APPENDIX E

FISH PASSAGE STUDY REPORT

Loup River Hydroelectric Project
FERC Project No. 1256

Fish Passage

Loup Power District
Hydro Project

August 26, 2010

Study 7.0 - Fish Passage

Loup River Hydroelectric Project
FERC Project No. 1256

Study 7.0
Fish Passage

August 26, 2010

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STUDY 7.0 FISH PASSAGE

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 begins at the Headworks, which is located midway between Fullerton and Genoa, Nebraska, and consists of a Diversion Weir, Intake Gate Structure, and Sluice Gate Structure. The low-head Diversion Weir diverts a portion of the Loup River flow through the Intake Gate Structure into the Loup Power Canal. 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 limit of the Loup River Public Power District's (Loup Power District's or the District's) water right.

The Loup River provides habitat for a variety of migratory, riverine fish species indicative of the region. Specific species include channel catfish, walleye, sauger, white bass, and suckers. All of these species are strong swimmers that generally commence their spawning migration between April and June. The ability of these fish to move upstream, past the Diversion Weir and Sluice Gate Structure, may be restricted by the hydraulic characteristics (flow, velocity, and stage) at the Diversion Weir. During the May 28, 2009, Study Plan Meeting, Nebraska Game and Parks Commission (NGPC) fisheries staff stated that previous fish sampling efforts performed by NGPC on the Loup River Basin in 1996 and 1997 indicate that the Diversion Weir may act as a seasonal barrier to upstream fish movement. That is, NGPC is of the opinion that the structure is not a permanent or year-round barrier to upstream fish movement. This fish passage study was conducted to determine if, to what degree, and during what periods of the year the Diversion Weir and Sluice Gate Structure impede riverine fish passage in the Loup River.

2. GOALS AND OBJECTIVES OF STUDY

The goal of the fish passage study is to determine if a useable pathway exists for fish movement upstream and downstream of the Diversion Weir.

The objectives of the fish passage study are as follows:

1. To evaluate the hydraulic flow, velocity, and stage parameters at the Diversion Weir and Sluice Gate Structure.
2. To determine whether fish pathways exist over the Diversion Weir, through the Sluice Gate Structure, or by other means.

3. STUDY AREA

The study area includes the Loup River reach directly upstream and downstream of the Headworks. The following two U.S. Geological Survey (USGS) gage stations were used to obtain data for the analysis:

- USGS Gage 06793000, Loup River near Genoa, NE – Available data for this station includes 15-minute interval discharge data from April 1, 1929, to current and 15-minute interval gage height data from June 12, 1997, to current.
- USGS Gage 06792500, Loup River Power Canal near Genoa, NE – Available data for this station includes 15-minute discharge data from January 1, 1937, to current and 15-minute interval gage height data from August 30, 2000, to current.

The study area and the locations of the USGS gages from which data were obtained are shown in Figure 3-1.

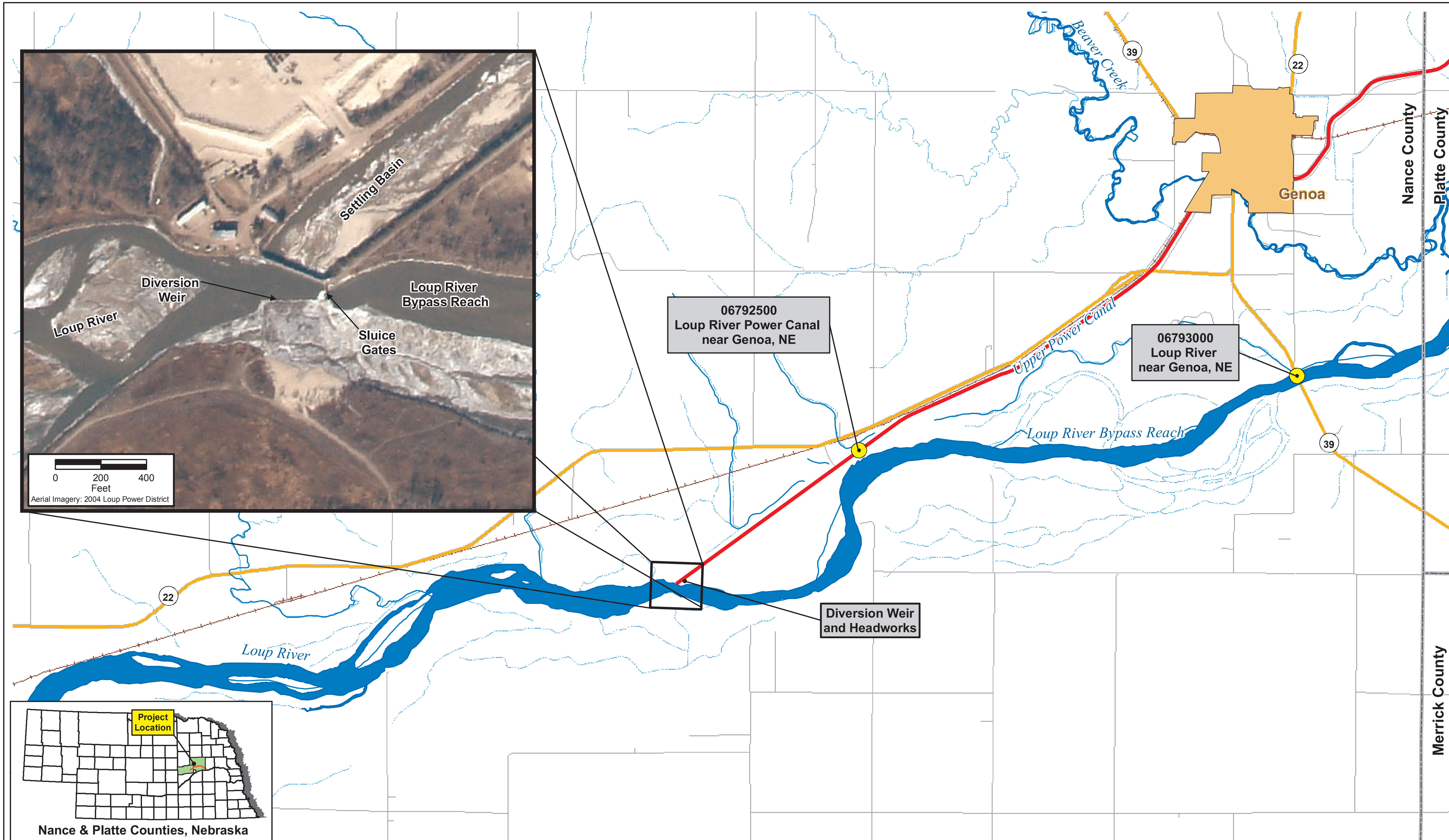
4. METHODOLOGY

The methodology for the fish passage study includes the three tasks described below.

Task 1 Data Review

Stage and discharge data available at nearby USGS Gage 06793000, Loup River near Genoa, NE, and USGS Gage 06792500, Loup River Power Canal near Genoa, NE, were reviewed. This information was used to develop the flow duration curve at the Diversion Weir as described in Section 5 of the Pre-Application Document (PAD) (Loup Power District, October 16, 2008). A flow duration curve is a plot of discharge vs. percent exceedance, which is percent of time that a particular discharge is equaled or exceeded. The flow duration links the discharges, flow depth, and velocities (through the hydraulic model discussed under Task 3, below) with the percent exceedance, or the percentage of time that these discharges were equaled or exceeded at the Diversion Weir. Figure 4-1 is a seasonal subset of the annual flow duration curve provided in Section 5 of the PAD in that it represents only the months of April, May, and June, the period of analysis for the fish passage study.

Near Genoa, a river discharge of 10 cfs has more than a 95 percent exceedance probability, a river discharge of 100 cfs has close to a 50 percent exceedance probability, and a river discharge of 3,000 cfs has close to a 5 percent exceedance probability. Because the Diversion Weir is located upstream of the Genoa gage, these exceedance probabilities are indicative of the water passing over the Diversion Weir or through the sluice gates after water has been diverted into the Loup Power Canal. In one year of spawning season, there are 91 days. Using the past 63 years as a guide, there are typically around 45 days during the season where the flow in the Loup River at Genoa is between 100 and 10 cfs.



Fish Passage Study Area

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FIGURE 3-1

In addition to the data described above, literature was reviewed to determine the hydraulic conditions (flow velocity and water level differential [head] across the Diversion Weir) that may limit movement of migratory riverine fish species, including white bass, channel catfish, walleye, sauger, and suckers.

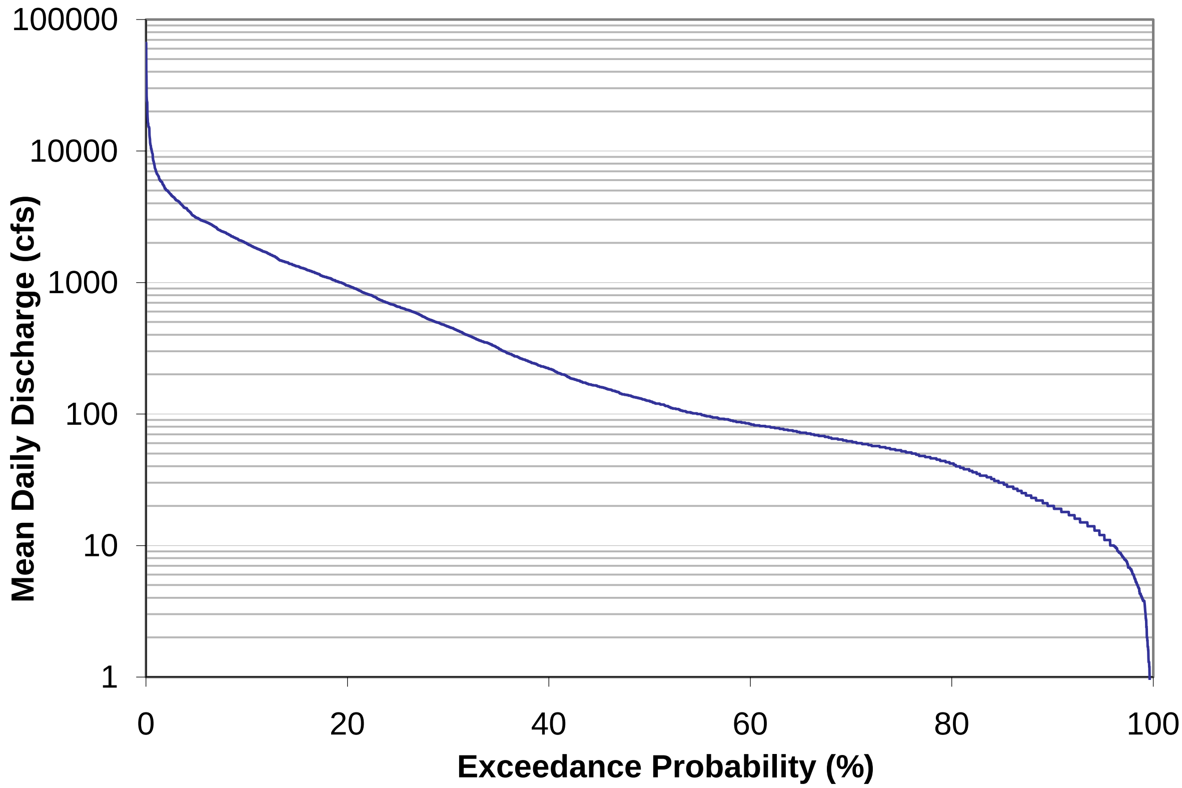

Figure 4-1. Flow Duration Curve (Mean Daily Discharge) for USGS Gage 06793000, Loup River near Genoa, NE, during April, May, and June over the Period of Record, 1943 – 2006

Task 2 Data Collection

As-built drawings of the Headworks were obtained. As a supplement to the as-built drawings, two additional river cross sections were surveyed, one 200 feet upstream and one 200 feet downstream of the Diversion Weir. The as-built drawings and cross sections provided a basis from which to create a hydraulic model that describes the water levels and velocities associated with the Diversion Weir and the Sluice Gate Structure over a range of flow conditions. The cross sections are located at an adequate distance upstream and downstream of the Headworks to properly represent the nature of the river channel beyond the Diversion Weir and Sluice Gate Structure.

In addition, a series of Diversion Weir headwater and tailwater elevations collected by District personnel was correlated with the discharge measured at USGS Gage 06793000, Loup River near Genoa, NE. This defined the hydraulic relationship between flow in the Loup River and tailwater elevation at the Diversion Weir that is presented in Figure 4-2. In Figure 4-2, the tailwater elevation is reported as a depth above 1571.13 feet, which serves as the point of zero flow (or a gage zero). Tailwater elevations from the last decade, recorded twice daily (at 8:00 a.m. and 4:00 p.m.) downstream of the Diversion Weir, were used for the months of April, May, and June. These elevations were correlated to 30-minute flow data at USGS Gage 06793000, Loup River near Genoa, NE, using an estimated lag time of 2.5 hours, derived from a comparison of District operation records for the Sluice Gate Structure and the USGS flow data.

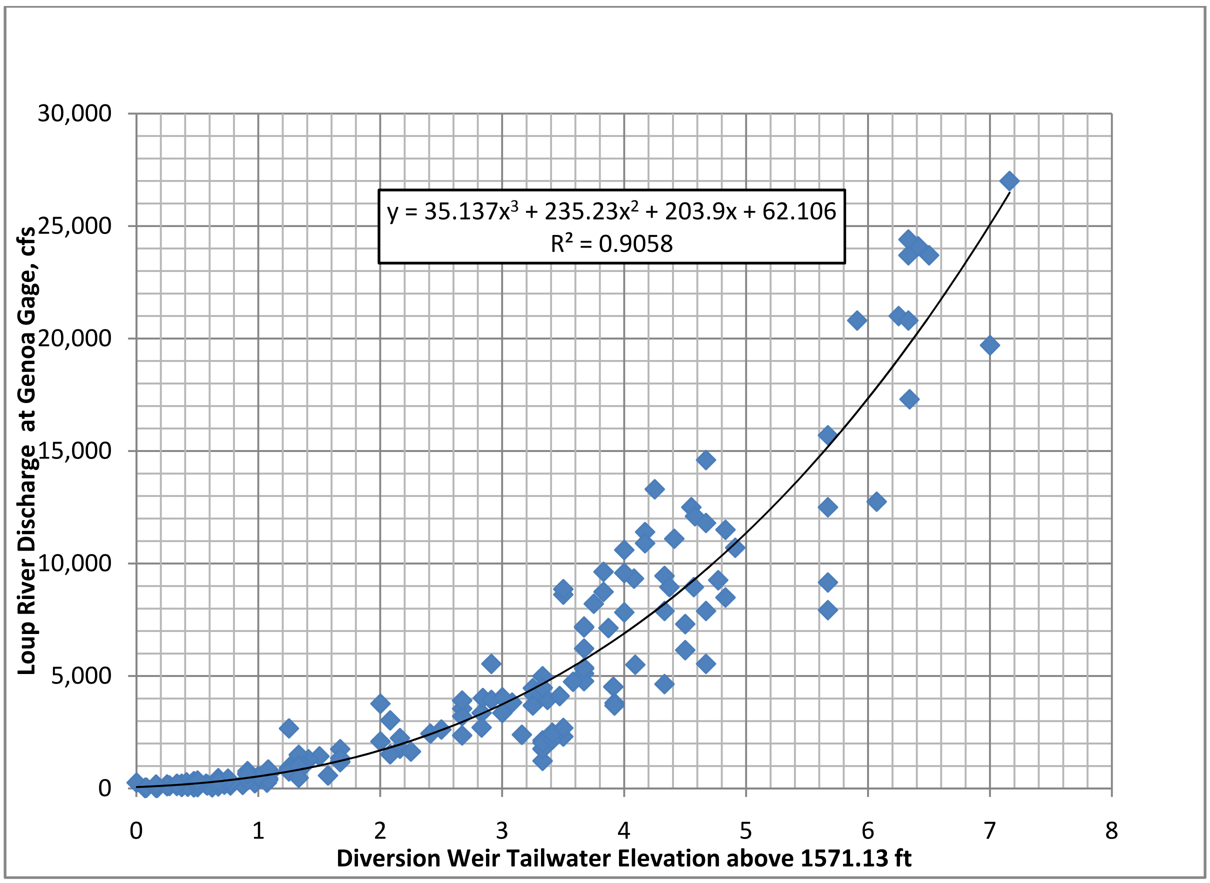

Figure 4-2. Relationship between Discharge at USGS Gage 06793000, Loup River near Genoa, NE, and Tailwater Elevation at Diversion Weir

Task 3 Data Analysis

Hydraulic Modeling

A hydraulic model relating flow in the Loup River bypass reach, headwater and tailwater elevations, flow velocity over the Diversion Weir, and flow velocity through the Sluice Gate Structure was created using the structure dimensions defined as follows.

The Sluice Gate Structure spans the portion of the river flowing between the downstream leg of the Diversion Weir and the Intake Gate Structure. The elevation of the sluice gate sills is 1,568 feet. Each steel gate is 20 feet long with a maximum opening of 7 feet. Headwater elevation is primarily controlled by the Diversion Weir. The fixed crest of the concrete weir is at elevation 1,574 feet (concrete weir crest). Wooden flashboards (or planks) are normally maintained along the top of the weir to create an effective crest elevation of 1,576 feet[1] (flashboard crest). While not explicitly incorporated into the model, the Intake Gate Structure geometry is included here for reference. There are 11 steel radial gates that make up the Intake Gate Structure. The elevation of the concrete gate sills is 1,569.5 feet, and each gate is 24 feet long with a maximum opening of 5 feet.

The geometry of the Diversion Weir and Sluice Gate Structures was incorporated into a HEC-RAS 4.1 model. The model was subsequently used to calculate headwater elevations and velocity through and over the structures using discharge and tailwater elevations from the relationship derived in the data collection process.

A tailwater rating curve was developed, based on Figure 4-2, and used as a downstream boundary condition (just downstream of the Headworks). The hydraulic model estimated the flow velocity and depth over the Diversion Weir and the velocity through the Sluice Gate Structure at all of the gate settings from 0 to 7 feet (increments of 0.25 foot) and during discharges from 5 to 20,000 cfs (increments of 5 cfs from 5 to 1,000 cfs and increments of 100 cfs from 1,000 to 20,000 cfs).

These flows bracket the range of expected flows during the migration and spawning season. All of these data have been used to link the frequency of river conditions at the Headworks during spawning season to the presence of fish pathways through the infrastructure associated with the Headworks.

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[1] The flashboards are often damaged or completely destroyed during winter flow conditions. In these instances, the flashboards are generally not reinstalled until late March or early April, when flow conditions allow reinstallation. Reinstallation takes four to eight hours, depending on the severity of damage. Since 1996, during the months of April, May, and June, the flashboards have been repaired 14 times.

Hydraulic Conditions at the Diversion Weir

With respect to the evaluation of potential fish pathways at the Diversion Weir, the important hydraulic parameters include:

- The difference in upstream and downstream water surface elevations at the Diversion Weir
- The velocity of water moving over the Diversion Weir
- The velocity of water moving through the Sluice Gate Structure at various gate settings

These parameters will be measured against fish passage criteria established in Section 5, Results and Discussion, over a full range of operating conditions and river discharges.

Alternative Fish Pathways

In addition to evaluating the presence of fish pathways at the Diversion Weir and Sluice Gate Structure, the possibility of alternative fish pathways was investigated. Specifically, the investigation was to determine whether the right bank of the Loup River (looking downstream) has a low enough elevation that fish can swim around the Diversion Weir.

5. RESULTS AND DISCUSSION

Results of the fish passage study are provided below. Section 5.1 details the hydraulic conditions at the Headworks from April through June, including the submergence of the Diversion Weir, the average flow velocity over the Diversion Weir, and the average flow velocity through the Sluice Gate Structure. Section 5.2 defines adult fish swimming performance. Section 5.3 compares modeled hydraulic results to the fish pathway criteria to determine if pathways exist for migrating fish at the Headworks during April, May, and June.

5.1 Hydraulic Conditions at the Diversion Weir during the Months of April through June

Hydraulic results are discussed below and are summarized in Figures 4-2, 5-1, 5-2, and 5-3. Figure 4-2 indicates that the Diversion Weir is not submerged by the downstream tailwater elevation (Crest Elevation 1576.0) until a river discharge of nearly 10,700 cfs, which has an exceedance probability of 0.5 percent (see Figure 4-1). Submergence of the Diversion Weir due to high flows during the spawning season happens (on average) less than one time per spawning season.

Average flow velocities over the Diversion Weir for discharges that submerge the weir are shown in Figure 5-1. When the Diversion Weir is not submerged (Q < 10,700 cfs), no data is reported as no fish pathway exists over the Diversion Weir. The colored contours indicate the degree of submergence, which is defined by the ratio of downstream depth of flow above the Diversion Weir crest to upstream depth of flow above the Diversion Weir crest. The degree of submergence ranges from 0 to 0.3 at the highest river discharge.

The Sluice Gate Structure is operated periodically to keep the Intake Gate Structure from being obstructed by debris, ice, or sediment. Additionally, the Sluice Gate Structure is used to maintain an upstream elevation of at least 1,576 feet. During times of higher flows, one gate is opened to maintain 1,576 feet. Additional gates are then opened, as necessary, to maintain this water surface elevation. Average flow velocities through the Sluice Gate Structure depend on the hydraulic conditions at the structure (Discharge and Tailwater Elevation) and the gate opening. Figures 5-2 and 5-3 use the results from the hydraulic model for each discharge, tailwater, and gate setting. Figure 5-2 illustrates average velocity of water passing through the Sluice Gate Structure during the full range of river flows (5 to 20,000 cfs) and for the operating condition in which one gate is open. Figure 5-3 is equivalent to Figure 5-2, but it examines the smaller range of flows that are pertinent to analyzing fish pathways through the Sluice Gate Structure. What is apparent from these plots is that during the condition in which one gate is open and when river discharge is greater than 500 cfs, the average velocities in the gate opening range from 12 to 15 feet per second (fps) (see Figure 5-2). When river discharge is less than 500 cfs, the average velocities range from 0 to 14 fps, with some possibility that a fish pathway exists based on velocity criteria (see Section 5.3).

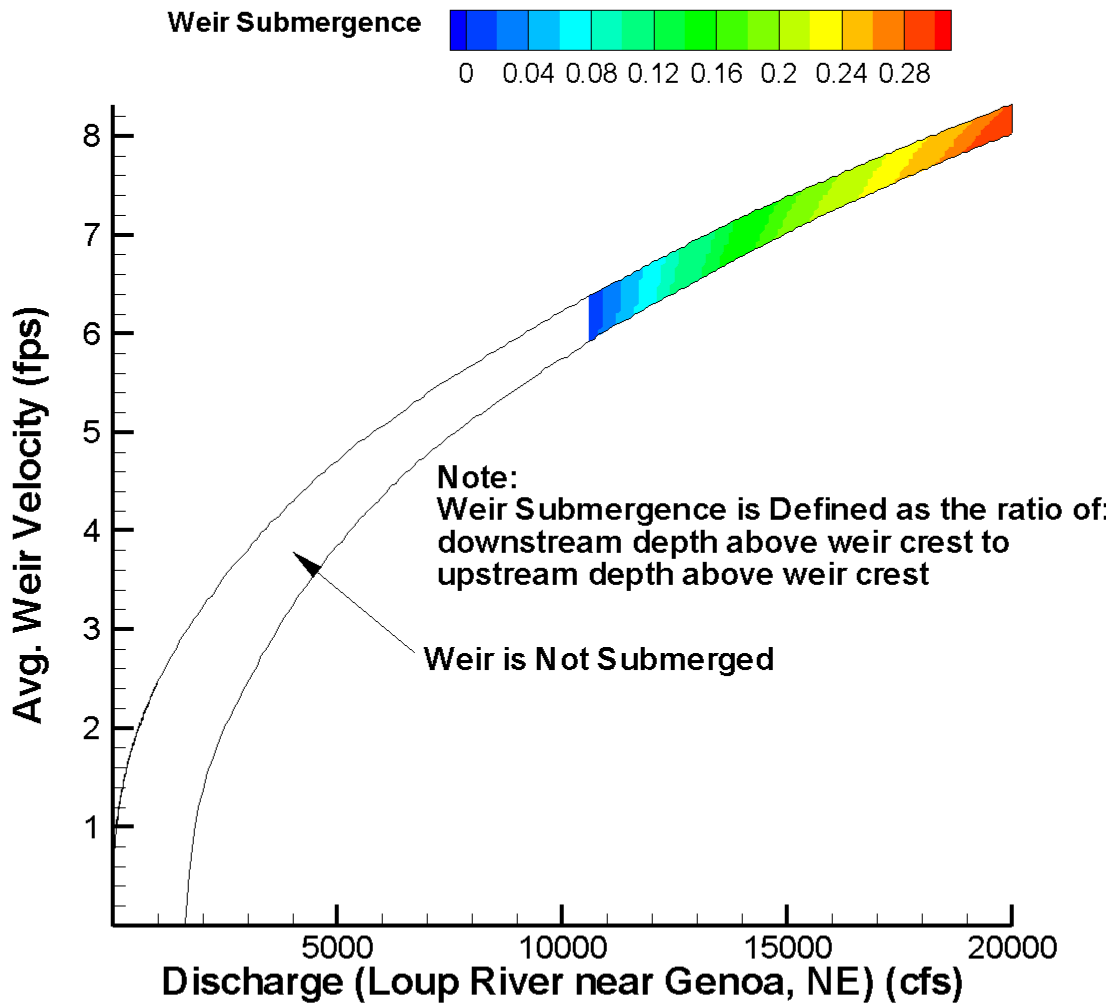

Figure 5-1. Average Velocity of Discharge Passing over Diversion Weir as Loup River Discharge Increases

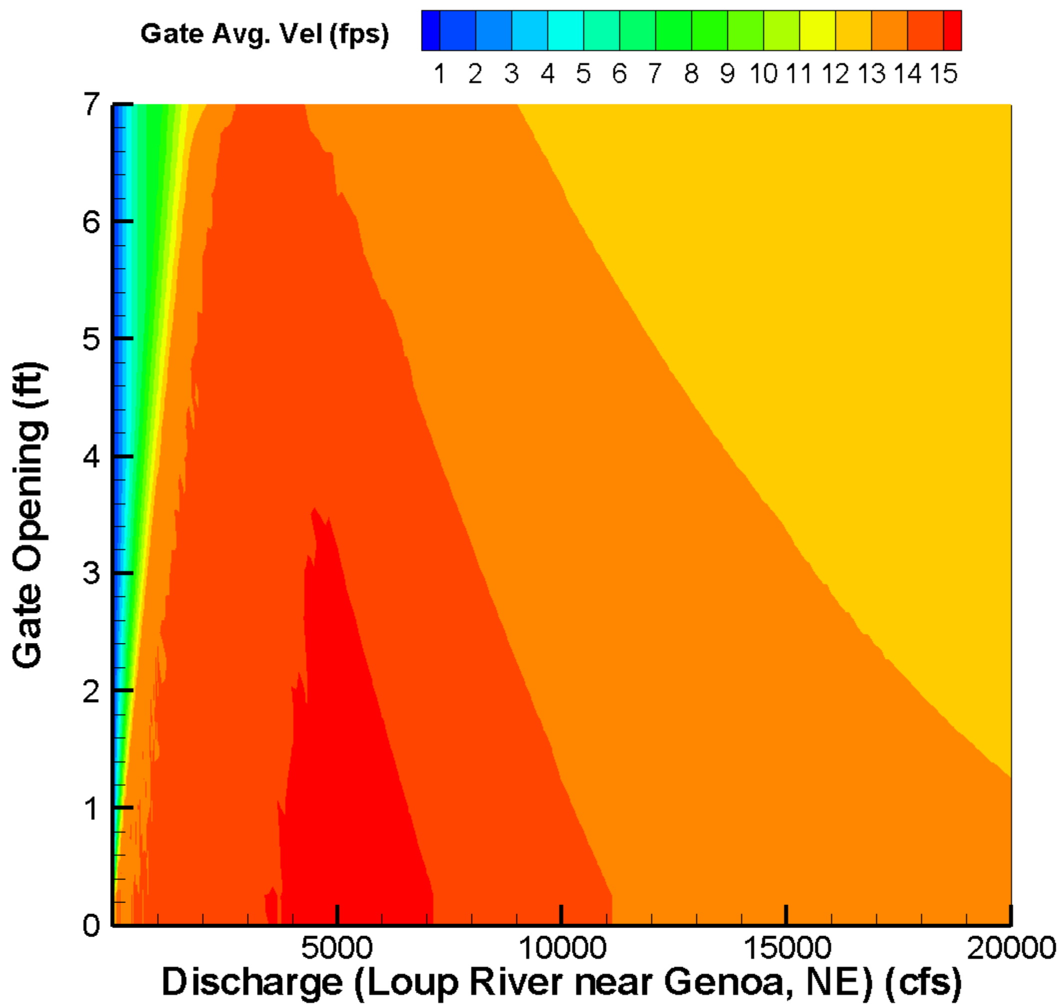

Figure 5-2. Average Velocity of Discharge Passing through one Sluice Gate as Loup River Discharge Increases

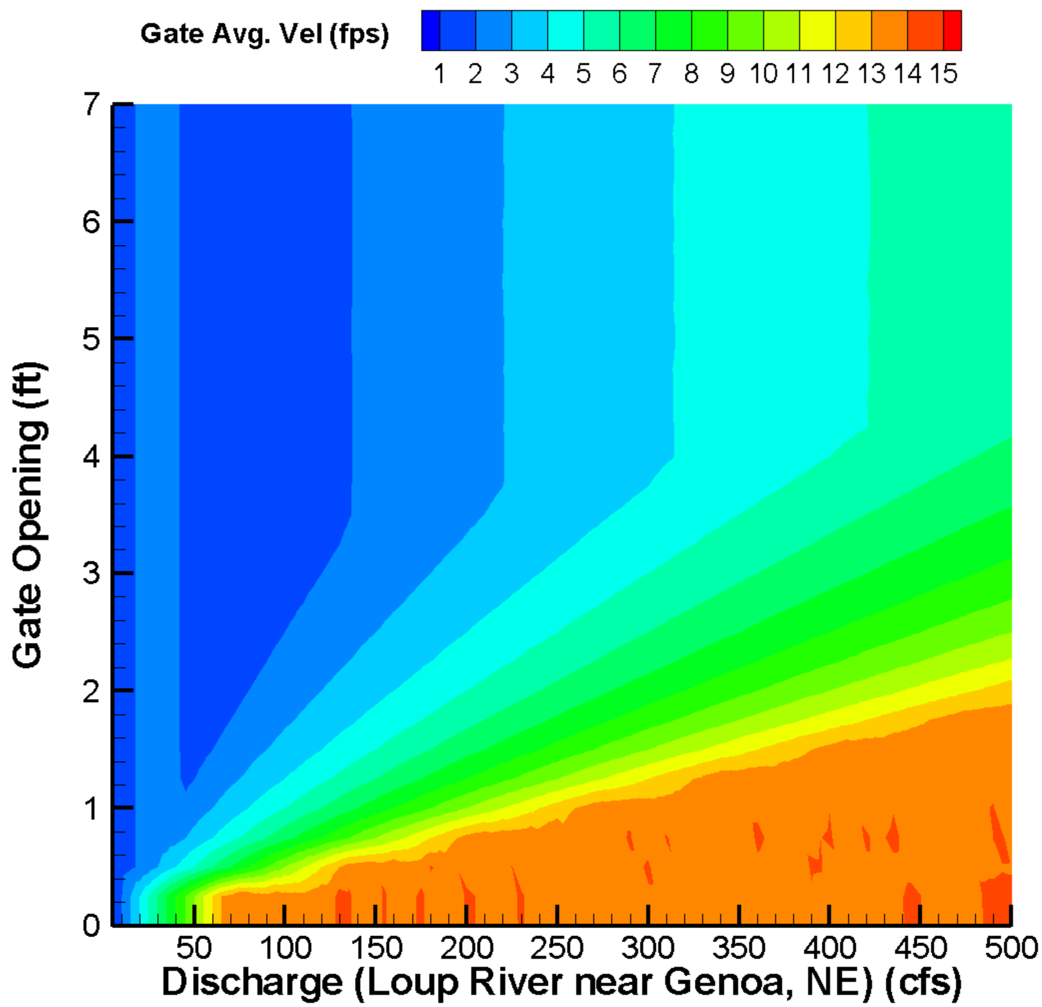

Figure 5-3. Average Velocity of Discharge Passing through one Sluice Gate as Loup River Discharge Increases (0 to 500 cfs)

5.2 Fish Swimming Performance

Fish swimming performance is defined as "the capability plus the behavioral motivation to swim at a maximum rate of speed" (McPhee and Watts, 1976, as cited in U.S. Army Corps of Engineers [USACE], October 2004). Three swimming activity levels have been defined based on the duration of activity for a given speed: burst, prolonged, and sustained speed (Blaxter, 1969, as cited in USACE, October 2004). "Burst speed can be sustained for less than about 15 s[econds]" (Farlinger and Beamish, 1977, as cited in USACE, October 2004). "Prolonged swimming, with periods of cruising and occasional bursts, can be maintained for 15 s[econds] to

200 min[utes]. Sustained swimming activity can be maintained for longer than 200 min[utes]" (USACE, October 2004).

In addition to burst speed, critical swimming speed was evaluated in this fish passage study. "Critical swimming speed is the maximal swimming speed that can be maintained without exhaustion over a specified period of time" (USACE, October 2004).

Critical swimming speed estimates (U_{crit}) and burst swimming speed estimates (U_{burst}) for adult migratory fishes are listed in Table 5-1. The critical swimming performance trials listed in Table 5-1 were for a 10-minute duration (that is, a prolonged swimming mode of activity).

Table 5-1. Estimates of Prolonged Swimming Performance of Loup River Migratory Fishes

Species	Estimated Adult Fish U_{CRIT} (fps)	Estimated Adult Fish U_{BURST} (fps)
White Bass	3.9	Undetermined[1]
Channel Catfish	2.7	3.9
Walleye	2.7	5.2-8.5
Sauger	2.6	Undetermined[2]
White Sucker	2.1	5.0-10.0

Sources: Bell, Milo C .,1990, *Fisheries Handbook of Engineering Requirements and Biological Criteria,* U.S. Army Corps of Engineers North Pacific Division, Portland, Oregon.
Peake, S., R.S. McKinley, and D.A. Scruton, 2000, "Swimming Performance of Walleye (*Stizostedion vitreum*)," NRC Canada, Retrieved on June 14, 2010. http://www.humboldt.edu/~storage/pdfmill/Batch_8/walleye.pdf.
USACE, October 2004, *Interim Report for the Upper Mississippi River – Illinois Waterway System Navigation Study, Improving Fish Passage Through Navigation Dams on the Upper Mississippi River System*, Rock Island District, St. Louis District, St. Paul District.
Venn Beecham, Rachal, et al., 2007, "Comparative Swimming Performance of Juvenile Pond-Cultured and Wild-Caught channel catfish," *North American Journal of Fisheries Management* 27:729-734, American Fisheries Society, Lawrence, Kansas.

Notes:

[1] Unable to determine via literature review.

[2] Unable to determine via literature review, but assumed similar to walleye due to close relation of species and ability to hybridize.

With the exception of white bass, all of the above-listed species are bottom-dwellers that would likely intercept the Diversion Weir near the flowline of the Loup River during upstream migration. White bass swim higher in the water column (USACE, 2004). None of the analyzed species are known to "jump" in efforts to pass obstructions in riverine systems.

5.3 Fish Passage Feasibility

The modeled hydraulic results were compared to the fish pathway criteria. This analysis documents the hydraulic conditions in the Loup River and the percent of time during the spawning period when the conditions in the river (that is, over the Diversion Weir and through the Sluice Gate Structure) serve as a barrier to upstream migrating fish (white bass, channel catfish, walleye, sauger, and suckers).

Hydraulic Conditions at Diversion Weir

The primary criteria for determining if a fish pathway exists at the Diversion Weir is whether the discharge in the Loup River is high enough to submerge the Diversion Weir. A fish pathway does not exist at the Diversion Weir if the weir is not submerged. The secondary criterion is the average velocity of the flow conveyed over the Diversion Weir during submergence.

Table 5-1 lists the critical swimming speeds for white bass, channel catfish, walleye, sauger, and white sucker and burst swimming speed (sustainable for up to 15 seconds) for only channel catfish, walleye, and white sucker. Figure 5-4 plots the average Diversion Weir velocity against the exceedance probability of discharge in the Loup River near Genoa. When the Diversion Weir is not submerged, the data are reported as a blank or white area in Figure 5-4. The thin band of colored contours describes the hydraulic conditions when the Diversion Weir is submerged. Figure 5-4 indicates that conditions in the Loup River cause the Diversion Weir to be submerged less than 1 percent of the time. When the Diversion Weir is submerged, the average velocities across the Diversion Weir range from 6 to 8 fps. These velocities are well higher than all critical swimming speeds listed in Table 5-1; however, they are comparable to the burst swimming speeds listed for walleye and white sucker in the same table. The comparable nature of submergence flow velocities and maximum burst swimming speeds necessitates additional fish passage feasibility analysis. The results of this analysis are provided in Table 5-2.

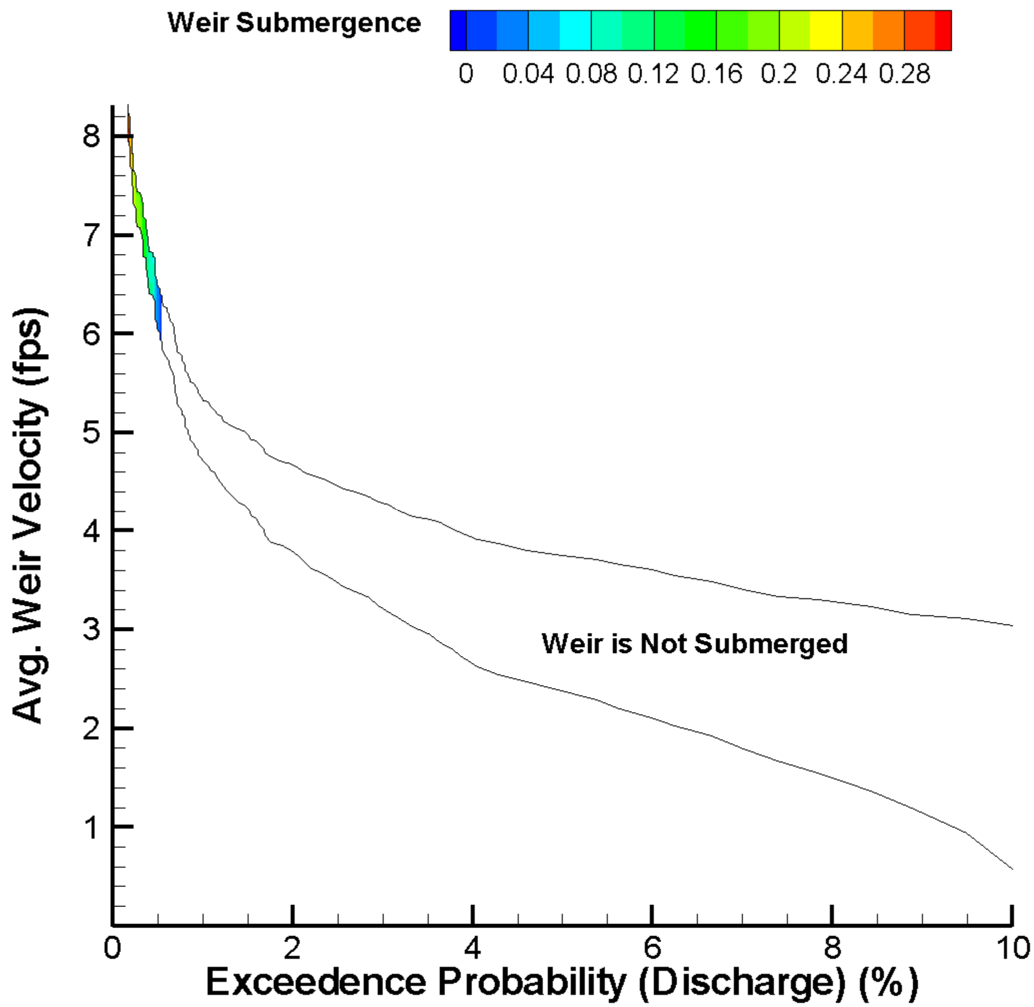

Figure 5-4. Average Velocity of Discharge Over the Diversion Weir and Percentage of the Time the Weir is Estimated to be Submerged

Table 5-2. Upstream Travel of Loup River Migratory Fishes Against Flow Velocities Resulting from Diversion Weir Submergence

Species	Maximum Burst Swimming Speed U_{BURST} (fps)	Distance Traveled Against 6 fps Submergence Velocity (ft)	Distance Traveled Against 8 fps Submergence Velocity (ft)	Ability to Travel Over Diversion Weir During Submergence (6 fps / 8 fps)
White Bass	Undetermined[1]	--	--	Undetermined
Channel Catfish	3.9	-31.5	-61.5	No[2] / No[2]
Walleye	8.5	37.5	7.5	Yes[3] / No[2]
Sauger	Undetermined [1]	--	--	Undetermined
White Sucker	10.0	60.0	30.0	Yes[2] / Yes[4]

Sources: Bell, Milo C .,1990, *Fisheries Handbook of Engineering Requirements and Biological Criteria,* U.S. Army Corps of Engineers North Pacific Division, Portland, Oregon.
Peake, S., R.S. McKinley, and D.A. Scruton, 2000, "Swimming Performance of Walleye (*Stizostedion vitreum*)," NRC Canada, Retrieved on June 14, 2010. http://www.humboldt.edu/~storage/pdfmill/Batch_8/walleye.pdf.
USACE, October 2004, *Interim Report for the Upper Mississippi River – Illinois Waterway System Navigation Study, Improving Fish Passage Through Navigation Dams on the Upper Mississippi River System*, Rock Island District, St. Louis District, St. Paul District.
Venn Beecham, Rachal, et al., 2007, "Comparative Swimming Performance of Juvenile Pond-Cultured and Wild-Caught channel catfish," *North American Journal of Fisheries Management* 27:729-734, American Fisheries Society, Lawrence, Kansas.

Notes:

1 Unable to determine via literature review.

2 Assumes that maximum burst speed can be conveyed for 15 seconds and that the zone of increased velocities due to the Diversion Weir extends 25 to 50 feet downstream of the Diversion Weir.

3 Assumes that maximum burst speed can be conveyed for 15 seconds and that the zone of increased velocities due to the Diversion Weir extends up to 37.5 feet downstream of the Diversion Weir. If flow-increased velocities extend beyond 37.5 feet downstream of the Diversion Weir, passage is not anticipated.

4 Assumes that maximum burst speed can be conveyed for 15 seconds and that the zone of increased velocities due to the Division Weir extends up to 30 feet downstream of the Diversion Weir. If flow-increased velocities extend beyond 30 feet downstream of the Diversion Weir, passage is not anticipated.

As depicted in Table 5-2, walleye and white sucker are documented as having a maximum burst swimming speed substantial enough to pass over the Diversion Weir during instances of flow submergence, as follows:

- White sucker can pass the Diversion Weir during the lower flow submergence velocity (6 fps) if the high end of its 5.0 to 10.0 fps burst swimming speed range is applied for the entire 15 second burst period.
- White sucker can also pass the Diversion Weir during the higher flow submergence velocity (8 fps) if the high end of its 5.0 to 10.0 fps burst swimming speed range is applied for the entire 15 second burst period and the reach of the Loup River influenced by increased flow velocities does not extend more than 30 feet downstream of the Diversion Weir.
- Walleye can pass the Diversion Weir during the lower flow submergence velocity (6 fps) if the high end of its 5.2 to 8.5 fps burst swimming speed range is applied for the entire 15 second burst period and the reach of the Loup River influenced by increased flow velocities does not extend more than 37.5 feet downstream of the Diversion Weir.

This analysis considers that the zone of influenced flow velocity extends approximately 25 to 50 feet downstream of the Diversion Weir based on the geometry of the Diversion Weir and the range of flow conditions.

In summary, when the determined frequency of Diversion Weir submergence and resulting flow velocities over the Diversion Weir (when it is submerged) are analyzed against the critical and burst swimming speeds of applicable Loup River fish species, it can be determined that the Diversion Weir serves as a barrier to upstream fish movement 99 percent of the time.

Hydraulic Conditions at Sluice Gate Structure

As discussed in Section 5.1, the Sluice Gate Structure is operated periodically to keep the Intake Gate Structure from being obstructed by debris, ice, or sediment. It is also used to maintain an upstream elevation of 1,576 feet. During times of higher flows, gates are opened, one at a time and as needed, to maintain 1,576 feet. This process is implemented to minimize damage to the flashboards during times of high flows. The average flow velocities through the Sluice Gate Structure depend on the hydraulic conditions at the structure (Discharge and Tailwater Elevation) and the gate setting. The Sluice Gate Structure is not operated every day, but it is operated several times per month. If the Sluice Gate Structure is not open, there is not a fish pathway through the structure. The Sluice Gate Structure is evaluated in this fish passage study to determine if there are any hydraulic conditions that occur under normal operating procedures that result in a fish pathway. This analysis considers the full range of flows (5 to 20,000 cfs), gate openings (0 to 7 feet), number of gates open, and a normal operating water surface of 1,576 feet. The end result of this analysis determines if a fish pathway is present through the Sluice Gate Structure for any of the flow conditions present at the Diversion Weir by comparing the average velocity through the gate to the critical and burst swimming speeds for applicable fish species. From the downstream end of the spillway apron associated with the Sluice Gate Structure to the upstream end of the sluice gate entrance, the distance a fish travels is approximately 40 feet.

The average velocity at the Sluice Gate Structure was plotted against the water surface upstream of the Diversion Weir, and discharge in the Loup River near Genoa for all combinations of gate openings, as shown in Figure 5-5. The Diversion Weir is at an elevation of 1,576 feet almost all of the time during the fish migration season. This water surface creates a hydraulic head that drives water through the Intake Gate Structure and the Sluice Gate Structures if they are open. This is the normal operating condition for the Diversion Weir and Sluice Gate Structure.

When the upstream water surface elevation is at 1,576 feet, flow velocities through the Sluice Gate Structure ranges from 9 to 14 fps, depending on discharge and how many sluice gates are open (see Figure 5-5). When these findings are compared to the documented critical swimming velocities and burst swim speeds of applicable riverine fish species, as shown in Table 5-3, it was determined that none of the gate opening scenarios facilitate upstream riverine fish migration through the Sluice Gate Structure when the upstream water surface elevation is at 1,576 feet.

Under the infrequent scenario in which the flashboards are not in place during the fish migration season and the upstream water surface elevation is therefore maintained at 1,574 feet, flow velocities through the Sluice Gate Structures would range from 7 to 12 fps, depending on discharge and how many sluice gates are open (see Figure 5-5). When these findings are compared to the documented critical swimming velocities and burst swim speeds of applicable riverine fish species (see Table 5-3), it was determined that only the white sucker could potentially swim through the Sluice Gate Structure and only during a very specific discharge that results in the lowest flow velocity (7 fps) within the potential velocity range (7 to 12 fps).

In summary, the Sluice Gate Structure does not generally provide a fish pathway due to the lack of time that the gates are open as well as high flow velocities being conveyed through the structure. If the upstream water surface elevation is maintained at 1,574 feet (concrete weir crest) and under very specific flow conditions, flow velocities through the Sluice Gate Structure may facilitate the upstream passage of those riverine fish species that display the highest swimming performance.

Alternative Fish Pathways

As discussed in Section 4, Methodology, this fish passage study investigated whether alternative fish pathways exist at the Headworks. In particular, the study investigated whether the right bank of the Loup River (looking downstream) has a low enough elevation that fish can swim around the Diversion Weir.

Based on Figure 5-1, the Diversion Weir is submerged less than 1 percent of the time. This means that the discharge in the river downstream of the Diversion Weir is estimated, based on historical data, to be high enough to create an alternate fish pathway around the Diversion Weir less than 1 day out of every spawning season.

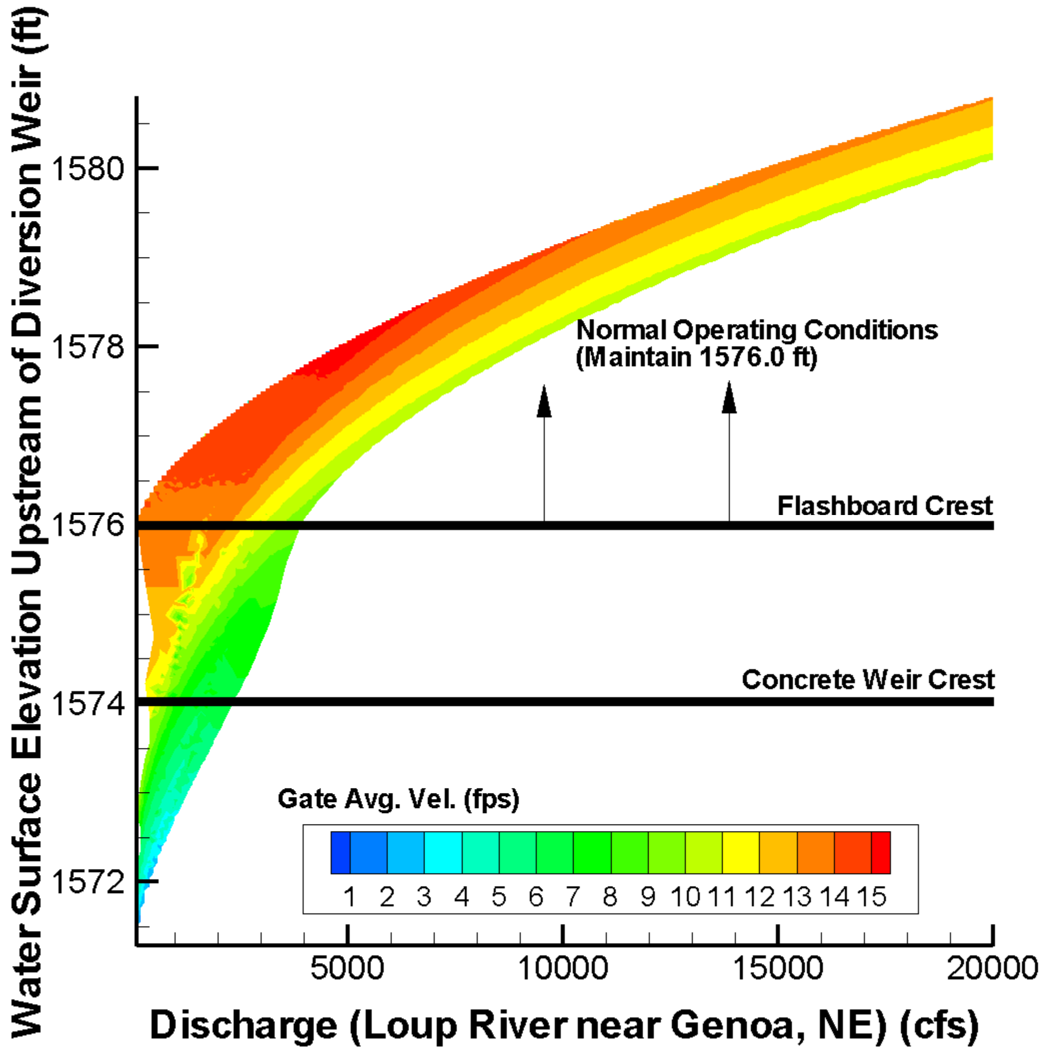

Figure 5-5. Average Gate Velocities for 1, 2, and 3 Gates Open During the Full Range of Water Surfaces Upstream of Diversion Weir and Full Range of Discharges in the Loup River Near Genoa, NE

Table 5-3. Upstream Travel of Loup River Migratory Fishes Through the Sluice Gate Structure

Species	Maximum Burst Swimming Speed U_{BURST} (fps)	Distance Traveled Against 7 fps Sluice Gate Velocity[1] (ft)	Distance Traveled Against 9 fps Sluice Gate Velocity[2] (ft)	Ability to Travel Through Sluice Gate Structure (7 fps / 9 fps)
White Bass	Undetermined[3]	--	--	Undetermined
Channel Catfish	3.9	-46.5	-76.5	No[4] / No[4]
Walleye	8.5	22.5	-7.5	No[4] / No[4]
Sauger	Undetermined [3]	--	--	Undetermined
White Sucker	10.0	45.0	15.0	Yes[4] / No[4]

Sources: Bell, Milo C .,1990, *Fisheries Handbook of Engineering Requirements and Biological Criteria,* U.S. Army Corps of Engineers North Pacific Division, Portland, Oregon.
Peake, S., R.S. McKinley, and D.A. Scruton, 2000, "Swimming Performance of Walleye (*Stizostedion vitreum*)," NRC Canada, Retrieved on June 14, 2010. http://www.humboldt.edu/~storage/pdfmill/Batch_8/walleye.pdf.
USACE, October 2004, *Interim Report for the Upper Mississippi River – Illinois Waterway System Navigation Study, Improving Fish Passage Through Navigation Dams on the Upper Mississippi River System*, Rock Island District, St. Louis District, St. Paul District.
Venn Beecham, Rachal, et al., 2007, "Comparative Swimming Performance of Juvenile Pond-Cultured and Wild-Caught channel catfish," *North American Journal of Fisheries Management* 27:729-734, American Fisheries Society, Lawrence, Kansas.

Notes:
1 Lowest flow velocity through Sluice Gate Structure during conditions when the upstream water surface elevation is 1,574 feet (concrete weir crest).
2 Lowest flow velocity through Sluice Gate Structure during conditions when the upstream water surface elevation is 1,576 feet (flashboard crest).
3 Unable to determine via literature review.
4 Assumes that maximum burst speed can be conveyed for 15 seconds and that the zone of analyzed flow velocities through the Sluice Gate Structure extends a total of 40 feet.

5.4 Summary

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 percent 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 exude 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). 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 during which the flashboards are absent and the upstream water surface elevation is maintained at elevation 1,574 (concrete weir crest). 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.

6. STUDY VARIANCE

This study has been performed consistent with the Fish Passage study plan, which was approved by the Federal Energy Regulatory Commission (FERC) in its Study Plan Determination on August 26, 2009. No discernable study variance has occurred.

7. REFERENCES

Bell, Milo C. 1990. *Fisheries Handbook of Engineering Requirements and Biological Criteria*. U.S. Army Corps of Engineers North Pacific Division, Portland, Oregon.

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Peake, S., R.S. McKinley, and D.A. Scruton. 2000. "Swimming Performance of Walleye (Stizostedion vitreum)." NRC Canada. Retrieved on June 14, 2010. http://www.humboldt.edu/~storage/pdfmill/Batch_8/walleye.pdf.

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