under the no diversion condition, the percentage of exposed channel width was similar to percentages above the Diversion Weir and ranged from 26 percent of the channel width under low flows in a dry year to 3 percent of the channel width under normal and high flows in a wet year.

Objective 5: To determine Project effects, if any, of consumptive use on fisheries and habitat on the lower Platte River downstream of the Tailrace Canal.

Because there are no measurable flow depletions to the lower Platte River, as discussed in Section 5.2, fisheries and habitat are not adversely impacted to a greater extent under current operations than they would be under the no diversion condition.

Objective 6: To determine the relative significance of the Loup River bypass reach to the overall fishery habitat for the Loup River.

The 1996 and 1997 NGPC fish sampling efforts indicate that similar species of fish exist in the reaches both above and below the Diversion Weir. The population structures for the reaches above and below the Diversion Weir are also similar, with similar sport fishery populations. In both 1996 and 1997, more fish were collected in the reach below the Diversion Weir than in the reach above the Diversion Weir.

With respect to fish passage over the Diversion Weir or via the Sluice Gates, Study 7.0, Fish Passage, published in the District's Initial Study Report, Appendix E, determined that the Diversion Weir is submerged and provides a potential pathway for upstream migrating fish during less than 1 percent of the spawning season (defined as April through June for this analysis). During the 1 percent of the spawning season in which the Diversion Weir is submerged, the resulting flow velocities over the Diversion Weir are higher than the critical swimming speeds of all analyzed fish species. Additionally, when the Sluice Gate Structure is open, average flow velocities through the structure are too great to allow fish passage.

However, it is acknowledged that fish passage is occurring and is likely the result of lower velocities near boundary layers near solid surfaces and hydraulic shadows associated with hydraulic structures, particularly at the interface of corners of the wall and floor. The velocity in these areas is very slow compared to the calculated average velocity through the gate. A fish could work its way up near the gate, rest in a hydraulic shadow, and then burst through, following the concrete along the gate housing. This type of behavior has been documented at hydraulic structures on the Mississippi River (USACE, May 2000). Given these hydraulic conditions and the known species diversity above and below the Diversion Weir, fish passage is likely occurring at the Project Headworks, particularly by larger and stronger adult fish.

The Montana method provided the following habitat assessment for the Loup River:

- Site 1 – Upstream of the Diversion Weir
    - Higher average of "Satisfactory[7]" ratings than the Loup River near Genoa gage
    - Less than "Satisfactory" rating in July, August, and September
    - No months during any of the years in the period of record were rated as "Degraded"
    - No conditions under "Satisfactory" from October through March
- Loup River near Genoa gage
    - Fewer years within the "Satisfactory" range than Site 1, particularly in July, August, and September
    - A majority of "Poor" and "Degraded" flows during the period of record in July, August, and September
    - Fewer months during the period of record with degraded flows occurred in October through March than in April through September (There were years with degraded stream flows during October, but these were reduced considerably from November until March.)

The Montana method provided the following habitat assessment for the Platte River:

- Platte River near Duncan gage
    - Degraded flows in July, August, and September
    - A large majority of "Satisfactory" ratings for all other months
- Site 3 – Upstream of the Tailrace Return
    - Degraded flows in July, August, and September
    - A large majority of "Satisfactory" ratings for all other months
    - Fewer years with "Degraded" ratings than the Platte River near Duncan gage

Based on this assessment for the Platte River, it appears that most months are meeting adequate flow requirements for satisfactory biological conditions. July, August and September are the only months where the Platte River has a "Poor" or "Severely Degraded" rating. However, because the Platte River near Duncan gage also exhibits the same (or slightly worse) ratings, flow depletions are likely due to other upstream causes or natural seasonal fluctuations in water availability and are not readily attributed to Project operations.

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7 Satisfactory ratings were considered ratings of Good, Excellent, Outstanding, or Optimum.

Objective 7: To determine the availability of potential whooping crane roosting habitat above and below the Diversion Weir under Project operations compared to the no diversion condition.

The aerial imagery review of whooping crane habitat parameters above and below the Diversion Weir yielded detectable differences in the measured parameters (channel widths, shallow water/wet sand areas, and unobstructed channel widths). Greater areas of shallow water/wet sand were located below the Diversion Weir, while above the Diversion Weir, there were less areas of shallow water/wet sand, which is a preferred roosting characteristic of whooping cranes. In general, the unobstructed widths above and below the Diversion Weir were consistent with active channel widths (bank to bank), with the exception of one location above the Diversion Weir. This location had an elevated vegetated sandbar, decreasing the unobstructed width of this section of the channel.

All unobstructed widths, both above and below the Diversion Weir, generally fall below the noted range for this habitat parameter. On average, the channel is wider above the Diversion Weir than below the Diversion Weir; however, all channel widths fall within the generally accepted habitat preferences of whooping cranes, so little difference of potentially suitable channel widths and unobstructed widths exists when comparing above to below the Diversion Weir.

The percentage of channel width with water depths of 0.8 foot or less was evaluated using the HEC-RAS model. For current operations, the percentage of channel width with water depths of 0.8 foot or less is generally greater above the Diversion Weir than below. This percentage generally decreases with higher flow rates and from dry to wet years for both Site 1, upstream of the Diversion Weir, and under the no diversion condition for Site 2, downstream of the Diversion Weir.

The percentage of channel width with water depths of 0.8 foot or less increases as flow increases and as classification years proceed from dry to wet under current operations at Site 2, downstream of the Diversion Weir. In dry years, with low flow conditions, there is a smaller percentage of channel width with water depths of 0.8 foot under current operations than under the no diversion condition (16 percent as opposed to 40 percent, respectively). Conversely, in a wet year, under high flow conditions, there is a higher percentage of channel width with water depths of 0.8 foot under current conditions than under the no diversion condition (36 percent as opposed to 8 percent, respectively). On average, above the Diversion Weir, percentages of the channel with water depths of 0.8 foot or less ranged from 39 percent of the channel width under low flows during a dry year to 25 percent under high flows during a wet year. Below the Diversion Weir under current operations, percentages of the channel with water depths of 0.8 foot or less ranged from 16 percent of the channel width during low flows in a dry year to 36 percent during high flows in a wet year. Below the Diversion Weir under the no diversion condition, percentages of the channel with water depths of 0.8 foot or less ranged from 40 percent of the channel width under low flows in a dry year to 8 percent under high flows in a wet year.

5.2 Objective 1: To determine the net consumptive losses associated with Project operations compared to the no diversion condition.

5.2.1 Consumptive Use

Consumptive uses were evaluated for both current operations and the no diversion condition. Evaporation losses were determined by calculating the area of open water under current operations and the no diversion condition and multiplying by the appropriate pan evaporation rate found in NWS data. Both open-water evaporation and riparian vegetation ET losses were determined using methodology developed and used by USFWS.

However, the consumptive losses associated with current operations would continue to occur under the no diversion condition because the Loup Power Canal and associated regulating reservoirs, though not operating, would continue to store water. Much of that water would come from riparian aquifers as the groundwater mound created over more than 80 years of operation would likely maintain open water in the canal and reservoirs, some of which would likely become overgrown with phreatopytes. This would continue to support the adjacent bands of riparian vegetation; thus open-water evaporation and ET losses would continue as well. Losses due to channel evaporation would increase in the Loup River bypass reach under the no diversion condition because of wider top widths of open water associated with higher daily discharges.

The consumptive loss analysis, summarized in Table 5-1, shows that flow depletions under current operations are less than would occur under the no diversion condition. Therefore, it is concluded that Project operations do not adversely impact fisheries and aquatic habitat relative to flow depletions in the lower Platte River.

An additional analysis for the no diversion condition was conducted assuming that the regulating reservoirs would contain no water. This provides a lower-end bracket for the no diversion condition consumptive use. The results, provided in Table 5-2, show that flow depletions due to consumptive use are lower for current operations than for the no diversion condition without regulating reservoirs. Therefore, it is concluded that Project operations do not adversely impact fisheries and aquatic habitat relative to flow depletions on the lower Platte River.

The monthly values for consumptive use for current operations, no diversion with regulating reservoirs, and no diversion without regulating reservoirs are provided in Attachment D.

Table 5-1. Summary of Consumptive Losses for Wet, Dry, and Normal Years With Regulating Reservoirs

		Current Operations	No Diversion Condition
Normal Year – 2005			
Loup Power Canal	Total Mean Open Water Evaporation (acre-feet [AF])	6,030	5,400
	Total Mean ET (AF)	870	870
	Total Consumptive Loss	6,900	6,270
Loup River Bypass Reach	Total Mean Open Water Evaporation (AF)	9,070	16,150
	Total Mean ET (AF)	2,110	2,110
	Total Consumptive Loss	11,180	18,260
	Total Depletion	18,080	24,530
Dry Year – 2006			
Loup Power Canal	Total Mean Open Water Evaporation (AF)	6,010	5,380
	Total Mean ET (AF)	870	870
	Total Consumptive Loss	6,880	6,250
Loup River Bypass Reach	Total Mean Open Water Evaporation (AF)	6,530	13,860
	Total Mean ET (AF)	2,100	2,100
	Total Consumptive Loss	8,630	15,960
	Total Depletion	15,510	22,210
Wet Year – 2008			
Loup Power Canal	Total Mean Open Water Evaporation (AF)	5,670	5,080
	Total Mean ET (AF)	810	810
	Total Consumptive Loss	6,480	5,890
Loup River Bypass Reach	Total Mean Open Water Evaporation (AF)	10,440	17,650
	Total Mean ET (AF)	1,960	1,960
	Total Consumptive Loss	12,400	19,610
	Total Depletion	18,880	25,500

Table 5-2. Summary of Consumptive Losses for Wet, Dry, and Normal Years Without Regulating Reservoirs

		Current Operations	No Diversion Condition
Normal Year – 2005			
Loup Power Canal	Total Mean Open Water Evaporation (AF)	6,030	1,090
	Total Mean ET (AF)	870	870
	Total Consumptive Loss	6,900	1,960
Loup River Bypass Reach	Total Mean Open Water Evaporation (AF)	9,070	16,150
	Total Mean ET (AF)	2,110	2,110
	Total Consumptive Loss	11,180	18,260
	Total Depletion	18,080	20,220
Dry Year – 2006			
Loup Power Canal	Total Mean Evaporation (AF)	6,010	1,090
	Total Mean ET (AF)	870	870
	Total Consumptive Loss	6,880	1,960
Loup River Bypass Reach	Total Mean Open Water Evaporation (AF)	6,530	13,860
	Total Mean ET (AF)	2,100	2,100
	Total Consumptive Loss	8,630	15,960
	Total Depletion	15,510	17,920
Wet Year – 2008			
Loup Power Canal	Total Mean Evaporation (AF)	5,670	1,030
	Total Mean ET (AF)	810	810
	Total Consumptive Loss	6,480	1,840
Loup River Bypass Reach	Total Mean Open Water Evaporation (AF)	10,440	17,650
	Total Mean ET (AF)	1,960	1,960
	Total Consumptive Loss	12,400	19,610
	Total Depletion	18,880	21,450

5.2.2 Consumptive Use of Irrigation Water

The study period for the consumptive use analysis of irrigation water extended from 1985 to 2009. This provided a wide range of hydrologic conditions in the Loup River basin. On average, approximately 71 percent of applied irrigation water from the Loup Power Canal would be expected to be lost from the system through consumptive use. During the study period, consumptive use of applied irrigation values ranged from 0 to 75 percent. This variation is typical due to such factors as timing of applied irrigation with respect to precipitation events. Based on the analysis described in Section 4.2 for the Loup River, 2005 was classified as a normal year, 2006 was classified as a dry year, and 2008 was classified as a wet year. The percentages of applied irrigation water consumed for those years are as follows:

- 2005 (normal) – 71 percent
- 2006 (dry) – 13 percent
- 2008 (wet) – 72 percent

As previously stated, there is great variability due to the timing of the irrigation water and the precipitation events. For example, 2003 and 2004 were also classified as dry years. The percentages of applied irrigation water consumed for those years were calculated to be 71 and 61 percent, respectively. On the other hand, 2009 was classified marginally as a wet year, and the percentage of applied irrigation water consumed was calculated as 26 percent. Therefore, for purposes of evaluating irrigation consumptive use, which is dependent on the timing of precipitation events, the annual average consumption—in this case, 71 percent—is most representative of the consumptive use from the Loup Power Canal. As stated in FERC's Study Plan Determination, the irrigation diversions will continue as they have historically, so these consumptive uses would be the same under the no diversion condition.

5.2.3 Consumptive Use of Lost Creek

The amount of Lost Creek flow discharged into the Tailrace Canal from the Lost Creek Flood Control Channel was estimated. Based on water markings on the low-flow channel, the daily base flow is approximately 12 cfs. The average annual runoff from the Lost Creek basin, conveyed in excess of the daily base flow, is 1,450 acre-feet, which if converted to steady flow, amounts to 2 cfs. Thus, the estimated total average daily flow into the Tailrace Canal from the Lost Creek Flood Control Channel, calculated as average base flow plus average annual runoff, is 14 cfs. In the District's PAD, it was noted that at full flow opening, the pipe could maintain a flushing flow of 20 cfs. The HY-8 calculations for this flow depletion and flow diversion study determined a full pipe flow of 27 cfs.

District gate opening records from 2003 to 2009 were used to estimate the day-to-day average daily flow discharged from the Loup Power Canal into the Lost Creek Siphon. Based on the gate opening records, the average daily discharge from the Tailrace Canal into the Lost Creek Siphon during this period was 12 cfs.

This reveals that Lost Creek flow entering the Tailrace Canal is essentially equal to the flow being returned to Lost Creek through the Project's Lost Creek Siphon. Therefore, it was concluded that there is no consumptive use of Lost Creek flows as a result of the Project.

5.3 Objective 2: To use current and historic USGS gage rating curves to evaluate change in stage in the Loup River bypass reach during Project operations and compare against hydrographs of a no diversion condition.

5.3.1 Loup River Stage Differences

The results of the Loup River stage difference between current operations and the no diversion condition are listed in Table 5-3 for the Loup River near Genoa gage and in Table 5-4 for the Loup River at Columbus gage. Table 5-3 shows that the Loup River near Genoa median discharge (50^{th} percentile) for a normal year (2005) increased from 573 cfs under current operations to 2,288 cfs under the no diversion condition. As expected, this results in an increase in stage, amounting in this case to 1.18 feet. All other changes in flow and stage for other percentiles and flow classifications can be seen by comparing current operations with the no diversion condition in Table 5-3. In all cases, both the flow and stages increased under the no diversion condition. Section 5.5.3 details the relative change in habitat.

As a similar example, Table 5-4 shows that the Loup River at Columbus median discharge for a normal year (2005) increased from 745 cfs under current operations to 2,456 cfs under the no diversion condition. This results in an increase in stage of 1.02 feet. Similar increases in flow rates and stages occur for other percentiles and flow classifications. Section 5.5.3 details the relative change in habitat.

Table 5-3. Loup River Stage (Loup River near Genoa Gage)

Year	Flow Classification	Operation	Percent Exceedance	Flow	Gage Height	Water Surface Elevation
2005	Normal	Current Operations	25	1,110	5.95	1,546.76
2005	Normal	Current Operations	50	573	5.42	1,546.23
2005	Normal	Current Operations	75	112	4.29	1,545.10
2006	Dry	Current Operations	25	794	5.68	1,546.49
2006	Dry	Current Operations	50	153	4.49	1,545.30
2006	Dry	Current Operations	75	47	3.79	1,544.60
2008	Wet	Current Operations	25	1,540	6.24	1,547.05
2008	Wet	Current Operations	50	642	5.51	1,546.32
2008	Wet	Current Operations	75	173	4.57	1,545.38
2005	Normal	No Diversion Condition	25	2,713	6.76	1,547.57
2005	Normal	No Diversion Condition	50	2,288	6.60	1,547.41
2005	Normal	No Diversion Condition	75	1,824	6.39	1,547.20
2006	Dry	No Diversion Condition	25	2,510	6.69	1,547.50
2006	Dry	No Diversion Condition	50	2,080	6.51	1,547.32
2006	Dry	No Diversion Condition	75	1,251	6.06	1,546.87
2008	Wet	No Diversion Condition	25	3,251	6.94	1,547.75
2008	Wet	No Diversion Condition	50	2,487	6.68	1,547.49
2008	Wet	No Diversion Condition	75	1,935	6.45	1,547.26

Table 5-4. Loup River Stage (Loup River at Columbus Gage)

Year	Flow Classification	Operation	Percent Exceedance	Flow	Gage Height	Water Surface Elevation
2005	Normal	Current Operations	25	1,354	4.54	1,433.43
2005	Normal	Current Operations	50	745	4.05	1,432.95
2005	Normal	Current Operations	75	251	3.31	1,432.20
2006	Dry	Current Operations	25	943	4.25	1,433.14
2006	Dry	Current Operations	50	320	3.46	1,432.35
2006	Dry	Current Operations	75	197	3.16	1,432.05
2008	Wet	Current Operations	25	1,741	4.75	1,433.64
2008	Wet	Current Operations	50	892	4.19	1,433.08
2008	Wet	Current Operations	75	426	3.65	1,432.54
2005	Normal	No Diversion Condition	25	2,952	5.25	1,434.14
2005	Normal	No Diversion Condition	50	2,456	5.07	1,433.96
2005	Normal	No Diversion Condition	75	1,946	4.85	1,433.74
2006	Dry	No Diversion Condition	25	2,708	5.16	1,434.05
2006	Dry	No Diversion Condition	50	2,235	4.98	1,433.87
2006	Dry	No Diversion Condition	75	1,435	4.58	1,433.47
2008	Wet	No Diversion Condition	25	3,482	5.41	1,434.30
2008	Wet	No Diversion Condition	50	2,732	5.17	1,434.06
2008	Wet	No Diversion Condition	75	2,156	4.95	1,433.84

5.4 Objective 3: To evaluate historic flow trends on the Loup and Platte rivers since Project inception.

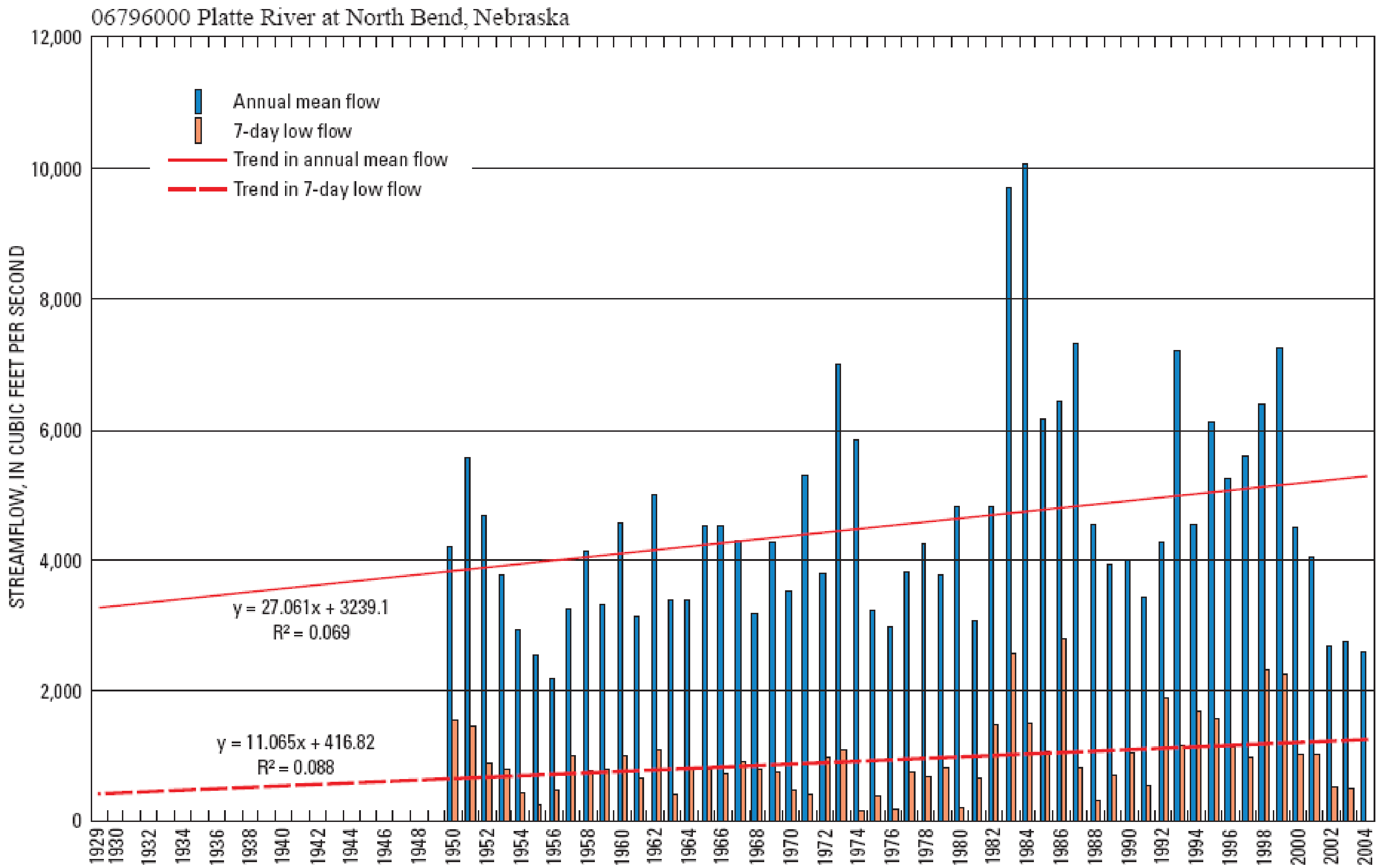
The most comprehensive recent study regarding Objective 3, evaluation of historic flow trends since Project inception, is provided by Dietsch, Godberson, and Steele (2009). Their analysis of streamflow records from 1928 through 2004 in the Platte River Basin revealed the existence of "significant positive temporal trends" in annual flow for the period of record for the Platte River near Duncan, at North Bend, and at Louisville.

An example of their results for the North Bend gage is shown in Figure 5-1. Similar, relatively steep upward trends in both the mean annual flows and 7-day low flows were discovered near Duncan and at Louisville as well as at a number of other gages on other tributary streams (Dietsch, Godberson, and Steele, 2009). The sharp decline in flows since around 2000 is evident in all three graphs. More importantly, the Duncan and North Bend gage locations bracket the Loup River confluence (as well as the Project), revealing that no declines in streamflow have occurred in the Platte River above or below the confluence since Project inception. The dry period starting around 2000 is the second lowest on record at North Bend.

Although highly fluctuating, as shown in Figure 5-1, the trends of increasing flows graphed for the three sites were considered statistically significant by USGS. By itself, this USGS report answers the question of historic flow trends in the Platte River just upstream and all the way downstream of the Project—all have been increasing since Project inception.

Both the fluctuations in annual flows as well as the positive trends are largely related to climate. In an earlier USGS study (Ginting, Zelt, and Linard, 2008) the authors compiled, analyzed, and summarized hydrologic information from long-term gage stations on the lower Platte River to determine any significant temporal differences among six discrete periods during 1895 to 2006 and to interpret any significant changes in relation to changes in climatic conditions or other factors. The study included the most downstream station within the central Platte River segment that flowed to the confluence with the Loup River and all four active streamflow gage stations (2006) on the lower Platte River mainstem extending from the confluence of the Loup River and Platte River to the confluence of the Platte River and Missouri River.

Neither of the USGS studies cited above evaluated Loup River trends. To assess whether the data for the Loup River near Genoa gage would demonstrate similar trends, annual mean flow data were compiled and are plotted in Figure 5-2, which provided a similar positive temporal trend. Insufficient data were available at the Loup River at Columbus gage to establish trends.



Source: Dietsch, Benjamin J., Julie A. Godberson, and Gregory V. Steele, 2009, "Trends in Streamflow Characteristics of Selected Sites in the Elkhorn River, Salt Creek, and Lower Platte River Basins, Eastern Nebraska, 1928–2004, and Evaluation of Streamflows in Relation to Instream-Flow Criteria, 1953–2004," USGS Scientific Investigations Report 2009-5011, available online at http://pubs.usgs.gov/sir/2009/5011/pdf/SIR2009-5011.pdf, Appendix 2, Figure 2-2.

Figure 5-1. USGS Graph of Annual Mean Flow, 7-day Low Flow, Trend in Annual Mean Flow, and Trend in 7-day Low Flow of the Platte River at North Bend

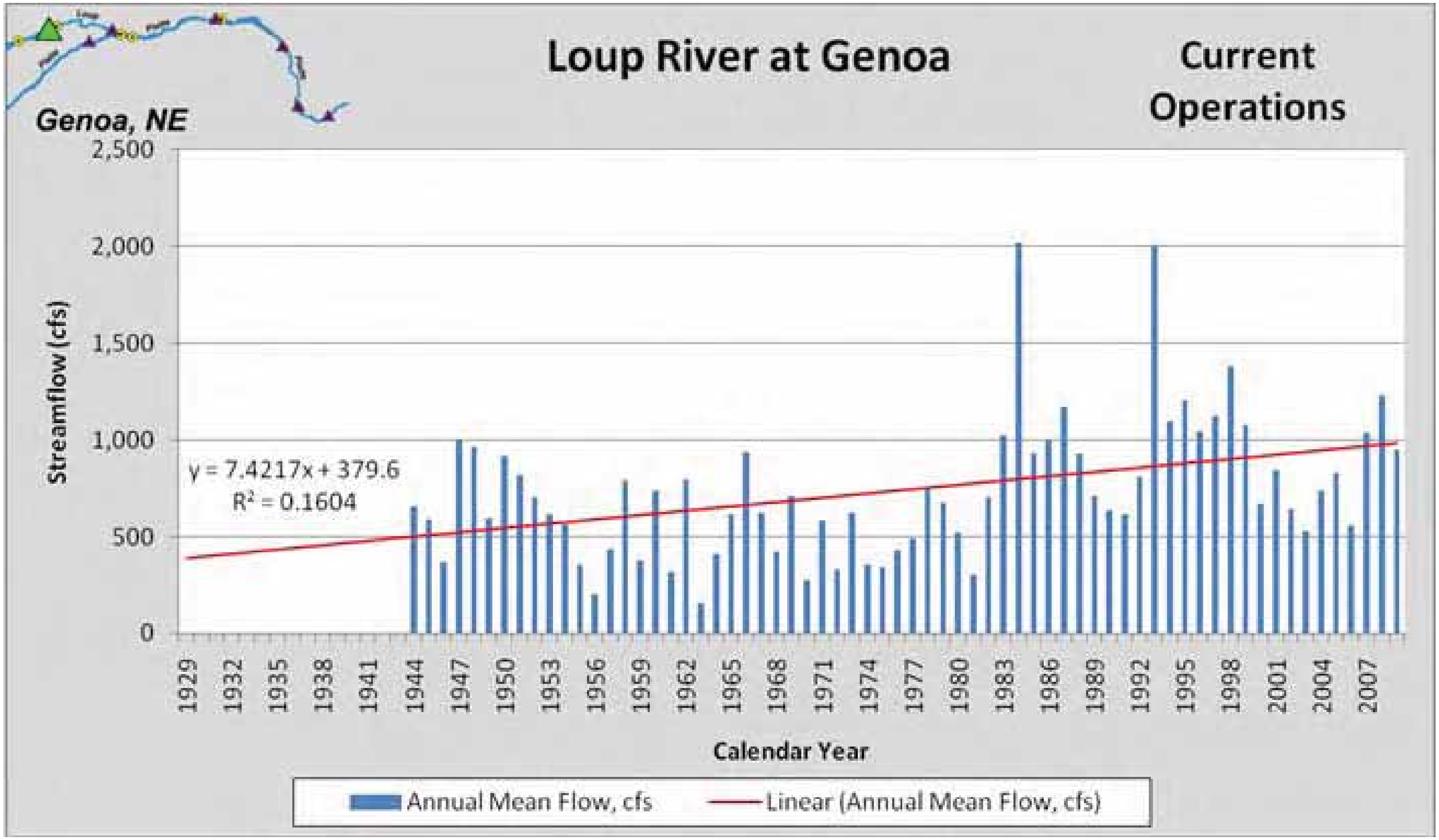


Figure 5-2. District's Graph of Annual Mean Flow and Trend in Annual Mean Flow for the Loup River at Genoa

As noted in the Initial Study Report, Appendix A, Sedimentation Study Report, and as shown in Figures 5-1 and 5-2, long-term positive trends and short-term cyclic streamflow patterns occur. With regard to the fluctuations, Ginting, Zelt, and Linard (2008) noted that the lower Platte River Basin was under a widespread drought (moderate to severe) from 1934 to 1944. This widespread drought was preceded by a widespread wet period (mildly to moderately wet) from 1895 to 1905, followed by an incipient drought to incipiently wet period (1951 to 1961) and an incipient drought to mildly wet period (1966 to 1976). Another widespread wet period (moderately wet) occurred in the Platte River Basin from 1985 to 1995, and an incipient drought to mildly wet period was noted from 1996 to 2006. These climatic impacts are readily visible in Figures 5-1 and 5-2.

Ginting, Zelt, and Linard (2008) note that the monthly minimum, mean, and maximum streamflow in the 1934 to 1944 drought period were significantly lower than those in the 1985 to 1996 moderately wet period. Their report did not directly mention the Project nor its effects on flows in the Platte River, but as explained in the report, the wide variations in flow since the Project began operations were in large part linked to climate.

Long-term graphical depictions of the annual mean flow and 7-day low-flow rates were provided by Dietsch, Godberson, and Steele (2009), with all exhibiting the long- and short-term cyclic patterns noted by Ginting, Zelt, and Linard. The 1985 to 2009 streamflow records analyzed in the Initial Study Report, Appendix A, Sedimentation Study Report, and shown in the Initial Study Report, Appendix A, Figures 5-6 to 5-12, revealed that a downward trend in Platte River flow, especially severe from Duncan to Leshara, existed from around 2000 to 2009. As described in the Sedimentation Study Report, use of even a 25-year period of record is not sufficient to establish long-term trends.

Thus, the trend is that annual Platte River flows upstream and downstream of the Loup River confluence are increasing. This phenomenon is attributed largely by USGS to natural climatic cycling of hydrology and should not be credited to, nor charged against, the Project because the Project does not impact flows in the Platte River near Duncan.

5.5 Objective 4: To determine the extent of interior least tern and piping plover nesting on the Loup River above and below the Diversion Weir.

5.5.1 Nest Count Data

The comparison of nesting occurrences of interior least terns and piping plovers above and below the Diversion Weir yielded inconclusive results. Limited riverine nesting data have been recorded for the Loup River throughout the last 25 years; the river has not been surveyed regularly due to the relatively small number of these species that use this river. Because of the small sample size and limited dataset, it was concluded that data were insufficient to accurately determine if there is a significant difference between nesting occurrences above and below the Diversion Weir.

5.5.2 Aerial Imagery Review

The aerial imagery review to compare potential habitat parameters above and below the Diversion Weir demonstrated that on average, the potentially available habitat above the Diversion Weir has more sandbars per river mile than below the Diversion Weir. This potential habitat is characterized by smaller areas, a wider channel, wider wetted widths, a lower percentage of vegetation on sandbars, a higher percentage of mid-channel sandbars, and less bare sand area on sandbars per river mile because, on average, sandbars are smaller and contain more wet sand/shallow water. Conversely, the potential habitat below the Diversion Weir has fewer sandbars per river mile, on average, than above the Diversion Weir. However, this potential habitat is characterized by much larger areas, a narrower channel with a narrower wetted width, a higher percentage of vegetation on sandbars per river mile but also a higher percentage of bare sand on sandbars per river mile, a higher percentage of point bar locations, and larger shallow water/wetted sand areas.

During the field visit, large dike structures were noted in the river below the Diversion Weir, as well as large areas of bank armoring with rock riprap and other debris. These features were not noted in most areas above the Diversion Weir and may also explain the variation in channel width above as compared to below the Diversion Weir. Aerial interpretation figures are located in Attachment H. Tables 5-5 and 5-6 show the results of the aerial interpretation for each river mile examined. Table 5-7 shows the averages of each parameter by year.

Table 5-5. Results of Aerial Interpretation of the Loup River Downstream of the Diversion Weir

Variable	2003 (Dry)					2004 (Normal)					2005 (Normal)					2006 (Normal)					2009 (Wet)				
	RM 5	RM 7	RM 13	RM 26	RM 32	RM 5	RM 7	RM 13	RM 26	RM 32	RM 5	RM 7	RM 13	RM 26	RM 32	RM 5	RM 7	RM 13	RM 26	RM 32	RM 5	RM 7	RM 13	RM 26	RM 32
Number of Sandbars per RM	3	4	5	6	7	5	3	5	4	8	2	3	3	5	8	2	5	7	4	5	4	3	6	7	3
Avg. Size of Sandbars (acres)	14.15	10.31	10.13	11.36	9.06	10.86	16.59	10.1	13.29	8.12	25.31	17.49	17.82	11.69	8.56	23.44	8.56	5.43	12.87	13.32	7.11	1.73	5.48	4.86	11.08
Avg. Channel Width (Trees to Trees) (feet)	585.59	593.18	639.92	729.11	797.03	584.27	597.11	653.90	688.63	821.18	610.88	589.05	639.28	748.05	756.29	613.40	594.31	558.70	737.38	756.29	588.07	551.02	665.68	708.95	781.22
Avg. Wetted Width (feet)	198.46	251.34	226.31	125.99	219.57	123.03	173.24	119.14	55.51	185.29	172.11	152.78	82.06	126.93	192.93	196.09	237.68	138.86	167.87	171.23	339.14	498.08	313.05	380.79	476.92
Percent vegetation on bars per RM (acres veg/acres sandbar)	5.68	19.36	39.22	6.78	6.97	13.52	14.28	16.77	3.61	10.24	17.08	13.59	13.47	0.89	10.03	29.39	21.56	13.58	2.12	12.21	11.78	0	11.71	0.18	10.79
Percent bare sand per RM (acres bare sand/acres in RM Bank to Bank)	35.66	30.32	20.7	52.55	39.72	36.07	34.64	37.85	49.2	50.62	45.67	44.27	35.66	53.49	56.34	39.52	29.69	42.83	46.72	55.08	23.95	0.1	25.6	37.48	21.1
Percent Shallow water/wet sand per RM (acres SW-WS/acres in RM	25.92	17.28	19.68	21.13	25.03	31.74	25.98	19.64	27.06	13.97	12.25	20.04	29.56	11.8	9.54	8.32	18.03	11.41	2.65	11.14	12.44	9.65	16.34	2.65	12
Percent Mid-channel bars per RM (# mid-bars/total # bars)	33	50	40	33	28	20	0	40	0	37	0	0	0	0	50	0	40	57	50	20	50	100	50	43	33
Percent Point bars per RM (# point bars/total # bars)	67	50	60	67	72	80	100	60	100	63	100	100	100	100	50	100	60	43	50	80	50	0	50	57	67
Avg. Shallow water/wet sand area of sandbars per RM (acres SW-WS/# of sandbars)	4.98	2.86	2.9	2.89	3.19	4.31	5.91	2.62	2.75	1.52	4.29	4.6	6.32	1.96	1.05	2.24	2.44	0.55	2.31	1.86	2.1	1.72	1.45	0.31	3.2
Avg. bare sand area of sandbars per RM (acres BS/# of sandbars)	8.37	5.45	3.25	7.7	5.23	5.08	8.31	5.79	10.06	5.14	16.7	10.52	9.1	9.62	6.65	14.31	4.28	4.14	10.29	9.83	4.18	0	3.39	4.54	6.64

Table 5-6. Results of Aerial Interpretation of the Loup River Upstream of the Diversion Weir

Variable	2003 (Dry)					2004 (Normal)					2005 (Normal)					2006 (Normal)					2009 (Wet)				
	RM 38	RM 49	RM 54	RM 60	RM 65	RM 38	RM 49	RM 54	RM 60	RM 65	RM 38	RM 49	RM 54	RM 60	RM 65	RM 38	RM 49	RM 54	RM 60	RM 65	RM 38	RM 49	RM 54	RM 60	RM 65
Number of Sandbars per RM	6	8	7	12	12	7	7	10	3	7	7	9	13	13	8	7	7	12	4	10	5	7	6	10	10
Avg. Size of Sandbars (acres)	3.44	2.42	2.69	2.91	2.16	3.77	1	4.73	12.18	5.05	3.97	3.04	3.62	2.84	4.76	3.96	6.53	2.96	15.12	3.88	5.58	6.15	3.91	3.31	2.68
Avg. Channel Width (Trees to Trees)(feet)	1116.42	805.06	1535.19	999.33	828.58	1066.30	796.66	1550.12	1014.72	823.26	1100.39	813.88	1538.55	1006.06	833.50	1103.83	822.97	1547.37	1009.05	832.21	1120.71	829.17	1566.86	1014.76	853.93
Avg. Wetted Width (feet)	478.48	526.11	649.70	690.24	502.20	281.01	631.32	346.63	671.82	434.73	333.85	477.95	364.79	676.07	420.55	299.29	330.48	457.60	474.83	430.64	323.74	281.89	641.63	697.15	542.12
Percent vegetation on bars per RM (acres veg/acres sandbar)	10.79	1.5	2.71	24.63	1.78	3.37	0	7.88	21	2.94	3.2	0.33	6.57	19.4	2.66	2.27	6.94	28.5	40.24	36.82	0	0	10.91	16.52	1.23
Percent bare sand per RM (acres bare sand/acres in RM bank-to-bank)	12.3	9.79	5.93	8.35	16.71	9.55	2.89	14.62	9.17	18.57	12.69	13.29	12.61	6.99	24.09	13.32	22.49	9.85	19.11	18.02	16.36	26.73	7.37	6.7	12.51
Percent Shallow water/wet sand per RM (acres SW-WS/acres in RM	8.21	12.39	5.69	13.47	11.76	22.71	6.8	12.77	16.69	7.22	14.05	16.7	13.26	18.44	14.19	11.71	22.16	7.31	12.3	8.38	12.66	26.66	5.61	19.16	15.39
Percent Mid-channel bars per RM (# mid-bars/total # bars)	83	63	57	75	75	57	57	30	33	86	29	55	23	62	57	57	57	33	75	90	40	43	17	90	80
Percent Point bars per RM (# point bars/total # bars)	17	37	43	25	25	43	43	70	67	14	71	45	77	38	43	43	43	67	25	10	60	57	83	10	20
Avg. Shallow water/wet sand area of sandbars per RM (acres SW-WS/total acres sandbars)	1.22	1.25	1.23	1.27	0.77	2.22	0.64	1.82	6.17	2.33	1.78	1.58	1.66	1.66	1.69	1.94	2.93	0.75	3.41	0.73	1.72	2.58	1.32	2.02	1.45
Avg. bare sand area of sandbars per RM (acres BS/total acres sandbars)	1.85	1.13	1.39	0.81	1.35	1.42	0.36	2.54	3.45	2.57	2.06	1.46	1.72	0.63	2.98	2.2	3.16	1.36	5.63	1.72	3.86	3.57	2.16	0.75	1.34

Table 5-7. Average Results of Aerial Interpretation by Year

Variable	2003 (Dry)		2004 (Normal)		2005 (Normal)		2006 (Normal)		2004, 2005, 2006 Average (Normal)		2009 (Wet)	
	Downstream of Diversion Weir	Upstream of Diversion Weir	Downstream of Diversion Weir	Upstream of Diversion Weir	Downstream of Diversion Weir	Upstream of Diversion Weir	Downstream of Diversion Weir	Upstream of Diversion Weir	Downstream of Diversion Weir	Upstream of Diversion Weir	Downstream of Diversion Weir	Upstream of Diversion Weir
Average Daily Flow (cfs)	180	1474	195	1006	268	1633	195	550			3614	4844.00
Number of Sandbars per RM	25	45	25	34	21	50	23	40	23.00	41.33	23	38.00
Avg. Size of Sandbars (acres)	11.00	2.72	11.79	6.14	16.17	3.65	12.72	8	13.56	5.93	6.04	4.33
Avg. Channel Width (Trees to Trees)(feet)	668.97	1056.92	669.02	1050.21	668.71	1058.48	652.0171	1063.09	663.25	1057.26	658.99	1077.09
Avg. Wetted Width (feet)	204.33	569.34	131.24	473.1	145.36	454.64	182.35	398.57	152.98	442.10	401.6	497.30
Percent vegetation on bars per RM (acres veg/acres sandbar)	15.6	8.28	11.68	7.04	11.01	6.43	15.77	22.954	12.82	12.14	6.89	5.73
Percent bare sand per RM (acres bare sand/acres in RM)	35.79	10.62	41.68	10.96	47.09	13.93	42.77	16.56	43.85	13.82	21.65	13.93
Percent Shallow water/wet sand per RM (acres SW-WS/acres in RM	21.81	10.3	23.68	13.24	16.64	15.33	12.73	12.37	17.68	13.65	10.61	15.9
Percent Mid-channel bars per RM (# mid-bars/total # bars)	36.8	70.6	19.4	52.6	10	45.2	33.4	62.4	20.93	53.40	55.2	54.00
Percent Point bars per RM (# point bars/total # bars)	63.2	29.4	80.6	47.4	90	54.8	66.6	37.6	79.07	46.60	44.8	46.00
Avg. Shallow water/wet sand area of sandbars per RM (acres SW-WS/total acres sandbars)	3.64	1.15	3.42	2.64	3.64	1.67	1.88	1.95	2.98	2.09	1.76	1.82
Avg. bare sand area of sandbars per RM (acres BS/total acres sandbars)	6	1.31	6.88	2.07	10.52	1.77	8.57	2.81	8.66	2.22	3.75	2.34

In considering the review of aerial images, the analysis of some of the habitat parameters may be affected by the flow condition on the day that the aerial image was taken as well as preceding conditions. The number of exposed sandbars, percentage of bare sand, and shallow water/wet sand may be influenced as much or more by preceding conditions than the wet, dry, or normal years may indicate. Habitat parameters such as the vegetation on sandbars and the sandbar location may be influenced more by yearly conditions than by conditions the day that the aerial image was taken or preceding conditions.

Based on the habitat parameters identified as used by interior least terns and piping plovers, shown in Table 4-5, potential habitat above the Diversion Weir demonstrates parameters similar to those used by these species. Potential interior least tern and piping plover habitat below the Diversion Weir contains large areas of bare sand; however, the majority of the sandbars have developed as point bars directly attached to the banks. This could potentially provide easy access by predators to nesting interior least terns and piping plovers and may typically be avoided by these species in favor of riverine nesting sites.

Overall, a comparison of valley width above and below the Diversion Weir revealed valley widths above the Diversion Weir to be wider than valley widths below the Diversion Weir. Average valley widths both above and below the Diversion Weir ranged from 15.2 to 24.3 miles. The range of valley widths selected as most frequently used habitat in a study conducted by USGS (Elliott et al., 2009) found the majority of birds nesting in the Eastern Platte River Gorge, which had a range of valley widths from 0.68 to 4.72 miles. The valley widths located in the study area all appear to be wider than those typically selected by interior least terns and piping plovers, potentially making the Loup River a less desirable portion of the Platte River valley for nesting.

5.5.3 Habitat Evaluation

Effects on Potential Interior Least Tern and Piping Plover Nesting Habitat

The HEC-RAS model results were used to show how changes in Project operations would affect potential interior least tern and piping plover nesting habitat. The existing conditions at Site 1, upstream of the Diversion Weir are shown in Table 5-8, and the change in percentage of exposed channel width at Site 2, downstream of the Diversion Weir as a result of different flow conditions, operating conditions, and hydrologic (wet/dry/normal) classifications is shown in Table 5-9. For both Sites 1 and 2, the average percentage of channel width exposed is shown in Table 5-10. Figures that show the percentage of channel width exposed for each cross section for both Sites 1 and 2 for the various flow conditions, operating conditions, and hydrologic (wet/dry/normal) classifications are provided in Attachment I.

Table 5-8. Percentage of Exposed Channel Width – Site 1, Upstream of the Diversion Weir

Calendar Year of Analysis	Low Flow (75% Exceedance)		Medium Flow (50 % Exceedance)		High Flow (25% Exceedance)	
	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer
2006 (Dry)	38	36	11	16	7	12
2005 (Normal)	17	18	9	14	5	11
2008 (Wet)	13	17	7	12	2	8

Table 5-9. Percentage of Exposed Channel Width – Site 2, Downstream of the Diversion Weir

Calendar Year of Analysis	Low Flow (75% Exceedance)				Medium Flow (50 % Exceedance)				High Flow (25% Exceedance)			
	Current Operations		No Diversion Condition		Current Operations		No Diversion Condition		Current Operations		No Diversion Condition	
	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer	Early Summer	Late Summer
2006 (Dry)	86	87	16	26	69	65	4	19	40	31	3	15
2005 (Normal)	75	70	5	22	80	35	3	16	22	26	3	13
2008 (Wet)	67	63	5	21	46	33	3	15	10	24	3	10

Table 5-10. Average Percentage of Exposed Channel Width[1]

Calendar Year of Analysis	Site 1	Site 2	
		Current Operations	No Diversion Condition
Channel width (linear feet)	825	640	640
2006 (Dry)	20	63	14
2005 (Normal)	12	46	10
2008 (Wet)	10	41	10

Note:
1 Averages for channel widths and for all flow conditions for early summer cross sections.

When considering the results of this analysis, a key understanding is that the analysis considered only the percentage of exposed channel width as potential habitat. However, the analysis did not make a distinction as to suitable habitat. Suitable habitat, or habitat in which interior least terns and piping plovers would choose to nest, would factor in conditions such as percentage of bare sand, location and configuration of the percentage of exposed channel width, percentage of vegetated cover, and potential for predation. Therefore, differences in exposed channel width do not necessarily indicate more or less suitable nesting habitat.

Further, the time periods when the cross sections were taken also need to be considered when comparing between the early and late summer conditions. Depending on when high-flow events occurred that affected the wet, dry, and normal year classifications, the river morphology may have reflected a drier or wetter condition than the wet, dry, and normal year classification actually would represent.

Dry Year (2006)

The analysis of percentage of exposed channel width at Site 2, downstream of the Diversion Weir, for the dry year yielded fairly predictable results. For current operations, the early summer cross sections generally had higher percentages of exposed channel width than the late summer cross sections; however, the average of all flow conditions indicated a marginal difference. As expected, the lower flow condition yielded a higher percentage of exposed channel width than the higher flow condition. Compared to current operations, the no diversion condition had a smaller percentage of exposed channel width for all flow conditions. The margin of difference between current operations and the no diversion condition was the greatest under low flow conditions. This result is predictable because under the no diversion condition, more flow would be passing through Site 2, thereby reducing the amount of exposed channel width.

For all flow conditions for both early summer and late summer cross sections, Site 1, upstream of the Diversion Weir, had a smaller percentage of exposed channel width than Site 2, downstream of the Diversion Weir, under current operations. Site 1 ranged from 7 to 38 percent exposed channel width, while Site 2, under current operations, ranged from 31 to 87 percent exposed channel width. This is likely because the average daily flows at Site 2, as identified in the synthetic hydrographs provided in Attachment C, are typically much lower than those at Site 1 due to the reduction in flows entering the Loup River bypass reach. The percentages of exposed channel width at Site 1, upstream of the Diversion Weir, under the various flow conditions is similar to the percent exposed channel width at Site 2, downstream of the Diversion Weir, under the no diversion condition.

Overall, there are differences in the percentage of exposed channel widths between Sites 1 and 2 (under current operations) and between current operations and the no diversion condition when considering all flow conditions for the early summer survey.

Normal Year (2005)

The analysis of percentage of exposed channel width for the normal year was consistent under all flow conditions and between current operations and the no diversion condition. For both current operations and the no diversion condition, as expected, the normal year yielded a smaller percentage of exposed channel width than the dry year. The trends of more exposed sand under current operations than under the no diversion condition with lower flows than higher flows remained consistent.

At Site 2, downstream of the Diversion Weir, under current operations, there was little difference in percentage of exposed channel width between the early summer and late summer cross sections for all flow conditions (an average of 49 percent as opposed to 44 percent of exposed channel width, respectively). There was more of a difference between the early and late summer cross sections under the no diversion condition.

For all flow conditions for both early summer and late summer cross sections, Site 1, upstream of the Diversion Weir, had a smaller percentage of exposed channel width than Site 2, downstream of the Diversion Weir. This is likely because the average daily flows, as identified in the synthetic hydrographs provided in Attachment C, are typically much lower than those at Site 1 due to the reduction in flows entering the Loup River bypass reach. The percentages of exposed channel width at Site 1, upstream of the Diversion Weir, under the various flow conditions are similar to the percentage of exposed channel width at Site 2, downstream of the Diversion Weir, under the no diversion condition.

Wet Year (2008)

The analysis of percentage of exposed channel width at Sites 1 and 2 is consistent with previous results. Generally, the wet year resulted in a smaller percentage of exposed sand than the normal and dry years. However, results for the wet year are fairly close to the results for the normal year, with an average percentage of exposed channel in both early summer and late summer of 46 and 41 percent, respectively. The results for the no diversion condition were fairly consistent across the dry (14 percent exposed channel width), normal (10 percent), and wet (10 percent) years and are generally consistent with conditions above the Diversion Weir.

Conclusions

The generalized results for each year of analysis (wet, dry, and normal years) indicate that the percentage of exposed channel width under current operations is consistently greater downstream of the Diversion Weir than upstream. Additionally, current operations downstream provide a greater percentage of exposed channel width than the no diversion condition. Early summer cross sections yielded a greater percentage of exposed sand than late summer cross sections downstream of the Diversion Weir under current operations. Conversely, late summer cross sections upstream of the Diversion Weir yielded a greater percentage of exposed channel width. This is likely due to a decrease in runoff events during this time period; however, differences were marginal.

When reviewing these results, it must be considered that increasing exposed channel width does not necessarily provide more suitable interior least tern and piping plover nesting habitat. Increased size of exposed channel width where interior least terns were nesting did not appear to be a selected feature in Brown and Jorgensen (2009), where "the mean surface area without nesting least tern colonies was greater than that of sandbars with nesting colonies." Further, the processes for sandbar formation and destruction are complex. The conditions exhibited in this flow depletion and flow diversion study provided only a difference in the surface water elevations that would be present at surveyed cross sections under the various operation and flow conditions.

By examining the cross sections taken during different times of the year, the effects of seasonal sandbar erosion and channel morphology changes that existed under actual conditions (precipitation events and operations) between the early summer and late summer periods were also considered. While the percentage of exposed channel width is a good indicator of potential habitat (defined in this study as dry, exposed sandbars), other factors that influence sandbar formation, habitat suitability, and general river morphology—such as frequency and occurrence of precipitation events, bank protection, riparian area land use, percentage of vegetation cover on sandbars, and valley width—are all factors that ultimately affect the development of potentially suitable habitat.

The areas upstream and downstream of the Diversion Weir differ with respect to amount of exposed channel under current operations; however, the nesting data for these two areas do not show a significant difference in interior least tern and piping plover use of the Loup River above or below the Diversion Weir, considering the limited amount of riverine nesting that has occurred on the Loup River. Therefore, it is difficult to conclude that the changes in percentage of exposed channel width alone provide more or less suitable habitat. Further, the adult population counts and nesting data generally show that in these areas, interior least terns and piping plovers show a preference for nesting on sand pits rather than the river. For example, 43 interior least tern nests and 15 piping plover nests were documented on two sandpits (not including the North SMA) in 2005. No nests were documented on the Loup River in 2005 (NGPC Interior Least Tern and Piping Plover Database).

In a study conducted on the lower Platte River downstream of Columbus by Kirsch (1996), interior least terns were found to show no preference of riverine sandbars over sand pits. Productivity and mortality of young also did not differ between river sandbars and sand pits, thereby suggesting that interior least terns may not perceive sandbars and sand pits as different habitat and may consider such habitat to be equally suitable (Kirsch, 1996).

In surveys conducted on the central Platte River, as reported by Jenniges and Plettner (2008), over 90 percent of all interior least tern nests counted have been on human-created habitats, such as sand pits and man-made sandbar complexes (Sidle et al., 1991; Lingle, 1993; Sidle and Kirsch; Jenniges, 2005; all as cited in Jenniges and Plettner, 2008). Although the central Platte River differs in some ways from the Loup River, it is similar in that it contains a flat, wide channel.

In a study conducted by Ziewitz et al. (1992), it was concluded that rivers containing wide enough channels to attract interior least terns may be too flat to provide islands high enough in elevation to offer protection from flooding. Jenniges and Plettner (2008) conducted a study on the effectiveness of habitat management strategies at sand pits. The study found that managed sandpits had higher productivity rates than sand pits with no species management. Jenniges and Plettner (2008) discuss the need for increased management of sandpit habitat because interior least terns and piping plovers are continually choosing these sites in the central Platte River to nest, despite an abundance of human-created islands in the river. Thus far, creation of riverine habitat on the central Platte has had limited success, leaving management and restoration of sand pits as an important option of increasing nesting interior least tern numbers in Nebraska (Jenniges and Plettner, 2008).

Sedimentation Analysis

To assess the effects of flow diversion on sediment transport, sediment transport indicators were determined for the selected wet, dry, and normal years for both current operations and the no diversion condition. The methods applied were consistent with the methodology outlined in the Initial Study Report, Appendix A, Sedimentation Study Report.

As stated in the District's Revised Study Plan, if the literature review, sediment transport parameter calculations, and regime analyses indicate that short-term fluctuations in the morphology of the Loup River bypass reach under current operations versus the no diversion condition are not transitioning to another form, it would be further affirmed that the Loup and Platte rivers are currently in dynamic equilibrium. If the literature review and calculations indicate that the Loup River bypass reach is transitioning to another form and either aggrading or degrading, it would be concluded that the Loup River bypass reach is currently not in dynamic equilibrium. Furthermore, if the analysis of the morphology under current operations indicates that the Loup River bypass reach is in dynamic equilibrium and not supply limited based on the adjusted yields and sediment transport capacity calculations, then the no diversion condition would not be considered in management decisions.

Because the no diversion condition only changes flows in the Loup River bypass reach, the calculations were limited to the four gaged and ungaged sites in the Loup River as well as at Site 3 on the Platte River, upstream of the Tailrace Return. In addition, the regime classification that would result for the no diversion condition was analyzed for comparison with the regime classification that exists for current operations.

Sediment Transport Indicators

Effective and dominant discharges and total sediment transport for current operations at the gaged and ungaged sites were provided in the Initial Study Report, Appendix A, Sedimentation Study Report, and the Second Initial Study Report, Appendix A, Sedimentation Addendum, respectively. Effective discharges for the no diversion hydrology described in Section 4.2.2 were derived from the daily transport rates by grouping the transport rates in bins and determining "modal" values and ranges of the discharges that transport the greatest amounts of sediment. The histograms are provided in Attachment J. Dominant discharges and total sediment transport for the no diversion condition were calculated using identical methods described in the Initial Study Report, Appendix A, Sedimentation Study Report, and the Second Initial Study Report, Appendix A, Sedimentation Addendum.

Results comparing current operations and the no diversion condition for a normal year (2005), dry year (2006), and wet year (2008) are shown in Tables 5-11 through 5-13, respectively. The average values of the sediment transport indicators for the study period from 2003 to 2009 are shown in Table 5-14.

Longer-term, 1985 to 2009 values of the indicators for current operations at the gaged sites were reported in the Initial Study Report, Appendix A, Sedimentation Study Report. For comparison with values in Tables 5-11 through 5-14, the 25-year, long-term average values for the Loup River near Genoa gage (from the Initial Study Report, Appendix A, Table 5-2) were as follows:

- Mean daily discharge – 950 cfs
- Effective discharge – 2,400 cfs (range of 1,800 to 3,000 cfs)
- Dominant discharge – 1,350 cfs
- Average annual total sediment transport at capacity – 1,760,000 tons per year
- Average annual sediment yield – 2,030,000 tons per year

Because the Loup River near Genoa gage is the only long-term gage site in Tables 5-11 through 5-14 at which synthesized flows were not used, the following paragraphs provide the District's analysis of the sediment transport and morphology results of the comparison between current operations and the no diversion condition for only the Loup River near Genoa gage. However, even though synthesized data were used at the other sites in Tables 5-11 through 5-14, the sediment transport indicators follow the same patterns and same conclusions noted for the Loup River near Genoa gage.

Table 5-11. Sediment Transport Indicator Results for Flow Depletion and Flow Diversion Analysis, 2005 (Normal)

Location on the Loup or Platte River	Current Operations			No Diversion Condition		
	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)
Site 1 – Loup River Upstream of the Diversion Weir	2,300	2,500	2,240	2,300	2,500	2,240
Site 2 – Loup River Downstream of the Diversion Weir	1,000	2,900	890	2,400	2,500	2,370
Loup River near Genoa gage	1,100	3,000	1,260	2,600	2,500	3,410
Loup River at Columbus gage	1,200	1,400	950	2,700	2,400	2,290
Site 3 – Platte River Upstream of the Tailrace Return	1,200	1,400	950	3,400	3,600	1,760

Note:

Q_d = dominant discharge; Q_e = effective discharge.

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Table 5-12. Sediment Transport Indicator Results for Flow Depletion and Flow Diversion Analysis, 2006 (Dry)

Location on the Loup or Platte River	Current Operations			No Diversion Condition		
	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)
Site 1 – Loup River Upstream of the Diversion Weir	1,900	2,400	1,750	1,900	2,400	1,750
Site 2 – Loup River Downstream of the Diversion Weir	730	2,300	560	2,000	2,400	1,840
Loup River near Genoa gage	790	2,300	800	2,200	2,400	2,670
Loup River at Columbus gage	890	400	590	2,300	2,600	1,790
Site 3 – Platte River Upstream of the Tailrace Return	1,300	1,500	430	2,600	3,200	1,180

Note:

Q_d = dominant discharge; Q_e = effective discharge.

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Table 5-13. Sediment Transport Indicator Results for Flow Depletion and Flow Diversion Analysis, 2008 (Wet)

Location on the Loup or Platte River	Current Operations			No Diversion Condition		
	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)
Site 1 – Loup River Upstream of the Diversion Weir	3,100	2,800	3,550	3,100	2,800	3,550
Site 2 – Loup River Downstream of the Diversion Weir	1,600	2,800	1,830	3,300	2,800	3,730
Loup River near Genoa gage	1,700	2,100	2,540	3,400	2,800	5,220
Loup River at Columbus gage	2,000	3,400	1,780	3,700	3,100	3,600
Site 3 – Platte River Upstream of the Tailrace Return	4,000	2,100	2,260	5,700	3,900	3,740

Note:

Q_d = dominant discharge; Q_e = effective discharge.

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Table 5-14. Sediment Transport Indicator Results for Flow Depletion and Flow Diversion Analysis, 2003-2009

Location on the Loup or Platte River	Current Operations			No Diversion Condition		
	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)	Q_d (cfs)	Q_e (cfs)	Sediment Capacity (1,000 tons)
Site 1 – Loup River Upstream of the Diversion Weir	2,500	2,300	2,585	2,500	2,300	2,585
Site 2 – Loup River Downstream of the Diversion Weir	1,100	1,700	996	2,600	2,300	2,570
Loup River near Genoa gage	1,200	1,700	1,400	2,700	2,300	3,670
Loup River at Columbus gage	1,300	1,800	1,030	2,900	2,700	2,500
Site 3 – Platte River Upstream of the Tailrace Return	2,400	2,100	1,040	3,900	3,300	2,110

Note:

Q_d = dominant discharge; Q_e = effective discharge.

As demonstrated in the Initial Study Report, Appendix A, Sedimentation Study Report, values of the sediment transport indicators fluctuate widely from year to year and experience periods of declines and rises. The analysis reported in the Initial Study Report, Appendix A revealed that all indicators at gaged sites were moderately lower from 2003 to 2009 than the longer-term 1985 to 2009 values, which was attributed to this relatively dry period overall.

As shown in Table 5-14, average 2003 to 2009 values of effective discharge, dominant discharge, and total sediment transport for current operations at the Loup River near Genoa are 1,700 cfs, 1,200 cfs, and 1,400,000 tons per year. These are 29, 11, and 21 percent less, respectively, than the long-term 1985 to 2009 values. Figure 5-3 (reproduced from the Initial Study Report, Appendix A, Figure 5-6) and the narrative in the Initial Study Report clearly demonstrated that the reduced effective and dominant discharges for 2003 to 2009 were associated with low flows in those years compared to longer-term averages and not attributed to any known change in Project operations.

For the no diversion condition, the 2003 to 2009 effective and dominant discharges for Site 1, upstream of the Diversion Weir, are relatively unchanged at Site 2, downstream of the Diversion Weir, as shown in Table 5-14. This is also true for the individual wet, dry, and normal years. This indicates that the surveyed channel geometries and associated sediment transport characteristics are similar at the two locations, yielding nearly equal values of the indicators for equal discharge hydrographs. For current operations, reductions in the indicators across the Diversion Weir are consistent with diversions averaging 1,600 cfs, which is about equal to the difference in dominant discharge for current operations.

From just downstream of the Diversion Weir to Genoa, the 2003 to 2009 effective and dominant discharges and sediment transport amounts increase in the same increasing pattern described for the Loup and Platte rivers in the Initial Study Report, Appendix A, Sedimentation Study Report. A discrepancy in this pattern for total transport occurs at the Loup River at Columbus gage, but the effective and dominant discharges follow the pattern.

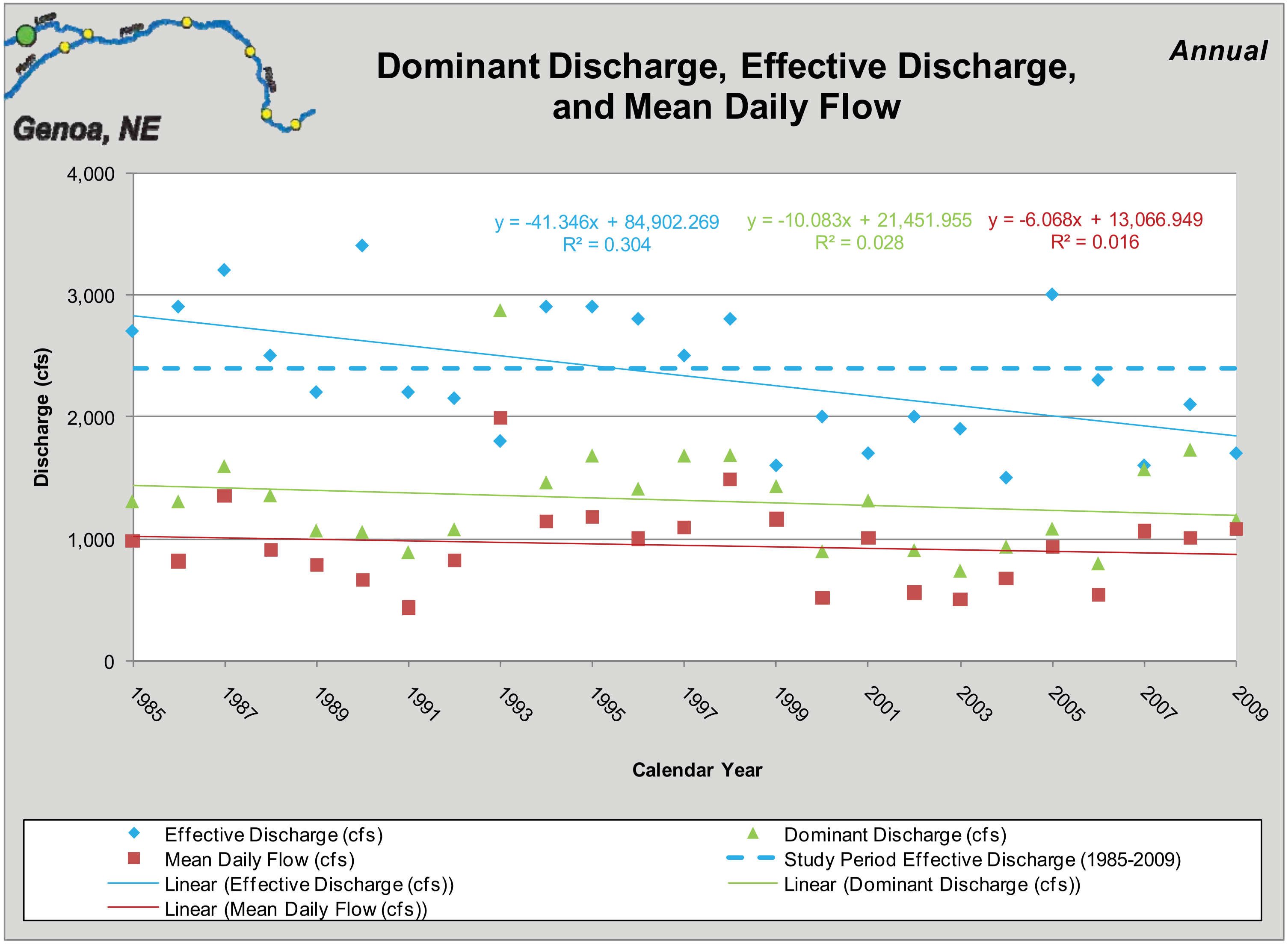

Figure 5-3. Annual Dominant Discharge, Effective Discharge, and Mean Daily Flow at the Loup River near Genoa (USGS Gage 06793000)

The current operations indicators at Site 3, on the Platte River upstream of the Tailrace Return, were shown by spatial analysis in the Second Initial Study Report, Appendix A, Sedimentation Addendum, to be consistent with patterns in the Platte River. The 2003 to 2009 effective and dominant discharges shown in Table 5-14 at Site 3 for the no diversion condition are increased over current operations values. This is expected because the flows at Site 3 for the no diversion condition include the otherwise diverted amounts, and an increase in transport capacity and other indicators would be expected because of the increase in flow rates.

The indicators for both current operations and the no diversion condition at Site 3 fall within the Platte River patterns between Duncan and Louisville discovered by the District and other investigations cited in the Initial Study Report, Appendix A, Sedimentation Study Report. For the 1985 to 2009 data, the dominant discharge near Duncan was 2,240 cfs, and the dominant discharge at North Bend was 5,280 cfs. The no diversion condition dominant discharge at Site 3 of 3,900 cfs fits the pattern. Similarly, the total sediment transport capacity at Site 4 for the no diversion condition (2,110,000 tons per year) falls comfortably between the long-term average values near Duncan and at North Bend of 1,870,000 and 5,770,000 tons per year, respectively.

The amount of sediment that could be transported at capacity is directly linked to the amount of flow passing any point. An increase in the capacity to transport at Site 3 because of the increase in flow under the no diversion condition should not be considered evidence of possible degradation if the diversions were discontinued. No physical data or studies by others, including the cross-section measurements by the District, reveal a problem with aggradation or degradation under current operations at this location, but the results above reveal that the transport indicators for the no diversion condition are actually an improved fit in the overall pattern of indicators. As long as supplies are abundant, as they are, changes in transport capacity do not affect the equilibrium condition.

The fact that no degradation in the Platte River at Site 3 has been documented, the fact that sediment supply exceeds transport capacity, and the fact that the effective and dominant discharges and total transport capacities for both current operations and the no diversion condition at Site 3 fit the overall Platte River pattern indicate that morphology is not being impacted by this localized decrease in transport capacity under current operations. The flow rates that transport the most sediment (effective or dominant rates) would need to be significantly "out of kilter" with the overall river's pattern and would need to be in excess of the supply rates in order to conclude that aggradation or degradation is or would occur for either current operations or the no diversion condition. The flow rates controlling the Platte River's width, depth, and overall morphology are consistent with the overall braided river morphology.

Channel Geometry Impacts

As specified in the District's Revised Study Plan, the channel geometry parameters (width [W], depth [D], and velocity [V]) associated with each years' values of effective and dominant discharge were calculated for the normal, wet, and dry years, as well as averages for 2003 to 2009. These results are provided in Figures 5-4 through 5-11.

The W, D, and V values in Figures 5-4 through 5-11 reflect the results of inputting the effective and dominant discharges for each year or combination of years on the abscissas of the actual (at gaged sites) or HEC-RAS-synthesized (at ungaged sites) channel geometry relationships shown in the Initial Study Report, Appendix A, Sedimentation Study Report, and the Second Initial Study Report, Appendix A, Sedimentation Addendum. Respective values of W, D, and V were obtained from the best fit curves through the data.

As expected, the W, D, and V below the Diversion Weir would be different under the no diversion option due to the increased flow rates. Because averages over several years are better indicators than individual years, examination of the 2003 to 2009 rows in Figure 5-11 reveal that the W, D, and V values for the no diversion condition would all be larger than under current operations at all locations downstream, including Site 3. Most of the individual year values show the same results. The average 2003 to 2009 widths for the no diversion condition range from 18 to 54 feet wider, the depths range from 0.2 to 0.5 foot deeper, and velocities range from 0.3 to 0.8 foot per second greater than the current operating condition.

As shown for the USGS measurements of these parameters in the Initial Study Report, Appendix A, Figures 4-5 through 4-8 and Attachment A, and for the synthesized HEC-RAS W, D, and V in the Second Initial Study Report, Appendix A, Figures 4-4 and 4-5 and Attachment A, the actual and synthesized values of W, D, and V cover a wide range for any individual discharge rate, particularly at the ungaged sites. In all cases, the values selected for both scenarios using the best-fit equations have variabilities for any given discharge rate that exceed the differences between current operations and the no diversion condition.

Although it is expected that eliminating the Diversion Weir would increase the overall W, D, and V values in the Loup River bypass reach if sustained for long periods (due to increased flow rates and increased effective and dominant discharges), the changes shown in Figure 5-11, although relatively small (a maximum of 7 percent for width and 30 percent for depth and velocity), should not be considered to be predictions of morphologic changes that would occur under the no diversion alternative. Use of daily flows for any given year, or even for a period of 7 years (2003 to 2009), to try to establish morphologic changes is not advised (see discussion in the Initial Study Report, Appendix A, Sedimentation Study Report, and the Second Initial Study Report, Appendix A, Sedimentation Addendum).

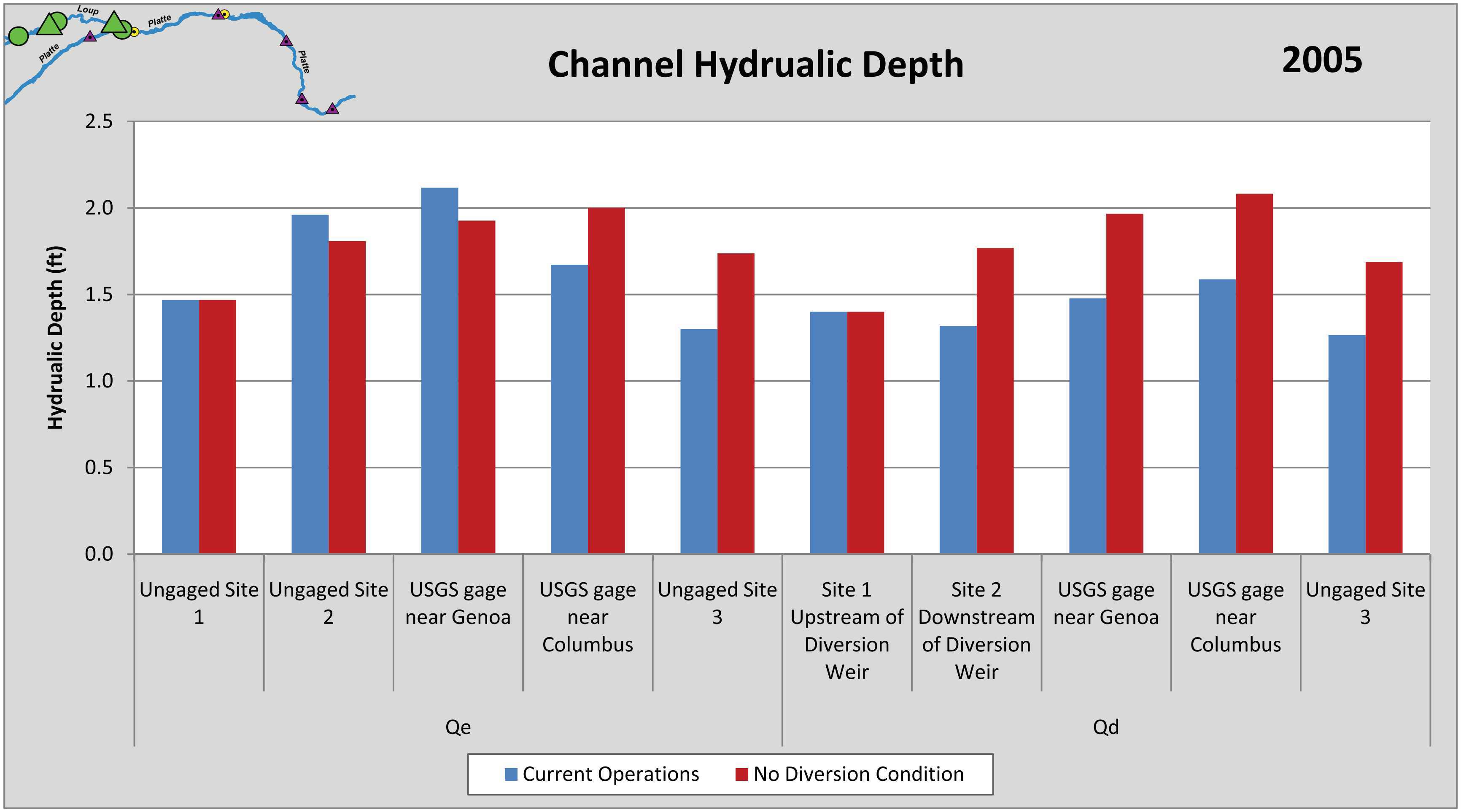

Figure 5-4. Depth Values for Current Operations and No Diversion Condition, 2005

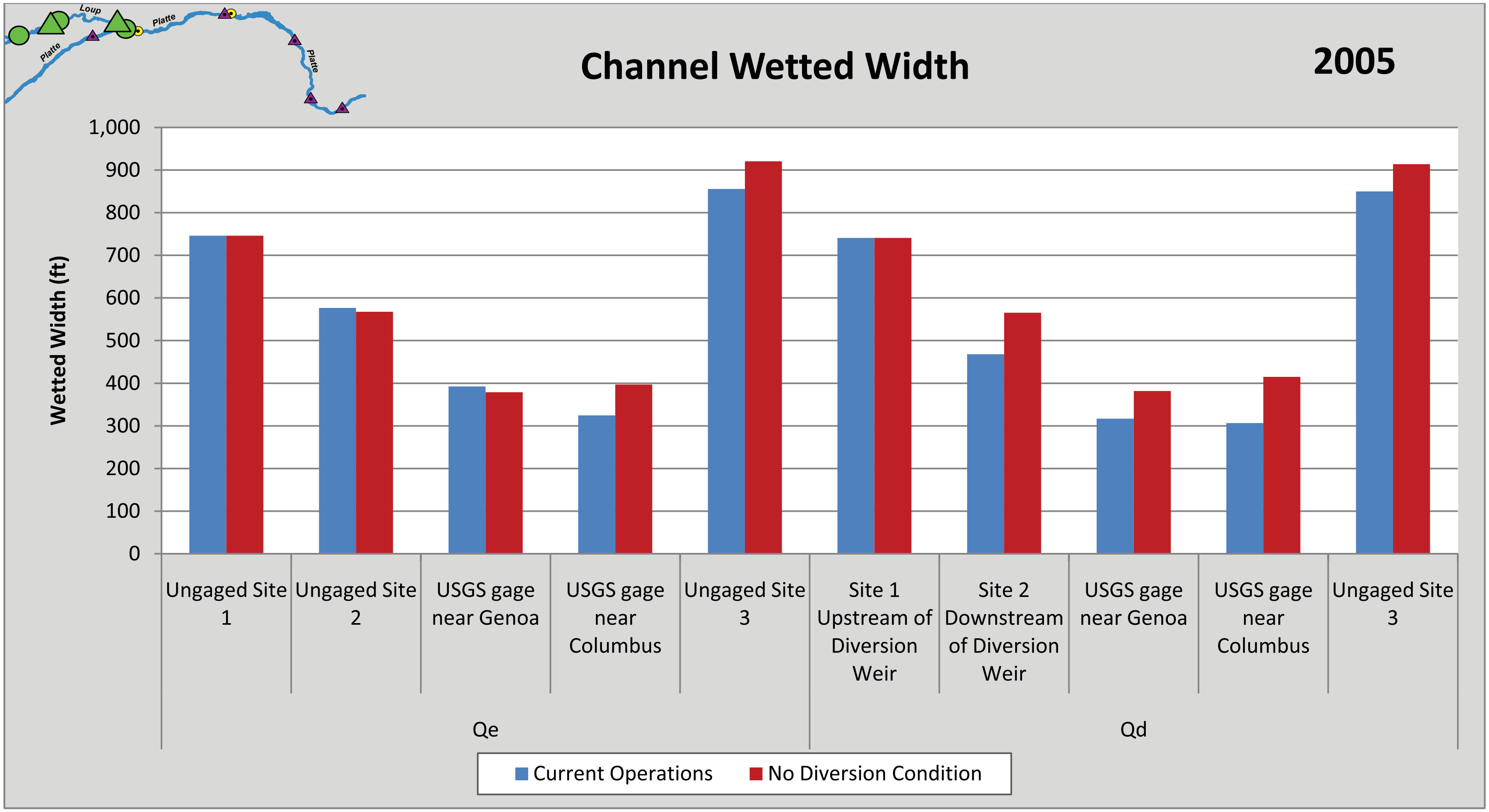

Figure 5-5. Width Values for Current Operations and No Diversion Condition, 2005

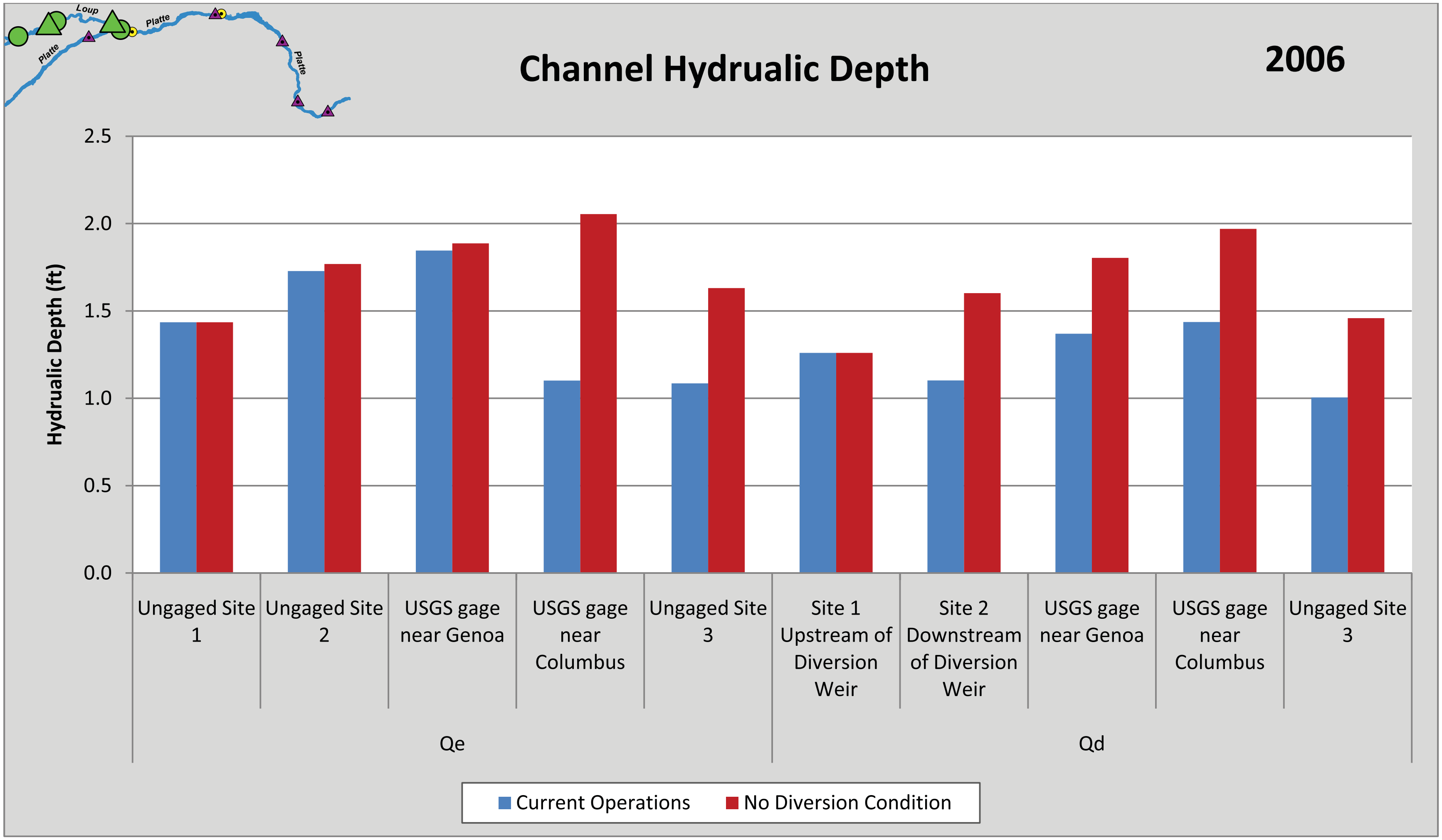

Figure 5-6. Depth Values for Current Operations and No Diversion Condition, 2006

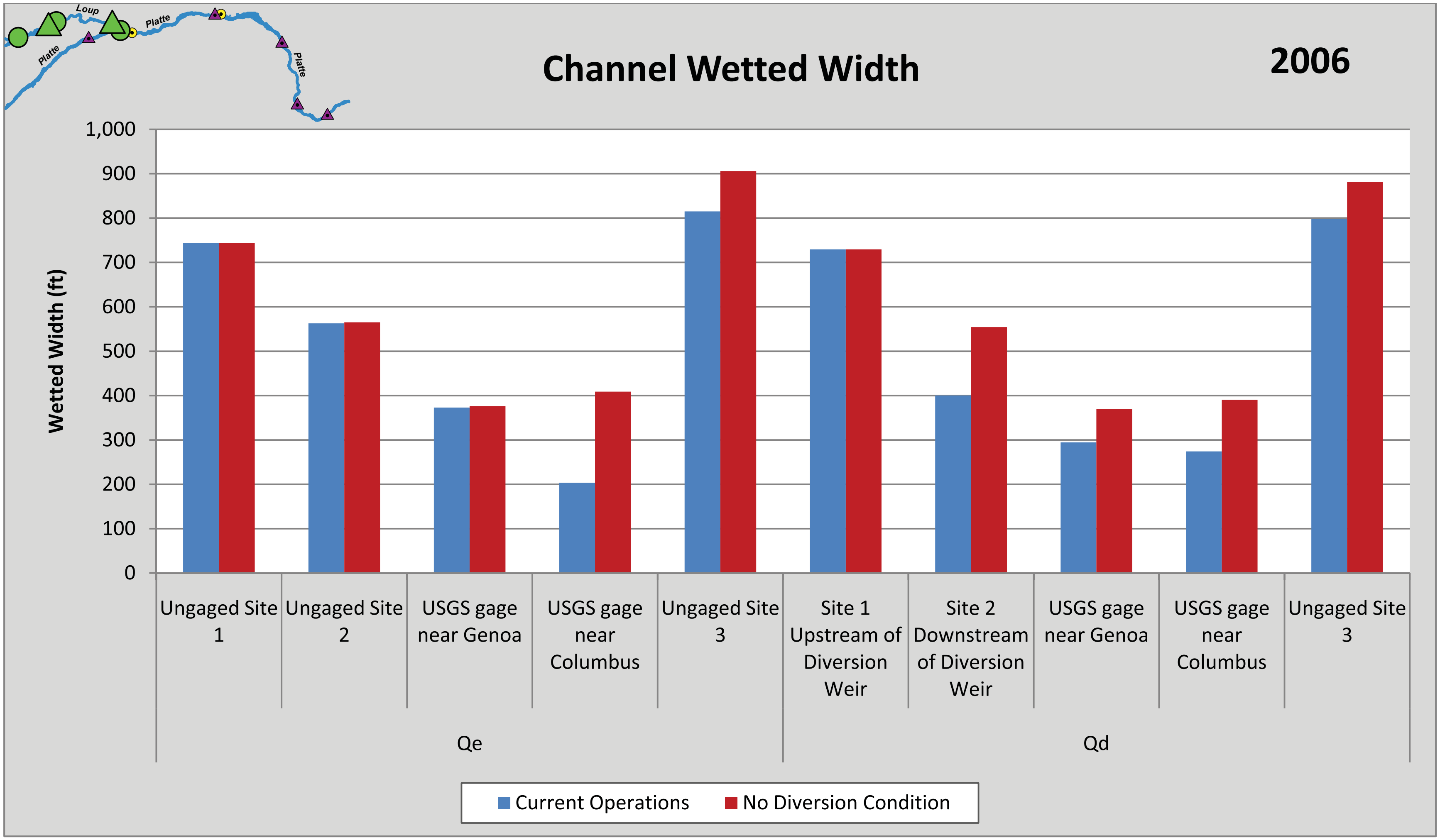

Figure 5-7. Width Values for Current Operations and No Diversion Condition, 2006

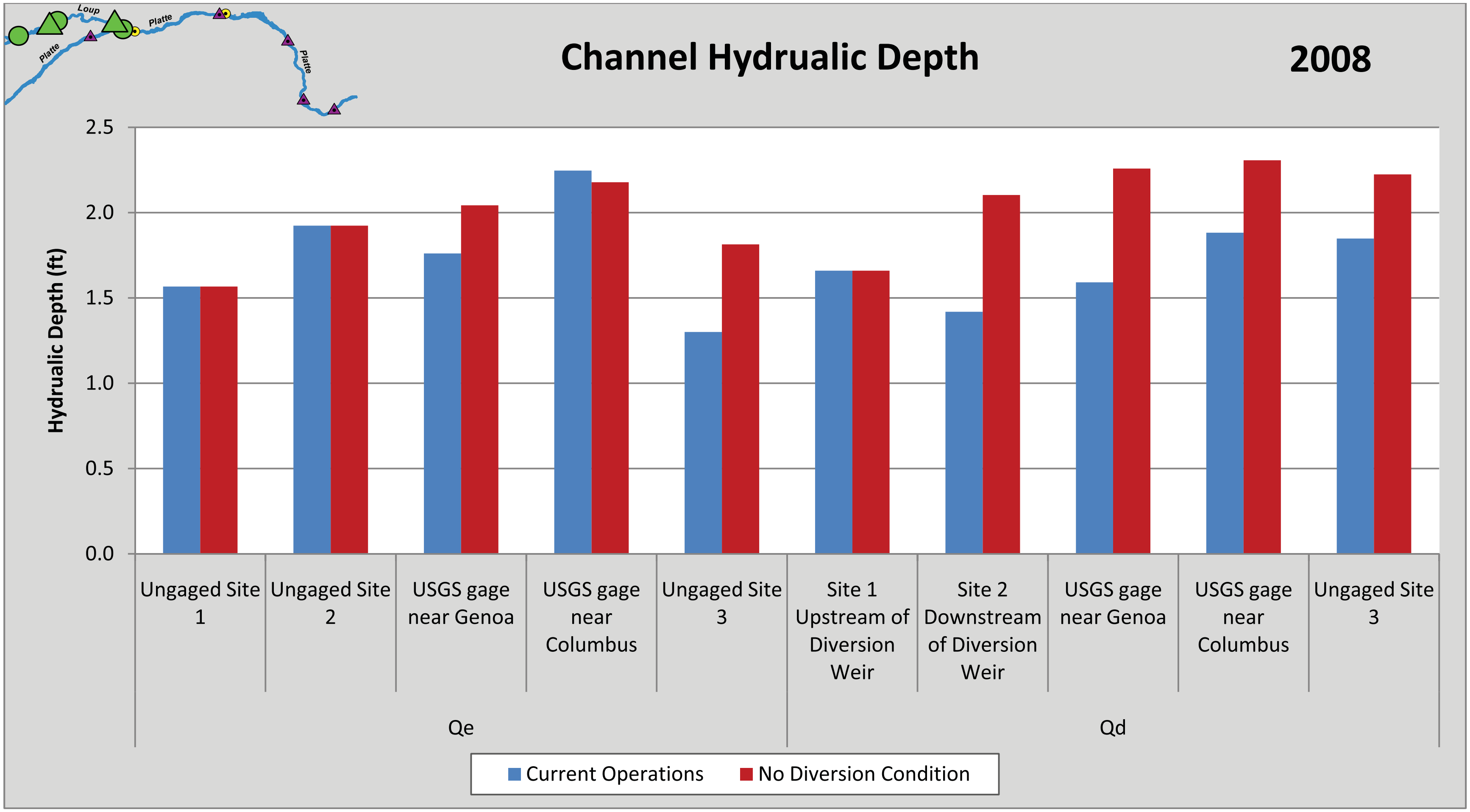

Figure 5-8. Depth Values for Current Operations and No Diversion Condition, 2008

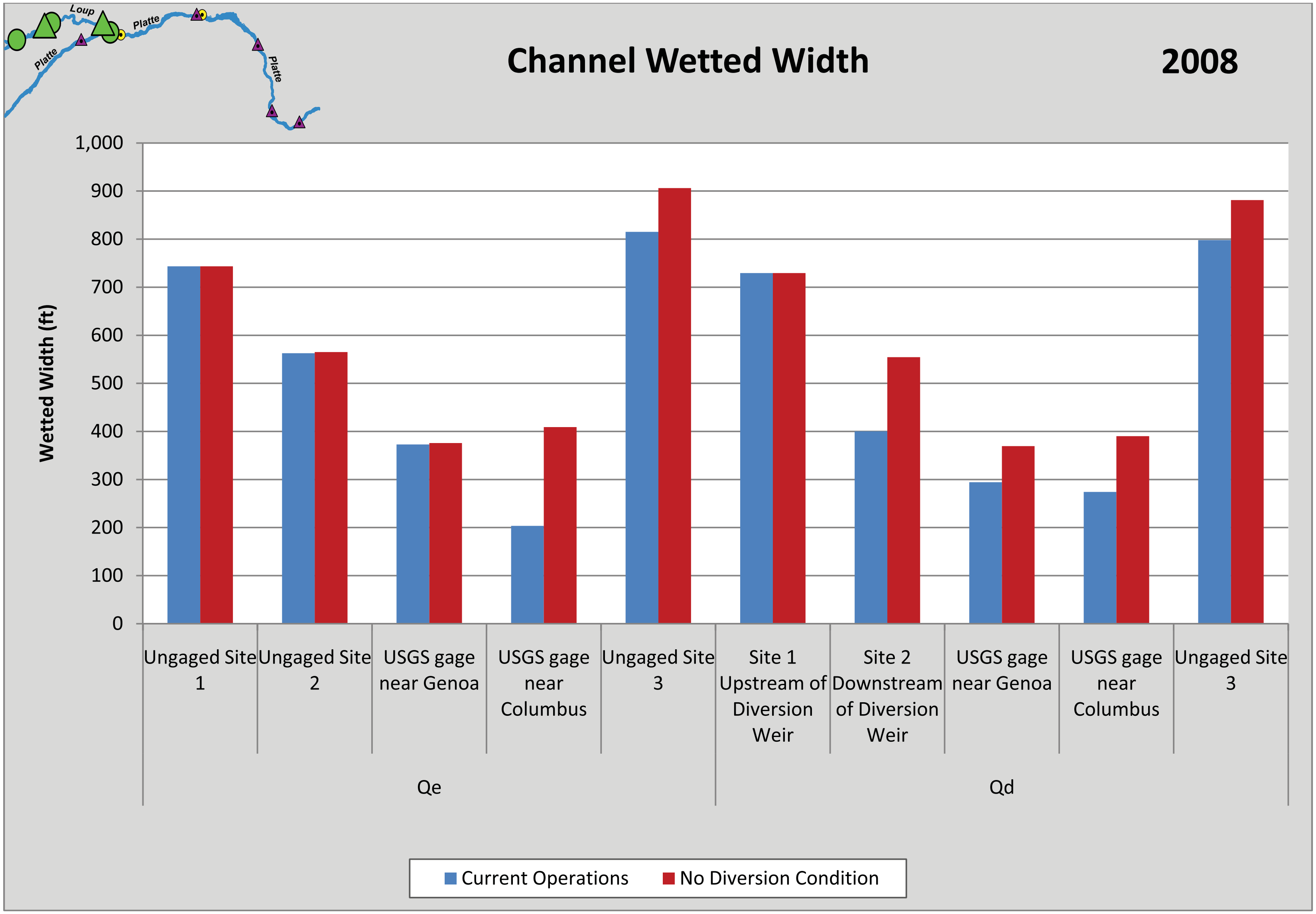

Figure 5-9. Width Values for Current Operations and No Diversion Condition, 2008

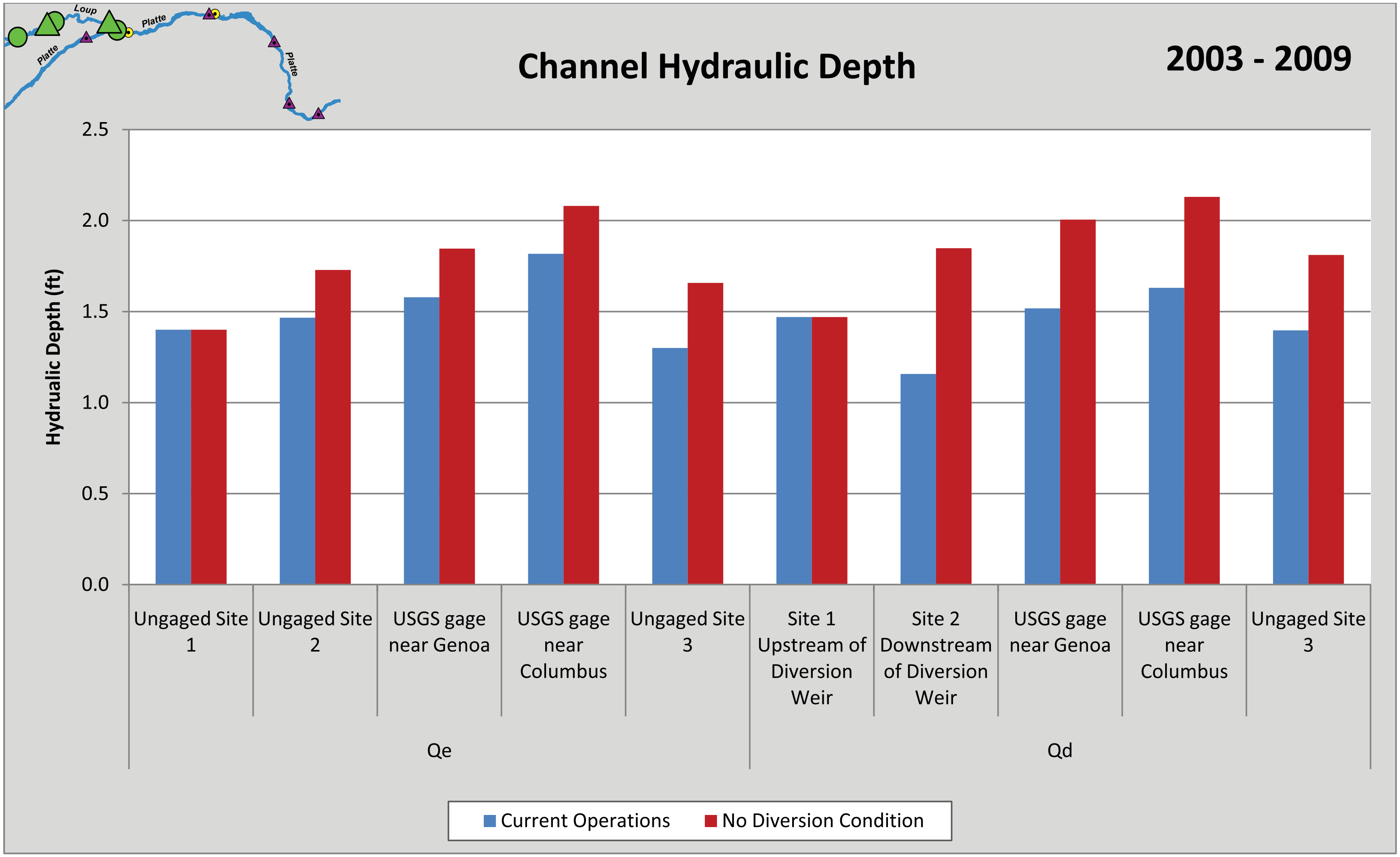

Figure 5-10. Depth Values for Current Operations and No Diversion Condition, 2003-2009

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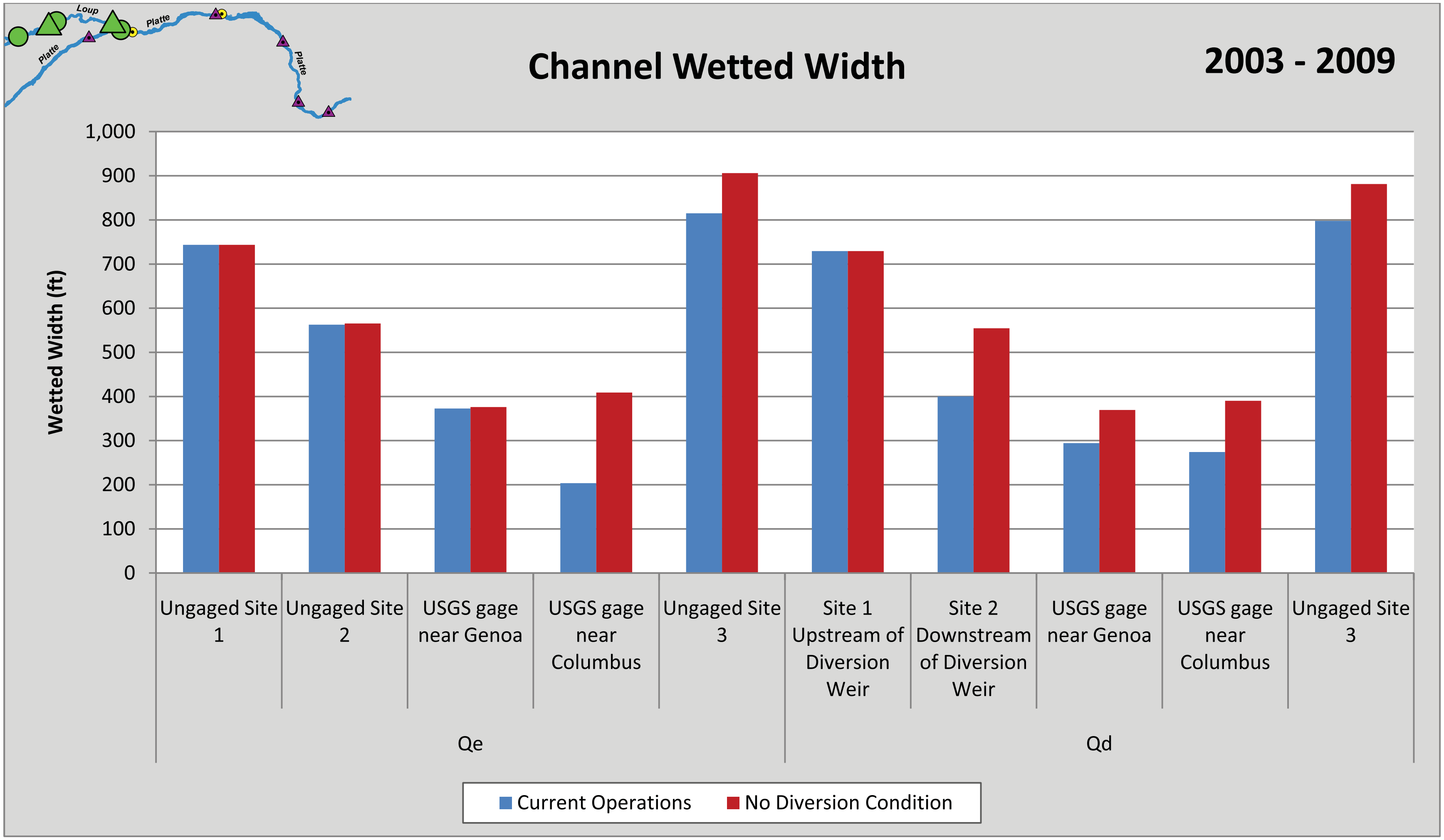


Figure 5-11. Width Values for Current Operations and No Diversion Condition, 2003-2009

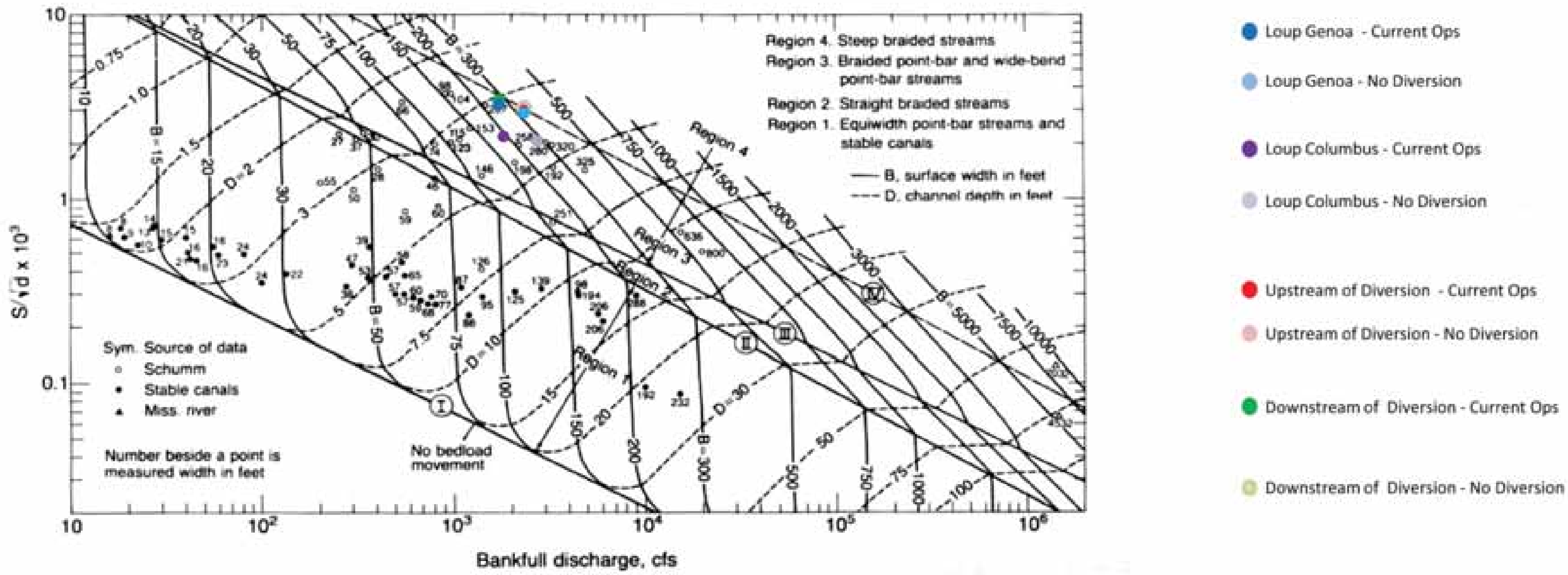
The current morphologies of sites affected by the Project, as well as sites not affected by the Project, are the result of long-term variations in discharge and sediment transport leading up to the present. Today's widths and depths are not the result of today's flows, but instead are the average result of an indefinite period of prior discharge and transport conditions. On the other hand, it is true that the effective or dominant discharges calculated over sufficiently long periods of time will provide reliable estimates of the equilibrium (but not necessarily present) channel geometry because these are measures of the flow rates that transport the greatest amount of sediment and thereby shape the channel.

Regime Analysis

The final measure of the differences in impacts of the Project's current operations and the no diversion condition is whether the morphology, measured by regime analysis, is impacted by current operations compared with the no diversion condition. This is state-of-the-art methodology, especially when coupled with the sediment transport calculations that provide both short- and long-term dominant discharges that are entered along the abscissa of the regime relationships.

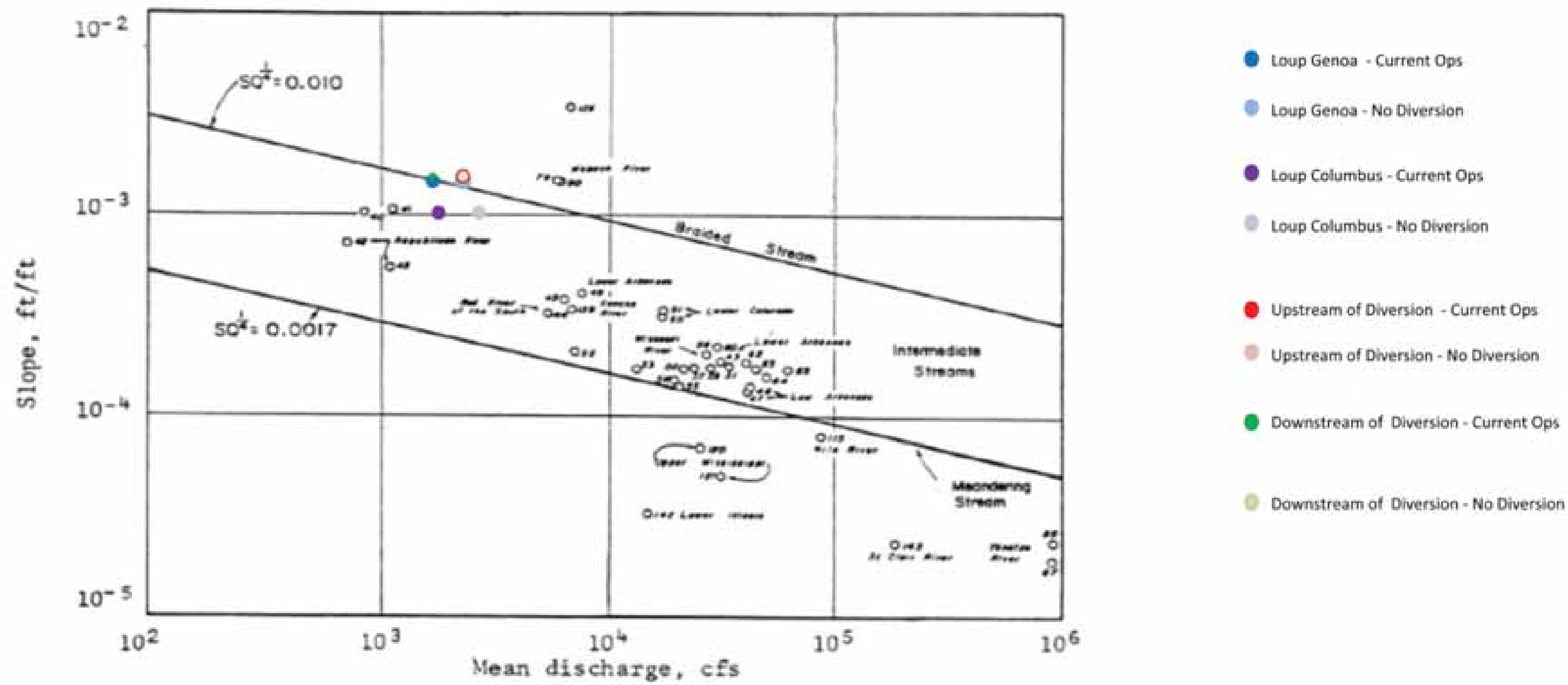
Figures 5-12 and 5-13 show the results of inputting the dominant discharges and channel slopes in the same regime theory charts used in the Initial Study Report, Appendix A, Sedimentation Study Report, and the Second Initial Study Report, Appendix A, Sedimentation Addendum. Because of the subjectivity of determining effective discharges from the sediment transport histograms, especially for seasonal or single-year data, the average 2003 to 2009 dominant discharges at the sites were input along the abscissa of each graph.

The methodology adopted in the Initial Study Report, Appendix A, Sedimentation Study Report, and the Second Initial Study Report, Appendix A, Sedimentation Addendum, for testing whether the sites were in dynamic equilibrium under current operations or the no diversion condition was applied. This included determining the daily transport capacity at each site based on actual or synthesized flow data; determining the wet, dry, and normal year and average 2003 to 2009 sediment transport indicators for each site; comparing the indicators with the long-term indicators at the gaged sites; and plotting the current operations and no diversion condition data on the regime graphs.



Regime channel bed geometry for sand bed rivers, from Chang (1985). For the historic Platte River channel (1900), the bankfull discharge was about 10,000 cfs, the median grain size was about 0.4 mm, and the slope was 0.00126. Therefore, the term $[(S/d^{0.5})1000]$ was equal to 2.0. For the present Platte River channel (2000), the bankfull discharge is about 4,000 cfs, the median grain size near Overton, Nebraska is about 1.5 mm, and the slope is still 0.00126. Therefore, the term $[(S/d^{0.5})1000]$ is now equal to 1.0. Based on the classification by Chang (1985), the Platte River evolved from a steep braided channel (Region 4) to a braided point-bar and wide bend point-bar channel (Region 3).

Figure 5-12. Chang's (March 1985) Regime Morphology Chart for Sand Bed Rivers with Current Operations and No Diversion Condition Sedimentation Study Results Plotted



Lane's (1957) regime diagram for sandbed streams based on slope and mean discharge, taken from Richardson, et al. (1990). Red points shown are for the central Platte River with a slope of 0.0026 ft/ft and a mean discharge of 3,700 cfs for the year 1900, and a mean discharge of 2,100 cfs for the year 2000.

Figure 5-13. Lane's (1957) Regime Morphology Chart for Sand Bed Rivers with Current Operations and No Diversion Condition Sedimentation Study Results Plotted

The body of literature and the supplemental calculations demonstrate that the Loup River bypass reach is in regime and is seated well within regime zones considered as braided streams (see Figures 5-12 and 5-13). Further, the analyses and other supporting literature cited in the Initial Study Report, Appendix A, Sedimentation Study Report, clearly indicate that the Loup River bypass reach is in regime, is not supply limited, and is not aggrading or degrading, with no indications of adverse channel geometry changes over time.

This combined use of effective discharge and regime theory at both the gaged and ungaged sites is state-of-the-art technology and supports the consensus among investigators that the Loup and Platte rivers are in regime and would continue to be in regime under the no diversion condition. Further, this combination of analytical tools is the best available technology for determining whether any changes, whether climatic or operational, could impact a river's morphology.

5.6 Objective 5: To determine Project effects, if any, of consumptive use on fisheries and habitat on the lower Platte River downstream of the Tailrace Canal.

Under Objective 1, Task 2, the net consumptive use was calculated for the Loup Power Canal and the Loup River bypass reach for current operations and the no diversion condition. This analysis determined that flow depletions under current operations are less than would occur under the no diversion condition. Based on the consumptive use calculations, the difference between current operations and the no diversion condition would result in a gain of water of approximately 3,000 acre-feet per year. These results indicate that fisheries and habitat, from a flow depletion standpoint under current operations, are not adversely impacted to a greater extent than would occur under the no diversion condition.

5.7 Objective 6: To determine the relative significance of the Loup River bypass reach to the overall fishery habitat for the Loup River.

5.7.1 Fishery Populations Above and Below the Diversion Weir

NGPC's 1996 and 1997 annual reports on angler use and fish community dynamics in the Loup River Basin (NGPC, June 1997 and April 1998) provide an assessment on fish population above and below the Diversion Weir. NGPC evaluated the fish populations within the Loup River Basin, including several reaches above the Diversion Weir and two reaches below the Diversion Weir. By looking at two reaches directly above and two reaches directly below the Diversion Weir, inferences can be made about the fish community differences caused by the diversion of water from the Loup River.

In 1996, the highest counts of fish were collected in the lowest reach below the Diversion Weir, referred to as the Columbus reach, with 11,433 fish collected. The reach just below the Diversion Weir, referred to as the Genoa reach, had 4,564 fish collected. In total, the reaches above the Diversion Weir had less fish, with

1,673 collected at Fullerton and 4, 059 collected at Palmer. Fish communities were similar throughout the reaches, as shown in Table 5-15.

In 1997, more fish were collected in the two reaches below the Diversion Weir than in the two reaches above the Diversion Weir. The Columbus and Genoa reaches had 4,804 and 4,737 fish collected, respectively. Only 1,552 fish were collected from the Fullerton reach just above the Diversion Weir, and 3, 386 were collected in the Palmer reach further upstream. The 1997 data also showed similar fish species throughout all reaches, as shown in Table 5-16.

Community structure differed slightly between the reaches above and below the Diversion Weir. The red shiner remained a highly dominant fish species in both years and among all four sample reaches. Other fish common among all four reaches included the sand shiner and the river carpsucker. However, other species were far more common either above or below the Diversion Weir. The western silvery minnow composed a large portion of the sample collection in the reaches below the Diversion Weir but was far less common above the Diversion Weir. In 1997, emerald shiners made up an average of 6 percent of the total fish collected in the reaches below the Diversion Weir, but made up less than 1 percent in the reaches above the Diversion Weir. The number of sport fish collected above and below the Diversion Weir were similar, and the Diversion Weir did not appear to greatly alter their populations, as shown in Table 5-17.

Table 5-15. Percentages of the Most Common Fish in the Loup River Within Two Sampling Reaches Above and Below the Diversion Weir, 1996

	Above the Diversion Weir		Below the Diversion Weir	
	Palmer	Fullerton	Genoa	Columbus
Red Shiner	55%	75%	62%	23%
Sand Shiner	14%	3%	14%	17%
Western Silvery Minnow	0%	0%	6%	33%
Brassy Minnow	16%	7%	1%	4%
Flathead Chub	1%	5%	1%	1%
River Carpsucker	5%	3%	2%	7%

Table 5-16. Percentages of the Most Common Fish in the Loup River Within Two Sampling Reaches Above and Below the Diversion Weir, 1997

	Above the Diversion Weir		Below the Diversion Weir	
	Palmer	Fullerton	Genoa	Columbus
Red Shiner	54%	45%	20%	35%
Sand Shiner	5%	12%	15%	9%
Western Silvery Minnow	0%	<1%	34%	25%
Channel Catfish	6%	7%	3%	9%
Emerald Shiner	<1%	1%	5%	7%
River Shiner	<1%	<1%	6%	5%
Brassy Minnow	7%	4%	6%	1%
Large-mouth Bass	1%	6%	1%	<1%
River Carpsucker	19%	7%	6%	4%

Table 5-17. Numbers of Popular Sport Fishes Collected Within Two Sampling Reaches Above and Below the Diversion Weir, 1996 and 1997

	Above the Diversion Weir				Below the Diversion Weir			
	Palmer		Fullerton		Genoa		Columbus	
	1996	1997	1996	1997	1996	1997	1996	1997
Channel Catfish	49	189	8	110	77	151	134	14
Bluegill	0	3	1	16	4	11	12	3
Largemouth Bass	16	42	18	94	8	47	4	14
White Crappie	0	4	0	0	2	2	0	2
Walleye	6	2	1	2	3	0	0	1
Freshwater Drum	4	6	0	1	4	12	0	2

The 1996 and 1997 NGPC fish collection data indicates a similar population structure both above and below the Diversion Weir. The NGPC annual reports on angler use and fish community dynamics in the Loup River Basin (NGPC, June 1997 and April 1998) state that the Loup River basin fish population and associated habitat are "somewhat typical of rivers found in the agriculturally impacted areas of the central Great Plains grassland ecosystems," which tend to be sand-bottomed, shallow, low-current velocity rivers. The fish collected from the Loup River were primarily generalist species, but other species that have a more limited distribution were also caught both above and below the Diversion Weir (for example, emerald shiner and brassy minnow).

The reaches below the Diversion Weir have similar sport fish populations to those above the Diversion Weir, and sport fisheries do not appear to be greatly affected by the diversion of water from the Loup River. Some inferences may be made on the available habitat for fish communities above and below the Diversion Weir. Because fish communities are similar, it may be safe to assume that fish habitats are relatively similar both above and below the Diversion Weir. Based on the 1996 and 1997 NGPC fish collection data, the Diversion Weir does not appear to be altering fish communities significantly.

5.7.2 Fish Passage

In Study 7.0, Fish Passage, which was published in the Initial Study Report, Appendix E, hydraulic data were analyzed to determine whether usable fish pathways exist over the Diversion Weir, through the Sluice Gate Structure, or by other means. From this analysis, the percentage of time that the Diversion Weir is a barrier to upstream movement during the migration season was characterized. The Diversion Weir is submerged and provides a potential pathway for upstream migrating fish during less than 1 percent of the spawning season (defined as April through June for this analysis). During the 1 percent of the spawning season in which the Diversion Weir is submerged, the resulting flow velocities over the Diversion Weir are higher than the critical swimming speeds of all analyzed fish species. With the exception of the white sucker and walleye, the flow velocities that result from Diversion Weir submergence are also too great to allow fish passage of the analyzed fish species, even when burst swimming speeds are considered. Findings suggest that white sucker and walleye may be able to pass over the Diversion Weir during the 1 percent of the spawning season when the Diversion Weir is submerged, assuming that these species can achieve the top end of their documented burst swimming speed for 15 seconds.

The Sluice Gate Structure is typically closed during normal operations; no fish passage occurs during closure. When the Sluice Gate Structure is open, flow velocities through the structure depend on a variety of factors, including the water surface elevation immediately upstream of the Diversion Weir. Normal Headworks operations during the fish migration season include maintaining the water surface elevation upstream of the Diversion Weir at elevation 1,576 (flashboard crest[8]). During these conditions, flow velocities through the Sluice Gate Structure are too great to allow fish passage of any analyzed fish species. Occasionally, situations may exist during the fish migration season where flashboards are absent and the upstream

[8] Wooden flashboards (or planks) are normally maintained along the top of the Diversion Weir to create an effective crest elevation of 1,576 feet, defined as flashboard crest.

water surface elevation is maintained at elevation 1,574 (concrete weir crest[9]). Flow velocities through the Sluice Gate Structure during this scenario are such that the fish species that exhibit exceptionally strong swimming performance may achieve fish passage.

An alternative fish pathway around the Diversion Weir on the right bank of the Loup River (looking downstream) exists (on average) less than 1 day out of every spawning season. The findings summarized for the Diversion Weir above are also applicable to an alternative fish pathway around the Diversion Weir.

The District's analysis of fish passage at the Diversion Weir and Sluice Gates used a 1-D hydraulic model that, unless Manning's n-value changes across the channel bed, assumes a constant velocity across the channel. A spatially varying, lateral velocity field is beyond the capability of a 1-D model. Although the model assumes a constant velocity, in reality there are boundary layers near solid surfaces and hydraulic shadows associated with hydraulic structures, particularly at the interface of corners of the wall and floor. The velocity in these areas is very slow compared to the calculated average velocity through the gate. A fish could work its way up near the gate, rest in a hydraulic shadow, and then burst through following the concrete along the gate housing. This type of behavior has been documented at hydraulic structures on the Mississippi River (USACE, May 2000). Given these hydraulic conditions and the known species diversity upstream and downstream of the Diversion Weir, fish passage is likely occurring at the District's Headworks, particularly by larger and stronger adult fish.

Additionally, there are other possible fish passage situations for which a 1-D model does not account:

- Debris build-up – Debris could build up near the Sluice Gates and block flow, thereby reducing velocities enough to allow fish to pass through the Sluice Gates.
- Ice build-up – Ice could also build up near the Sluice Gates and block flow, thereby reducing velocities enough to allow fish to pass through the Sluice Gates.

5.7.3 Montana Method

The Montana method is one of the most common methodologies used for evaluating stream fisheries habitat and uses flow data to determine the habitat condition of a stream or river. The Montana method was used to determine fisheries habitat in the Loup River above and below the Diversion Weir using Site 1 and the Loup River near Genoa gage, respectively, and in the Platte River above and below the Loup River

[9] The fixed crest of the concrete Diversion Weir is at elevation 1,574 feet, defined as concrete weir crest.

confluence using the Platte River near Duncan gage and Site 3, respectively. Data used for the Montana method analysis are provided in Attachment K.

Loup River

On the Loup River, Site 1 had more years within the period of record (1954 to 2009) with a "Satisfactory" rating than the Loup River near Genoa gage, as shown in Figure 5-14. From April through September, Site 1 had few ratings with less than a "Satisfactory" rating, and those occurred primarily in July, August, and September. No months during any of the years in the period of record were rated as degraded, as shown in Figure 5-15. From October through March, Site 1 showed no conditions less than "Satisfactory," as shown in Figure 5-15.

The Loup River near Genoa gage had fewer years within the "Satisfactory" range, particularly in July, August, and September, as shown in Figures 5-16. The Loup River near Genoa gage displayed the highest amount of "Poor" and "Degraded" ratings during the months of April through September. This reach exhibited the highest amount of "Poor" and "Degraded" ratings in July, August, and September. Overall, the period from October through March exhibited more "Satisfactory" years than April through September months, though the month of October also has a majority of "Degraded" years.

Platte River

The Platte River exhibited a majority of years rated as "Satisfactory" for both the Platte River near Duncan gage (upstream of the Loup River confluence) and Site 3 (downstream of the Loup River confluence). Results for both Site 3 and the Platte River near Duncan gage were similar, with well over half the years during the period of record meeting the "Satisfactory" rating, as shown in Figure 5-17. A majority of "Degraded" flows were recorded for August and September at the Platte River near Duncan Gage, as shown in Figure 5-18. "Satisfactory" ratings were the far majority for all other months both from April through September and from October through March.

The habitat at Site 3, below the confluence of the Loup River bypass reach, fared better, with no months exhibiting a majority of "Degraded" ratings, as shown in Figure 5-19. However, August and September still had a majority of "Poor" ratings and had several years that were rated as "Degraded." Site 3 also showed a large majority of "Satisfactory" ratings for all other months both from April through September and from October through March.

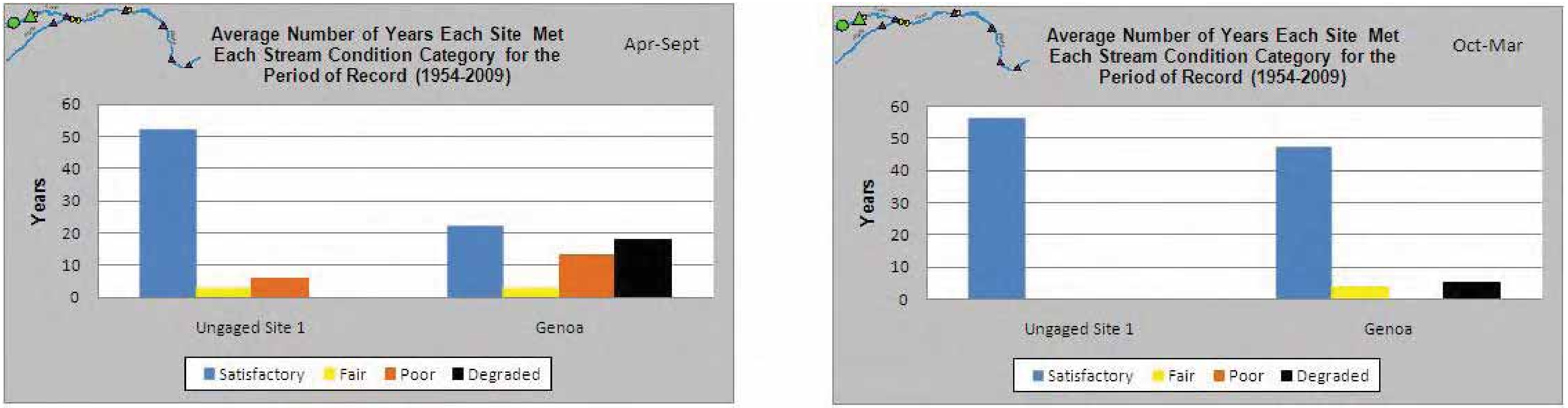


Figure 5-14. Average Number of Years Within the Period of Record that Site 1 and the Loup River near Genoa Gage Met Each Stream Condition Category

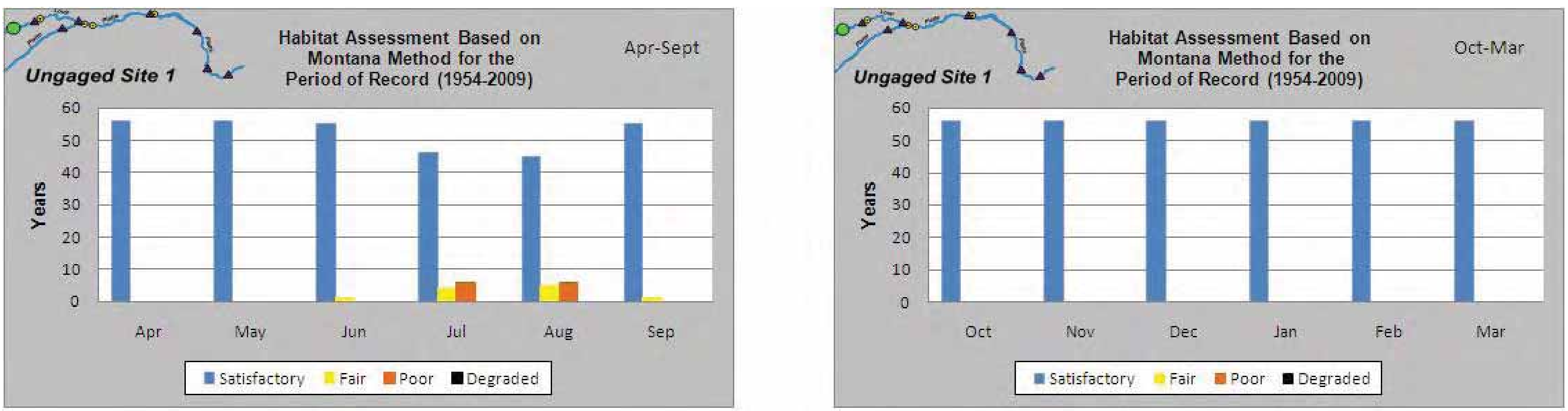


Figure 5-15. Average Number of Years Each Month Met Each Stream Condition Category (Site 1)

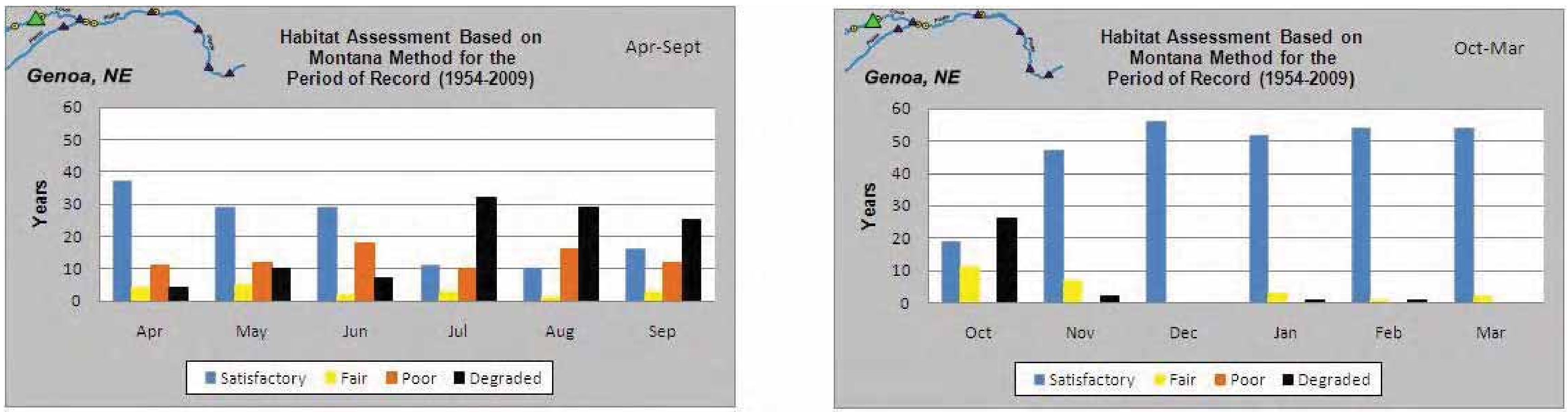


Figure 5-16. Average Number of Years That Each Month Met Each Stream Condition Category (Loup River near Genoa Gage)

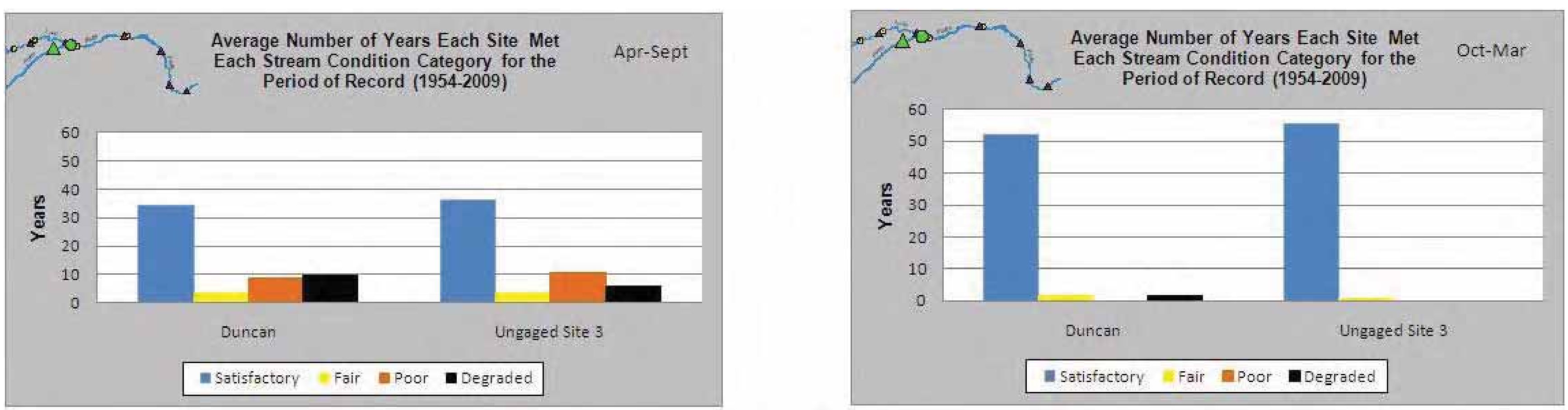


Figure 5-17. Average Number of Years Within the Period of Record that the Platte River near Duncan Gage and Site 3 Met Each Stream Condition Category

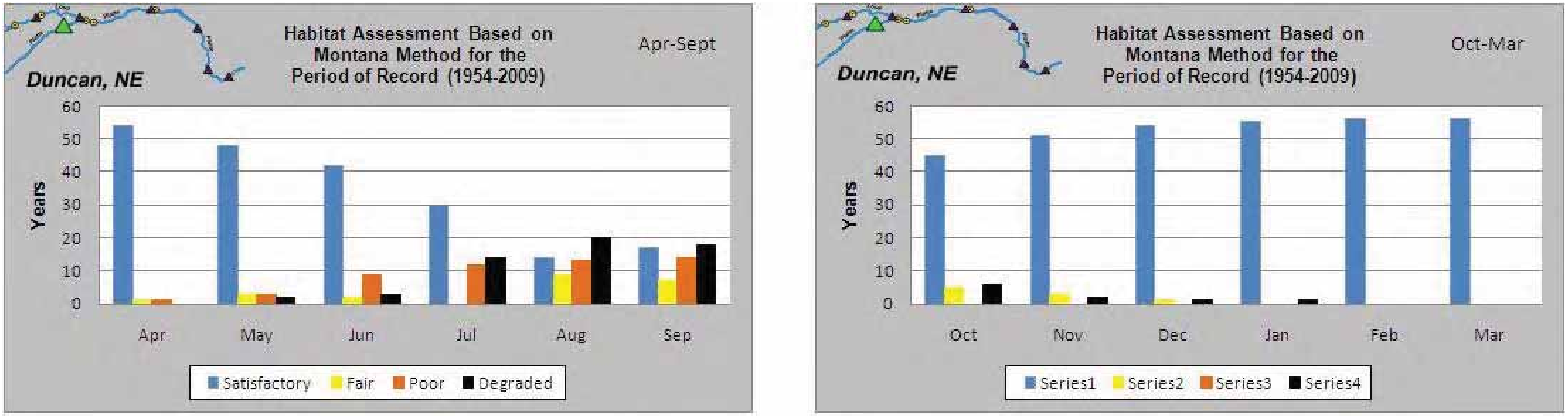


Figure 5-18. Number of Years Each Month Met Each Stream Condition Category (Platte River near Duncan Gage)

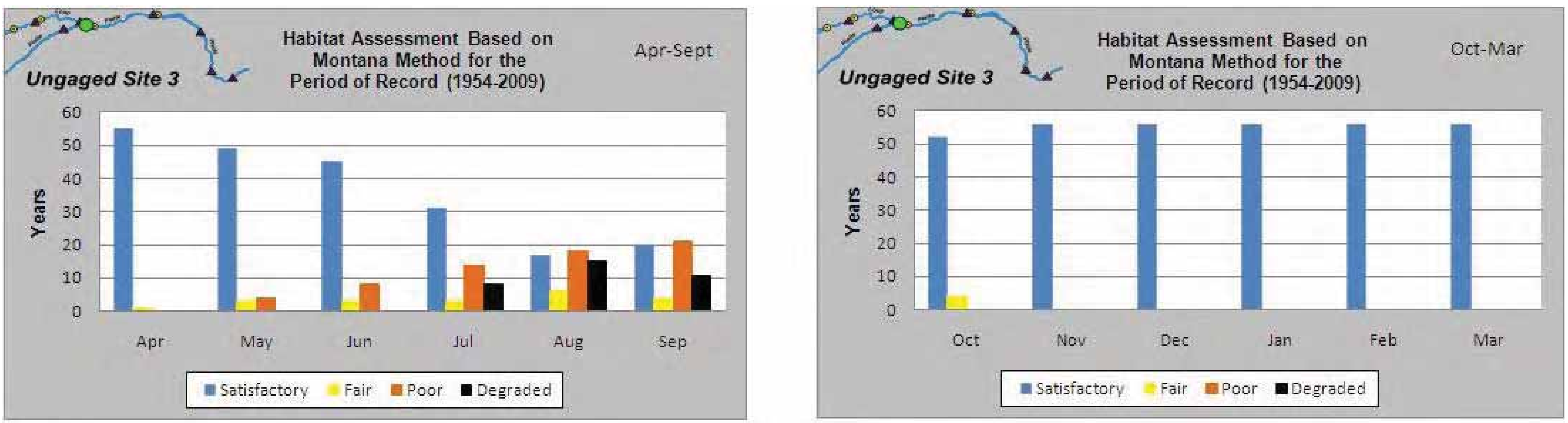


Figure 5-19. Number of Years Each Month Met Each Stream Condition Category (Site 3)

Discussion

Habitat below the Diversion Weir varies throughout the year. Based on the Montana Method, in July, August, September, and October, habitat is rated as "Poor" or "Degraded" for the majority of years. Although flows are naturally lower during this time period, these ratings could be attributed, at least in part, to the diversion of water, as Site 1 had a majority of years with a "Satisfactory" rating and yearly fluctuations in streamflow did not seem to affect habitat conditions. From October through March, flows at the Loup River near Genoa gage have a majority of years in the "Satisfactory" or "Fair" category, although at Site 1, the reach had a greater total of years within the "Satisfactory" category.

Using the Montana method, it appears that habitat below the Diversion Weir is somewhat degraded compared to upstream habitat; though some lower flows are natural during July through September, data from Site 1 is not exhibiting "Degraded" habitat from these fluctuations. However, it is likely that fish are still using this reach for the majority of the year, as many months still exhibit suitable habitat, especially during key spawning and migration months between April and June. Furthermore, the NGPC fish data collection report (NGPC, June 1997 and April 1998) found similar fish communities both upstream and downstream of the Diversion Weir, suggesting that habitat is available for these fish both above and below the weir.

Based on the Montana Method assessment, it appears that the Platte River is meeting adequate flow requirements for satisfactory biological conditions for nearly all months. July, August, and September are the only months where the Platte River has a "Poor" or "Severely Degraded" stream rating, and this is exhibited both at the Platte River near Duncan gage and at Site 3. Because these ratings are exhibited both upstream and downstream of the Loup River confluence, lower ratings on the Platte River are likely due to natural seasonal fluctuations in flow and other upstream factors. Because conditions at the Platte River near Duncan gage and Site 3 were very similar, it is unlikely that the diversion of water from the Loup River is adversely affecting fisheries habitat in the Platte River.

5.8 Objective 7: To determine the availability of potential whooping crane roosting habitat above and below the Diversion Weir under Project operations compared to the no diversion condition.

5.8.1 Aerial Imagery Review

Based on the roosting habitat parameters identified as used by the whooping cranes, shown in Table 4-10, potential habitat above and below the Diversion Weir demonstrates parameter values generally smaller than those studied and documented. Channel widths, ranging from 652 to 1,077 feet, as shown in Table 5-7, both above and below the Diversion Weir were similar to those noted at whooping crane roosting sites in Nebraska (average 764±276 feet), although channel widths were greater above the Diversion Weir than below. Unobstructed widths were generally synonymous with active channel widths (bank to bank), with a few areas that narrowed, due to permanent vegetation, such as trees, on point bars. Almost all unobstructed width measurements (in almost all cases, equal to the active channel width measurement, ranged from 652 to 1,077 feet, as shown in Table 5-7) were below the typical range of unobstructed widths noted at whooping crane roost sites in Nebraska (1,165 to 2,625 feet). The average percentage of the channel that consisted of shallow water/wet sand upstream of the Diversion Weir ranged from approximately 11 to 24 percent, while downstream the average percent of the channel classified as shallow water/wet sand ranged from 10 to 16 percent. These percentage ranges are well below the percentage of the channel with preferred shallow water depths that have been noted at whooping crane roost sites (40 percent). Further information is provided in Tables 5-5 through 5-7.

Because unobstructed widths and shallow water channel percentages are below the range typically noted at whooping crane roost sites, it appears that the Loup River, both above and below the Diversion Weir in the study area, does not contain whooping crane preferred roost site habitat. The Loup River is much narrower and does not provide the same type of habitat as the central Platte River in the main migratory corridor. Aerial interpretation figures are located in Attachment H.

5.8.2 Habitat Evaluation Using HEC-RAS Model

The HEC-RAS analysis was developed to show how changes in Project operations would affect potential whooping crane roosting habitat. The habitat parameter, percentage of channel width with water depths of 0.8 foot or less, changes as a result of different flow conditions, operating conditions, and hydrologic (wet/dry/normal) classifications, as shown in Table 5-18. For each study site, the average percentage of channel width with water depths of 0.8 foot or less is shown in Table 5-19. Figures that show the percentage of channel width with water depths of 0.8 foot or less for each cross section for both Sites 1 and 2 for the various flow conditions, operating conditions, and hydrologic (wet/dry/normal) classifications are provided in Attachment L.

When considering the results of this analysis, a key understanding is that the analysis considered only percentage of channel width with water depths of 0.8 foot or less as potential habitat. However, the analysis did not make a distinction as to suitable habitat. Suitable habitat, or habitat in which whooping cranes would choose to roost, would factor in conditions such as unobstructed view from bank to bank, location and configuration of the shallow water areas, presence or absence of vegetation, proximity to human development and feeding sites, and potential for predation (Faanes et al., 1992). Therefore, differences in channel width with water depths of 0.8 foot or less does not necessarily indicate more or less suitable roosting habitat.

Table 5-18. Percentage of Channel Width with Water Depths of 0.8 Foot or Less

Calendar Year of Analysis	Low Flow (75% Exceedance)			Medium Flow (50 % Exceedance)			High Flow (25% Exceedance)		
	Upstream	Downstream		Upstream	Downstream		Upstream	Downstream	
		Current Operations	No Diversion Condition		Current Operations	No Diversion Condition		Current Operations	No Diversion Condition
2006 (Dry)	39	16	40	41	27	30	34	28	19
2005 (Normal)	42	25	34	38	24	24	33	40	15
2008 (Wet)	43	29	33	34	26	19	25	36	8

Table 5-19. Average of Percentage of Channel Width with Water Depths of 0.8 Foot or Less

Calendar Year of Analysis	Upstream	Downstream	
		Current Operations	No Diversion Condition
Channel width (linear feet)	825	640	640
2006 (Dry)	38	24	30
2005 (Normal)	38	30	24
2008 (Wet)	34	30	20

Further, the time periods when the cross sections were taken also need to be considered when comparing between the early and late summer conditions. Depending on when high-flow events occurred that affected the wet, dry, and normal year classifications, the river morphology may have reflected a drier or wetter condition than the wet, dry, and normal year classification actually would represent.

Upstream of the Diversion Weir showed relatively consistent results among all hydrologic classifications for all flow events. The maximum was 43 percent for the low-flow condition in a wet year, and the minimum was 25 percent for the high-flow condition in the wet year. This was the largest fluctuation between percentages between any of the flow conditions or hydrologic classifications. Generally speaking, for each hydrologic classification, as flow increased, the percentage of channel width with water depths of 0.8 foot or less decreased.

Downstream of the Diversion Weir showed mixed results between the percentage of channel width with water depths of 0.8 foot or less. Typically, for current operations, the trend is that this percentage increased as flow increased for each hydrologic classification. This trend held true in comparison of dry, normal, and wet years, where the dry year had, on average, a smaller percentage of channel width with water depths of 0.8 foot or less than the normal or wet years (which were nearly equal, on average). Conversely, under the no diversion condition, the percentage of channel width with water depths of 0.8 foot or less tended to decrease both as flow increased and from dry to wet years. The lowest single percentage is 8 percent under the wet year, high-flow condition.

Conclusions

It appears that the trends are similar under the no diversion condition both above and below the Diversion Weir. The percentage of channel width with water depths of 0.8 foot or less is greater for nearly all conditions above the Diversion Weir than below under the no diversion condition, with the exception being the low-flow condition for the dry year, when upstream was 39 percent and downstream, under the no diversion condition, was 40 percent. This could be explained that as flow increases, surface water elevations and, subsequently, water depths increase, thus decreasing areas of shallow water.

However, downstream of the Diversion Weir under current operations, the trends are opposite of the no diversion condition. The percentage of channel width with water depths of 0.8 foot or less are generally increasing as flow increases, and are generally higher in the normal and wet years than in the dry year. This could be explained by a general increase in wetted width due to more flow entering the Loup River bypass reach. The District has the ability to divert up to 3,500 cfs. Any flows exceeding this amount would enter the Loup River bypass reach. Due to the channel width and the gradual increase in flows that would enter the Loup River bypass reach as flows increase between dry to wet years, the model indicated that flows would be distributed within the channel and a higher percentage of channel width with water depths of 0.8 foot or less are present.

When reviewing these results, it must be considered that increasing the wetted channel width with the appropriate depths for roosting does not necessarily provide more suitable whooping crane roosting habitat. A number of factors determine roosting habitat suitability for whooping cranes, including complex geomorphic processes that move, create, and degrade sandbars.

6. STUDY VARIANCE

Changes to the Flow Depletion and Flow Diversion study plan, which was approved with modifications by FERC in its Study Plan Determination on August 26, 2009, were necessary to produce consistent results between the study objectives. These variances, the reasons for the variances, and the consequences of the variances are discussed below.

6.1 Consumptive Use

The methodology for calculating consumptive use was modified for consistency in data and hydrologic conditions. The District's Revised Study Plan indicated that the consumptive use analysis would be calculated for years 1980 through 2009. Those years were initially selected to ensure that wet, dry, and normal cycles were included. However, a review of the available atmospheric data showed inconsistencies between the gages for that time period (such as monthly versus daily data). In addition, as directed in FERC's Study Plan Determination, sedimentation and habitat evaluations were conducted for a typical wet, dry, and normal year. There were consistent daily atmospheric data between gages to establish typical wet, dry, and normal years from 2003 to 2009 used for this study. Therefore, due to data availability, data consistency, and comparison with other studies (such as habitat), evaluating for a typical wet, dry, and normal year was considered representative and reasonable for this analysis.

6.2 Fish Passage

The Revised Study Plan indicated that flow information from Task 3 would be used to calculate the opportunity for fish species to migrate upstream of the Diversion Weir during high flows when the Diversion Weir is submerged or the Sluice Gates are opened. Specific analysis of the flows from Task 3 was not conducted. Instead, the results from Study 7.0, Fish Passage, which were presented in the Initial Study Report, Appendix E, were summarized.

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