US Army Corps
of Engineers®
St. Paul District

Attachment K-2: Fish Passage

Fargo Moorhead Metropolitan Area
Flood Risk Management Project

Reach 4

Diversion Channel and Rush River Inlet/Drop Structure

Engineering and Design Phase

P2# 370365

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Attachment K-2: Fish Passage

List of Figures

List of Tables

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K2.1 Introduction

The fundamental purpose of the proposed fish passage structure is to provide a pathway for the immigration and emigration of fish between the Red River and the Rush River. Currently, the Rush River flows directly to the Red River but this connection will be severed when the proposed diversion channel is constructed. Important factors for establishing fish passage within a structure include: (1) species of interest -identified through agency and stakeholder coordination, (2) design limitations – identified by essential goals and objectives of the project, including swim speed, (3) ability to monitor – stemming from a pre- and post- construction design, and (4) geomorphologic components of the system.

Fish species known from the Red River Basin are included in the Environmental Impact Statement (July 2011), (Table K2-1*, [Table 30 – Fish Species observed in the Red River Basin, Source: Aadland et al.* 2005]). Fifty-eight species in 17 families have been identified as occurring or historically (since 1962) known to occur in the Red River basin. This includes lake sturgeon, which currently has a reintroduction program underway in the Red River basin (Aadland et al. 2005). By comparison, 22 species were known from the Rush River. In general, fish observed in the Rush River are smaller bodied, silt tolerant and are adapted to slower moving waters. However, some species such as the channel catfish can grow to be 20 pounds and are considered highly migratory. Species of interest will be determined through agency and other stakeholder coordination in subsequent design phases particularly in light of behavioral and reproductive characteristics of fishes known from the Rush River or revealed during monitoring (Table K2-2). However, it's anticipated that fish passage would be desired for a wide range of species especially sport fish like channel catfish and walleye. Focus for fish passage will be on providing a range of hydraulic conditions that target the needs of different life-stages of several species, including those identified from recent surveys.

Table K2-1. Fishes of the Red River. From the Fargo-Moorhead Metropolitan Area Environmental Impact Statement (July 2011) - Table 30 – Fish Species observed in the Red River Basin: Aadland et al. 2005. "X" indicates a species presence, "E" indicates species extirpated from the indicated waterbody, "N" indicates native to the drainage, and "I" indicates introduced. No mark represents a species within the Red River Basin, but not found in the indicated waterbody.

Taxon	Scientific Name	Common name	N or I[1]	Red	Wild Rice	Sheyenne	Maple	Rush
Petromyzontidae								
	Ichthyomyson castaneus	chestnut lamprey	N	X				
	Ichthyomyson unicuspis	silver lamprey	N	X				
Acipenseridae								
	Acipenser fulvescens[2]	lake sturgeon	N	E				
Lepisosteidae								
	Lepistoseus osseus[2]	longnose gar	N					
Amiidae								
	Amia calva	bowfin	N					
Hiodontidae								
	Hiodon alosoides	goldeneye	N	X		X		
	Hiodon tergisus	mooneye	N	X		X		
Salmonidae								
	Coregonus artedii	ciscoe	N					
	Coregonus clupeaformis	whitefish	N	X				
	Oncorhynchus mykiss	rainbow trout	I			X		
	Salmo trutta	brown trout	I					

Taxon	Scientific Name	Common name	N or I[1]	Red	Wild Rice	Sheyenne	Maple	Rush
	Salvelinus fontinalis	brook trout	I					
	Salvelinus namaycush	lake trout	I					
Catostomidae								
	Carpiodes cyprinus	quillback carpsucker	N	X		X	X	X
	Catostomus commersonii	white sucker	N	X	X	X	X	X
	Hypentelium nigricans	northern hog sucker	N					
	Ictiobus bubalus	smallmouth buffalo	N					
	Ictiobus cyprinellus	bigmouth buffalo	N	X	X	X	X	
	Moxostoma anisurum	silver redhorse	N	X	X	X		
	Moxostoma erythrurum	golden redhorse	N	X		X		
	Moxostoma macrolepidotum	shorthead redhorse	N	X	X	X	X	
	Moxostoma valenciennesi	greater redhorse	N	X		X	X	
Cyprinidae								
	Campostoma anomalum	central stoneroller	N					
	Campostoma oligolepis	largescale stoneroller	N					
	Carassius auratus	goldfish	I	X				
	Cyprinella spiloptera	spotfin shiner	N	X	X	X	X	X
	Cyprinus carpio	common carp	I	X	X	X	X	X
	Hybognathus hankinsoni	brassy minnow	N			X	X	
	Luxilus cornutus	common shiner	N	X		X	X	X
	Macrhybopsis storeriana	silver chub	N	X		X		
	Margariscus margarita	pearl dace	N					
	Nocomis biguttatus	hornyhead chub	N	X		E	E	
	Notemigonus chrysoleucas	golden shiner	N	X		X		
	Notropis anogenus	pugnose shiner	N			E		
	Notropis atherinoides	emerald shiner	N	X		X	X	X
	Notropis blennius	river shiner	N	X	X	X	X	X
	Notropis dorsalis	bigmouth shiner	N	X		X	X	X
	Notropis heterodon	blackchin shiner	N			X		
	Notropis heterolepis	blacknose shiner	N			X		
	Notropis hudsonius	spottail shiner	N	X		X		
	Notropis percobromus	carmine shiner	N			X		
	Notropis rubellus	rosyface shiner	N					
	Notropis stramineus	sand shiner	N	X		X	X	
	Notropis texanus	weed shiner	N					
	Notropis volucellus	mimic shiner	N					
	Phoxinus eos	northern redbelly dace	N			X		X
	Phoxinus neogaeus	finescale dace	N					
	Pimephales notatus	bluntnose minnow	N	X		X	X	X
	Pimephales promelas	fathead minnow	N	X	X	X	X	X
	Platygobio gracilis	flathead chub	I	X				
	Rhinichthys atratulus	blacknose dace	N					
	Rhinichthys obtusus	western blacknose dace	N			X	X	
	Semotilus atromaculatus	creek chub	N	X		X	X	X

Taxon	Scientific Name	Common name	N or I[1]	Red	Wild Rice	Sheyenne	Maple	Rush
	Rhinichthys cataractae	longnose dace	N	X		X		
Ictaluridae								
	Ameiurus melas	black bullhead	N	X	X	X	X	X
	Ameiurus natalis	yellow bullhead	N	X				
	Ameiurus nebulosus	brown bullhead	N	X		X		
	Ictalurus punctatus	channel catfish	N	X	X	X	X	X
	Noturus flavus	stonecat	N	X		X		
	Noturus gyrinus	tadpole madtom	N	X	X	X	X	
Umbridae								
	Umbra limi	central mudminnow	N	X				
Esocidae								
	Esox lucius	northern pike	N	X	X	X	X	X
	Esox masquinongy	muskellunge	I			X		
Osmeridae								
	Osmerus mordax	rainbow smelt	N	X				
Cyprinodontidae								
	Fundulus diaphanus	banded killfish	N	X		E		
Gadidae								
	Lota lota	burbot	N	X				
Percopsidae								
	Percopsis omiscomaycus	trout-perch	N	X	X	X	X	X
Moronidae								
	Morone chrysops	white bass	I	X		X		
Centrarchidae								
	Ambloplites rupestris	rock bass	N	X	X	X		
	Lepomis cyanellus	green sunfish	N	X		X	X	
	Lepomis gibbosus	pumpkinseed	N		X	X		
	Lepomis humilis	orangespotted sunfish	N	X		X		
	Lepomis macrochirus	bluegill	N	X		X		
	Micropterus dolomieu	smallmouth bass	N	X		X		
	Micropterus salmoides	largemouth bass	N			X		
	Pomoxis annularis	white crappie	N	X		X	X	
	Pomoxis nigromaculatus	black crappie	N	X	X	X	X	
Percidae								
	Etheostoma caeruleum	rainbow darter	N					
	Etheostoma exile	Iowa darter	N		X	X	X	X
	Etheostoma microperca	least darter	N					
	Etheostoma nigrum	johnny darter	N	X	X	X	X	
	Perca flavescens	yellow perch	N	X	X	X		
	Percina caprodes	logperch	N	X				
	Percina maculata	blackside darter	N	X	X	X	X	X
	Percina shumardi	river darter	N	E		E		
	Sander canadensis	sauger	N	X		X	X	X
	Sander vitreus	walleye	N	X	X	X		X
Scianidae								
	Aplodinotus grunniens	freshwater drum	N	X	X	X		X

Taxon	Scientific Name	Common name	N or I[1]	Red	Wild Rice	Sheyenne	Maple	Rush
Cottidae								
	Cottus bairdi	mottled sculpin	N					
	Cottus cognatus	slimy sculpin	N					
	Cottus ricei	spoonhead sculpin	N					
Gasterosteidae								
	Culaea inconstans	brook stickleback	N		X	X	X	X
	Pungitius pungitius	ninespine stickleback	N					
[1] Species that are native (N) or introduced (I) to the Red River Basin.								
[2] Species which are known only from historical records and most likely no longer exist in the Red River basin.								

Table K2-2. Table of behavioral and reproductive characteristics of fishes known from the Rush River. Includes species collected during Rush River fall 2011 sampling and those historically know from the Rush River (summarized from above table). Depth, velocity and substrate are based on HSI values of 0.8 to 1.0 (Aadland and Kuitenun 2006). A = Adult, J = Juvenile, Y = Young of Year, (spawn) = spawning preference. (Additional data from: Aadland 2010, Wilcox et al. 2004, Becker 1983).

Species	Fall 2011	Hist	Spawning Time	Migration Behavior	Prolonged Swim Speed (ft/s)[1]	Burst Swim Speed (ft/s)[1]	Preferred Depth (ft)	Preferred Velocity (ft/sec)	Preferred Substrate
Spotfin Shiner	X	X	May into September in crevices between rocks or in bark on submerged fallen trees	Not in Becker but likely highly migratory considering its range expansion			(A) 0.33 -1.31 (Y) 0 .16 - 0.82 (spawn) 0.16 -1.00	(A) 0.33 -1.31 (Y) 0.33 -1.31 (spawn) 0.00 -2.13	(A) cobble, sand, gravel (Y) cobble, silt, sand (spawn) detritus, boulder rubble
Common Carp	X	X	May – August. Eggs scattered over available vegetation	May migrate long distances to find suitable spawning conditions			(A) 1.48 -2.62 (J) 1.31-2.80 (Y) 0.50 -.82	(A) 0.00 -.66 (J) 0.33 -1.50 (Y) 0 .00 - 0.66	(A) silt, detritus, sand (J) bedrock, sand, silt (Y) silt, rubble, gravel
Common Shiner	X	X	Late May – end of July in stream riffles over gravel, 15.6-18.3°C	Migrate upstream from deeper pools where they overwinter		3.8	(A) 1.64 - 4.92 (J) 0.66 -2.30 (Y) .16 -1.31 (spawn) .82-1.64	(A) 0.66-2.30 (J) 0.33 - 0.98 (Y) 0.16 - 0.98 (spawn) 1.31 - 2.30	(A) cobble, gravel, rubble (J) sand, gravel, cobble (Y) sand, gravel, cobble (spawn) cobble, gravel, rubble
Emerald Shiner		*X*	Considered a "summer spawner", May - August, gravel shoals, sand, mud swept clean of detritus 20.1-23.2°C	Ascend tributaries in the spring – adults descending after spawn.			(A) 0.49 - 0.98 (Y) 0.00 - 0.16	(A) 0.00 - 2.13 (Y) 0.00 - 0.66	(A) detritus, silt, sand (Y) detritus, boulder, silt
River Shiner		*X*	Late spawner – June - August	Migrates from the Red River into tributaries to in late spring, early summer			(A) 0.49 - 0.98 (Y) 0.16 - 0.82	(A) 0.82 – 2.13 (Y) 0.33 – 1.48	(A) silt, gravel, rubble (Y) bedrock, gravel, sand
Bigmouth Shiner		*X*	Late May – August – considered a late spawner,	? but considered a pioneer species			(A) 0.33 - 0.82 (Y) 0.33 - 0.66	(A) 0.66 – 1.31 (Y) 0.33 - 0.66	(A) silt, sand, gravel (Y) sand, gravel, cobble
Sand Shiner	X		Late May-mid-August – able to spawn in high temperatures – up to 37°C, in summer	Migrate upstream from the Red River then return after spawn. Similar to emerald shiner			(A) 0.16 - 0.82 (Y) 0.16 - 0.66 (spawn) 0.66 – 1.00	(A) 0.66 -1.64 (Y) 0.16 -1.64 (spawn) 1.15 -2.46	(A) gravel, sand cobble (Y) sand, gravel, bedrock (spawn) gravel, boulder, sand, submersed veg.

Species	Fall 2011	Hist	Spawning Time	Migration Behavior	Prolonged Swim Speed (ft/s)[1]	Burst Swim Speed (ft/s)[1]	Preferred Depth (ft)	Preferred Velocity (ft/sec)	Preferred Substrate
Northern Redbelly Dace		*X*	Late May into August, in algae filaments – 21.1-26.7°C	Not in Becker					
Bluntnose Minnow		*X*	May to August, 21.1 – 26.1°C, eggs stuck to the underside of any flat object	Obligate , seasonal migrations depending on water depths and temperatures			(A) 0.50 -1.50 (Y) 0.16 - 0.66	(A) 0.00 -1.64 (Y) 0.16 - 0.66	(A) sand, gravel, silt (Y) sand, gravel, silt
Fathead Minnow	X	X	May to August, 21.1 – 26.1°C, eggs stuck to the underside of any flat object	Obligate , seasonal migrations depending on water depths and temperatures, pioneer species		2.6	(A) 0.33 - 0.98 (Y) 0.16 - 0.66 (spawn) 0.66 - 1.31	(A) 0.00 - 0.82 (Y) 0.00 - 0.49 (spawn) 0.49 - 0.98	(A) gravel, rubble, boulder (Y) silt, boulder, sand (spawn) gravel, rubble, cobble
Longnose Dace	X		Early, late April to mid-June. 11.1-23.3°C	Move to areas of fine gravel, swifter currents			(A) 0.16 - 0.82 (Y) 0.00 - 0.49 (spawn) 0.33 – 0.82	(A) 2.46 - 3.77 (Y) 0.00 - 1.15 (spawn) 1.48 - 1.97	(A) rubble, cobble, boulder (Y) gravel, cobble, rubble (spawn) gravel, cobble, sand
Creek Chub	X	X	May – July 12.8°C-17°, over course gravel in currents	Short upstream migrations to suitable habitats			(A) 0.82 - 2.13 (J) 0.66 - 1.15 (Y) 0.16 - 0.82	(A) 0.33 - 1.64 (J) 0.16 - 0.82 (Y) 0.00 - 0.49	(A) boulder, cobble, gravel (J) silt, gravel, sand (Y) sand, gravel, silt
Quillback	X	X	May – September 19.0-28.0 °C	Ascends small creeks in spring	1.6	4.8-6.4	(A) 3.28 - 5.74 (Y) 0.66 - 1.31	(A) 0.00 - 1.64 (Y) 0.00 - 0.33	(A) gravel, sand, boulder (Y) sand, detritus, boulder
White Sucker	X	X	April to early May >7.2°C	Migrates upstream to spawn	2.1	6.3-8.4	(A) 3.28 -7.55 (J) 0.16 -1.15 (Y) 0.66 - 0.98	(A) 0.33 -2.46 (J) 0.66 - 1.97 (Y) 0.82 -1.64	(A) gravel, boulder, sand (J) rubble gravel, coble (Y) gravel, detritus, rubble
Black Bullhead	X	X	April – July, >21°C, in mud or sand	Nocturnal migrants			(J) 0.82 - 1.48 (Y) 0.98 - 1.64	(J) 0.33 - 0.98 (Y) 0.00 - 0.16	(J) rubble, gravel, silt (Y) silt, cobble, gravel
Brown Bullhead	X		June, July, 21-25°C, sand, gravel, mud	No mention in Becker					
Channel Catfish	X	X	April-October >23.9°C	Random feeding movements. Movements to and from wintering areas	2.3	6.9-9.2	(A) 1.64+ (J) 2.46 - 8.20 (Y) 0.33 - 2.46	(A) 0.00 - 0.33 (J) 0.00 - 0.33 (Y) 0.49 - 1.48	(A) boulder, sand, rubble (J) sand, boulder, gravel (Y) bedrock, gravel, sand
Stonecat Madtom	X		June-August, >27.8°C, under stones,	Migrate from riffles to deeper pools as temperatures drop			(A) 0.66 - 1.31 (J) 0.16 - 0.82 (Y) 0.00 - 0.33	(A) 1.64 - 4.27 (J) 2.13 - 4.27 (Y) 1.64 - 2.62	(A) boulder, rubble, cobble (J) boulder, rubble, cobble (Y) cobble, gravel, boulder
Tadpole Madtom	X		June-July, under objects, in cavities	Not in Becker			(A) 0.82 - 2.46 (Y) 0.66 - 1.64	(A) 0.49 - 1.64 (Y) 0.00 - 0.49	(A) sand, gravel, silt (Y) detritus, silt, boulder
Northern Pike	X	X	March – April 1.1-2.8°C	Migrations to spawning areas	1.5	4.5-6.0	(A) 1.64 - 3.61	(A) 0.00 - 0.33	(A) silt, detritus, sand
Trout Perch	X	X							

Species	Fall 2011	Hist	Spawning Time	Migration Behavior	Prolonged Swim Speed (ft/s)[1]	Burst Swim Speed (ft/s)[1]	Preferred Depth (ft)	Preferred Velocity (ft/sec)	Preferred Substrate
Brook Stickleback		*X*					(A) 0.66 - 0.98 (Y) 0.82 - 1.64	(A) 0.16 - 0.33 (Y) 0.00 - 0.16	(A) boulder, detritus, silt (Y) detritus, silt, sand
White Bass	X		April – June 12.5-26.1°C	Homing to spawning areas, extensive feeding movements	3.8	11.7-15.6	(Y) 1.31 - 2.46	(Y) 0.16 - 0.49	(Y) boulder, sand, detritus
Rock Bass	X						(A) 0.82 - 2.46 (Y) 2.95 - 3.77	(A) 0.00 - 0.16 (Y) 0.00 - 0.16	(A) bedrock, boulder, cobble (Y) silt, sand, gravel
Orangespotted Sunfish	X						(A) 0.82 - 1.97 (Y) 0.82 - 1.48 (spawn) 1.64 - 2.30	(A) 0.00 - 0.33 (Y) 0.00 - 0.33 (spawn) 0.66 - 1.31	(A) cobble, bedrock, boulder (Y) boulder, sand, cobble (spawn) boulder, detritus, gravel
Bluegill	X					3.3-4.2	(A) 4.92+ (J) 0.66+ (Y) 0.82 - 1.64	(A) 0.00 - 0.16 (J) 0.00 - 0.49 (Y) 0.00 - 0.16	(A) detritus, boulder, cobble (J) gravel, cobble, silt (y) detritus, silt, gravel
Black Crappie	X						(A)8.37 - 9.84+ (J) 2.62+ (Y) 7.38+	(A)0.00 - 0.33 (J) 0.00 - 0.66 (Y) 0.00 - 0.16	(A)silt, rubble, sand (J) detritus, boulder, rubble (Y) silt, detritus, cobble
Iowa Darter		*X*					(A) 0.49 - 2.46	(A) 0.00 - 0.16	(A) detritus, silt, boulder
Yellow Perch	X					3.8	(A) 1.64 - 2.13 (J) 1.64 - 3.28 (Y) 0.16 - 1.64	(A) 0.49 - 1.15 (J) 0.00 - 0.66 (Y) 1.48 - 2.62	(A) silt, sand, gravel (J) detritus, sand, gravel (Y) detritus, boulder, sand
Blackside Darter	X	X					(A) 20-50 (Y) 10-40	(A) 0.33 - 1.64 (Y) 0.33 - 1.80	(A) boulder, gravel, sand (Y) boulder, gravel, sand
Sauger		*X*	April - May 6.1-11.7°C	Downstream movements probably related to spawning.					
Walleye	X	X	March – April 3.3-6.7°C (pre-spawning movements) 5-10°C (spawning)	Adult-learned homing to spawning areas. Dispersal, possible homing to summer feeding areas. Movements to and from feeding areas.	3.3	9.9-13.2	(A) 4.27+ (J) 2.79+ (Y) 3.44 - 5.74 (spawn) 1.31 - 2.30	(A) 0.16 - 0.82 (J) 0.16 - 0.49 (Y) 0.00 - 0.16 (spawn) 1.31 - 2.30	(A) boulder, rubble, gravel (J) bedrock, gravel, rubble (Y) silt, sand, cobble (spawn) gravel, sand, cobble
Freshwater Drum	X	X	May-June 18.9-22.2°C	Possible upstream pre-spawning movements			(Y) 0.98 - 2.46	(Y) 0.16 - 0.49	(Y) detritus, sand, gravel

[1] As stated by Wilcox et al. (2004), prolonged swim speeds can typically be sustained for a period of time ranging from 15 seconds to 200 minutes. Burst swim speeds are typically 3 to 4 times greater than prolonged swim speeds and usually are sustained no longer than 15 seconds. The reliability of the experimentally determined swim speeds and their applicability to UMR fishes is limited by the species tested, sizes and numbers of test fish, water temperatures used during the swimming performance tests, and statistical results of the swimming performance trials. For the species that this information is available, these swim speeds should be treated with caution

K2.2 Aquatic Habitat Connectivity

Connectivity is an important attribute of aquatic habitat for river fishes. Connectivity refers to the continuous nature of aquatic habitats in main channels, floodplain water bodies and tributaries. Natural rivers contain a heterogeneous mosaic of aquatic habitats that are very dynamic in both a spatial and temporal sense. River habitats can substantially vary over scales from short- (e.g., flood events) to medium- (e.g., seasonal) or long-term (annual, decadal, or longer). Fish in rivers have evolved migratory and life history strategies that take advantage of these complex, changing riverscapes.

Habitat connectivity is important in terms of fulfilling seasonal and life-stage specific habitat needs for river fishes. Fish undergo alimental (food procurement), climatic (seasonal habitat movements), and gametic (reproduction) migrations in rivers (McKeown 1984). For some time, biologists (e.g., Fauch et al. 2002; Schlosser 1991) have identified refinements regarding migrations that are common features of fish life histories including migrations that occur between different feeding habitats, and migrations associated with refugia during catastrophic events such as floods, droughts, and extreme water quality conditions (i.e., high temperature, low dissolved oxygen).

Agencies have always supported the idea that fish passage be provided across the widest range of conditions practicable. For example, fish passage during floods is important as fish often move in response to pulse events, particularly during spring floods. The Fargo-Moorhead project has strived to provide fish passage during all but the largest flood events. Fish passage at the Rush River inlet is justified provided project costs do not substantially increase. Coordination with the project team has previously suggested that fish passage during floods would not be problematic at this site as Red River elevations would typically rise up to the level of the diversion channel.

Dams and similar structures reduce the connectivity of aquatic habitat by restricting movement of river fish. Impeded fish movements resulting from dams have been implicated in altering fish community structure and declining fish populations in rivers throughout the world (Northcote 1998; Pringle et al. 2000). Restrictions on movements of migratory fish in a river system can potentially limit the extent and quality of habitats that they can occupy. Effects of reduced access to habitats can be expressed at the individual, population, and community levels. Further, it is commonly accepted that impeding migrations that freshwater fish use to optimize growth, reproduction and survival can ultimately affect fish production (Northcote 1978). Reduced access to prime foraging habitat can result in greater expenditure of energy for foraging and reduce growth of individual fish. Reduced access to suitable winter habitat can limit winter survival. Restrictions on movements of migratory fish can have significant adverse effects on pre-spawning movements, can limit access to suitable spawning habitats, and limit the size of spawning aggregations.

Species known from the Rush and Lower Rush rivers that likely perform regular migrations include, but are not limited to, quillback, white sucker, channel catfish, northern pike, white bass, walleye and freshwater drum. In addition to the tributaries in the study area, tributaries throughout the basin may have fish populations that migrate back and forth from the Red River. Aadland (2010) provided approximate migration periods for select Red River fishes. For the fish identified, migrational periods on the Red River would be expected to occur over a period of a month or more. Key Red River species of concern include lake sturgeon and channel catfish. Lake sturgeon would be expected to migrate from early- to mid-May thru mid-June. Channel catfish would be expected to migrate over a period of a couple months, generally from May through early July. Aadland (2010) noted channel catfish migrations on the Otter Tail (a tributary just north of the study area) in 2004 began in late-April. However, he observed that the largest individuals (600 mm and larger) were captured in July. Aadland (2010) noted these large fish were likely spawners and the late migration of large individuals could have significant ramifications for catfish populations. Thus, migration during these summer months could be particularly important for these species.

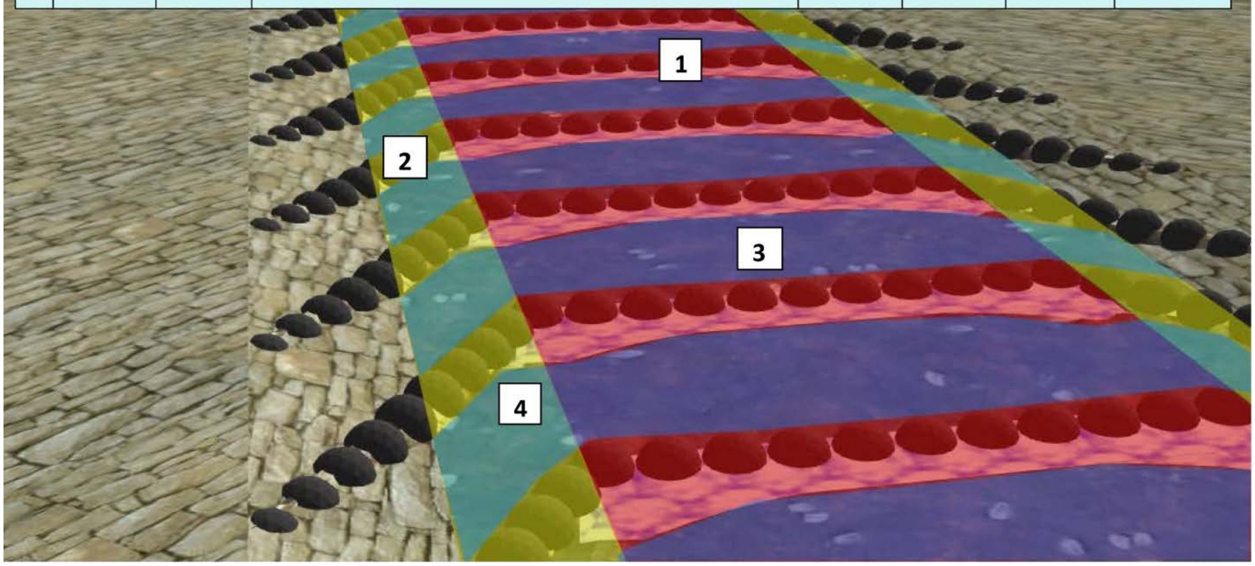
K2.3 Nature-Like Fishway

Fishways are structures that allow fish to pass barriers and are designed to provide hydraulic conditions suitable for fish to pass the obstruction without undue stress, delay or injury. A nature-like fishway is a broad term for several styles of structures constructed with natural materials - rock being the most common. Nature-like fishways have proven effective for a wide range of fish species with varying swimming abilities (DVWK 1996; 2002; Gaboury et al. 1995). The purpose of these nature-like fishways is to simulate natural river channels. In addition to improving fish passage past dams or other obstructions, nature-like fishways provide benefits for many aquatic organisms – i.e., such as a food source for fish; Figure K2-1 is a conceptual layout of the proposed natural fishway. Note that, although rock riffles are not common on the Red River mainstem, the key to the design is that the small drops down the ramp are built to a height that gives fish the opportunity to rest between each drop. Aadland (2010) described the advantages of emulating natural channel geomorphology and materials in a fishway as:

1. Fish react to complex current and bathymetry cues, and channels similar to natural channels are less likely to cause disorientation than channels that are not.
2. Natural channel design allows fishways to provide important spawning habitat as well as passage.
3. Use of natural substrates, rather than concrete or other smooth materials, provides roughness and interstitial spaces that allow small fishes and benthic invertebrates to pass and, in many cases, colonize the fishway.
4. A fishway built with natural channel design techniques provides habitat that in some cases may be rare due to reservoir inundation.

Figure K2-1. Conceptual Layout of Full-Width Rock Ramp Fishway.

	Location	Feature	Description	Peak Velocities			
				100 cfs	1000 cfs	7000 cfs	20000 cfs
1	Center	Weir	High velocity area at the center of the channel through the boulder weirs which can accommodate passage for fish with stronger ***maximum burst speeds***	5.5 ft/s	8.5 ft/s	10.8 ft/s	3.6 ft/s
2	Fringe	Weir	Fringe area through boulder weirs with moderate velocity to accommodate fish passage for ***a full range of burst speeds***	4 ft/s	5 ft/s	6.4 ft/s	2.4 ft/s
3	Center	Pool	Pool area at the center of the channel with velocities in the range of ***sustained swim speeds*** for most flows	0.4 ft/s	2.2 ft/s	6.3 ft/s	3.3 ft/s
4	Fringe	Pool	Fringe areas of the pools with low velocities for ***resting***	0.3 ft/s	1 ft/s	2.7 ft/s	2.3 ft/s



Nature-like fishways are gradually sloping open channels with a rough bottom or a series of riffles and pools (Wildman et al. 2003, Acharya et al. 2004). The closer a nature-like fishway matches the morphological characteristics of natural river habitat for the species present, the less likely hydraulic conditions will reach thresholds that limit fish passage (Parasiewicz et al. 1998). Nature-like fishways have proven effective for a wide range of fish species with varying swimming abilities (Katopodis and Aadland 2006).

Rock ramps are nature-like fishways that simulate conditions of natural rapids. Rock ramps can be constructed to create continuous rapids where most of the ramp is fairly turbulent and has higher velocities or they can be constructed to create pool/riffle conditions where the head loss occurs at steps with resting pools in between those steps. Rock ramps have been used effectively to restore lake sturgeon spawning habitat (Aadland et al. 2005) and enhance macroinvertebrate communities (Litvan et al. 2006).

In addition to improving fish passage, nature-like fishways can also provide year-round habitat for fish and macroinvertebrates adapted to higher gradient river conditions. Rock riffles may provide important spawning habitat for a number of native species (Wilcox et al. 2004). Riffles provide a boundary layer very near the streambed or other surface that has zero or very low flow and a viscous sublayer (Vogel 1994) that combine to form a three dimensional flow microenvironment that is critical to the recruitment of microbes and invertebrate larvae to surfaces of all kinds (Nowell and Jumars 1984). Edwards et al. (1984) reported higher total macroinvertebrate densities on artificial riffles; however these densities can vary annually (Walther and Whiles 2008).

K2.3.1 Design Criteria

An inlet structure at the confluence of the Rush River and the diversion channel will accommodate the head loss from the Rush River to the main diversion using a series of rock armored drops. This multi-drop ramp consists of a gradual drop of 1V:50H from the invert of the Rush River to the low-flow channel, and will contain a series of boulder steps to create a pool-riffle system to accommodate fish passage for a wide range of flow conditions. The boulder steps will consist of lines of 5 ft median diameter boulders placed in rows perpendicular to the direction of flow to create the appropriate water depths and resting areas for fish passage, while also providing the required energy dissipation and erosion protection necessary for the inlet structure. Additional rock structures will be placed upstream of the ramp to reduce velocities and maintain the existing 1% chance exceedance elevation in the Rush River channel upstream of the inlet structure.

With this type of design, the riffles serve as the steps of the fishway. For example, the pool and riffle details shown below (Figure K2-2, Figure K2-3, Figure K2-4) illustrate a rock ramp that drops roughly 10 feet in elevation over approximately 500-foot of the structure at the centerline. The riffles are designed with 4H:1V slopes (or flatter) from a geotechnical standpoint, and a riffle top length of 5 feet to ensure stability, with more than 2 feet of depth between the boulders at the riffles. The space between the boulders would be graduated from tightly spaced near the shores to wider gaps between boulders in the middle of the fishway. This creates lower flow areas near the bank and higher flow areas in the middle to accommodate the swimming ability of both small and large fish. The bed of the fishway would have an elliptical shape; being deepest in the middle section of each riffle. The layout of the riffles extends across the bottom of the fishway and may extend slightly up the side slopes. While curved riffles were evaluated for structure layouts during the study phase, other layouts could be as successful.

It should be noted that straightening the shape of the riffles may oversimplify the velocity profile created by the riffles making the fishway less suitable for passing both large and small fish. Fish orient their body in flowing water using the helical flow pattern found in channels to identify the upstream direction and using current breaks (eddies) for resting and feeding. The arched configuration with the associated complex flows through the riffle step is desirable in emulating a natural stream and has been effective in other fishways. In the example, the pool between the riffles was designed to be 20 feet in length at 5 feet deep to ensure that there is adequate resting room for fishes before and after each riffle passage. Ideally, the slope of any nature-like fishway would be gradual, with few very low vertical drops and bed materials to replicate the riverbed found below the dam (Wilcox et al. 2004).

The general design to date follows the same concept of many fish passageways previously designed and built by USACE, St. Paul District. In coordination with agency partners the desire for fish passage design criteria has been to not focus on individual species, life stages or burst speed requirements. Rather, the focus has been on providing a range and diversity of hydraulic conditions that would likely meet the broadest range of conditions needed for fish passage. This has included focusing on key design parameters such as general slope across structure length, drop at individual rock weirs, boulder size and spacing, pool depth between weirs, etc. Agency representatives believe this has resulted in many successful projects. While modeling can be performed to compare potential velocities to swim speed performance, resource agency preference will likely focus on providing this diverse range of hydraulic conditions. Monitoring following construction will help verify the effectiveness of this design approach. This can include how fish passage compares to both modeled and observed velocities across a range of flow conditions. The next design phase will consider whether detailed assessment of modeled velocity and swim speed performance of select species is warranted. More specific design detail will be provided in future report phases.

K2.3.2 Size

In general, the more a fishway recreates the natural habitat of a species the greater the likelihood that species will be able to use the fishway. Velocities will be similar to that of natural river conditions so that fish will be able to use the fishway as if it was part of the original stream. Larger fishways would be a benefit to the project. A larger fishway could pass more fish, could have greater attracting flows, and could be less likely to behaviorally deter fishway usage due to crowding. A smaller fishway could form a bottleneck for fish and could make the fish vulnerable to predation by birds.

Figure K2-2. Pool and riffle design.

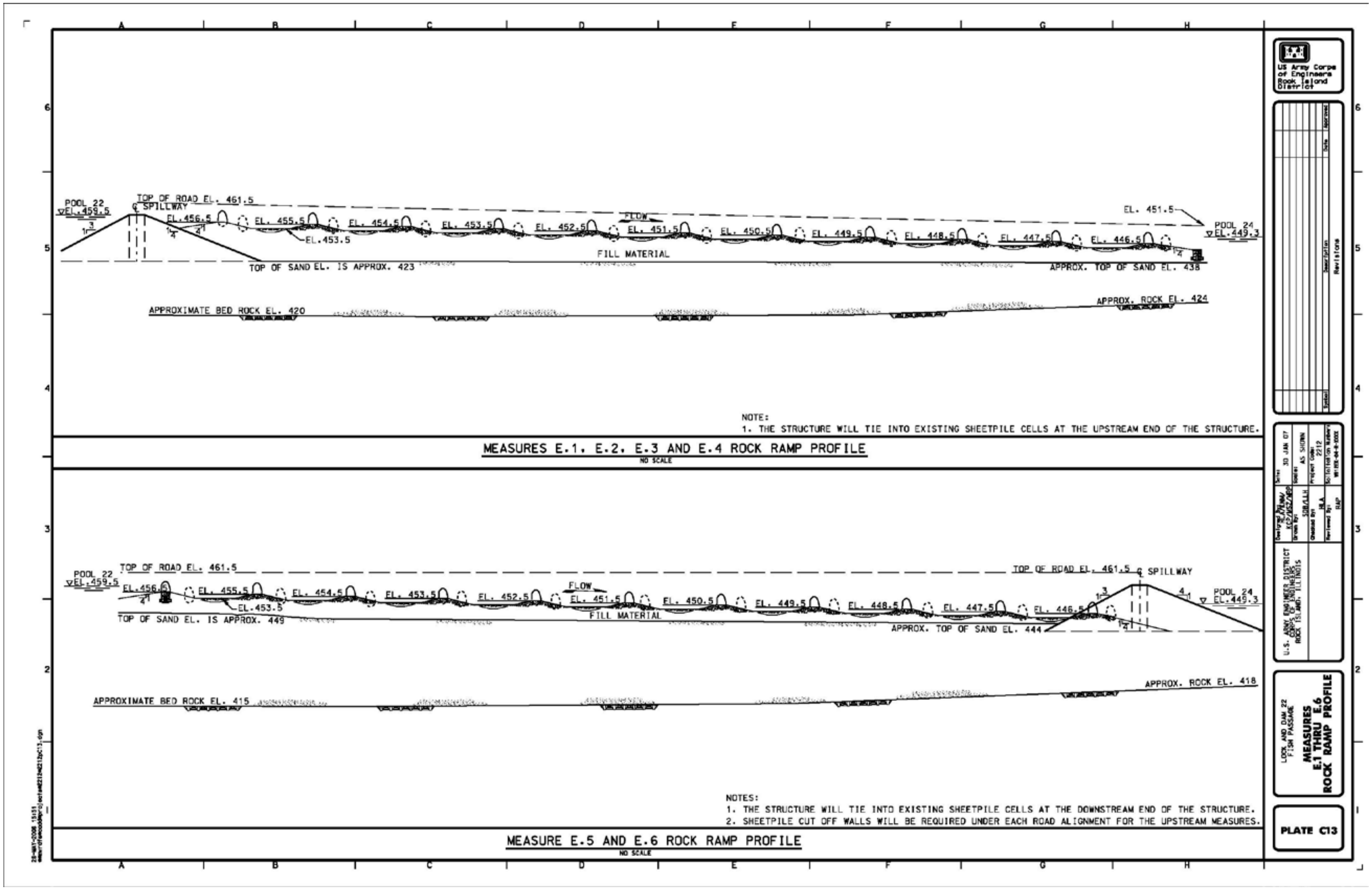


Figure K2-3. Pool Riffle Section.

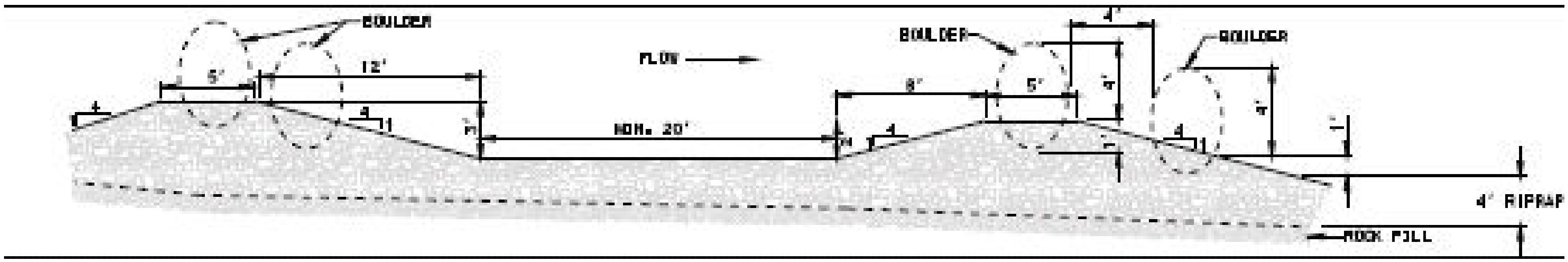
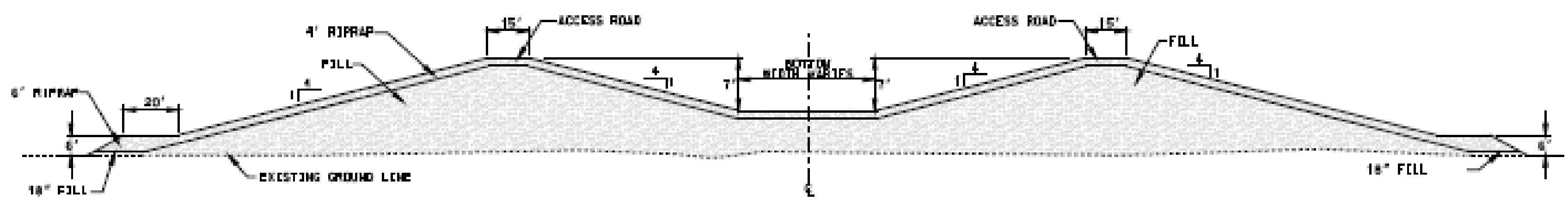


Figure K2-4. Rock Ramp Section.



K2.3.3 Operation and Maintenance

The site will be inspected annually to determine if the structure is meeting the project goals and objectives. If these inspections determine that debris within the structure is impacting fish passage, then work on debris removal within the structure. This does not include debris removal after a major event, which would fall under the area of rehabilitation.

- *The rock ramps evaluated for this project were of a pool and riffle design, with a rock bottom. Details for these designs are shown in the plates attached to this report.*

K2.3.4 Pre- and Post-Project Monitoring

Monitoring will be performed post-construction to assess fish migration through various project features, including Red and Wild Rice river control structures, aqueducts and other features. Monitoring activities specific to this fish passage feature will be considered within the context of overall fish passage monitoring for the entire system. The exact methodology for assessing this issue is under discussion, but could include activities such as electro-fishing, netting and/or radio telemetry. Netting could be done immediately above a feature and would provide insight into which species are able to migrate through these features. Netting is a fairly easy and inexpensive method to use to evaluate whether fish are able to pass through project structures. However, it is not as complete as radio telemetry work. Conversely, radio telemetry could be used to assess how many fish approach the identified structures, and what portions of those fish are able to migrate through these features. This information would be extremely beneficial for not only assessing fish movement through project structures, but also providing general knowledge on effectiveness of features like fish passage channels and nature-like fishways that have not been evaluated in great detail.

K2.4 REFERENCES

Aadland, L.P. 2010. Reconnecting Rivers: Natural Channel Design in Dam Removals and Fish Passage. Division of Ecological Resources Stream Habitat Program, Minnesota Department of Natural Resources, St. Paul, MN.

Aadland, L.P. and A. Kuitenun. 2006. Habitat suitability criteria for stream fishes and mussels of Minnesota. Special Publication 162.

Aadland, L.P., T.M. Koel, W.G. Franzin, K.W. Stewart, and P. Nelson. 2005. Changes in Fish Assemblage Structure of the Red River of the North. Symposium 45:293-321, American Fisheries Society, Bethesda, MD.

Acharya, M., J.A. Kells, and C. Katopodis. 2004. Some Hydraulic Design Aspects of Nature-like Fishways. Proceedings of the Joint Conference on Water Resources Engineering and Water Resources Planning & Management, American Society of Civil Engineers, Reston, VA.

Becker, G. C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison.

Domenici, P. and R. W. Blake. 1997. The kinematics and performance of fish fast-start swimming. The Journal of Experimental Biology 200:1165-1178.

DVWK (German Association for Water Resources and Agriculture). 1996. Upstream Fish Passage Facilities, Dimensioning, Configuration, and Operational Checks. Instructional Bulletins on Water Research, P. Parey, Hamburg/Berlin, Federal Republic of Germany 232/1996. 49 pp.

DVWK (German Association for Water Resources and Agriculture. 2002. Fish Passes: Design, Dimensions and Monitoring. Food and Agriculture Organization of the United Nations in arrangement with Deutscher Verband fur Wasserwirtschaft und Kulturbau e.V. Rome, Italy. 118 pp.

Edwards, C.J., B.L. Griswold, R.A. Tubb, E.C. Weber, L.C. Woods. 1984. Mitigating Effects of Artificial Riffles and Pools on the Fauna of a Channelized Warmwater Stream. North American Journal of Fisheries Management 4:194-203.

Fausch, K. D., Torgersen, C. E., Baxter, C. V., and Li, H. W. (2002). “Landscapes to Riverscapes: bridging the gap between research and conservation of stream fishes,” Bioscience 52, 483-498.

Gaboury, M.N., R.W. Newberry, and C.M. Erickson. 1995. Pool and Riffle Fishways for Small Dams. Manitoba Natural Resources Fisheries Branch. Winnipeg, Manitoba 30 pp.

Katopodis C., and L.P Aadland. 2006. Effective dam removal and river channel restoration approaches. IAHR International Journal of River Basin Management, Special Issue on Ecohydraulics, Vol. 4(2) pp. 1-16.

Litvan, M.E., C.L. Pierce, and T.W. Stewart. 2006. An Evaluation of Effects of Grade Control Structures on Fish Movement and Fish Communities in Turkey Creek, Cass County, IA and Macroinvertebrate Communities in Walnut Creek, Montgomery County, IA. Iowa State University, Department of Natural Resources Ecology and Management, Ames, IA.

Lyons, J. editor. 2012. Fishes of Wisconsin E-book. Wisconsin Department of Natural Resources, Madison, and U.S. Geological Survey, Middleton, WI. http://www.fow-ebook.us; accessed on (give date of access).

McKeown, B.A. 1984. Fish Migration. Timber Press, Portland, OR

Northcote, T. G. (1978). “Migratory strategies and production in freshwater fishes.” Ecology of freshwater fish production. S. D. Gerking, ed., Halsted Press, New York, 326-359.

Northcote, T.G. 1998. Migratory Behavior of Fish and Its Significance to Movement Through Riverine Fish Passage Facilities. In Fish Migration and Fish Bypasses. Jungwirth, M., S. Schmutz, and S. Weiss, eds. Fishing News Books, Blackwell Science Ltd. Oxford, U.K.

Nowell, A.R.M., and P.A. Jumars. 1984. Flow environments of aquatic benthos. Annual Review of Ecology and Systematics 15: 303-328

Parasiewicz, P., J. Eberstaller, S. Weiss, and S. Schmutz . 1998. Conceptual Guidelines for Nature-Like Bypass Channels. Pages 348-362 in Jungwirth, M., S. Schmutz, and S. Weiss, editors. Fish Migration and Fish Bypasses. Blackwell Science Inc., Malden, MA. 438 pp.

Pringle, C.M., M.C. Freeman, and B.J. Freeman. 2000. Regional Effects of Hydrologic Alterations on Riverine Macrobiota in the New World: Tropical-Temperate Comparisons. BioScience 50, 807-823. The American Institute of Biological Sciences, Washington, DC

Schlosser, I. J. (1991). “Stream fish ecology: A landscape perspective,” Bioscience 41, 704-712.

Vogel, S. 1994. Life in Moving Fluids, the Physical Biology of Flow, Second Edition. Princeton University Press, Princeton, NJ.

Walther, D.A., and M.R. Whiles. 2008. Macroinvertebrate Responses to Constructed Riffles in the Cache River, Illinois, USA. Environmental Management 41:516-527

Wilcox, D.B., E.L. Stefanik, D.E. Kelner, M.A. Cornish, D.J. Johnson, I.J. Hodgins, S.J. Zigler, and B.L. Johnson. 2004. Environmental Report 54, 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, IL

Wildman, L, P. Parasiewicz, C. Katopodis, U. Dumont. 2003. An Illustrative Handbook on Nature-Like Fishways - Summarized Version. American Rivers, Washington D.C.