Report to Congress
Section 1226 America's Water Infrastructure Act of 2018
Interception and Rearing Complex Report

US Army Corps of Engineers
February 2020

Executive Summary

This report fulfills the requirements set forth in Section 1226 of the America's Water Infrastructure Act of 2018 requiring the Secretary to submit a report to U.S. Congress regarding the impacts of Interception and Rearing Complex (IRC) habitat construction on navigation, flood control, and other authorized purposes set forth in the Missouri River Master Water Control Manual (Master Manual) and on the population recovery of endangered pallid sturgeon. In the Missouri River pallid sturgeon Effects Analysis (Jacobson et al., 2016), IRC habitat is anticipated to benefit early life stages of the pallid sturgeon and is included in a suite of management actions committed to by the U.S. Army Corps of Engineers (USACE) in the Missouri River Recovery Management Plan Environmental Impact Statement and Record of Decision to abate the effects of the operation of the Missouri River Mainstem Reservoir System (System) and operation and maintenance of the Missouri River Bank Stabilization and Navigation Project (BSNP) on species listed under the Endangered Species Act. IRC construction, based on the best available science, will provide suitable off-channel habitat for pallid sturgeon by providing hydraulic conditions and depths preferred by young-of-year individuals. Through monitoring the biological response of the species, effectiveness of the IRC can be determined and adaptively managed leading to a cost-effective and biologically sound approach to addressing ESA-required actions. Creation of IRC habitat is being completed to enhance the survival of age-0 (first year) pallid sturgeon leading to an overall increase in population size.

Because IRC projects are located in the lower Missouri River below Gavins Point Dam, IRCs will not change the water regulation guidelines outlined in the Master Manual. As such, construction of IRCs will not affect releases from Gavins Point Dam and all the System authorized purposes will be met. USACE also monitors IRC project sites to ensure BSNP authorized purposes are being met. This consists of routine monitoring of channel dimensions to ensure authorized navigation channel dimensions are met, yearly assessments to detect changes in navigation channel dimensions over time, and assessments to detect changes in flow patterns that may affect navigation. The post-construction monitoring, conducted at the two existing IRC sites, confirmed that the navigation channel remains essentially unchanged from pre-project conditions, and that flow patterns remain unchanged within the navigation channel. If changes are detected that threaten the navigation channel, steps will be taken to address the problem. Post-construction monitoring also includes the collection of data and numeric modeling to evaluate whether any change in water surface elevations have occurred as a result of IRC projects. At this time, no impacts to water surface elevations have been observed and, if changes are detected, steps will be taken to rectify the situation.

A substantial amount of new knowledge about pallid sturgeon has been developed since the 2003 Biological Opinion on the Operation of the Missouri River Main Stem Reservoir System, Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project, and Operation of the Kansas River Reservoir System. The new knowledge prompted the USACE and U.S. Fish and Wildlife Service (USFWS) to enter formal consultation under Section 7 of the Endangered Species Act (ESA). During consultation, both USACE and USFWS recognized the uncertainty regarding the type and extent of management actions needed to meet the needs of pallid sturgeon and that this uncertainity necessitated an adaptive management (AM) approach to guide evaluation and implementation of management actions based on the best available science. The Missouri River Recovery Program Independent Science Advisory Panel (ISAP) and the Missouri River Recovery Implementation Committee also recommended adaptive management. The AM approach benefits both the pallid sturgeon and stakeholders by reducing the risk of implementing costly and ineffective actions on a large scale or for extended periods

of time. In previous biological opinions for the Corps Missouri River projects, USACE received rigid, spatially and temporally broad habitat construction requirements that did not address uncertainty in pallid sturgeon life requisites. AM, however, allows for the more careful selection of actions over time through evaluating success at smaller scales to address uncertainty in a more efficient manner.

The biological benefits of IRC habitat are based upon the best available scientific information. A phased approach (beginning with twelve projects) is being used for IRC habitat projects allowing for monitoring and evaluation following an AM framework to assess biological effectiveness before making a decision on implementation of additional projects. In response to stakeholder concern regarding construction of twelve IRC projects and associated potential impacts to socioeconomic considerations, USACE participated in a series of eight IRC Stakeholder Coordination and Outreach engagement activities from February to July 2018. Attendance at these sessions included commercial dredging and navigation stakeholders, business owners, municipalities, the Osage Nation, and other state and federal agencies. The session agendas varied by the specific purpose of each session. These sessions were intended to identify stakeholder concerns and understand how USACE could address those concerns. For example, USACE worked closely with the commercial sand and gravel dredging industry to develop a list of potential IRC sites that would not overlap with active or planned dredging areas. Based on information provided through this engagement, USACE worked with this stakeholder group to identify six project locations that would have little to no impact to the dredgers. Moving forward, the USACE will continue to take a proactive approach to engage stakeholders when identifying potential project locations.

USACE is assessing the benefits of IRC projects to pallid sturgeon by determining if IRC habitat can increase catch of young shovelnose sturgeon, which are used as a surrogate for the closely related but rare age-0 pallid sturgeon. The ISAP review of the study design concluded “the monitoring of IRC as outlined in [the monitoring plan] likely will begin to provide the understanding necessary to relate habitat parameters to species performance and consequently to develop forecast models.” To determine if catch of young sturgeon can be increased at IRC locations, USACE conducted a statistical power analysis to estimate the number of sites and corresponding monitoring durations to achieve statistically meaningful results. One scenario from the power analysis showed it is necessary to construct and monitor twelve IRC sites over a period of seven years, which was subsequently recommended by the USFWS (USFWS letter dated 14 SEP 16). Only two of the twelve IRC study sites have been constructed and sampling has only occurred for 1 – 3 years. Therefore USACE cannot yet determine if IRC sites have increased catch of young sturgeon. Monitoring of the depths and velocities at constructed IRC sites indicate that physical changes have occurred and the sites are developing as intended in the project design.

USACE is also engaged in other studies to assess the benefits of IRC projects to pallid sturgeon and evaluate other, alternative hypotheses that may result in successful recruitment of pallid sturgeon. Adaptive management of the IRC project will continue as new information is learned from the studies and applied to future habitat actions.

Table of Contents

1.0 Introduction 1

1.1 IRC Habitat 2
1.2 Background and Authority 5
1.3 The Use of Best Available Science 7
1.4 Environmental Impact Statement, Federal Plan, and ESA Consultation 10
1.5 MRRIC/Public Engagement 11
1.6 Independent Review 12

2.0 Missouri River Authorized Purposes, Human Considerations, and IRCs 13

2.1 System Authorized Purposes, BSNP Authorized Purposes and IRCs 13
2.1.1 Navigation 14
2.1.2 Flood Risk Management 18
2.1.3 Water Supply and Water Quality 20
2.1.4 Fish and Wildlife 20
2.2 Additional Human Considerations 21
2.2.1 Bank Erosion 21
2.2.2 Commercial Sand and Gravel Mining 21

3.0 IRC Benefits to Pallid Sturgeon 24

3.1 Pallid Sturgeon Population Model 24
3.2 Pallid Sturgeon Adaptive Management Framework 25
3.3 IRC Study Design and the Need for Twelve Sites 26
3.3.1 IRC Monitoring Plan and ISAP Review 28
3.4 Pre- and Post-Construction Modeling and Monitoring of Existing IRC Projects 29
3.4.1 Biological Results 30
3.4.2 Physical Results 30
3.5 Ongoing and Planned IRC Research and Other, Alternative Hypotheses 34

4.0 Conclusion 35

5.0 References and Literature Cited 36

6.0 Appendices 39

Appendices

Appendix A. ISAP comments on the DRAFT IRC WRDA report (to be included in FINAL report)

Appendix B. Technical Memorandum to Support the IRC Report to Congress

Appendix C. Extended Abstract: Tracking the River Bed Response to Channel Mining on the Lower Missouri River

List of Figures

Figure 1. Map of the Missouri River basin and the location of IRC habitat construction (RM 0-321)....2

Figure 2. The reach of river young pallid sturgeon would begin to settle, feed, and grow in the lower Missouri River if spawning occurred at RM 800. 3

Figure 3. An example of a Missouri River IRC project. Note the removal and addition of stone to the dikes along the inside bend of the river. 4

Figure 4. A typical cross section view of the Missouri River showing the navigation channel, river training structures, and the addition or removal of stone to improve IRC habitat. 5

Figure 5. A timeline illustrating the science-based process from the initial development of Interception-Rearing Complexes (IRCs) concepts to the Record of Decision. Boxes shaded in green indicate significant interaction with stakeholder groups both within and outside of MRRIC. (Figure 5 courtesy of the Indepedant Science Advisory Panel)....9

Figure 6. A typical bend within the Missouri River with multiple dikes and revetments configured to maintain the navigation channel. 15

Figure 7. Velocity direction at Searcys Bend pre- and post-construction. Note the changes in velocities in the middle of the bend (Panel 2) due to scour of the pre-existing sandbar. The changed velocities quickly dissipate and will not impact the navigation channel which is on the outside bend. 17

Figure 8. Plot of near bank full modeled and actual water surface elevations at Searcy's Bend pre and post construction. Differences in pre and post construction within errors of models and scatter in data. 19

Figure 9. A simplified conceptual model of how IRC habitat construction will result in pallid sturgeon population growth. Included in the figure are questions to be answered from the IRC 12 site study and additional IRC related research and potential decisions resulting from information learned regarding IRC habitat. Image courtesy of Robert Jacobson, US Geological Society, Columbia, MO. 25

Figure 10. The number of IRC sites and monitoring duration (years) necessary to achieve 80% statistical power to detect an 80% increase in CPUE at IRC treatment sites. 28

Figure 12: Bed elevations at Moberly Bend for the pre-construction condition, the 2018 condition, and the PFS condition. 31

Figure 13. Depths and Velocity outputs from a numeric hydraulic model for Searcy Bend for a range of flow conditions. 32

List of Tables

Table 1. Potential IRC study site locations discussed with sand and gravel dredging stakeholders. It should be noted that construction of the two locations in 2019 (St. Albans and Pelican bends) is contingent upon completion of this report and may be delayed until 2020. 22

Table 2. Pallid sturgeon adaptive management framework 26

Table 3. Biological and physical data collection, by year, at IRC treatment and control sites. 29

Table 4. The modeled percent interception at the larval drift period median discharge at Moberly Bend and Searcy Bend IRC treatment sites before construction, at the predicted final state, and the 2018 condition. 33

Table 5. The estimated amount (acre-days/year) of food producing and foraging habitat at Moberly and Searcy Bend IRC treatment sites. Estimates are provided for pre-construction, predicted final state, and 2018 conditions using a standardized flow hydrograph, and also provided for 2018 using the actual 2018 hydrograph. 33

Acronyms

2-d	Two-dimensional
3-d	Three-dimensional
ADCP	Acoustic Doppler Current Profiler
AM	Adaptive Management
AWIA	America's Water Infrastructure Act of 2018
BACI	Before After Control Impact
BiOp	Biological Opinion
BSNP	Missouri River Bank Stabilization and Navigation Project
CEM	Conceptual Ecological Model
CPUE	Catch Per Unit Effort
EA	Effects Analysis
ESA	Endangered Species Act
IRC	Interception and Rearing Complex
ISAP	Independent Science Advisory Panel
Master Manual	Missouri River Master Water Control Manual
MRRIC	Missouri River Recovery Implementation Committee
MRRMP-EIS	Missouri River Recovery Management Plan and Environmental Impact Statement
MRRP	Missouri River Recovery Program
PFS	Predicted Final State
PTM	Particle Tracking Module
RM	River Mile
SAMP	Science and Adaptive Management Plan
System	Missouri River Mainstem Reservoir System
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
WRDA	Water Resources Development Act

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1.0 Introduction

Section 1226 of the America's Water Infrastructure Act of 2018 (AWIA) requires the Secretary to submit a report to the US Congress regarding the impacts of Interception and Rearing Complex (IRC) habitat construction on navigation, flood control, and other authorized purposes and on the population recovery of endangered pallid sturgeon. Specifically the Act states:

> *SEC. 1226. MISSOURI RIVER.*
> *(a) IRC REPORT — Not later than 18 months after the date of enactment of this Act, the Secretary shall submit to the Committee on Transportation and Infrastructure of the House of Representatives and the Committee on Environment and Public Works of the Senate a report regarding the impacts of interception-rearing complex construction on the navigation, flood control, and other authorized purposes set forth in the Missouri River Master Manual, and on the population recovery of the pallid sturgeon.*
> *(b) NO ADDITIONAL IRC CONSTRUCTION — Until the report under subsection (a) is submitted, no additional interception-rearing complex construction is authorized.*

IRC habitat projects are a management action included in the Federal Plan resulting from the Missouri River Recovery Management Plan and Environmental Impact Statement (MRRMP-EIS; USACE 2018) and Record of Decision (ROD). These projects are included as a requirement in the Biological Opinion on the Operation of the Missouri River Main Stem Reservoir System, the Operation and Maintenance of the Bank Stabilization and Navigation Project, the Operation of Kansas River Reservoir System, and the Implementation of the Missouri River Recovery Management Plan (USFWS 2018) for the U.S. Army Corps of Engineers (USACE) to comply with the Endangered Species Act (ESA). The best available science indicates that IRC habitat is necessary for young federally endangered pallid sturgeon to survive and grow. This is accomplished by providing hydraulic conditions that entrain young pallid sturgeon away from the swift navigation channel into channel margins where adequate food production and foraging opportunities exist (Jacobson et al. 2016a).

While the Federal Plan included a suite of management actions to be undertaken on the Missouri River from Ft. Peck Dam (RM 1771) to the confluence with the Mississippi River (RM 0), to benefit the pallid sturgeon, piping plover, and interior least tern, this report focuses on IRC construction to benefit pallid sturgeon, which is limited in geographic scope from RM 0-321 (Figure 1) and sites only being constructed adjacent to publicly owned lands.

Specifically within this report, USACE will: 1) describe the steps undertaken to avoid and minimize impacts to the authorized purposes of the Missouri River Main Stem Reservoir System (System) and the Bank Stabilization and Navigation Project (BSNP), and other socioeconomic considerations; 2) describe the monitoring undertaken to assess impacts of IRC projects to the authorized purposes of the System and BSNP, and other socioeconomic considerations and; 3) describe the methods and strategy to assess the impacts of IRC construction on pallid sturgeon recovery.

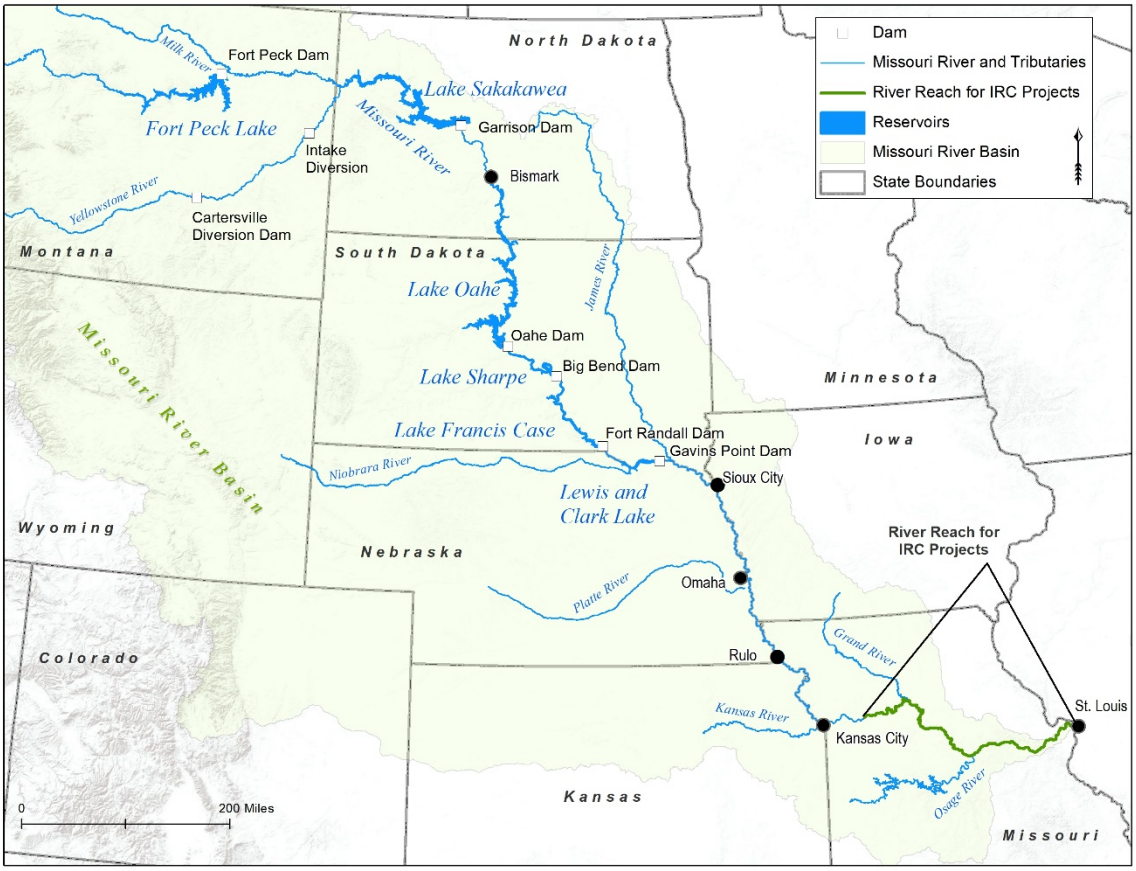


Figure 1. Map of the Missouri River basin and the location of IRC habitat construction (RM 0-321).

1.1 IRC Habitat

Reproductive pallid sturgeon often migrate great distances upstream to spawn. At the apex of the spawning migration, eggs are fertilized and deposited on course rock or gravel where they reside for several days. After hatching, young pallid sturgeon are not mobile and drift with river currents for approximately 8-11 days until they settle to the bottom of the river and begin to feed. In the lower Missouri River, the upstream spawning migration is limited by Gavins Point Dam (the lowermost dam in the System). As part of an effects analysis, a type of analysis that uses the best available science to study the effects of federal agencies' actions on species protected under the ESA, scientists have hypothesized that young pallid sturgeon are not surviving to later life stages for three possible reasons. These include (1) the inability of larval pallid sturgeon to exit the fast moving channel, (2) insufficient amounts of food production, and (3) insufficient feeding habitat for young pallid sturgeon. Therefore, IRC projects are designed to assess the biological response of very young pallid sturgeon (8-11 days post-hatch) that are entrained from the highly engineered and fast moving Missouri River channel into more hospitable channel margin areas for rearing. Once intercepted to the channel margins, IRC habitats are intended to provide adequate food and foraging opportunities for young sturgeon. Increased amounts of IRC habitat, therefore, should lead to increased survivorship of young sturgeon.

During the effects analysis, advection and dispersion models were used to predict the reach of river where young sturgeon would be expected to settle. Construction of IRC habitat in this reach, therefore, should provide the most benefit for pallid sturgeon and is where the IRC projects are currently proposed for construction (Figure 2). Collections of wild-produced young pallid sturgeon in 2014 and 2018 provide empirical evidence to support the modeled predictions of where young sturgeon would be expected to settle.

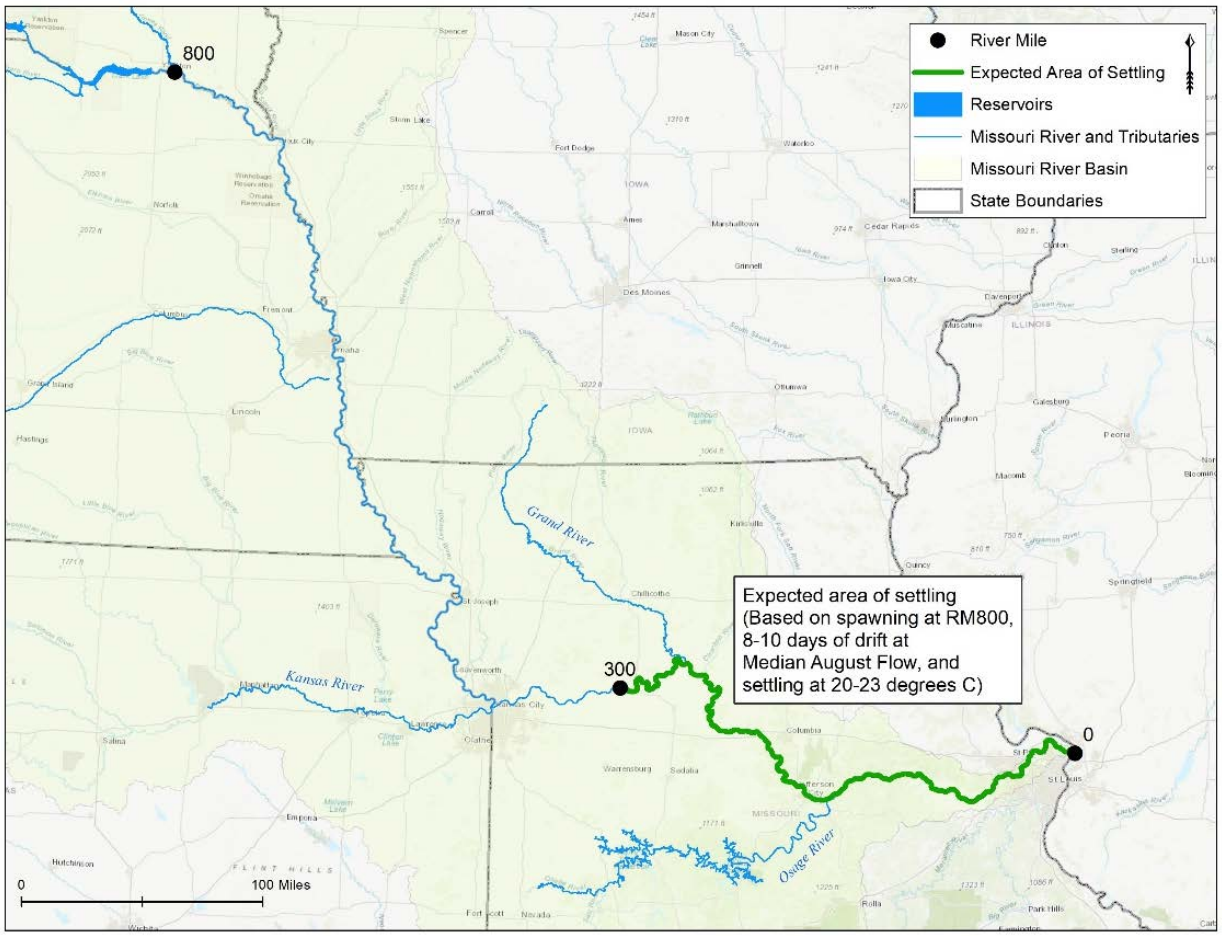


Figure 2. The reach of river young pallid sturgeon would begin to settle, feed, and grow in the lower Missouri River if spawning occurred at RM 800.

Section 1226 of the AWIA requires USACE to report on the impacts of IRC construction on "the population recovery of the pallid sturgeon," or how the construction of IRC habitat affects pallid sturgeon survival and population growth. This presents a unique set of challenges that requires an understanding of age-specific survival rates of pallid sturgeon and an understanding of the relationship between IRCs and survival of young sturgeon. Construction and monitoring of the 12 IRC sites, as well as other ongoing research, will provide this information. Section 3 of this report describes the necessary steps to be undertaken to accurately answer the question.

Careful planning and study design are important in ensuring these questions can be answered in the future. Employing the same engineering concepts and methods used to construct the BSNP, but on a much smaller scale, IRC projects are designed and constructed to harness the natural erosion and deposition processes in the Missouri River to do the work of reforming the

streambed within the IRC project site. That is, projects are not initially built to the desired end state, rather construction initiates the process through structure modifications that then direct river flows in a manner which develops the desired habitat conditions over a period of approximately 1 to 3 years. Two IRC projects have been constructed to date located at Searcys Bend (River Mile [RM] 178-181) and Moberly Bend (RM 297-302) and were both completed in 2017. These sites are not fully developed at this time due to the short time frame since construction. Monitoring twelve IRC sites for a minimum of seven years is necessary to determine if interception of young sturgeon can be increased via river structure modifications (see Section 3.3).

The same engineering expertise (and personnel) used to ensure the navigability of the Lower Missouri River is employed in the design of the structure modifications to generate IRC habitat. Existing and planned IRC projects are located on inside bends and generally extend from the upstream crossing for two to three miles downstream. The design of IRC projects consists of adjusting the river training structures. Depending on the site, these adjustments might include extending existing inside bend dikes riverward into the main channel, removing portions of the same inside end dikes closer to the bank, or constructing new dikes (Figure 3). With this design, a small percentage of the flow is blocked by the dike extensions, some of which is redirected into the main channel, while the remainder is redirected into the area of river where portions of the dikes have been removed (channel margin area; Figure 4). It is anticipated that young sturgeon drifting within this blocked flow will settle out within the channel margin area.

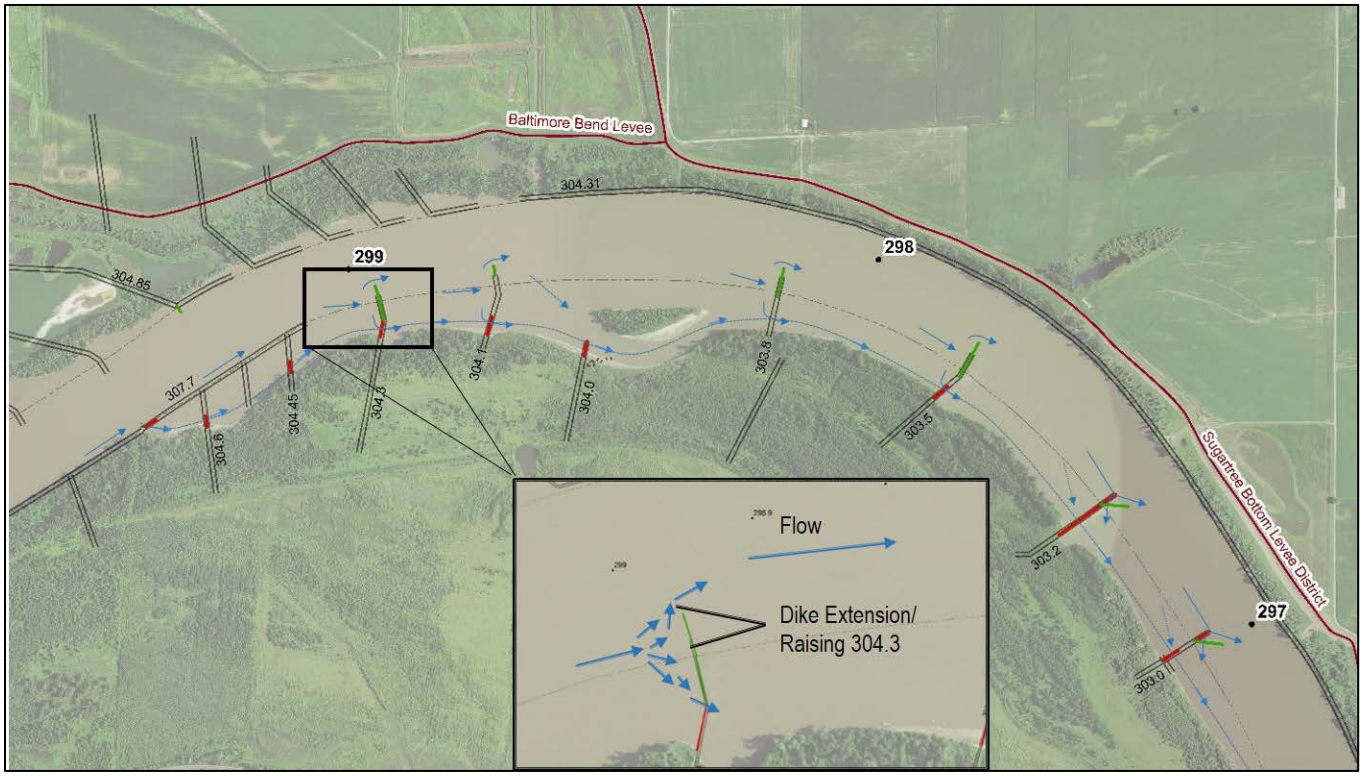


Figure 3. An example of a Missouri River IRC project. Note the removal (red) and addition (green) of stone to the dikes along the inside bend of the river. Blue lines depict desired flow path (post construction) to increase larval interception into channel margin areas and maintain the navigation channel. The inset illustrates the conceptual redirection of flow to both the navigation channel and the channel margins.

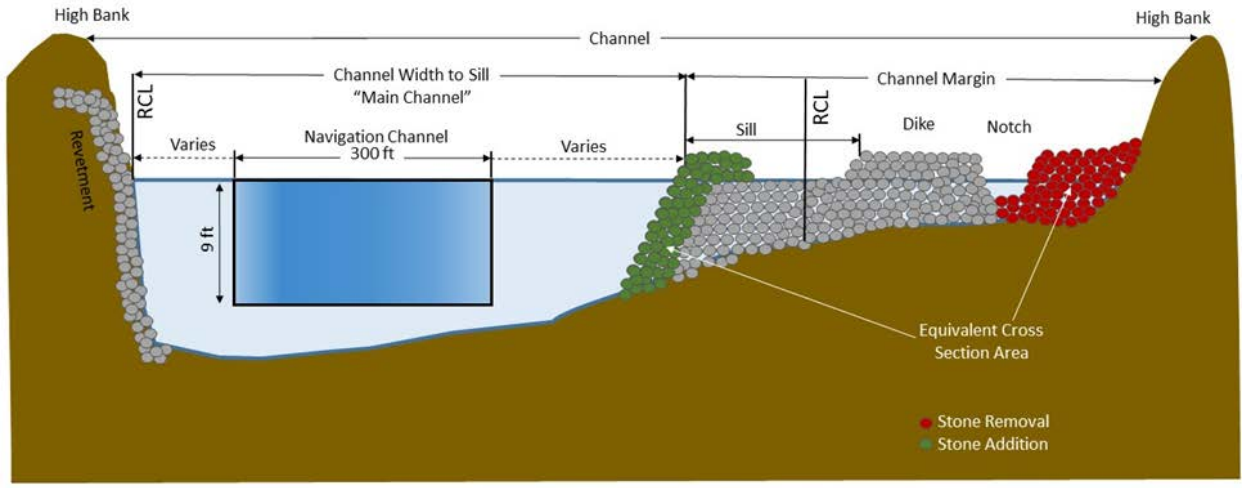


Figure 4. A typical cross section view of the Missouri River showing the navigation channel, river training structures, and the addition or removal of stone to improve IRC habitat.

1.2 Background and Authority

USACE has responsibility for the operation and maintenance of the Main Stem Missouri River Reservoir System which includes six dams and reservoirs on the main stem of the Missouri River located in Montana, North Dakota, South Dakota, and Nebraska (System hereinafter). USACE operates the System for the congressionally authorized project purposes of flood control, navigation, irrigation, hydropower, water supply, water quality, recreation, and fish and wildlife. Authorization for the construction and operation of the projects can be found in the following legislation: the Rivers and Harbors Act of 1935, the Fort Peck Power Act of 1938, and the Flood Control Act of 1944. The operation of the System is guided by the Missouri River Master Water Control Manual (Master Manual; USACE 2018).

USACE also constructed and maintains the Bank Stabilization and Navigation Project (BSNP) from Sioux City, Iowa, to the mouth of the Missouri River near St. Louis, Missouri. The River and Harbor Acts of 1912, 1927, 1935 and 1945 all authorized work on the BSNP, culminating in an authorized channel 9 feet deep by 300 feet wide, from the mouth of the river to Sioux City, Iowa, for a total of 732 river miles. The project consists of outside bend revetments and transverse dikes along inside bends to force the river into a self-maintaining single channel. Construction of the BSNP was considered complete in 1981.

Fish and wildlife mitigation for the BSNP was first authorized in the Water Resources Development Act (WRDA) of 1986. Section 601(a) of WRDA 1986 provided the authority to purchase lands and construct fish and wildlife habitat on 48,100 acres on the lower Missouri River in accordance with the 1984 Chief of Engineers' Report. Section 334 of WRDA 1999 modified the BSNP Fish and Wildlife Mitigation Project by adding an additional 118,650 acres. The BSNP Fish and Wildlife Mitigation Project authority was then amended in Section 3176 of WRDA 2007, allowing the use of lower basin recovery or mititgation funds to be used for recovery or mitigation activities in the upper basin states of Montana, Nebraska, North Dakota, and South Dakota.

While the System and BSNP have had many socioeconomic benefits for people in and near the Missouri River Basin, the projects have also led to the alteration of the ecosystem and loss of aquatic and terrestrial habitats. The System and BSNP have also contributed to the ESA listing of the piping plover and interior least tern in 1986 and the pallid sturgeon in 1990. Under the ESA, USACE has a responsibility to ensure that operation of the System and operation and maintenance of the BSNP is not likely to jeopardize the continued existence of threatened and endangered species. Beginning in 1989, in compliance with Section 7 of the ESA, USFWS and USACE conducted informal and formal consultations as part of the Master Manual update. This culminated in a Biological Opinion in 1990 with a "jeopardy" determination. For most of the next 10 years, the Corps' operation of the System was the subject of multiple lawsuits concerning water use interests and operations for endangered species. The next Biological Opinion, issued in 2000, also determined the operation and maintenance of the System and BSNP jeopardized the three endangered species. In 2003, USACE reinitiated consultation with the USFWS which resulted in an amendment to the 2000 BiOp, although the ultimate "jeopardy" determination, at least with respect to the pallid sturgeon, remained unchanged (USFWS 2003).

The Missouri River Recovery Program (MRRP) was established by USACE in 2005 and enables USACE to operate the System in accordance with the Master Manual and to operate and maintain the BSNP to meet their authorized purposes while also complying with the ESA and other federal laws and regulations. The MRRP is an umbrella program that coordinates the following:

- Compliance with the USFWS 2018 Biological Opinion on the operation of the System, operation and maintenance of the BSNP, operation of the Kansas River Reservoir System, and implementation of the Missouri River Recovery Management Plan (2018 BiOp);
- Acquisition and development of lands to mitigate for lost habitats as authorized by Section 601(a) of WRDA 1986 and modified by Section 334(a) of WRDA 1999 (BSNP Fish and Wildlife Mitigation Project); and
- Implementation of WRDA 2007, including section 501, which established the Missouri River Recovery Implementation Committee (MRRIC) and Section 3176, which allows USACE to use recovery and mitigation funds in the upper basin states of Montana, Nebraska, North Dakota, and South Dakota.

MRRIC is a congressionally authorized committee composed of over 70 members representing various interests, Tribes, states, and agencies from within the Missouri River basin. MRRIC makes recommendations and provides guidance to federal agencies on the MRRP.

A substantial amount of new knowledge about the species, their habitats, and potential actions to benefit ESA listed species has been developed since the 2003 Amended BiOp. In 2011, the MRRP Independent Science Advisory Panel (ISAP), an independent panel of scientists established by MRRIC, recommended completing an effects analysis (Murphy and Weiland 2011, mentioned Section in 1.1 and further discussed in Section 1.3), which would describe new knowledge accrued since the 2003 Amended BiOp (Doyle et al. 2011) and serve as a foundation for developing science-based actions to benefit pallid sturgeon. The ISAP further recommended development of a science and adaptive management plan (SAMP) to guide actions undertaken to benefit pallid sturgeon, monitoring, research, and assessment. The MRRIC subsequently endorsed these recommendations to the USACE in 2012.

1.3 The Use of Best Available Science

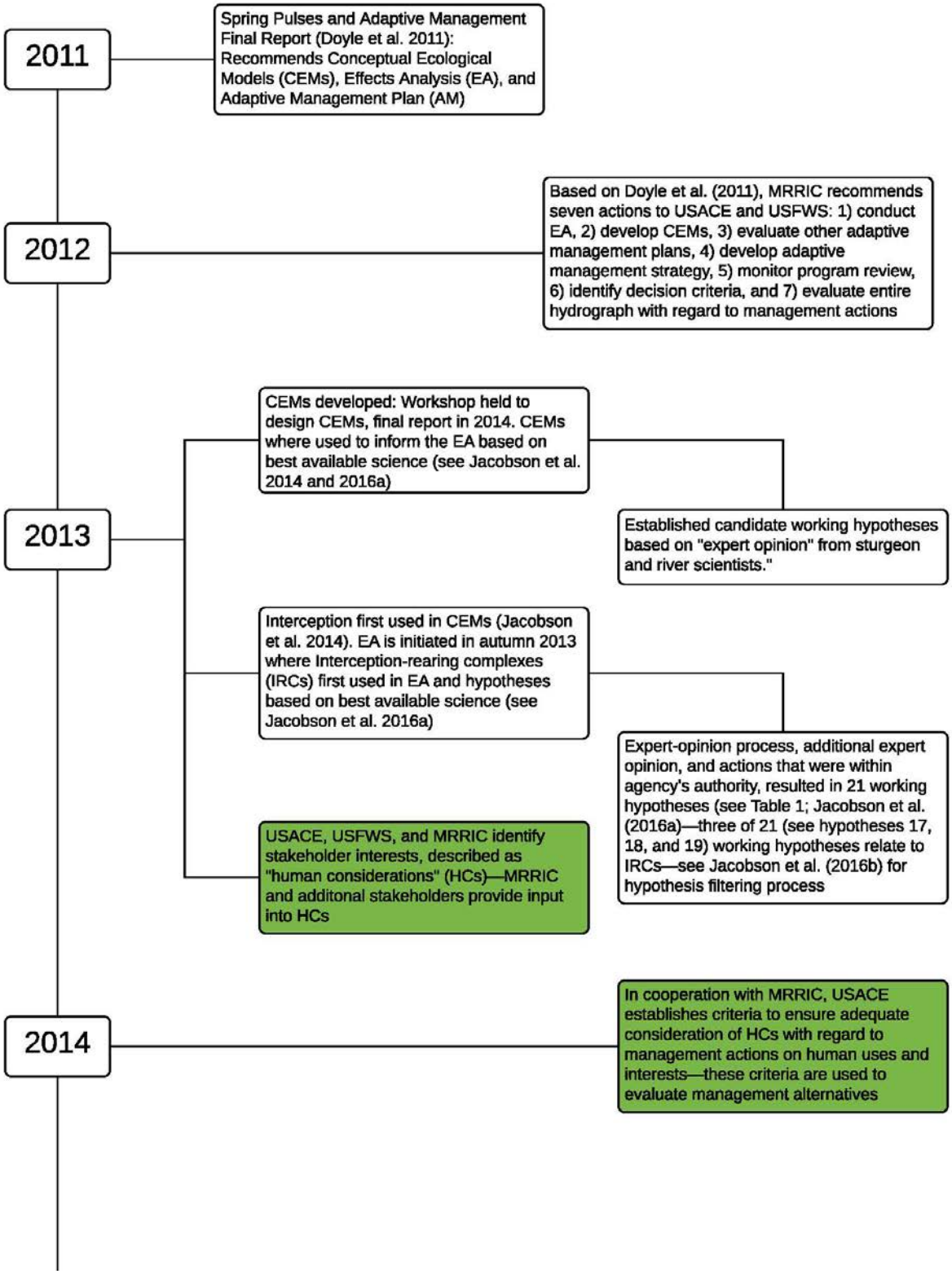
The ESA requires the "best scientific and commercial data available" to be used when evaluating the effects of a federal action to an ESA listed species. Members of Congress further urged USACE (and USFWS) to develop alternatives (management actions) that "guided by the best available science, should seek to minimize risks to stakeholders, and should be constrained by the guidelines set out in the current Master Manual" (letter dated Dec. 17, 2015 to the Honorable Jo-Ellen Darcy, Assistant Secretary of the Army (Civil Works). To ensure the best available science was used and impacts to stakeholders was minimized, USACE engaged in a multiyear (2011-2018) transparent and collaborative effort with stakeholders in the region and the MRRIC to identify and use the best available science to develop reasonable management actions to benefit the pallid sturgeon. This process was guided by an effects analysis (as described by Murphy and Weiland 2011) and involved multiple reviews by the ISAP which included individuals with expertise in pallid sturgeon, large-river hydrology, population modeling, and socio-economics. In addition, USACE completed this effort in a transparent process while seeking input from stakeholder groups (see Sections 1.5 and 2.2.2).

Effects analyses are rooted in the requirement within the ESA to evaluate the effects of actions proposed by federal agencies on listed species or designated critical habitat, using the best available science. Completion of an effects analysis is preceded by developing conceptual ecological models (CEM) with written descriptions and visual representations of the physical and biological relationships between actions and species responses (Murphy and Weiland 2011). Murphy and Weiland (2011) advocated for a rigorous approach to the effects analysis that consists of three primary steps. The first step is to collect reliable scientific information, including observations about the stressor and the range of stressor conditions and information on population sizes and trends. The second step includes assessment of the data, including using quantitative models to integrate existing information and identifying and representing uncertainties. The third step is to analyze the effect of the actions on the species to determine costs and benefits and identify alternatives. Since the 2011 ISAP recommendation, effects analysis have been completed for pallid sturgeon (Jacobson et al. 2016a) interior least tern and piping plover (Buenau et al. 2016), and associated habitats (Fischenich et al. 2014).

In the Missouri River effects analyses, comprehensive CEMs were developed to link species' population dynamics to potential management actions and other stressors, based on current scientific understanding (Jacobson et al. 2014). These CEMs provide a broad framework of the factors affecting species population dynamics and are the foundation for developing hypotheses, with input from scientific experts, and predictive models. Concurrently, available scientific literature, databases, and models on the three species were compiled, reviewed, and synthesized, and will be updated over time. Based on the CEMs, existing scientific literature, and expert scientific opinion, hypotheses were developed about the effects of potential management actions for each species and their habitats (Jacobson et al. 2016b). This included channel reconfiguration to create IRC habitat (Jacobson et al. 2016) to increase survival of young pallid sturgeon which could ultimately lead to pallid sturgeon population growth (see Section 3.1).

The effects analysis effort culminated in a biological opinion and record of decision (see Section 1.4) that identified management actions, including IRC habitat, that utilize the best available science and minimize risks to stakeholders. Furthermore, the IRC habitat management action will not result in changes to the Master Manual. All of which is consistent with the letter from Members of Congress and United States Senators dated Dec. 17, 2015.

For a complete timeline and detailed description of the critical engagements that led to the development of the IRC hypothesis see Figure 5.



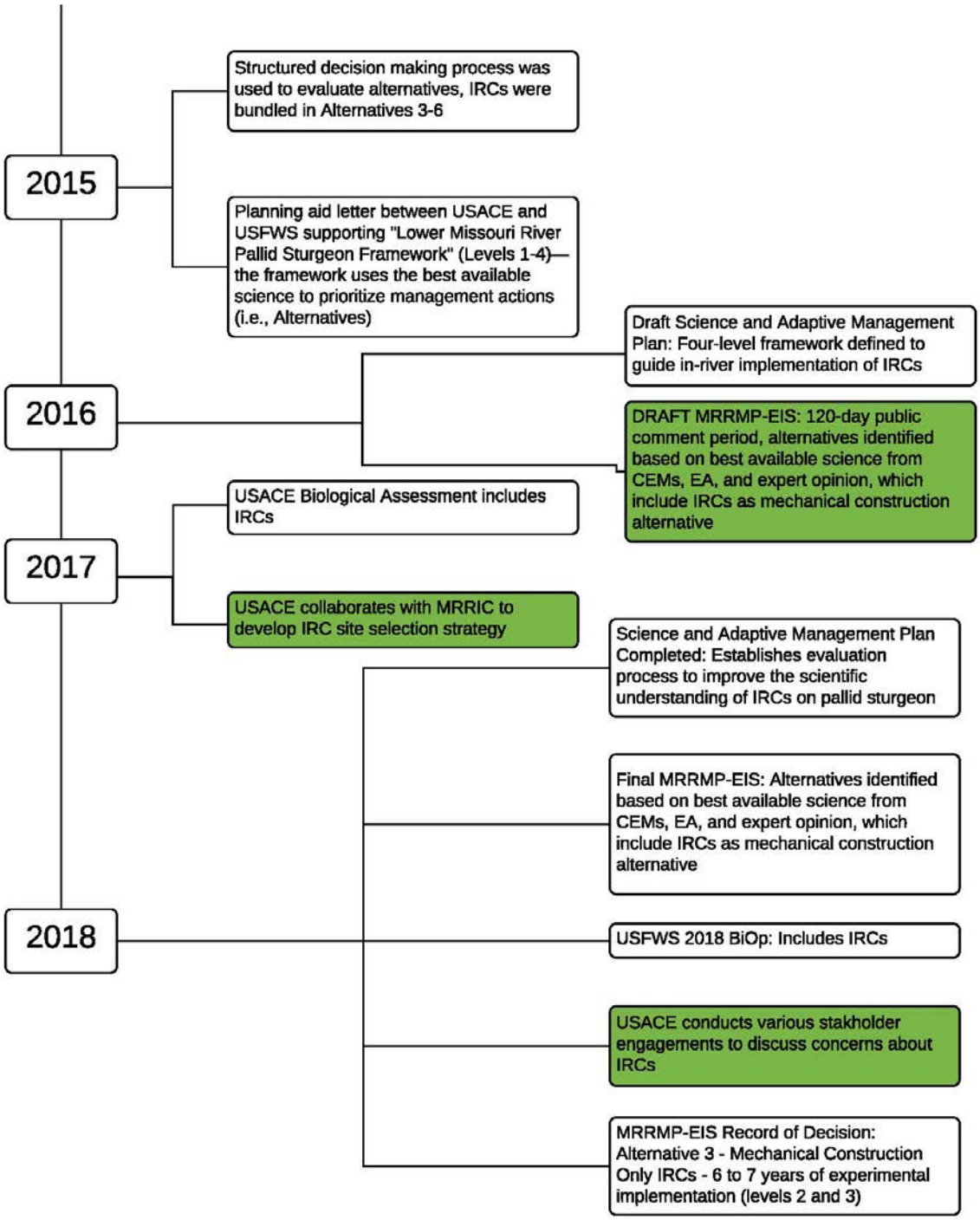


Figure 5. A timeline illustrating the science-based process from the initial development of Interception-Rearing Complexes (IRCs) concepts to the Record of Decision. Boxes shaded in green indicate significant interaction with stakeholder groups both within and outside of MRRIC. (Figure 5 courtesy of the Independent Science Advisory Panel)

1.4 Environmental Impact Statement, Federal Plan, and ESA Consultation

Upon completion of the Effects Analyses, USACE completed an EIS and received a Biological Opinion (BiOp) to implement the management actions outlined in the effects analyses that USACE could take to avoid jeopardizing the protected species. The uncertainty regarding the effectiveness of the actions, especially those targeting pallid sturgeon (Jacobson et al. 2016a), necessitates management actions be undertaken within an adaptive management (AM) framework that allows flexibility and modifications to the actions as new information becomes available. Therefore, USACE also began drafting a Science and Adaptive Management Plan (SAMP; Fischenich et al. 2018). The Federal Plan from the MRRMP-EIS Record of Decision and associated Biological Opinion included implementation of the SAMP, which includes such actions as focused research (Levels 1 and 2 studies; see Table 2, section 3.2), construction of pallid sturgeon spawning and IRC habitats, a one-time test flow (should new information be learned suggesting the need for a test flow), and continued stocking of pallid sturgeon.

The SAMP not only guides species-specific management actions but also describes the process for collaboration with states, Tribes, and other stakeholders via the MRRIC (this engagement is supplemental to and does not replace existing statutory requirements). The SAMP attempts to find the appropriate balance between three risks: (1) premature implementation of ineffective actions, which wastes resources; (2) excessive delay in implementing actions which would have helped the population; and (3) implementation of multiple concurrent actions without an ability to determine which actions are most effective, which makes future management adjustments more difficult. While there is a tradeoff between taking action and learning (decreasing uncertainty), implementing actions without strong evidence of their effectiveness may be costly and fail to yield the desired population level response (Murphy and Weiland 2014). There are constraints, however, on what can be learned from retrospective studies of past data, analyses of the current system, laboratory experiments and mesocosm experiments. Additionally, deferring full implementation of actions that may have potential benefits could delay the recovery of pallid sturgeon. Resources expended on ineffective actions (i.e., no benefit to the listed species) cannot be reclaimed and the trust, confidence, and support of stakeholders and partners in the basin will wane if resources are expended ineffectively. For example, the benefits and relevance of past pallid sturgeon management actions have been questioned (Doyle et al. 2011, NRC 2011) and have, in part, been responsible for the current process to reevaluate the best available science and forge a new management approach. The cornerstone of the new approach, and an emphasis of these previous independent reviews, is the development of a more structured, thoughtful approach to management, monitoring and assessment where management actions are truly approached as hypotheses to be tested.

Implementation of the Federal Plan including construction of IRC habitat and the SAMP, significantly contributed to the USFWS determination in its 2018 BiOp that USACE's continued operation of the System and operation and maintenance of the BSNP is not likely to jeopardize the continued existence of pallid sturgeon (USFWS 2018). This is an important determination because a jeopardy finding similar to that issued in the previous BiOps, would have resulted in prescriptive actions developed with less stakeholder involvement. The construction of the 12 IRC projects provides the unique solution to take some action to avoid jeopardizing the species as required by the ESA while systematically determining the effectiveness of the action and determining whether the hypotheses is correct. The ROD for the MRRMP-EIS was signed November 20, 2018.

1.5 MRRIC/Public Engagement

Since authorization of MRRIC in 2007 (WRDA 2007, Section 5018), USACE has been committed to the collaborative forum, earnestly listening and responding to the interests, recommendations, and concerns brought forth by committee members, and continually seeking ways to improve communication between USACE and Missouri River stakeholders. Stakeholder engagement within the MRRIC forum serves as a means to increase transparency of USACE actions to Missouri River stakeholders while also increasing visibility of stakeholder interests for the USACE staff to consider in the implementation of MRRP actions. Throughout the development of the MRRMP-EIS, USACE regularly coordinated with MRRIC including quarterly 3-day in-person plenary meetings, numerous webinars, and in-person and virtual meetings with MRRIC work groups. In addition, USACE has collaborated with MRRIC on the preparation and review of multiple technical reports and documents, including the EA, iterations of the SAMP, and IRC site selection criteria, all of which have been reviewed by the ISAP.

In addition to coordination with MRRIC, USACE adhered to the public involvement requirements of the NEPA process, which included public scoping webinars prior to initiation of the MRRMP-EIS and an extended comment period of 122 days on the draft MRRMP-EIS. During this review period, USACE conducted six public meetings, throughout the basin, to provide stakeholders an opportunity to interact with USACE staff and provide comments in person. USACE has also engaged the public, interested basin Tribes, and MRRIC in the development of site-specific Environmental Assessments for each IRC construction project. Opportunities for public input included a 30-day comment period and a public meeting close to each project location. Most recently, USACE has shared the preliminary design of the next two proposed IRC projects with MRRIC to solicit input prior to development of the site-specific Environmental Assessments. When the draft Environmental Assessments are released for the 30-day comment period, USACE will also conduct a public meeting to solicit additional input on the projects.

In addition to the coordination above and based on concerns about the locations of IRC sites raised by some stakeholders, USACE engaged in meetings with multiple stakeholder groups, including those from the navigation industry, commercial sand and gravel mining industry, agricultural businesses, and other state and government agencies, to identify mutually agreeable locations where IRCs could be constructed to provide their intended benefit to the pallid sturgeon while minimizing concerns of stakeholders. This was accomplished through a series of eight IRC stakeholder coordination and outreach engagement activities, and coordinated through MRRIC from February to July 2018. Attendance at these sessions varied depending on the specific purpose of each session, but generally included commercial dredgers, navigators, business owners and interest groups including AGRIServices, the Coalition to Protect the Missouri River, and Missouri and Associated Rivers Coalition, and other state and federal agencies including the Missouri Department of Natural Resources. Through these sessions, USACE staff and stakeholders:

- Solicited and reviewed input on the overall IRC study, site selection process, current IRC designs and site considerations.
- Informed stakeholders on the ongoing work related to IRCs, provided an opportunity for them to give input or express concerns regarding IRC projects, and discussed how USACE would address those concerns.
- Improved the understanding of the interaction between navigation, dredging, and IRC projects and learned from commercial users of the river about their typical operations, with a focus on identifying potential overlap with IRC sites.

- Worked with navigators and dredgers to reprioritize the list of identified IRC sites, based on the original USACE list and impacts to stakeholder interests.
- Discussed potential future project sites to gain specific feedback with respect to sedimentation, bend navigation, and business operations in relation to potential project sites.

These engagements were invaluable for USACE to identify opportunities to avoid or minimize impacts to other river users. USACE will continue to engage with MRRIC and other stakeholders in order to better understand their concerns, including how they use the river and how IRCs might affect that use, and collaborate to find ways to avoid and minimize impacts where possible.

1.6 Independent Review

A draft of this report, and all of the information contained in it, was reviewed by the ISAP. This review provided opportunity for critical, independent, and transparent evaluation of experimental designs, scientific findings and interpretations. The final version of this report incorporates comments from the ISAP. Those comments can be found in Appendix A.

2.0 Missouri River Authorized Purposes, Human Considerations, and IRCs

The authorized purposes of the System as set forth in the Master Manual include flood control, navigation, irrigation, hydropower, water supply, water quality, recreation, and fish and wildlife. Navigation is the authorized purpose of the BSNP. Some members of MRRIC have made the USACE aware, however, that there is also concern about IRC impacts on other interests such as the in-river commercial sand and gravel mining industry. To address the breadth of concerns, this section describes the effects of IRCs on the authorized purposes and other interests as requested by MRRIC. Additional supporting information can be found in Appendix B, Technical Memorandum to Support the IRC Report to Congress.

To ensure that impacts to the authorized purposes and other socioeconomic considerations are avoided or minimized, two-dimensional (2-d) hydrodynamic modeling is used both before and after construction of IRC projects. 2-d modeling is regarded as state-of-the-art for modeling the hydraulics of multi-mile reaches of large rivers. With sufficient quality input data, a well-structured, comprehensive 2-d model produces the information needed to assess navigation impacts, including channel depths, widths, and velocities, at a resolution in excess of that normally needed to assess potential impacts to tug boats and tow barges. Three-dimensional (3-d) numerical modeling of flow hydraulics is impractical due to the exceptional computing power and time required to run a sufficiently detailed model for a reach of several miles (Lane 1999). Flow in the Missouri River is predominately downstream with a secondary transverse flow component with very little flow in the vertical direction, which is the flow component accounted for in a 3-d model. In these cases, a 3-d model will not provide information beyond that provided by a 2-d model to aid in decisions for IRC designs or for analysis of potential impacts to navigation and other authorized purposes. In order to predict how the bed of the river will respond to IRC projects, the historical bedform response of similar dike configurations on the existing river was examined. Bedform responses assumed in the existing models of the constructed IRCs have been confirmed with updated post-construction bathymetry and reflect the expected trend of bedform change initially predicted. A mobile bed model was not used as it would add unnecessary complexities to the design process and assessment of any navigation impacts.

2.1 System Authorized Purposes, BSNP Authorized Purposes and IRCs

USACE's Missouri River Basin Water Management Division regulates the System in accordance with the guidelines outlined in the Master Manual. Construction of IRCs will not change the regulation guidelines outlined in the Master Manual, and will not affect releases from Gavins Point Dam, the lowermost System dam, to meet the authorized purposes in the lower river.

The benefits from the statutory authorization to provide irrigation, hydropower, and recreation are primarily derived from System operations. Because IRC construction will not affect the guidelines outlined in the Master Manual and therefore will not affect the timing and amount of water releases from Gavins Point Dam, IRC construction projects will not affect the quantity and value of hydropower produced (USACE 2018b) and will not affect the water surface elevations for permitted Missouri River irrigation intakes (USACE 2018c). Additionally, IRC construction projects will not affect the reservoir levels and downstream river flow for recreational use and has the potential to result in increased abundance and diversity of fish and wildlife species that

could provide small localized benefits for recreational opportunities (USACE 2018d). IRC construction projects have no impact on these authorized purposes and, therefore, they are not further discussed in this report.

2.1.1 Navigation

As stated above, construction of IRCs will not change the regulation guidelines outlined in the Master Manual and will not affect releases from Gavins Point Dam. Therefore, IRC will not impact USACE's operation of the System or its ability to provide flow support for navigation.

The authorized purpose of the BSNP is to secure a 9-foot deep by 300-foot wide navigation channel for a total of 732 river miles, from Sioux City, Iowa to the mouth of the river immediately north of St. Louis, Missouri. Navigation industries operate barges and freight vessels along the Missouri River which transport various commodities including agricultural and petroleum products, manufactured goods, and manufacturing materials such as gravel and sand. The required 9-foot depth for the full authorized 300-foot width can and will be maintained in the navigation channel in the vicinity of the IRC sites (Appendix B, Section 3.1.1 and 3.1.2). The BSNP is comprised of approximately 7,000 river training structures (dikes and revetments) that concentrate a significant portion of the river's flow within the main channel of the river (Figure 6). The main channel is defined as the open river area between the river training structures on both sides of the river. The width of the main channel increases in the downstream direction to accommodate increasing discharge and ranges from 600 to 750 feet in the portion of river where IRC projects are being planned and built. Generally, dikes are used perpendicular to flow on the inside of bends to concentrate flow into the main channel and revetments are used on the outside of bends to stabilize the location of the outside bank. Channel crossings occur where an outside bend on one side of the river transitions to an outside bend on the opposite side of the river. The location of the 300-foot wide navigation channel is not set within the wider main channel, but is generally located toward the outside on bends and in the middle of the river at the channel crossings. Figure 4 and Figure 6 provide the typical layout of the channel and river structures.

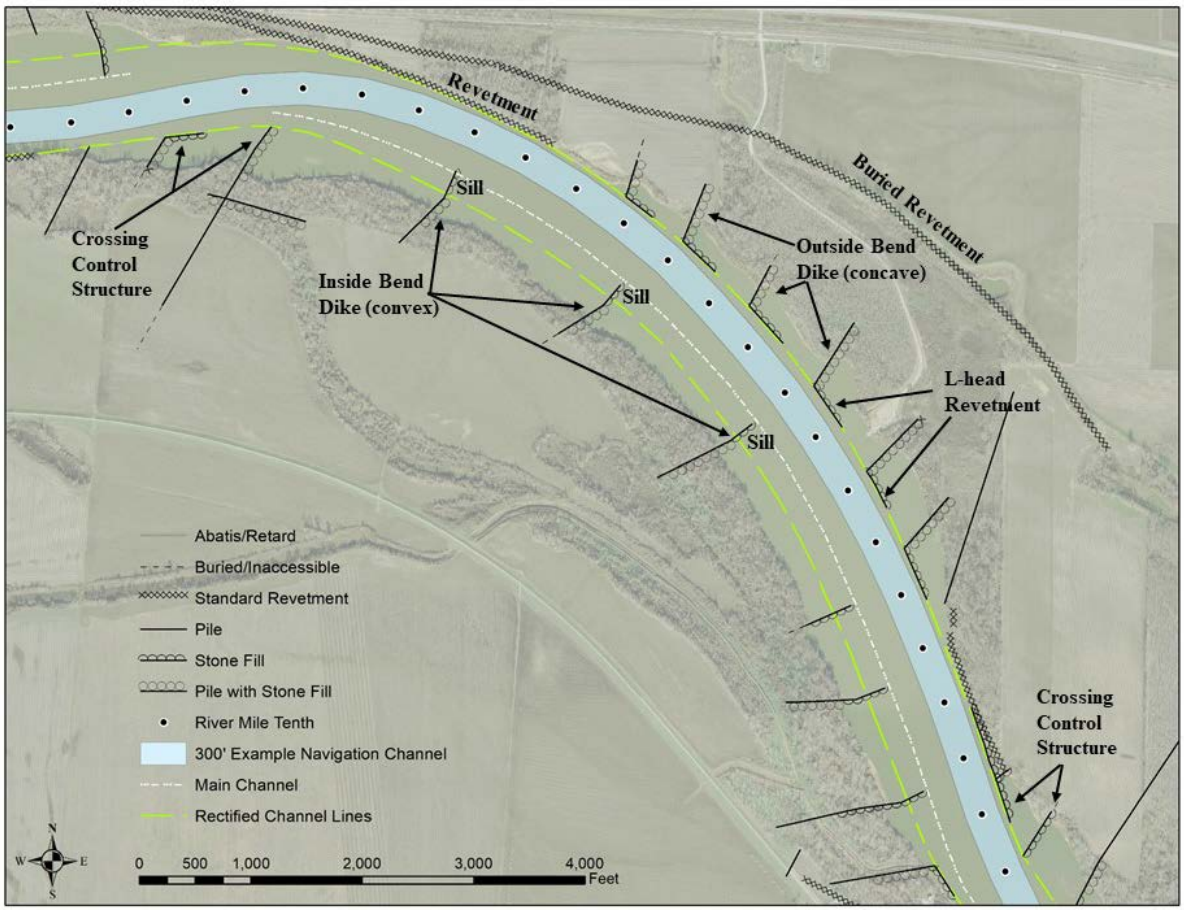


Figure 6. A typical bend within the Missouri River with multiple dikes and revetments configured to maintain the navigation channel.

Pre-construction (design and public engagement)

During the design of IRC projects, engineering analysis is performed and measures are taken to prevent adverse impacts to the navigation channel. The dike extensions and new dikes are constructed in areas where portions of existing dikes are removed. The area of flow blocked from a dike extension or a new dike is balanced by the removal of a corresponding area of dike, so that the flow per unit cross-sectional area in the navigation channel remains the same. This helps ensure that the scouring ability of the river within the navigation channel is unchanged and navigation channel dimensions remain constant. This type of dike extension is commonly used to improve channel conditions for navigation in less reliable reaches of the river (Appendix B, page 15). At IRC sites, they are strategically paired with other changes to preemptively avoid future navigation concerns. Areas where dike extensions have been used for navigation channel improvement have been positively reviewed by industry navigators on the river. Dike extensions and new dikes are located in areas where dikes already exist so as to not pose a hazard to navigators and are sized and placed to maintain a main channel width of at least 550 feet. At the constructed IRC locations, unobstructed main channel widths exceed 550 ft and do not result in channel width encroachment (Appendix B, Section 3.1.2). The twelve IRCs that are proposed for construction are located below RM 321 (near Lexington, MO). The main channel width where IRCs are planned generally ranges from 600 feet to 750 feet.

In addition to the measures described above, USACE also coordinates with navigation stakeholders and MRRIC to solicit input on the preliminary design plans and specifications. Information learned through this process allows the design to be modified to address concerns. For example, it is helpful to understand challenges navigators experience with the existing dike fields and how their navigation and maneuvering may be affected by alternative flow patterns or main channel widths in bends. During the preliminary design phase, USACE also meets with adjacent levee district personnel to solicit input on project design. Engagement at this point allows the opportunity to adjust the project design to address concerns.

Post-construction

Post-construction physical monitoring of the navigation channel adjacent to each IRC project is undertaken to verify that there are no adverse impacts to the navigation channel from the IRC project. Post-construction monitoring consists of routine assessments of channel depths and alignment by in-house channel reconnaissance crews, an annual assessment of changes in channel dimensions using pre and post-construction collected bathymetry (depths) data, and an annual assessment of changes in flow patterns using pre- and post-construction 2-d modeling velocity outputs. Channel reconnaissance crews have not reported any reduced navigation channel dimensions or adverse navigation channel alignments around the two existing IRC projects. The navigation channel dimensions are also monitored at unmodified, non-IRC sites (controls) to track the natural fluctuations that occur in the channel in response to varying flow conditions (Appendix B, Section 3.1.1). Additionally, an analysis of the available pre and post-construction bathymetry data and the applicable 2-d modeling outputs shows that post-construction main channel dimensions and main channel flow patterns (Figure 7) are essentially unchanged post-construction (Appendix B, Section 3.1.1, 3.1.2, and 3.1.4). River discharges during 2018 were generally above normal which ensure channel dimensions were far in excess of authorized dimensions. For future years, main channel bathymetry data will be collected up to five times per year, with more frequent collections during periods of low water when channel dimensions are generally reduced. If navigation channel issues are detected, steps will be taken to rectify the problem. These steps might include constructing additional dikes in critical locations, raising existing dikes to increase flow in the main channel, or reducing or adding the length of dike extensions.

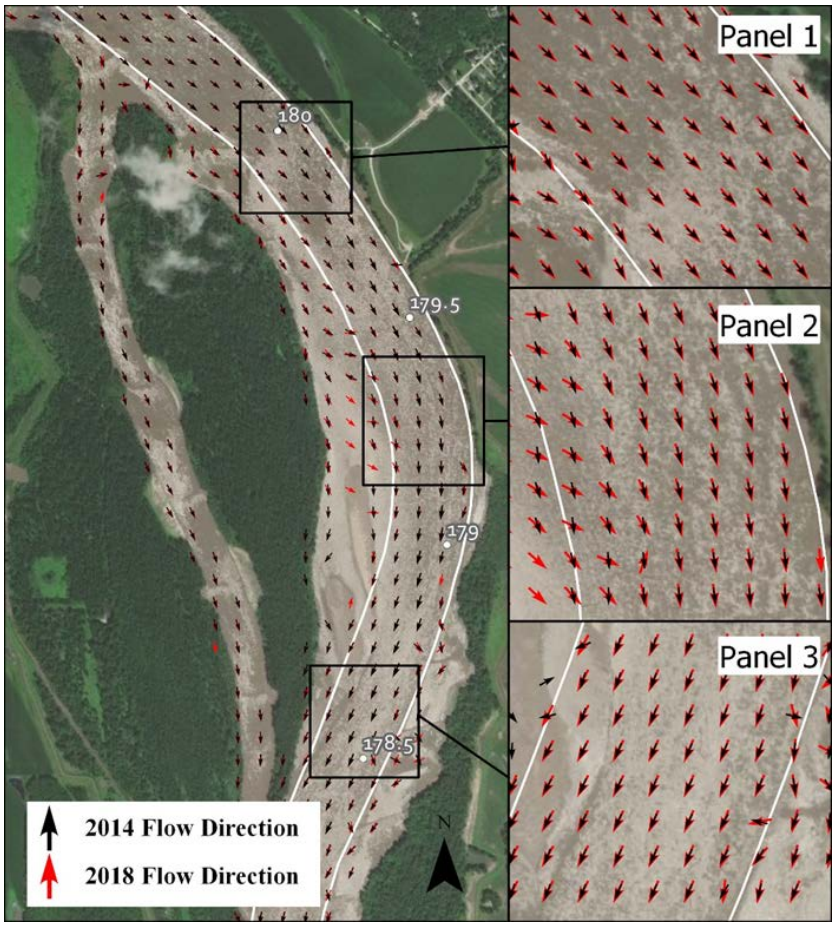


Figure 7. Velocity direction at Searcys Bend pre- and post-construction. Note the changes in velocities in the middle of the bend (Panel 2) due to scour of the pre-existing sandbar. The changed velocities quickly dissipate and will not impact the navigation channel which is on the outside bend.

In addition to the IRC surveys, routine monitoring of the BSNP includes inspecting the height and length of all dikes and revetments, collecting bathymetry data to monitor navigation channel dimensions and average bed elevations, monitoring the water surface, sampling sediment, analyzing gradation, estimating sediment load, and re-calculating daily flows to detect changes in flow distributions over time. Coordination meetings are held yearly with US Coast Guard, US Department of Transportation Maritime Administration, and basin navigation interests to share information and coordinate responses to identified issues.

Additional BSNP and IRC related concerns

Previously developed shallow water habitat (SWH) projects may be modified to provide IRC habitat as there are some similarities in dike and revetment modifications for SWH and IRC habitat. Utilizing past SWH sites would place IRC projects adjacent to publicly owned lands and may result in cost savings. Stakeholder inquiries concerning these efforts have revolved around the actions necessary to modify the projects to provide IRC habitat and the regulatory requirements for commercial sand and gravel dredging. Retrofitting SWH projects is still in the preliminary stages and answers to these questions will emerge as further analysis is

undertaken. Information learned during the design, construction and monitoring of the initial twelve IRC projects will be used to inform future project designs, including those using SWH projects. The MRRP Strategic Plan (USACE 2019b) documents that the planning process of converting existing SWH projects to IRC habitat is proposed in fiscal year 2023 with construction beginning in fiscal year 2025. USACE is committed to following the same previously described engagement processes with all stakeholders as information is learned.

Another stakeholder concern with regard to IRC project has to do with their long-term status should it be determined that they are not contributing to, or are no longer needed for, pallid sturgeon recovery. The structure modifications undertaken to increase interception (i.e., construction of rootless dikes and dike extensions) have been used to address navigation concerns regarding channel depths in many areas of the river. For example, relatively high catches of young sturgeon at a particular site occurred after nearby dikes were modified to address navigation channel shoaling concerns. In fact, the relatively high catches, coupled with the physical characteristics of this site, contributed to development of the IRC concept and served as a prototype for IRC structure designs. Therefore, removing or altering IRC structure modifications could be counterproductive to navigation interests. In addition, IRC projects create diversity in the depths and velocities in the Missouri River and contribute to the mitigation requirements set forth in the BSNP Fish and Wildlife Mitigation Project. However, if it is shown that an IRC construction project adversely impacts any Missouri River authorized purpose, actions will be taken to rectify the problem. The fate of each IRC project will be determined on a site-by-site basis and the structure modifications will either be maintained, removed, modified, or allowed to naturally degrade until the original structure condition is restored. For example, for an IRC project constructed via dike extensions and notching, the extensions may be allowed to degrade and the notch partially filled if it is determined that doing so would not negatively impact the navigation channel. Whatever decision is made regarding the fate of individual IRC projects, routine BSNP surveys and annual structure inspections, along with user feedback, will ensure that IRC projects do not negatively impact the navigation channel or adjoining lands. Like existing BSNP structures, IRC structure modifications are monitored for needed repair and maintained through annual surveys. No evidence indicates IRC structure modifications including notched dikes cause additional maintenance to the original structures.

2.1.2 Flood Risk Management

As previously mentioned, IRCs will not change the regulation guidelines outlined in the Master Manual and will not affect releases from Gavins Point Dam. There will therefore be no impact to water storage and flow releases or the USACE's operation of the System to meet the authorized purpose of flood control.

Pre-construction

During the design phase of each IRC project, engineering analysis is performed using a numeric 2-d model to evaluate the impacts of the design on water surface elevations in the river around each IRC project. Water surface elevations are modeled to reflect both pre- and post-project elevations. The pre-project model is calibrated with field-verified water surface elevation data and validated with field-verified water velocities to ensure model accuracy. If detectable increases in surface elevation or velocity are noted by the model, changes are made to the design to avoid such impacts.

Post-construction

Post-construction physical monitoring includes collecting water surface elevations three or more times a year between the months of May through October and comparing post-construction water surface elevations to the pre-project water surface elevations when data for comparable discharges is available. In addition, the numeric 2-d models developed during the design phase with pre-construction bathymetry data are updated with post-construction bathymetry data. When post-construction bathymetry is available at similar discharges as pre-construction surveys, the pre- and post-construction models are applied using the same flow and the water surface elevation outputs are compared to determine if the project has impacted water surface elevations. With appropriate input data, the modeling effort supplements the collected water surface elevations and allows for an evaluation of a wider range of flows than can be evaluated from collected data in any given year. The post-construction model also verifies the accuracy of the models employed during design. To date, no measurable impacts to water surface elevations have been noted (Figure 8; see also Appendix B, Section 3.21). If water surface changes are detected, steps will be taken to rectify the situation.

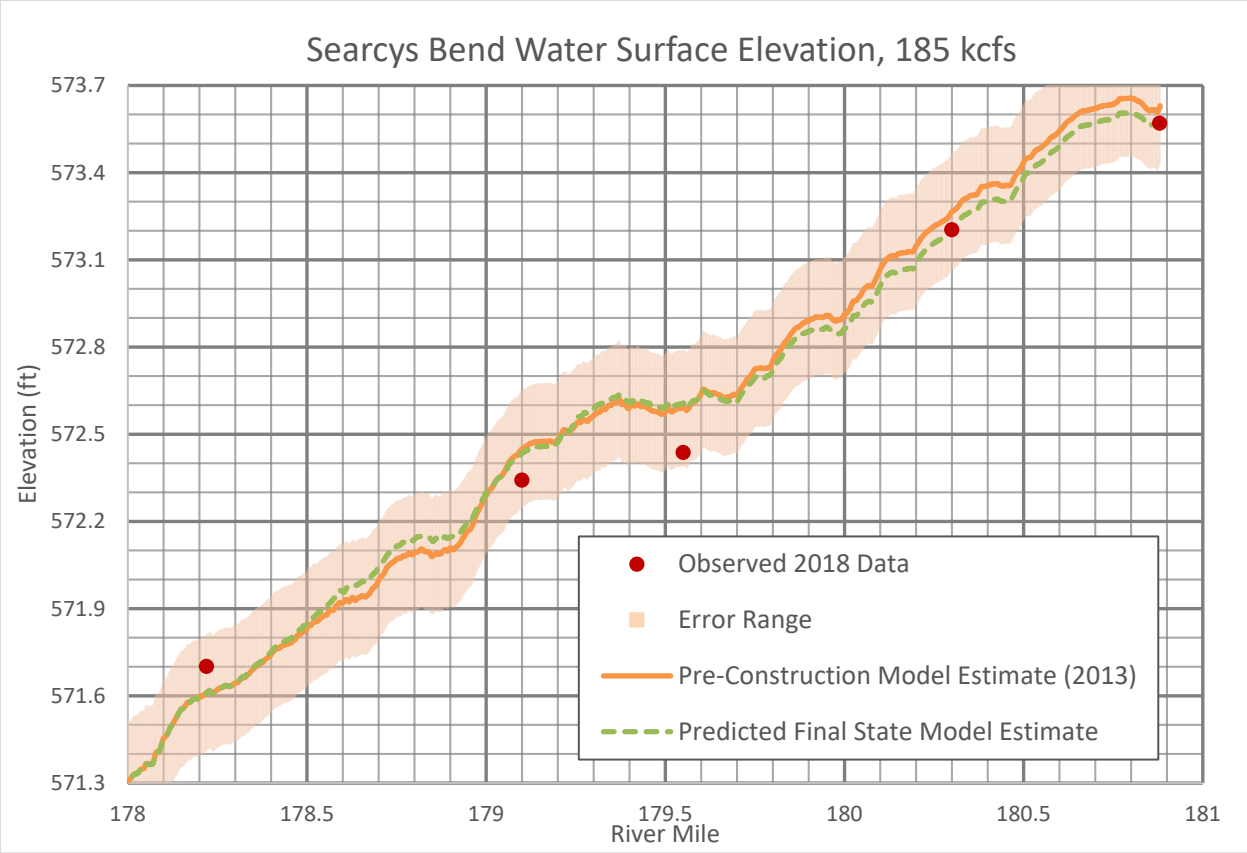


Figure 8. Plot of near bank full modeled and actual water surface elevations at Searcy's Bend pre and post construction. Differences in pre and post construction within errors of models and scatter in data.

Because IRC projects are designed to not impact water surface elevations and no change in water surface elevations have been noted post-construction, there is no increased flood risk due to water surface changes resulting from IRC projects. Basin stakeholders have, however, expressed concern regarding the effects of IRC projects on interior drainage of agricultural fields. The two constructed IRC projects and the next six proposed IRC projects shown in Table

1 are adjacent to public lands. Therefore, there should be no agricultural interior drainage issues. Additionally, analyses and monitoring results have demonstrated that IRC construction does not change the water surface elevation of the river adjacent to IRC projects. Therefore, IRC projects do not impede the flow of water from interior drainage conduits or flap gates beyond pre-construction conditions. IRC projects are designed not to and have not been shown to affect or change any of the topography, land use, or other drainage characteristics on the interior side of levee systems adjacent to IRC projects and therefore IRC projects will not affect interior drainage or hydrology. Moreover, should any IRC project have such effects in the future, the effects would be identified and remediated through the monitoring and adaptive management program.

2.1.3 Water Supply and Water Quality

Construction of IRCs will not require changing the regulation guidelines outlined in the Master Manual and will not affect releases from Gavins Point Dam. Therefore, IRC will not impact USACE's operation of the System to meet the authorized purpose of water supply or water quality through water storage and flow releases.

The location of water intake structures within the geographic extents of the IRC study are identified as a part of the IRC site selection process and avoided when identifying potential IRC site locations (USACE 2018e). Furthermore, water surface elevations are monitored and modeled at IRC projects, as described in the previous section, and no change in water surface elevations have been noted. Impacts to water quality were discussed in the Environmental Assessments completed for the two constructed IRC projects (USACE 2016a; USACE 2016b). Short-term minor impacts to water quality during project construction were anticipated (such as localized temporary increases in turbidity), however it is not expected that any State of Missouri water quality standards will be exceeded. These projects were in full compliance with section 404 of the Clean Water Act and a Clean Water Act Section 401 water quality certification was also received from the Missouri Department of Natural Resources for each project. Water quality monitoring was not conducted at the two constructed IRC sites during or following construction as past data indicates these activities would not result in any degradation of water quality. USACE conducted extensive water quality and sediment monitoring in the past to evaluate similar habitat construction projects and found no degradation of water quality neither during nor following construction (Gosch et al 2013; Heimann et al 2014; USACE 2015). It is anticipated that future IRC projects will be similar in nature and result in similar or less impacts as these past projects. Future projects will also comply with Clean Water Act Section 404 and obtain Clean Water Act Section 401 water quality certifications.

2.1.4 Fish and Wildlife

Construction of IRCs will not require changing the regulation guidelines outlined in the Master Manual and will not affect releases from Gavins Point Dam. Therefore, IRC will not impact USACE's operation of the System's water storage and flow releases to meet the authorized purpose of fish and wildlife.

The construction of IRC habitat could cause conversion from terrestrial habitat to aquatic habitat (i.e., upland grassland to emergent wetland) due to project designed bank erosion on public land. An overall conversion of terrestrial habitat (e.g., forest, upland grassland) to aquatic habitat (e.g., open water, emergent wetland) could impact species dependent on terrestrial habitat, while species that are dependent on aquatic habitat would benefit. The scale of

proposed IRC construction and the potential conversion of terrestrial habitat to aquatic habitat would be negligible compared to the amount of terrestrial habitat available on the Missouri River.

IRC habitat could also benefit a number of other fish species. Most riverine fish depend on low-velocity, shallow water habitat at some point in their life history. Several species spawn in such habitat, and the juveniles of most species rear in lower-velocity, channel margin areas until they are large enough to maintain themselves in the Missouri River main channel. Construction of IRCs will increase the availability of these habitats, providing benefits to native aquatic fish species and contribute to the BSNP mitigation goals (USACE 2018a).

2.2 Additional Human Considerations

2.2.1 Bank Erosion

Bank erosion and the corresponding loss of private property is another major concern to landowners along the river. To increase channel margin areas, IRC projects are designed to cause a controlled amount of bank erosion immediately adjacent to the project. To avoid impacts to private property, IRC projects are only located adjacent to publicly owned property and only with permission of the landowner (i.e. state-owned lands). Furthermore, USACE ensures there exists an adequate buffer between the IRC project and any private property adjacent to the public property.

2.2.2 Commercial Sand and Gravel Mining

Commercial dredgers on the Missouri River extract sand and gravel from the bed of the river and sell the material as construction aggregate. USACE permits sand extraction pursuant to section 404 of the Clean Water Act and Sections 10 and 14 of the Rivers and Harbors Act of 1899. Dredging location information submitted to the USACE indicates that a preferred dredging location is the channel margin area downstream of inside bend dikes. At IRC projects, this location coincides with an area of desirable sandbar formation. Sandbar margins are likely areas of larval pallid sturgeon retention and also offer diverse habitat over a wide range of flows. Analysis has shown that sand extraction via hydraulic dredging creates a depression in the bed and the depression can extend up to 200 feet laterally (Appendix C, Extended Abstract: Tracking the River Bed Response to Channel Mining on the Lower Missouri River). Therefore, dredging within 200 feet of sandbars could adversely impact their dimensions. In addition, dredging-induced depressions in the bed in the main channel near the upstream end of IRC projects could change the ability of the project to intercept drifting sturgeon embryos, and therefore the ability of the study to assess if increases in interception occur. To date, IRC projects have only been constructed in areas of the river with no active sand dredging. If an IRC project is proposed in an actively dredged reach or a dredging company proposes to dredge in a reach with an existing IRC project, USACE will perform a detailed analysis of potential impacts on the IRC project. That analysis may show that additional permit conditions or restrictions are warranted to avoid adverse impacts.

To avoid and minimize impacts to dredgers, USACE has coordinated with sand and gravel dredging stakeholders to identity locations where IRC projects could be constructed with minimal impacts to dredging operations. This coordination is fully described in Section 1.4.

Based on information provided through the engagement sessions and the broader list of available sites, USACE identified six sites that would have little to no impact to the dredgers. USACE has also worked with the sand and gravel dredgers to identify areas for paired control sites that will not significantly impact dredging. It is important that modification to control sites be minimized during the study period to maximize study success; however, there is more flexibility in the selection of control sites as construction does not occur at these locations; hence, they can be located in areas of the river not adjacent to land in public ownership.

Table 1. Potential IRC study site locations discussed with sand and gravel dredging stakeholders. It should be noted that construction of the two locations in 2019 (St. Albans and Pelican bends) is contingent upon completion of this report and may be delayed until 2020.

CURRENT POTENTIAL IRC STUDY SITE SCHEDULE					
Schedule	**IRC Treatment Site Bend**	**Adjacent Land**	**Approx. River Mile Range**	**Paired Control Site**	**Control Site River Mile**
2016	Moberly Bend	Baltimore Bottom - USFWS	297 - 302	Sni Bend	320 - 323
2017	Searcy's Bend	Overton Bottoms - USFWS	178 - 181	Wilhoite Bend	232 - 234
2019	St. Albans Bend	*Weldon Springs CA*	52 - 55	Morrison Bend	110 - 112
2019	Pelican Bend	*Pelican Island NA*	11 - 15	Portland Bend	112 - 116
2020	Providence Bend	*Plowboy CA*	168 - 171	Gilliam Bend	234 - 237
2020	Straubs Bend	*Heckman Island- USACE*	105 - 108	Isbell Bend	125 - 128
2021	Prunty Bend	*Grand Pass CA*	266 - 272	Berlin Bend	305 - 307
2021	Plowboy Bend	*Eagle Bluffs CA*	171 - 177	Arrow Rock Bend	208 - 211
2022	*TO BE DETERMINED*				
2022					
2023					
2023					

Constructed and monitoring

In-Design and monitoring

The MRRMP-EIS provides an economic assessment of the impacts to the sand and gravel dredging community using two sources of information. The EIS estimated impacts by assessing the overlap of the area of potential IRC study site locations with the area where dredging took place between 2010 and 2017. Based on this analysis, it was estimated that the total miles of IRC study overlap with commercial sand and gravel dredging ranged from 42 to 65 miles, the average annual tonnage extracted in areas that overlap with IRC could range from 16,025 to 93,540 tons, accounting for 0.3 to 1.5 percent of total tonnage (MRRMP-EIS; Table 3-60). Given the very small percentage of affected tonnage and availability of other sites to conduct commercial sand and gravel dredging within the permitted areas, it is anticipated that adverse impacts to commercial sand and gravel dredging would be small.

The analysis in the EIS relied upon a previous list of twelve potential IRC sites which included Overton North, Bryan Island, DeWitt Bend, and Cora Island sites. Due to stakeholder concerns, these four sites have been replaced with sites that are more amenable to the dredging stakeholders. Therefore, assuming the additional 4 IRC treatment and control sites yet to be identified are compatible with the sand and gravel stakeholders, the impacts could be less than those described in the MRRMP-EIS. This analysis also assumed that the locations where dredging has occurred from 2010 to 2017 provided an accurate prediction of future dredging locations.

Moving forward, USACE will continue to take a proactive approach to engage stakeholders to find, to the extent possible, mutually acceptable IRC locations. The availability of sites on which to build IRCs is an issue of strategic importance for the MRRP; the program needs to build twelve IRCs (each with a control site, for a total of 24 sites), and there is currently a limited amount of public land where an IRC project could be located riverward. If monitoring data show dredging does not impact IRC projects, public land adjacent to actively dredged reaches could be selected for IRC design and construction. The USACE could also acquire additional land for IRC construction. The land would need to be sourced from a willing seller, in a location that is both technically and biologically viable, with minimal stakeholder concerns.

3.0 IRC Benefits to Pallid Sturgeon

Section 1226 of the AWIA requires USACE to report on the impacts of IRC construction on “the population recovery of the pallid sturgeon;” essentially, how the construction of IRC habitat affect pallid sturgeon survival and population growth. To accurately answer the question requires a functional pallid sturgeon population model (Section 3.1) which demands an understanding of age-specific survival rates for accurate predictions and some understanding of the relationship between IRCs and survival of young sturgeon in order to make useful predictions. Specific to IRC habitat, the current rates of interception, the interception changes due to IRCs (Section 3.3), and the survival response are unknown. Future research and monitoring activities are directed at collecting this information, partly through the construction and evaluation of the twelve IRC sites (Section 3.3).

Information from monitoring the first two constructed sites will provide insight into potential benefits by showing if projects are progressing as intended and information learned via construction and monitoring of existing IRC sties can and will be utilized in future IRC project designs. Upon completion of the pallid sturgeon population model (Section 3.1) the impact of IRC construction on pallid sturgeon recovery can be understood. Section 3 of this report describes (1) the relationships in the population model, (2) testing if interception can be increased, (3) ongoing and planned research to evaluate food limitations, (4) and research and monitoring plans to address other competing hypotheses that may result in increased survivorship of young pallid sturgeon to age-1 (Section 3.5).

3.1 Pallid Sturgeon Population Model

A species population model is often used to understand how changes in age-specific survivorship (first feeding to age-1 for IRCs) can lead to changes in population size. While a pallid sturgeon population model was developed during the Effects Analysis process, there is uncertainty in the survivorship of pallid sturgeon during the first year of life. The primary purpose of the model is to evaluate the population-level effect of management actions and provide metrics (e.g., population viability, abundance) that link to fundamental objectives for pallid sturgeon. The model also provides a mechanism for extrapolating observed changes at specific life-history stages (from field data) to their long term population consequences.

Most fish populations, including pallid sturgeon, experience extremely high mortality rates during the first year of life. Survivorship of pallid sturgeon significantly increases after the first year so increasing the numbers of individuals surviving to age-1 can result in population-level increases as these additional individuals reach reproductive maturity. The intent of IRC habitat is to increase survival of young pallid sturgeon to age-1 allowing more individuals to eventually grow and reach reproductive maturity. Specifically, IRC habitat will benefit pallid sturgeon populations by transferring young individuals from the inhospitable river thalweg to suitable nursery habitat in channel margins resulting in increased growth and survival. This increased recruitment to age-1 pallid sturgeon will eventually lead to increased numbers of reproducing adult pallid sturgeon and lead to an increase in the overall population size of pallid sturgeon. Figure 9 provides a conceptual model of how implementation of IRC habitat will ultimately increase pallid sturgeon population size and how the 12 site IRC study (Section 3.3) and other ongoing research (Section 3.5) are used to help understand the relationship between IRC habitat and pallid sturgeon population growth. As we increase understanding of the lift in survival IRCs provide, the population model can be refined and will be a valuable tool in ultimately understanding the types and quantities of management actions (including IRC habitat) that lead to population growth. As such, much of the research and monitoring that is planned

and currently being undertaken (see the SAMP; Fischenich et al. 2018) is to reduce these uncertainties and allow future parameterization of the pallid sturgeon population model. Upon understanding the relationship between IRC habitat construction and pallid sturgeon population growth, a more accurate assessment regarding the impact of IRC construction on pallid sturgeon recovery can be made.

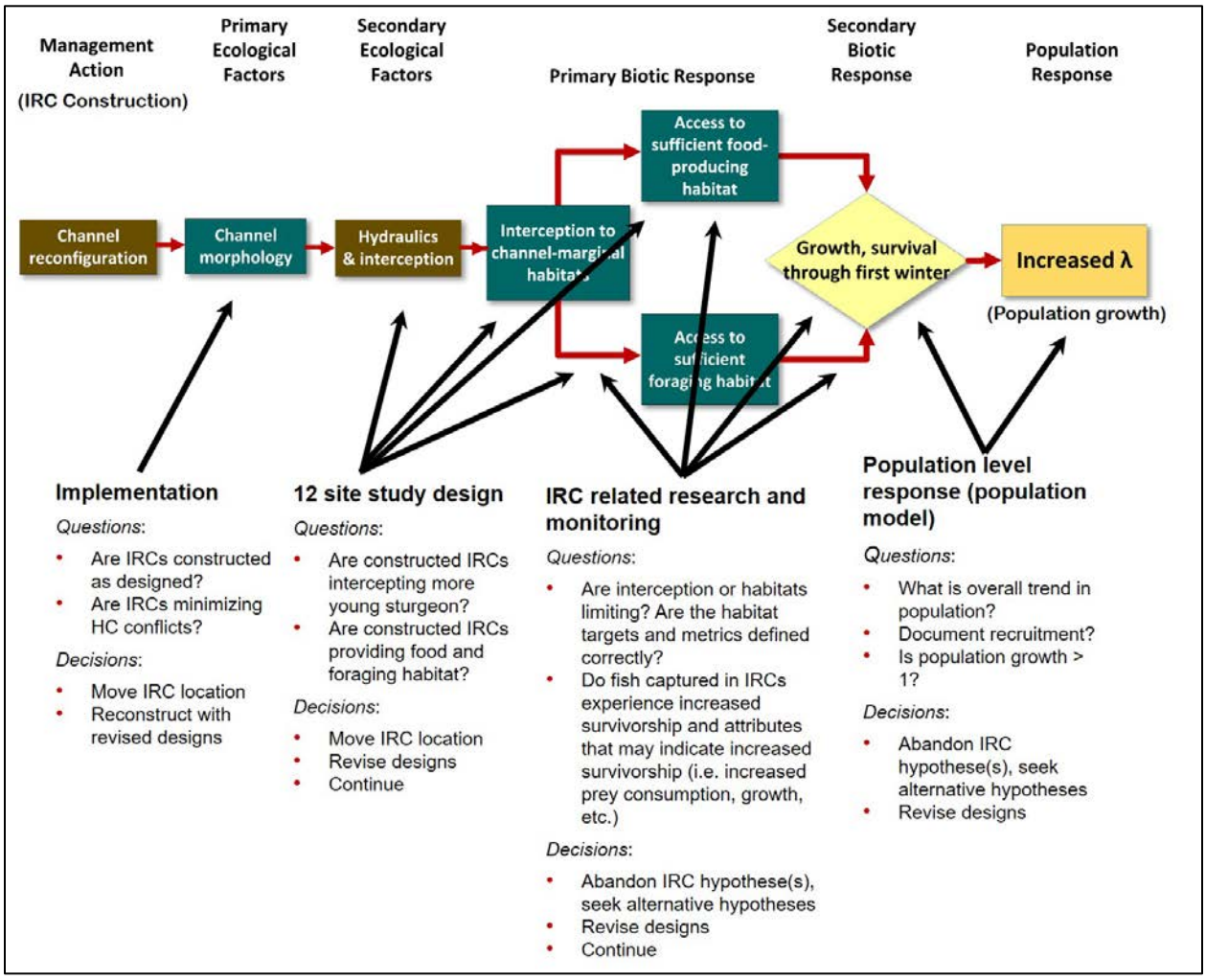


Figure 9. A simplified conceptual model of how IRC habitat construction will result in pallid sturgeon population growth. Included in the figure are questions to be answered from the IRC 12 site study and additional IRC related research and potential decisions resulting from information learned regarding IRC habitat. Image courtesy of Robert Jacobson, US Geological Society, Columbia, MO.

3.2 Pallid Sturgeon Adaptive Management Framework

Despite considerable effort, the identification of factors causing recruitment failure for pallid sturgeon and a clear nexus between management actions and population response remains uncertain for the lower Missouri River below Gavins Point Dam (Jacobson et al. 2016a). Given the uncertainties regarding the scope and scale of the management actions necessary for USACE to avoid jeopardizing the continued existence of pallid sturgeon by operation and maintenance of the System, an adaptive management (AM) strategy is the most effective way to

achieve the management objectives of increasing pallid sturgeon survivorship to age-1 and contributing the recovery of the species.

USACE and USFWS collaborated, in conjunction with stakeholder involvement, to develop a framework for adaptively managing actions intended to avoid jeopardy to the pallid sturgeon on the lower river. The pallid sturgeon AM framework, including the experimental design for IRCs, was developed using the best available science and as reviewed and improved through interactive engagement with the ISAP. The pallid sturgeon AM framework was included in USACE's 2017 Biological Assessment and incorporated into the no-jeopardy finding of the USFWS's 2018 BiOp. It consists of four levels of activity as described in Table 2. As information is developed through research and experiments or through monitoring of effectiveness of management actions (Levels 1 and 2 activities, Table 2), decision criteria described in the pallid sturgeon framework will be used to determine when and what actions should follow. Decisions might include (a) accepting that the scientific information supports the hypothesized action; (b) determining that the scientific information does not support the hypothesized action; or (c) deciding to implement at Level 3 because an agreed-upon time limit has been reached and results remain equivocal. At any time during implementation, it may become apparent that: 1) a particular action is not needed; 2) a proposed action requires modification to be effective; or 3) some new action not previously evaluated is required. The pallid sturgeon framework is expected to accelerate the identification of recruitment bottlenecks, resulting in a strategic and focused implementation of appropriate management actions. This differs from the Reasonable and Prudent Alternative provided in the 2003 Amended BiOp, which simply set a restoration target of 20,000 acres of SWH on the lower Missouri River without testing of alternative, competing hypotheses, or providing for assessment and improvement of SWH to ensure it was providing benefits to pallid sturgeon. This new approach benefits both the pallid sturgeon and stakeholders by reducing the risk of implementing costly and ineffective actions for extended periods of time. With respect to IRC habitat, the construction of twelve IRC projects included in the IRC study (see section 3.3) are considered a mix of Level 2 and 3 activities.

Table 2. Pallid sturgeon adaptive management framework

Level 1: Research	Population Level Biological Response IS NOT Expected	Studies without changes to the system (Laboratory studies or field studies under ambient conditions)
Level 2: In-river Testing		Implementation of actions at a level sufficient to expect a measurable biological, behavioral, or physiological response in pallid sturgeon, surrogate species, or related habitat response.
Level 3: Scaled Implementation	Population Level Biological Response IS Expected	In terms of reproduction, numbers, or distribution, initial implementation should occur at a level sufficient to expect a meaningful population response progressing to implementation at levels which result in improvements in the population. The range of actions within this level is not expected to achieve full success (i.e., Level 4).
Level 4: Ultimate Required Scale of Implementation		Implementation to the ultimate level required to remove as a limiting factor.

3.3 IRC Study Design and the Need for Twelve Sites

Study design

For IRC habitat to provide benefits to drifting larval pallid sturgeon, those recently hatched sturgeon must first be intercepted from the fast moving Missouri River main channel into the channel margin. While IRCs are designed to provide this interception function, it has not been confirmed that interception can be influenced via manipulation of river training structures. The primary hypothesis to be evaluated, via construction of IRC projects, is whether or not interception can be increased. Specifically, the hypothesis[1] is:

> $H_{0,1}$: Catches of age-0 sturgeon within river bends that include IRC habitat restoration sites are similar to control sites before and after habitat restoration actions.
>
> $H_{A,1}$: Catches of age-0 sturgeon within river bends that include IRC habitat restoration sites increase relative to control sites after habitat restoration actions.

Therefore the metric to assess IRC effectiveness at increasing interception will be an increase in catch-per-unit effort (CPUE) of young sturgeon. Given the low number of age-0 pallid sturgeon in the lower Missouri River, increases in catch of the closely related shovelnose will be used, as a surrogate, to assess IRC effectiveness. Shovelnose sturgeon are closely related to pallid sturgeon, found in relatively high numbers, and often used as a surrogate for assessing benefits to pallid sturgeon, especially at early life stages.

The Before-After-Control-Impact (BACI) design is the standard design for investigating the effect of an action while controlling for temporal effects and site effects. In some cases, it is not logistically possible to apply the treatment simultaneously to multiple sites, and often it is not feasible to do many years of pre-treatment monitoring, which is the case for the currently planned twelve IRC sites. Walters et al. (1998) and Hussey and Hughes (2007) discuss a variant called the staircase where each new treatment (typically) starts one year later. Additionally, the staircase design can be modified in various ways. For example, it is possible to implement the treatment at more than one site in a year; the number of years monitored before any treatment applied can be increased; control sites can be "paired" with particular treatment sites; and treatments can be implemented on a more irregular schedule rather than in successive years. Given the nature of IRC implementation, the staircase design is a logical approach to assessing IRC effectiveness.

The need for twelve sites

The power[2] of the staircase design to detect the treatment effect depends on a number of factors including: 1) the size of the effect[3]; 2) the noise in the response[4]; 3) the alpha level[5]; and 4; the sample size[6].

---

[1] H_O denotes the null hypothesis and H_A denotes the alternate hypothesis.
[2] The statistical power of a hypothesis test is the probability of detecting an effect, if there is a true effect present to detect
[3] The effect size is the quantified magnitude of a result present in the population. In this case, it is 80%
[4] For an explanation of "noise", see SAMP Appendix E.1.A.
[5] The Alpha Level is the significance level, in this case 0.05
[6] The sample size is the number of observations in the sample, in this case twelve treatment and twelve control sites

In the case of the IRC staircase design, the power is a function of the number of IRCs proposed; how quickly the IRCs develop; the number of control sites; and the length of time these sites are monitored.

A power analysis was undertaken to provide information on noise components – in particular the site-year interaction variation. This information is useful in determining how many sites and the number of monitoring years are necessary to determine if IRCs are effective at increasing catch of age-0 sturgeon (Figure 10). To estimate the power of a proposed IRC design we utilized previously collected age-0 sturgeon data from sampling that occurred from 2005 to 2009 and 2014 to 2015 and computed the power for the IRC experiments under a number of scenarios.

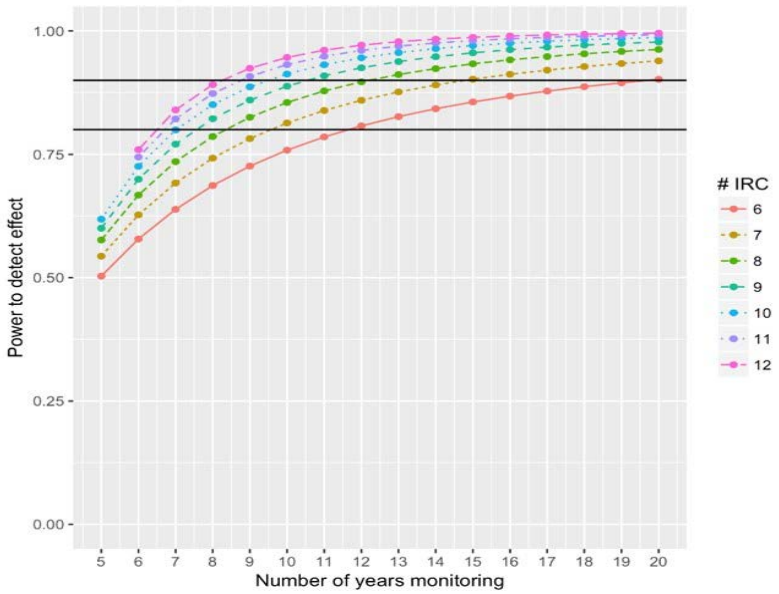


Figure 10. The number of IRC sites and monitoring duration (years) necessary to achieve 80% statistical power to detect an 80% increase in CPUE at IRC treatment sites.

The analysis showed that monitoring twelve IRC control and treatment site pairs, implemented over seven years at the rate of 2 sites/year, would generate 80% statistical power with an effect size of 80% increase in CPUE. Some stakeholders have suggested that monitoring the two constructed sites should be sufficient to detect increases in catch of young sturgeon however, the same analysis indicated monitoring in excess of 20 years would be necessary to detect an increase (of 80%) in catch if only four IRC sites were constructed.

For further details on the study design and power analysis that led to the need for twelve IRC sites see Appendix E.1 in the SAMP (Fischenich et al. 2018).

3.3.1 IRC Monitoring Plan and ISAP Review

Appendix E.1 of the SAMP (Fischenich et al. 2018) provides a description of the IRC study design and subsequent monitoring (IRC monitoring plan) to evaluate the response of age-0 sturgeon to IRC habitat development activities. The monitoring focuses primarily on the interception component of IRCs, while the rearing portion of the Effects Analysis hypothesis (food producing and foraging habitats) are currently being addressed by additional focused research efforts (see Section 3.5). Specifically, this monitoring will test the hypothesis described

in Section 3.3 of this report. Coupled with the measurement of the biological response (CPUE of age-0 sturgeon), physical monitoring will characterize the hydrodynamics of interception habitat at treatment and control bends. The measure of hydrodynamics will include depth and velocity magnitude and direction. Specific to the physical response, these physical characteristics will be integrated into physical models to estimate the percent change in interception. Additionally, the amount of food-producing and foraging habitat pre- and post-construction will be calculated. Specifically, this study will test the following hypothesis on the physical response to the construction of IRC restoration sites:

$H_{0,2}$: The hydraulic and physical characteristics of river bends that include IRC habitat restoration sites are similar to control sites before and after habitat restoration actions.

$H_{A,2}$: The hydraulic and physical characteristics of river bends that include IRC habitat restoration sites are different than control sites before and after habitat restoration actions.

The approach to address this uncertainty is similar to methods used to assess impacts to authorized purposes and other human considerations. Prior to constructing an IRC project, the design phase utilizes 2-d modeling to evaluate the efficacy of design alternatives in intercepting young pallid sturgeon. Additional predictions regarding changes to the bedform are used to provide estimates in the changes in depths and velocities that are likely to occur at the project location. Following construction, bathymetry and Acoustic Doppler Current Profiler (velocity measurement) surveys are undertaken to allow for new 2-d models to be developed, which are compared to the pre-construction models either confirming or refuting pre-construction predictions. This information will also be used to determine if the project should be adjusted to meet the intended purpose.

The ISAP reviewed the IRC monitoring plan as part of their review of the SAMP. The ISAP concluded “the monitoring plan for IRC in Appendix E serves as a model for the other proposed actions and actions that will emerge from the Pallid Sturgeon Framework” and “the monitoring of IRC as outlined in Appendix E likely will begin to provide the understanding necessary to relate habitat parameters to species performance and consequently to develop forecast models”. The ISAP also suggested that the SAMP should describe how results from monitoring of IRCs will be “related or scaled to specific Level 4 management action(s).” In response, much of the Levels 1 and 2 science that is currently being undertaken will be used to better predict survivorship benefits derived from IRC projects and progress towards increasing pallid sturgeon recruitment to age 1.

3.4 Pre- and Post-Construction Modeling and Monitoring of Existing IRC Projects

The staircase study design requires a minimum of one year of data collection prior to construction of IRC habitat at each treatment and control site and monitoring in subsequent years post construction. All planned physical and biological data at constructed and planned IRC treatment and control sites (Table 3) has been collected.

Table 3. Biological and physical data collection, by year, at IRC treatment and control sites.

Site (RM)		2016	2017	2018

	Year Constructed	Physical Data Collection	Biological Data Collection	Physical Data Collection	Biological Data Collection	Physical Data Collection	Biological Data Collection
Moberly Bend (296-302)	2017	X	X	X	X	X	X
Upper Sni Bend (320-324)	Control	X	X	X	X	X	X
Searcy's Bend (178-181)	2017	X	X	X	X	X	X
Wilhoite Bend (232-234)	Control	X	X	X	X	X	X
St Albans Bend (52-55)	TBD					X	X
Morrison Bend (110-112)	Control					X	X
Pelican Bend (10-16)	TBD					X	X
Portland Bend (112-116)	Control					X	X

3.4.1 Biological Results

The primary biological response metric used to evaluate IRC sites is CPUE of young shovelnose sturgeon. This metric provides a performance indicator for IRC projects and it is hypothesized that interception will lead to growth, survival, and recruitment if it is currently limiting pallid sturgeon population growth. As previously described, the closely related shovelnose sturgeon are used in the IRC CPUE evaluation because of low numbers of young pallid sturgeon. Shovelnose sturgeon spawn throughout the lower Missouri River and given the similarities in early-life development, the two sturgeon species are likely to exhibit similar transport, interception, and feeding behaviors which allows shovelnose sturgeon to serve as an adequate surrogate for assessing interception and habitat use at IRC locations.

A linear mixed effects model will be used to compare age-0 CPUE of sturgeon from IRC treatment and control sites. At this point in time, only two sites have been constructed and sampling has been limited to three years (Table 3), so we cannot yet determine if IRC sites yield increased catches of young sturgeon, however catches of age-0 sturgeon have occurred at IRC treatment and control sites (USACE 2019a). Catch data will continue to be collected annually from the IRC treatment and control sites as described in Section 3.3.

3.4.2 Physical Results

As previously noted in Section 3.4, post-construction monitoring with physical data has been and will be conducted annually at all IRC treatment and control sites. Assessing the physical performance of IRC projects is critical to understanding if the physical aspects of the projects are performing as designed. Assessing and quantifying the changes to the metrics of interception/capture of young-of-year sturgeon (interception potential), the acreage of defined food and foraging habitat, and the acreage of habitat with various depths and velocities will determine if BSNP structure modifications have improved conditions for the survival of young sturgeon.

IRC projects consist of modifying the configuration and crest elevations of BSNP structures to block and direct a portion of the flow in the main channel into the channel margin area of the IRC. While the bedform in the main channel is expected to change minimally, the bedform in the channel margin is expected to change due to increased flow and eventually reach a semi-stable condition called the Predicted Final State (PFS). The rate of bedform change is dependent on the discharge in the river with high discharge rates leading to more rapid change. The blocked flow is expected to contain drifting free embryos that are also directed into the channel margin

area and then have an opportunity to settle out in the channel margin where the increased flow has diversified the aquatic habitat.

To date, two existing treatment sites (Moberly Bend and Searcy Bend) and their respective control sites (Upper Sni Bend and Wilhoite Bend), constructed during 2017, have been analyzed using data collected in 2018. As additional sites are constructed similar analyses will occur annually. The following is a brief summary of the highlights of the 2018 physical monitoring program as it relates to development of IRC habitat.

Bed elevation data were used to create topographical maps of the bed at each IRC and respective control bend. For the treatment sites, the 2018 maps were compared against their respective PFS topographic map and pre-construction topographic map to determine the current status of the bed (Figure 11). The PFS maps were developed during design and are based on extensive field experience with similar types of BSNP structure modifications. For control bends, where BSNP structures were not modified, the PFS is the same as the pre-construction topographic maps as these sites are not expected to change over time. The 2018 analysis shows that the treatment sites have progressed rapidly in the channel margin toward the PFS and the control sites have remained static except for normal year-to-year variation.

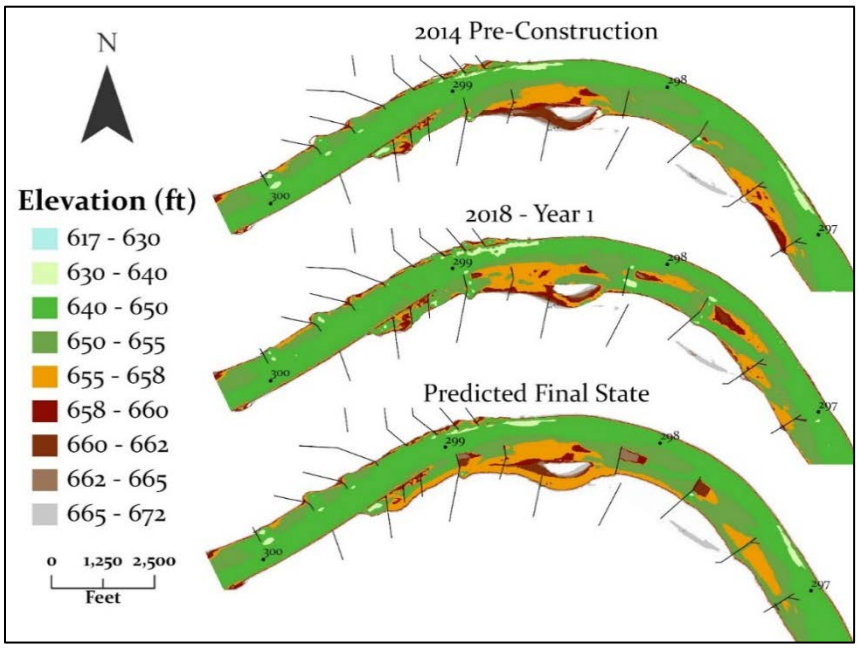


Figure 11: Bed elevations at Moberly Bend for the pre-construction condition, the 2018 condition, and the PFS condition.

Since IRC projects are designed to function over a wide range of flow conditions, changes in depths and velocities over a range of discharges must be evaluated to fully assess the physical performance of the project. For this analysis, the numeric hydraulic models developed during the design phase were updated with the 2018 depth data, calibrated with 2018 water surface elevation data, validated with 2018 velocity data, and used to replicate depths and velocities at a variety of discreet discharges. Figure 12 is an example of model outputs for depths and velocities at a variety of discharges.

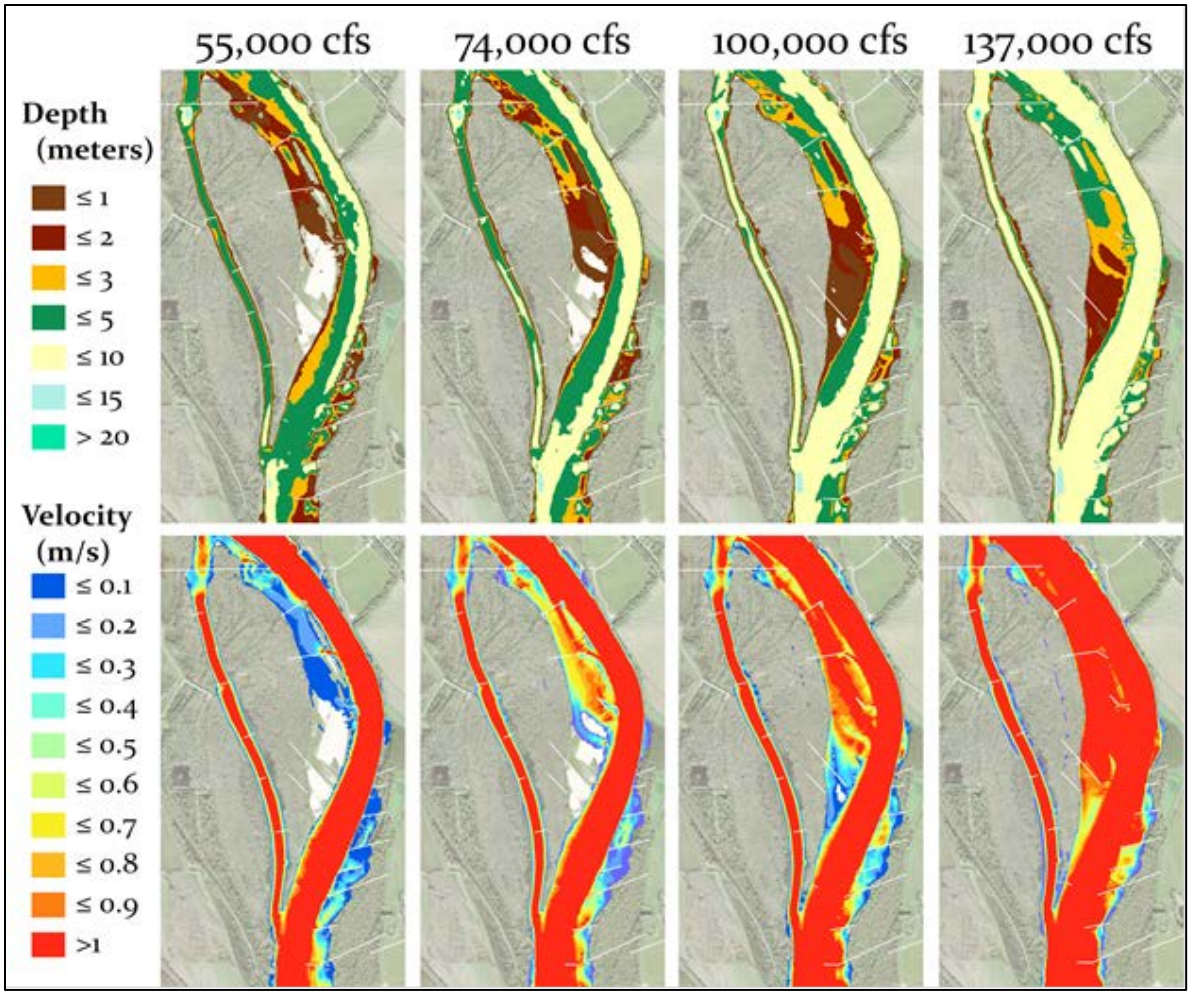


Figure 12. Depths and Velocity outputs from a numeric hydraulic model for Searcy Bend for a range of flow conditions.

An important metric, called interception potential, incorporates depth and velocity model output to simulate drifting particles that represent age-0 pallid sturgeon and is calculated by taking the percent of total particles that enter any part of the IRC channel margin area. The particle tracking model results are useful in predicting and assessing the relative change in interception potential at a particular site before and after IRC construction. It should be noted, however, the values should not be compared among IRC sites as differences in site characteristics could lead to an inaccurate comparison of interception potential among sites. Additionally, IRC projects are designed to intercept drifting particles over a range of discharges, but interception potential is only modeled at the median discharge during the larval drift period. As more information is learned regarding behavior and interception of young sturgeon the model will be updated to account for this new information and modeling at a range of discharges could become more useful in IRC site design.

Current results indicate that interception potential at the two treatment bends has increased from the pre-construction condition and surpassed the PFS condition. This is likely due to over-scour depths greater than what was assumed for the PFS condition in the channel margin areas. Both IRC projects are in a transitional geomorphic development period and interception

potential will change as the sites continue to mature towards a dynamic equilibrium. This, however, is not a source of concern as these areas are being closely monitored (both the channel margin and the main channel) to ensure the site develops as anticipated and there are minimal impacts to stakeholders.

Table 4. The modeled percent interception at the larval drift period median discharge at Moberly Bend and Searcy Bend IRC treatment sites before construction, at the predicted final state, and the 2018 condition.

Site (RM)	Pre-Construction	Predicted Final State	2018 Modeled
Moberly Bend (296-302)	25	36.7	44
Searcy's Bend (178-181)	14	18.1	25

Other metrics that incorporate velocity and/or depth are food-producing habitat (velocities less than 0.08 meters/second) and foraging habitat (1-3 meters deep with velocities between 0.5 and 0.7 meters per second). To assess changes in these metrics, the updated numeric models mentioned above were used to quantify the amount of food-producing and foraging acres available during the 2018 larval drift season (far right column in Table 5). The low values are due to above average flows during the 2018 larval drift season, which resulted in higher than optimum velocities and greater than optimum depths. Using a standardized flow hydrograph, the 2018 model, the pre-existing model, and the PFS model were then used to obtain acre values available for the exact same hypothetical flow condition (the first three columns in Table 5). Comparing these three values at each project provides the current status of these two metrics. The low 2018 numbers are due to greater than anticipated scour during the transitional phase as the bed adjusts to the BSNP modifications. These bed adjustments are being closely monitored to assure progression towards a stabilized PFS bedform. The values are expected to increase as the bed reaches the PFS bedform.

Table 5. The estimated amount (acre-days/year) of food producing and foraging habitat at Moberly and Searcy Bend IRC treatment sites. Estimates are provided for pre-construction, predicted final state, and 2018 conditions using a standardized flow hydrograph, and also provided for 2018 using the actual 2018 hydrograph.

Site	Habitat Type	Pre-Construction	Predicted Final State	2018 Modeled	2018 Actual Hydrograph
Moberly Bend (296-302)	Food Producing	589	1712	472	822
	Foraging	6891	8084	6441	2337
	Total	7480	9796	6913	3159
Searcy's Bend (178-181)	Food Producing	1657	724	1031	386
	Foraging	8008	6640	4945	4903

	Total	9665	7364	5976	5289

3.5 Ongoing and Planned IRC Research and Other, Alternative Hypotheses

Both the Effects Analysis (Jacobson et al. 2016) and SAMP (Fischenich et al. 2018) recognized the need for additional research to test hypotheses related to IRC habitat and address other competing hypotheses. For example, Jacobson et al. (2016a) wrote that the definitions for each functional component of IRC habitat were "preliminary" and "amenable to refinement as more data becomes available." Recent Levels 1 and 2 science activities further support this need as high captures of young sturgeon at known "hotspots" may change the current understanding of habitat requirements for young sturgeon and a growing body of evidence suggests that recruitment of Missouri River pallid sturgeon to age-1 is likely occurring at some level in the Mississippi River. In response, USACE has proposed multiple Levels 1 and 2 science activities to address these information gaps.

Recent studies (Hall et al. 2016; Gemeinhardt et al. 2019) have shown that young sturgeon are routinely captured from areas that do not meet the current depth and velocity criteria for the foraging component of IRC habitat. The MRRP 2018 Adaptive Management ESA Compliance Report further explored these and other data and proposed new depth and velocity criteria where captures of young sturgeon are maximized. Gemeinhardt et al. (2019) however, concluded there were no clear combination of depths and velocities associated with increased prey consumption and empty stomachs were rare. In the recent review of the MRRP 2018 Adaptive Management ESA Compliance Report, the ISAP addressed both of these concerns and advised that IRC treatment sites should be constructed using habitat definitions based on the best available science and further suggested that available scientific evidence may not support the hypothesis that young sturgeon are starving to death (ISAP 2019). The ISAP (2019) also suggested analyses that may provide additional clarity regarding potential starvation. In response, USACE intends to continue ongoing diet studies of young sturgeon and undertake the analyses recommended by the ISAP, subject to availability of appropriated funds. This and other information will be used to further evaluate the IRC hypotheses and, if necessary, adjust the metrics and targets that define IRCs following the process described in the SAMP (section 2.5.2.2; Fischenich et al. 2018).

As mentioned above, opportunistic "hotspot" sampling (known areas of high catch for young sturgeon) has been conducted in the past and this will become a primary focus for future research. Studying "hotspots" provides the opportunity to gain insights into IRC processes and begin to assess if a lack of interception or retention currently limits survival of young sturgeon. Studies to address these questions will be initiated in FY19 with the primary objective to better understand the interception process. Other secondary objectives will be evaluated, including a comparison of the relative condition and/or prey consumption of intercepted and non-intercepted young sturgeon and an attempt to determine the best suite of physical characteristics to describe young sturgeon foraging habitat. Additional Levels 1 and 2 science studies, using hatchery-reared young sturgeon, are planned to refine existing models and further understand the interception and retention processes at IRC or "hotspot" locations. This information can then be used to update IRC metrics or propose other biologically-relevant and cost-effective management actions to accomplish pallid sturgeon objectives while minimizing impacts to human considerations.

While IRC habitat is intended to increase survival of young sturgeon in the lower Missouri River, another potential hypothesis is that young sturgeon from the Missouri River enter the Mississippi River where they grow and develop. Collections of pallid sturgeon approximately 2-3 weeks old in 2014 and 2018 confirm that successful reproduction is occurring on the lower Missouri River. Other research has also suggested that wild adult catches in the Lower Missouri River have remained steady for the 16-year monitoring period and new wild fish (fish which have not been previously captured) comprise much of the catch of wild adults each year. It has been estimated that 8% of the pallid sturgeon present in the Lower Missouri River are the result of natural recruitment (Kirk Steffensen, Fall Science Meeting presentation). Despite these factors, monitoring efforts have failed to capture wild-origin, 1-3 year old pallid sturgeon on the Missouri River but routinely capture wild-origin adult pallid sturgeon. This information, coupled with young sturgeon drift models completed as part of the Effects Analysis, suggests that a substantial number of pallid sturgeon produced in the Missouri likely drift into the Mississippi River. Therefore, understanding the role that the Mississippi River plays in the life history of lower Missouri River pallid sturgeon is necessary to aid in evaluating the effectiveness of actions undertaken on the Missouri River to benefit young pallid sturgeon. Engagement with USACE and USFWS staff who conduct studies on the Mississippi River will be a high priority in upcoming years to ensure data needed to address these questions are being collected.

4.0 Conclusion

This report fulfills the requirements set forth in Section 1226 of the America's Water Infrastructure Act of 2018 requiring the Secretary to submit a report to US Congress regarding the impacts of Interception and Rearing Complex (IRC) habitat construction on navigation, flood control, and other authorized purposes set forth in the Missouri River Master Water Control Manual (Master Manual) and on the population recovery of endangered pallid sturgeon.

As described in this report, IRCs will not change the water regulation guidelines outlined in the Master Manual and IRC project sites are routinely monitored to ensure BSNP authorized purposes are being met. The post-construction monitoring, conducted at the two existing IRC sites, confirmed that the navigation channel remains essentially unchanged from pre-project conditions, and that flow patterns remain unchanged within the navigation channel. Further analyses and monitoring results have demonstrated that IRC construction, to date, has had no measureable change to water surface elevations that would impact flood risk management. It should also be noted that if an IRC construction project adversely impacts any Missouri River authorized purpose, actions will be taken to rectify the problem.

USACE is also assessing the benefits of IRC projects to pallid sturgeon by determining if IRC habitat can increase catch of young sturgeon. Only two of the necessary twelve IRC study sites have been constructed and sampling has only occurred for 1 – 3 years. Therefore USACE cannot yet determine if IRC sites have increased catch of young sturgeon but physical monitoring of two constructed IRC sites indicates the anticipated physical changes believed to improve interception are occurring as intended in the project design. Furthermore, USACE is engaged in additional studies to assess the benefits of IRC projects to pallid sturgeon. As part of this, other alternative hypotheses that may result in successful recruitment of pallid sturgeon are being evaluated. Through effectiveness monitoring and applying adaptive management to IRC construction, refinement of the temporal and physical aspects of implementation of these habitat actions are anticpated. This approach provides a cost-effective and biologically beneficial means of addressing the ESA requirements of pallid sturgeon. Ongoing monitoring will also ensure these actions do not negatively impact water management in the basin and the congressionally authorized purposes, including navigation.

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6.0 Appendices