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Environmental Laboratory

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Engineer Research and Development Center

Draft Version 6
Science and Adaptive Management Plan
Appendices and Attachments

Missouri River Recovery Program

Draft/Pre-decisional/For Review and Comment

December 2016

Draft Document for Review

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Draft Version 6

Science and Adaptive Management Plan

Appendices and Attachments

Missouri River Recovery Program

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Abstract

The Missouri River Recovery Program (MRRP) is undergoing a transformation resulting from 2011 recommendations by an Independent Science Advisory Panel and the Missouri River Recovery Implementation Committee (MRRIC). An Effects Analysis study established the best available scientific information and provided the foundation for an Adaptive Management Plan (AM Plan) that addresses lingering uncertainties and improves management decisions while implementing actions that avoid jeopardizing the three federally listed species in the system. This draft AM Plan includes a process for resolving critical uncertainties using a framework consisting of four implementation levels: 1) research, 2) in-river testing of hypotheses, 3) scaled implementation of select management actions, and 4) full implementation. The decision criteria for moving to higher levels of implementation are included. A NEPA evaluation of alternative management actions identified an initial suite of actions that will be implemented to meet the objectives of the MRRP. This Draft AM Plan accompanies the Draft Missouri River Recovery Management Plan-Environmental Impact Statement and provides the roadmap for the implementation of the selected alternative and for the identification of subsequent management needs should the initial suite of actions fail to meet objectives. The AM Plan will be implemented collaboratively by the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, and MRRIC following the governance process outlined in the AM Plan.

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Preface

These appendices accompany the Draft Adaptive Management Plan (AM Plan) for the Missouri River Recovery Program (MRRP). Further revision of this document is planned. A finalized draft will be submitted along with the draft Missouri River Recovery Management Plan-Environmental Impact Statement (MRRMP-EIS) in 2017.

The purpose of this draft is not to convey a determined suite of actions for adaptive management (AM) but rather to present AM concepts, methods and decision criteria that might be employed in the final AM plan. Alternative suites of actions and associated research are being evaluated under the National Environmental Policy Act (NEPA) as part of the MRRMP-EIS. The outcome of the NEPA process will be a selected alternative which, in conjunction with Endangered Species Act (ESA) Section 7 consultation outcomes, will constitute the actions for immediate implementation.

The authors have utilized the actions included in the draft EIS (DEIS) to illustrate the concepts, methods and decision criteria necessary to an AM Plan for the MRRP. These actions include those proposed in Planning Aid Letters (PALs) from the U.S. Fish and Wildlife Service (USFWS). Discussion of these actions in this draft report does not constitute selection of any potential actions; their inclusion is merely to help demonstrate how AM might be implemented for various actions. The final AM Plan will be based on the selected alternative in the Record of Decision.

Some details regarding the AM Program will be determined or refined through ongoing interactions with the agencies, stakeholders, and independent reviewers. Recognizing these limitations, it is intended that this draft provides sufficient insight into the scope and nature of the MRRP AM Plan that reviewers can fairly evaluate the plan, offer constructive comments and engage in discussions regarding improvements to be incorporated into the final AM Plan.

We gratefully acknowledge the many people who contributed to this draft. Robb Jacobson of the USGS and the Pallid Sturgeon EA Team, in particular, provided monumental assistance in the development of these appendices. We would like to acknowledge contributions to key sections of this work and technical reviews provided by the other two Effects Analysis Teams; Clayton Ridenour, Mary Roth, Mark Harberg and Aaron Quinn of the USACE Omaha District; and Casey Kruse, Wayne Nelson-Stastny, and Carol Smith of the USFWS. Technical reviews and comments were provided by Chantel Cook, Coral Huber, Brad Thompson, and Tim Welker of the USACE; Wyatt Doyle, Rob Holm, Steven Krentz, Landon Pierce, Dane Schuman and Ryan Wilson of the USFWS; David Adams, Justin Haas, Gerald Mestl and Kirk Steffensen of the Nebraska Game and Parks Commission; the Upper Bain Pallid Work Group; Michelle Klose, on behalf of a consortium of state representatives; and several members of the AM ad hoc

Task Group and MRRIC members at large. Natascia Tamburello of ESSA provided assistance in editing and formatting the appendices.

Unit Conversion Factors

Multiply	By	To Obtain
acres	4,046.873	square meters
acre-feet	1,233.5	cubic meters
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
foot-pounds force	1.355818	joules
gallons (U.S. liquid)	3.785412 E-03	cubic meters
hectares	1.0 E+04	square meters
inches	0.0254	meters
inch-pounds (force)	0.1129848	newton meters
microns	1.0 E-06	meters
miles (nautical)	1,852	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
ounces (mass)	0.02834952	kilograms
pounds (force)	4.448222	newtons
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic meter
pounds (mass) per square foot	4.882428	kilograms per square meter
pounds (mass) per square yard	0.542492	kilograms per square meter
square feet	0.09290304	square meters
square inches	6.4516 E-04	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
tons (force)	8,896.443	newtons
tons (long) per cubic yard	1,328.939	kilograms per cubic meter
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

Acronyms and Abbreviations

AAMR	Annual Adaptive Management Report
AAR	After Action Report
AM	Adaptive Management
ANOVA	Analysis-of Variance
API	Application Program Interface
AWP	Annual Work Plan
BA	Before-After
BACI	Before-After-Control-Impact
BiOp	Biological Opinion
BSNP	Missouri River Bank Stabilization and Navigation Project
CEM	Conceptual Ecological Model
CEP	Critical Engagement Point
cfs	Cubic Feet per Second
CI	Confidence Interval
CJS	Cormack-Jolly-Seber
CORE	Cooperating for Recovery Team
CPUE	Catch Per Unit Effort
CWA	Clean Water Act
CWT	Coded Wire Tag
DOI	Department of the Interior
DQO	Data Quality Objectives
EA	Effects Analysis
EIS	Environmental Impact Statement
ERDC	Engineer Research and Development Center
ESA	Endangered Species Act
ESC	Executive Steering Committee
ESH	Emergent Sandbar Habitat
FWG	Federal Working Group
HAMP	Habitat Assessment and Monitoring Program
H&H	Hydrology and Hydraulics
HQUSACE	Headquarters of the U.S. Army Corps of Engineers
IDM	Information Data Management
IP&S	Integrated Planning and Science
IRCs	Interception and Rearing Complexes

ISAP	Independent Science Advisory Panel
ISETR	Independent Social Economic Technical Review Panel
ISP	Integrated Science Program
ISPMT	Integrated Science Program Management Team
kcfs	thousand cubic feet per second
Master Manual	Missouri River Basin Mainstem Reservoir System Master Water Control Manual
Mitigation ACT	Mitigation Project Agency Coordination Team
MRBWMD	Missouri River Basin Water Management Division
MRRIC	Missouri River Recovery Implementation Committee
MRRMP	Missouri River Recovery Management Plan
MRRRP	Missouri River Regional Review Panel
MRRP	Missouri River Recovery Program
NEPA	National Environmental Policy Act
NRC	National Research Council
NWD	Northwestern Division
NWO	Omaha District
NWK	Kansas City District
O&M	Operation and Maintenance
PDT	Project Delivery Team
PIR	Project Implementation Report
PIT	Passive Integrated Transponder
PM	Program or Project Manager
PNNL	Pacific Northwest National Laboratories
PrOACT	Problem Definition, Objectives, Alternatives, Consequences, Tradeoffs
PSPAP	Pallid Sturgeon Population Assessment Program
QA/QC	Quality Assurance and Quality Control
QAPP	Quality Assurance Project Plan
Reclamation	U.S. Bureau of Reclamation
RM	River Mile
ROD	Record of Decision
RPA	Reasonable and Prudent Alternative
RPM	Reasonable and Prudent Measure
RPMA	Recovery Priority Management Area
SAM	Science and Adaptive Management workgroup
SPA	Strategic Programmatic Assessment task group
SPDT	Senior Project Delivery Team
SWH	Shallow Water Habitat

System	Missouri River Mainstem Reservoir System
TBD	To Be Determined
T&E	Threatened and Endangered
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WG	Working Group
WRDA	Water Resources Development Act

Glossary

Active adaptive management – The active form of adaptive management employs management actions in an experimental design aimed primarily at learning to reduce uncertainty; near-term benefits to the resource are secondary.

Adaptive action – A course of action to be implemented as defined in the Adjust step (Step 5b of the Adaptive Management (AM) process) if the performance of a particular management action is not as anticipated and requires correction. In cases where the action is pre-defined, it is referred to as a "contingency action".

Adaptive Management (AM) – Adaptive management is a decision process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process.

Alternatives –A specified combination of management actions that collectively are deemed to meet minimum performance levels for the endangered species. In the Problem Definition, Objectives, Alternatives, Consequences, Tradeoffs (PrOACT) process, the trade-offs associated with various alternatives on multiple interests are explored in order to find the alternative(s) that minimize unnecessary negative impacts and is/are otherwise thought to be the best balance of impacts on a wide range of interests. Alternatives are used to address the objectives.

AM Report – Annual or periodic report that documents new learning based on monitoring results, evaluates progress towards meeting species objectives, and contains recommendations for adjustments to management actions. The Annual AM Report is contained with the Annual Report on Biological Opinion (BiOp) compliance.

Annual Work Plan (AWP) – This document includes real estate actions, habitat creation actions, monitoring of physical and biological responses to actions, and research activities. It is used by product delivery teams to implement management actions annually.

Biological Opinion (BiOp) – Document stating the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) opinion as to whether a Federal action is likely to jeopardize the continued existence of a threatened or endangered species or result in the destruction or adverse modification of critical habitat. Specifically in the MRRP, the USFWS 2000 Biological Opinion (BiOp) found that the operation of the Missouri River Mainstem Reservoir System and Missouri River Bank Stabilization and Navigation Project (BSNP), as proposed by the Corps, would likely

jeopardize the continued existence of three federally listed species: the piping plover, least tern, and pallid sturgeon. The BiOp was amended in 2003 to note that, with additional mitigated actions proposed by the Corps, operation of the System and the BSNP would not likely jeopardize terns and plovers, but would jeopardize pallid sturgeon. In this document, the amended BiOp is referred to as the USFWS 2003 Amended Biological Opinion.

Conceptual Ecological Models (CEMs) – CEMs are graphical depictions of an ecosystem that are used to communicate the important components of the system and their relationships. They are a representation of the current scientific understanding of how the system works.

Contingency action – A pre-evaluated adaptive action that is implemented when triggered by defined decision criteria without the need for further deliberation or decision.

Critical uncertainties – Uncertainties that impede the identification of a preferred alternative management action.

Critical Engagement Point (CEP) – Specific points in the formulation or implementation phases of adaptive management when the agencies engage with the Missouri River Recovery Implementation Committee (MRRIC) for input. These can be concurrent with, or in addition to, routine MRRIC plenary meetings.

Decision criteria – Broadly refers to the set of pre-determined criteria used to make AM decisions. Performance metrics, targets, and decision triggers are considered to be different types of decision criteria. They can be qualitative or quantitative based on the nature of the performance metric and the level of information necessary to make a decision.

Decision space – A term used to characterize a range of operational discretion for flows (or potentially other actions) that is “acceptable” to stakeholders, effective in achieving objectives, and within the bounds of actions evaluated under NEPA. Management actions would generally occur within this region and any operation outside this decision space would require further coordination and approval.

Decision trigger – Decision triggers are pre-defined commitments (population or habitat metric for a specific objective) that trigger a change in a management action. Decision triggers are addressed in the Evaluate step (Step 4 of the AM process) specifying the metrics and actions that will be taken if monitoring indicates performance metrics are or are not reaching target values. In some cases a decision trigger may be learning a new piece of information that triggers the Continue/Adjust/Complete step (Step 5 of the AM process).

Delphi process – The Delphi process is a method of eliciting expert opinion (Normand et al. 1998). While many variations of the process exist, there are generally three common features: 1) qualified experts provide their responses to a set of questions in a structured format; 2) the answers to these questions are synthesized across all respondents and presented back to the same set of experts; and 3) the experts jointly discuss the reasons for variation in the first set of responses (or lack thereof), and through dialogue potentially revise their opinions. A modified Delphi process was applied by Jacobson et al. (2016b) to prioritize candidate hypotheses.

Effects Analysis (EA) – The purpose of this effort is to conceptually and quantifiably make explicit the effects of operations and actions on the listed species by specifically evaluating the effects of hydrologic and fluvial processes on the Missouri River, as well as ongoing management actions under the USFWS 2003 Amended Biological Opinion and other Mitigation actions, on the status and trends of the listed species (piping plover, interior least tern, and pallid sturgeon) and their habitats.

Environmental Impact Statement (EIS) – A document which summarizes and analyzes environmental impacts of a proposed action and alternatives.

Evaluation – Conduct analyses to compare measured results with anticipated outcomes related to decision criteria for specific management actions to determine whether the implementation should be continued, adjusted, or completed.

Event-driven reporting cycle – In addition to the annual and periodic AM reports (on a routine reporting schedule), reporting may also be event-driven, where new observations or data resulting from an unforeseen event suggest a decision trigger or targets have been reached.

First increment – The suite of proposed actions in the Management Plan that are collectively anticipated to “avoid jeopardy” in the foreseeable future (~10 – 15 years). The First Increment will include actions for pallid sturgeon for Levels 1 through 3 of the Lower Pallid Framework to ensure NEPA coverage for future implementation.

Fundamental objectives – Fundamental objectives are used to formalize the desired outcome of the program in terms of biological response. They are derived to achieve avoidance of jeopardizing the three species from USACE actions on the Missouri River and articulate the ends the program is trying to achieve.

Global hypotheses – Set of possible, biologically important hypotheses, relevant to population dynamics that are derived from conceptual ecological models.

Human considerations – A set of objectives with associated metrics and proxy metrics that are related to the wide array of uses and stakeholder interests on the

Missouri River. They form the basis for some of the monitoring and decision criteria in the AM Plan.

Hypotheses reserve – A concept that seeks to explicitly manage the broad suite of hypotheses developed through the (EA) and highlighted in the CEM. In this concept hypotheses can be brought forward or moved back into reserve as information and understanding directs. The hypotheses reserve concept includes; 1) hypotheses that are not deemed important to investigate at this time, 2) have high uncertainty and require further investigation, and/or 3) are outside USACE authority.

Initially modeled hypotheses – Subset of working management hypotheses determined by USACE to be within jurisdiction and applicable authorities, and therefore selected for modeling in Phase 1 of the (EA).

Integrated Science Program (ISP) – The component of the MRRP that is responsible for conducting scientific monitoring and investigations. The ISP monitors federally listed species under the Endangered Species Act (ESA), the habitats upon which they depend, and researches and monitors critical uncertainties.

Implement – Implementation of the preferred alternative.

Implementation Level (or Level) – Refers to one of four classifications of action that could be implemented to assist pallid sturgeon as part of the MRRP (see also *Pallid Sturgeon Framework*). The levels include:

- **Level 1: Research** – 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** – A range of actions not expected to achieve full success, but which yields sufficient results in terms of reproduction, numbers, or distribution to provide a meaningful population response and indicate the level of effort needed for full implementation.
- **Level 4: Ultimate required scale of implementation** – Implementation to the ultimate level required to remove an issue.

Investigations – Research activities that are intended to generate information that will fill the key gaps in understanding and reduce uncertainty associated with implementation of management actions.

Jeopardy – As defined by the Endangered Species Act (ESA), jeopardy occurs when there is an action that reasonably would be expected, directly or indirectly, to reduce

appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.

Limiting factor – A factor that controls the growth, abundance or distribution of an organism. For example, factors that limit the survival of terns, plovers and pallid sturgeon have been identified and serve to identify and organize potential management actions.

Lower Missouri River – The reach of the river downstream of Gavins Point Dam (RM 810) as it pertains to management for pallid sturgeon

Management actions – Proposed or potential actions to be taken by the Corps to address species needs on the Missouri River. Management actions were prescribed by the USFWS 2003 Amended Biological Opinion as Reasonable or Prudent Alternatives or actions outside the BiOp if necessary to achieve species objectives.

Management hypotheses – Statements (in affirmative hypothesis form) that a specific management action will be effective in eliminating factors that are thought to be limits to population growth.

Missouri River Recovery Management Plan (MRRMP; also MRRMP-EIS or Management Plan) – A suite of management actions that avoids jeopardizing the continued existence of piping plovers, interior least terns, and pallid sturgeon, thereby permitting the continued operation of the Missouri River reservoir System and the Bank Stabilization and Navigation Program (BSNP). It includes actions proposed by the Missouri River Recovery Implementation Committee, and complies with the National Environmental Policy Act (NEPA) and other statutory mandates, regulatory requirements and authorizations. MRRMP may also refer to the three-year process to programmatically evaluate the MRRP and develop a suite of actions that meet ESA responsibilities. The Management Plan or MRRMP-EIS are umbrella terms that include the MRRMP, the Environmental Impact Statement (EIS) and the AM Plan.

Means objectives – Describe ways of achieving the fundamental objectives and specify the way and degree to which the fundamental and sub-objectives can be achieved. They are used to further develop management actions and alternatives and are potentially useful in tracking progress towards fundamental objectives in the near-term when a response in the fundamental objectives may not be detectable in shorter time frames due to a delayed species response to management actions or other reasons.

Monitoring – In the context of the MRRP-AM Plan, monitoring is the process of measuring attributes of the ecological, social, or economic system. Monitoring has multiple purposes, including: to provide a better understanding of spatial and temporal variability, to confirm the status of a system component, to assess trends in a system component, to improve models, to confirm that an action was implemented as planned,

to provide the data used to test a hypothesis or evaluate the effects of a management action, and to provide an understanding of a system attribute which could potentially confound the evaluation of action effectiveness.

MRRP Adaptive Management Plan – The purpose of this Adaptive Management (AM) Plan is to describe a formal AM process led by the U.S. Army Corps of Engineers (USACE) and U.S. Fish and Wildlife Service (USFWS) in implementing the Missouri River Recovery Program (MRRP or Program).

National Environmental Policy Act (NEPA) – Requires federal agencies to integrate environmental values into their decision-making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions. To meet NEPA requirements federal agencies may be required to prepare a detailed statement known as an Environmental Impact Statement (EIS).

Objectives – Objectives define an endpoint of concern and the direction of change that is preferred. Objectives are concise statements of the interests that could be affected by a decision — the "things that matter" to people. In Problem Definition, Objectives, Alternatives, Consequences, Tradeoffs (PrOACT,) objectives typically take a simple form such as; minimize costs, increase population number, increase habitat availability.

Pallid Sturgeon framework– An organization of Missouri River Pallid hypotheses that allows for the description of activities (research to management actions), decision criteria, uncertainty, risk, impacts, costs, time frame and constraints.

Passive adaptive management – In passive AM, management actions are directed primarily at achieving resource objectives and those actions are improved using knowledge gained from monitoring and assessment.

Performance metric – A specific metric or quantitative indicator that is monitored and can be used to estimate and report consequences of management alternatives with respect to a particular objective. There are specific species, habitat, and economic performance metrics in this Adaptive Management Plan.

Problem – A question or concern that is being addressed in the decision making process.

Program – The "Program" refers to those elements that are at the level of the overall Missouri River Recovery Program such as the Annual Work Plan (AWP) and the Program Management Plan.

Project Implementation Report – Contains site-specific information, alternative designs and project features, the anticipated benefits of the project, and documentation

for compliance with the National Environmental Policy Act (NEPA) disclosing the potential affects to the quality of the human environment from project implementation.

Proxy metric – Type of performance metric. Generally a proxy metric is an indirect metric used to represent a natural metric like population number (e.g., number of boat ramp days). Proxy criteria are those that correlate well with objectives that are otherwise difficult to measure or estimate.

Quantitative predictive models – Numerical models used to predict biological and ecological responses as a function of management or restoration actions.

Risk – An uncertainty coupled with an adverse consequence; ideally expressed as the product of the two components, with uncertainty represented as a probability.

Species objectives – see fundamental and means objectives.

Strategy table – A visual tool for combining management actions into thoughtfully crafted alternatives.

Structured Decision Making (SDM) – Organized approach to identifying and evaluating creative options and making choices in complex decision situations. It is used to inform difficult choices, and to make them more transparent and efficient. PrOACT is a specific application of SDM to collaborative problem solving employed by USACE in the development of the Missouri River Recovery Management Plan.

Sub-objectives – The sub-objectives are aspects of the fundamental objective described in more detail that need to be addressed to achieve the fundamental objective. They are intended to provide direction in the short term, provide objectives meaningful for adaptive management, and focus efforts on the desired short-term outcomes while contributing to the fundamental objective.

Success criteria – A qualitative or (preferably) quantitative description of the conditions for which the parties agree that the objectives have been sufficiently met. Usually expressed in terms of the performance metrics.

Target – Targets are a specific value or range of performance metric that define success. Targets can be quantitative values or overall trends (directional or trajectory).

Trade-offs (also Trade-off analysis) – A trade-off is when one alternative performs well on one metric but poorly on another relative to another alternative. Reasonable people may disagree about which is the best alternative because they value the two metrics differently, thus value trade-offs involve making judgments about how much you would give up on one objective in order to achieve gains on another objective. By analyzing trade-offs, the PrOACT process tries to help find the alternative a) that

eliminates unnecessary trade-offs and b) that people agree is the 'best balance' of trade-offs possible.

Trigger – A form of decision criteria serving as a threshold or condition that, when met, initiates some action or decision.

Uncertainty – Circumstances in which information is deficient. Leaning while doing under the adaptive management process provides a framework for reducing program uncertainties over time.

Upper Missouri River – Mainstem of the Missouri River between Fort Peck Dam and the headwaters of Lake Sakakawea, and the Yellowstone River for an unspecified distance upstream of the confluence with the Missouri River.

Variability – A measure of how much a set of conditions differs from the mean or median state.

Working dominant hypotheses - Set of plausible, biologically important hypotheses, relevant to population dynamics of pallid sturgeon. Derived from importance values in conceptual ecological model, scored by expert elicitation survey.

Working management hypotheses - Set of management hypotheses linking management actions to working dominant hypotheses. Derived from pathways identified in conceptual ecological models and matched to working dominant hypotheses. Scored by expert elicitation survey.

Appendix A. Attachments

Note: This is an incomplete draft document. It has not received a substantive technical, policy or editorial review, and is being circulated for Agency review and comment prior to general release on May 25, 2016. Please see the Preface for related caveats. Comments or suggestions should be provided to the lead author at Craig.J.Fischenich@usace.army.mil

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Missouri River Recovery Implementation Committee Charter

July 1, 2008
(as amended August 14, 2014)

Preamble

The Secretary of the Army (Secretary) hereby establishes the Missouri River Recovery Implementation Committee (Committee) as authorized by Section 5018 of the 2007 Water Resources Development Act (WRDA) to make recommendations and provide guidance on a study of the Missouri River and its tributaries and on the existing Missouri River recovery and mitigation plan. The Committee will provide a collaborative forum for the basin to come together and develop a shared vision and comprehensive plan for Missouri River recovery. The Committee will help guide the prioritization, implementation, monitoring, evaluation, and adaptation of recovery actions. The Committee will include broad stakeholder representation to ensure a comprehensive approach to Missouri River recovery implementation while providing for congressionally authorized Missouri River project purposes and to ensure that public values are incorporated into the study and the recovery and mitigation plans.

I Purpose and Scope

a) The Purpose and Scope of the Committee are to:

i. Provide recommendations and guidance on a study of the Missouri River and its tributaries to determine actions required to:

1) Mitigate losses of aquatic and terrestrial habitat

2) Recover federally listed species under the Endangered Species Act of 1973

3) Restore the ecosystem to prevent further declines among other native species

ii. Provide guidance with respect to the existing Missouri River mitigation and recovery plan, including recommendations on:

1) Changes to the implementation strategy as a result of adaptive management

2) Coordination of the development of consistent policies, strategies, plans, programs, projects, activities, and priorities for the Missouri River recovery and mitigation plan

3) Exchange of information regarding programs, projects, and activities of the agencies and entities represented on the Committee to promote the goals of the Missouri River recovery and mitigation plan

4) Establishment of such working groups as the Committee determines to be necessary to assist in carrying out the duties of the Committee, including duties relating to public policy and scientific issues

5) Facilitation of the resolution of interagency and intergovernmental conflicts between entities represented on the Committee associated with the Missouri River recovery and mitigation plan

6) Coordination of scientific and other research associated with the Missouri River recovery and mitigation plan

7) Preparation of an annual work plan and associated budget requests

iii. Provide recommendations and guidance that will include:

1) Recognition of local stakeholders' social and economic, historical and cultural, flood control, irrigation, agriculture, internal drainage, water supply, water quality, navigation, hydropower, thermal power, science, natural resources, conservation, and recreation issues, and any other issues identified by the Committee

2) Identification of impacts to stakeholders

3) Identification of actions that will benefit multiple uses of the river

4) Avoidance, minimization, and/or mitigation of adverse impacts

b) Participation in the Committee by Tribal entities does not substitute for nor replace federal requirements to consult with Tribal entities pursuant to federal laws and regulations, such as: Executive Order 13175, Tribal Consultation; any federal agency's trust responsibilities to a federally recognized tribe in the Missouri River Basin or a tribe that has historically been on the Missouri River; and/or replace any treaty or right thereof such as: the Portage des Sioux Treaty (July 1815); the Treaty of Ft. Laramie, 11 Stat. 749 (Sept 17, 1851); the Treaty with the Omaha, 10 Stat. 1043 (March 16, 1854); the Treaty of Ft. Laramie, 15 Stat. 635 (April 29, 1868); Title VI-Cheyenne River Sioux Tribe, Lower Brute Sioux Tribe, and State of South Dakota Terrestrial Wildlife Habitat Restoration Act of the Omnibus Consolidated and Emergency Appropriations Act of 1999, PL 105-277, 112 Stat. 2681, 2861-660-670 (October 21, 1988), as amended by Title IV of the Water Resources Development Act of 1999, PL 106-53, 113 Stat 269, 385-397 (August 17, 1999), and as otherwise amended; and any other treaty or right. Cooperation with the federally recognized tribes engaged in this process should be interpreted as "in good faith."

c) Participation in the Committee by State, Tribal, or Federal entities does not limit their discretion; alter, affect, impair, delegate, or relinquish their

statutory or other legal rights and responsibilities, including any right to legal remedies; or otherwise waive their sovereign immunity under applicable law; create any new right to any type of administrative review or create any new right to judicial review or any other right or benefit, substantive or procedural, enforceable by or against these entities or any other stakeholder participating in the Committee; and affect Tribal reserved water rights, treaty rights, or water rights administered by the Tribes and/or States, including the "Winters' Doctrine", Winters v United States, 207 U.S. 564 (1908). If the processes and procedures of the Committee would impede the implementation of any action for which agencies of the States, Tribes, or United States are obligated under law, that agency reserves the right to proceed with fulfilling those obligations in such manners as it may deem appropriate.

d) Participation in the Committee by State, Tribal, or Federal entities is also contingent upon availability of funding or appropriation by their respective State, Tribal, or Federal authorities, and their participation does not obligate any specific amount of expenditures in furtherance of this Charter; such expenditures being at the discretion of the State, Tribal, or Federal entity.

II Convening Authority

The Committee is convened under the authority of Section 5018 of the Water Resources Development Act of 2007.

III Definitions - Glossary of Terms and Acronyms

a) Adaptive Management: A type of natural resource management in which decisions are made as part of an ongoing science-based process. Adaptive management involves testing, monitoring, and evaluating applied strategies and incorporating new knowledge into management approaches that are based on scientific findings and the needs of society. Results are used to modify management policy, strategies, and practices. The purpose of adaptive management is to help meet environmental, social, and economic goals, increase scientific knowledge, and reduce tensions among stakeholders. (Source: Adapted from Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management and the U.S. Department of the Interior Technical Guide)

b) Consensus: All non-federal members of the Committee can support or live with an action or recommendation when quorum requirements are met.

c) Guidance: The process by which recommendations are used to inform appropriate agencies about Missouri River recovery-related activities.

d) Lead Agency: The U.S. Fish and Wildlife Service (USFWS), the U.S. Army Corps of Engineers (Corps of Engineers), and other agencies as necessary for specific issues.

e) In Good Faith: The sincere intention to deal fairly and equitably with Tribes and others, without deception. The willingness of all Committee members to interact openly, honestly, and respectfully with all other members.

f) Meeting: A gathering of the Committee lasting one or more partial or full days, as defined in the Committee's operating procedures and guidelines.

g) Mitigation: This sequential process includes (a) avoiding the impact altogether by not taking a certain action or parts of an action; (b) minimizing impacts by limiting the degree or magnitude of the action and its implementation; (c) rectifying the impact by repairing, rehabilitating, or restoring the affected human or natural environment; (d) reducing or eliminating the impact over time by preservation and maintenance operations during the life of an action; (e) compensating for the impact by replacing or providing substitute resources or environments. (Source: Adapted from the Council on Environmental Quality, 40 CFR 1508.20)

h) Participating Agency: Federal agencies involved in the Committee process other than the USFWS or Corps of Engineers unless designated as a lead agency for a specific issue.

i) Plan: The Missouri River recovery and mitigation plan referenced in Section 5018 (B)(3)(b) of the Water Resources Development Act of 2007.

j) Public Notice: Notice given to members of the public at least thirty (30) days prior to an event. It shall include but not be limited to written notice given by e-mail and by regular mail to:

i. All members of interest groups who shall sign up to receive notice

ii. Persons who have been designated by members of the Committee to receive notice

iii. Newspapers and radio stations generally covering the basin and to four (4) specific newspapers recommended by members of the Committee

k) Quorum: A quorum shall consist of those Committee state representatives and those Committee tribal representatives who are present at the meeting and 51% of the stakeholders as identified in Section 5(a)(v), who are at the time appointed to the Committee.

l) Recommendations: Official suggestions, comments, or advice representing the consensus of the Committee and provided to the appropriate governmental or non- governmental agencies, groups, or persons.

m) Recovery: Improvement in the status of a species listed under the Endangered Species Act to the point that it is not likely to be in danger of extinction in the foreseeable future throughout all or a significant portion of its range. (Source: Adapted from USFWS Regulations and the Endangered Species Act)

n) Restoration: To fully or partially reestablish the attributes of a naturalistic, functioning, and self-regulating system. (Source: Engineer Pamphlet 1165-2-502: Ecosystem Restoration - Supporting Policy Information, USACE)

o) Secretary: Pursuant to 10 USC 3016(b)(3), the Assistant Secretary of the Army for Civil Works shall act for the Secretary of the Army for the purposes of this Charter.

p) Stakeholder: Any organization or individual that has a direct interest in actions or decisions of the Missouri River restoration, recovery and mitigation plan, or study. For the purposes of Section 5 of this Charter, representatives of Federal Agencies, Tribes, and States are not considered stakeholders. In the appointment process, all things being equal, preference will be given to residents of, or organizations located in or adjacent to, the basin.

q) Study: The study referenced in Section 5018 (a) of the Water Resources Development Act of 2007.

r) Substantive Issue: An issue for which the Committee is considering developing recommendations and other decisions identified as substantive in the Committee's operating rules and procedures.

IV Charter Amendment

The Committee may propose amendments to the Charter in accordance with its decision making process. Public notice will be given and public comments will be received prior to the Committee recommending the amendment to the Secretary for final adoption.

V Membership and Representation of Interests

a) Members and Alternates

i. The Secretary will maintain a list of the members and

alternates of the Committee.

b) Federal Agencies

i. Federal agencies with programs affecting the Missouri River may be members of the Committee. Federal agency membership may include those agencies currently represented on the Missouri River Basin Interagency Roundtable (MRBIR) and any other federal agency designated by the Secretary. This includes federal agencies with management responsibilities, jurisdiction by law, regulatory authorities, technical expertise, and/or resource responsibilities affecting the Missouri River. To initiate the Committee, the lead agencies will be the U. S. Army Corps of Engineers and the U. S. Fish and Wildlife Service. Participating federal agencies may include the Bureau of Reclamation, Natural Resource Conservation Service, Environmental Protection Agency, Western Area Power Administration, United States Geological Survey, Maritime Administration, the National Park Service, and any other agency designated by the Secretary.

ii. Federal agencies will not be counted for purposes of Committee quorum requirements and will not participate in the determination of consensus recommendations.

iii. Federal agencies that wish to participate in the Committee will inform the Secretary of their agency's interest, explaining why they wish to be involved, and provide the name of their Committee representative and an alternate.

iv. Lead Federal Agencies will be represented on the Committee by officials at the Senior Executive Service (SES) level or their deputies. Lead Federal Agency representatives will participate fully and completely in all Committee meetings and any sub-committees or panels formed by the Committee.

v. Participating Federal Agencies will be represented by officials appointed by their respective agencies. These representatives will be available to answer questions, provide information, and state their opinions and recommendations at Committee meetings (including any subcommittees and panels) on recommendations directly affecting the Participating Federal Agency's management or resource responsibilities, jurisdiction by law, or regulatory authorities.

vi. Participating Federal Agencies will be able to participate temporarily as a Lead Agency, at the SES or their deputy level, when any issue being discussed or considered by the Committee could directly affect the Participating Federal Agency's management or resource responsibilities, jurisdiction by law, or regulatory authorities.

c) States:

i. As states located in or near the basin, the following states are eligible for membership in the Committee. For those states that choose to participate, the governor shall appoint one (1) representative and one (1) alternate.

1) Iowa
2) Kansas
3) Missouri
4) Montana
5) Nebraska
6) North Dakota
7) South Dakota
8) Wyoming

d) Tribes:

i. The following tribes are eligible for membership in the Committee. Those tribes that choose to participate will appoint one (1) representative and one (1) alternate in accordance with tribal procedures.

1) Ft. Peck Assiniboine and Sioux Tribes
2) Blackfeet Tribe
3) Cheyenne River Sioux
4) Chippewa Cree Tribe
5) Crow Creek Sioux Tribe
6) Crow Nation
7) Eastern Shoshone Tribe
8) Flandreau Santee Sioux Tribe
9) Ft. Belknap Indian Community
10) Iowa Tribe of Kansas and Missouri
11) Kickapoo Tribe of Kansas
12) Lower Brute Sioux Tribe
13) Northern Arapaho Tribe
14) Northern Cheyenne Tribe
15) Oglala Sioux Tribe
16) Omaha Tribe of Nebraska
17) Ponca Tribe of Nebraska
18) Prairie Band of Potawatomi Nation
19) Rosebud Sioux Tribe
20) Sac and Fox Nation of Missouri in Kansas and Nebraska
21) Santee Sioux Nation
22) Sisseton - Wahpeton Sioux Tribe

23) Spirit Lake Sioux Tribe
24) Standing Rock Sioux Tribe
25) Three Affiliated Tribes
26) Turtle Mountain Band of Chippewa
27) Winnebago Tribe of Nebraska
28) Yankton Sioux Tribe
29) Osage Nation

e) Stakeholders:

i. There will be a maximum of twenty-nine (29) stakeholder members, broken down into the interests below. Each interest shall have a maximum of two (2) representatives and two (2) alternates.

1) Navigation
2) Irrigation
3) Flood Control
4) Fish and Wildlife
5) Recreation
6) Water Quality
7) Water Supply
8) Agriculture
9) Conservation Districts
10) Waterway Industries
11) Major Tributaries
12) Thermal Power
13) Hydro power
14) At large/other interests, e.g. cultural and historic preservation
15) Local Government
16) Environmental/conservation organizations

VI Appointment, Terms of Office, and Attendance

a) Terms

The standard Committee appointment will be for a term of three years. At the first organizational meeting of the Committee, through a random drawing, one-third of the stakeholders will be appointed to a one-year term. Another third will be appointed to a two-year term. The final third will be appointed to a three-year term. This provision applies to the initial terms of the founding Committee members. Thereafter, all terms will be three years.

b) Term Limits

There will be no limit to the number of terms a member may be appointed to serve.

c) Stakeholder Member Appointments and Vacancies:

i. Stakeholder vacancies will be published in the Federal Register and public notice will be given and broadly disseminated within the Missouri River basin by the U.S. Army Corps of Engineers. Interested parties will submit applications to the Secretary. Applications from interested parties will be forwarded to the Committee for the purpose of providing a recommendation of appointment following its decision-making process. For the initial appointments, the Planning Group, which assisted in the development of this Charter, will provide recommendations to the Secretary. The Secretary will appoint stakeholder members for terms in accordance with paragraph 5(a)(v)(2)(a).

ii. Each year the Committee will forward to the Secretary a list of those stakeholder members whose terms will expire and those who wish to remain on the Committee. Incumbent members wishing to remain on the Committee do not need to re-submit an application to the Secretary. Members may continue to serve until the Secretary appoints a replacement.

d) Stakeholder Application Qualifications:

Stakeholders will demonstrate they represent an interest in the Missouri River basin.

e) Alternate Members:

Alternates will apply in the same manner as stakeholder members and will be recommended by the stakeholder member. Upon appointment by the Secretary, the alternate will serve during the temporary absence of the member. In the instance of the permanent absence of the member, the alternate will fill the remainder of the term.

f) Termination

i. If a member is not in attendance or represented by an alternate at two consecutive meetings, the Committee may recommend termination of that member and alternate to the Secretary after giving notice to the affected parties and giving them the opportunity to respond.

ii. A member or alternate will notify the Chair if they are no longer able to serve. The Secretary will be notified of the vacancy.

VII Roles, Responsibilities, and Leadership

a) Chair and Vice-Chair

i. The Committee shall select a Chair and Vice Chair who may be a member of the Committee. The Chair will be responsible for protecting the interests of all Committee members and alternates. S/he will act in a fair and balanced manner with respect to the Committee's operation and the conduct of Committee meetings. The Chair will strive to determine the views of all Committee members regarding Committee advice and work to achieve consensus.

ii. The Chair will be responsible for running Committee meetings, including opening, enforcement of operating rules, and adjournment. The Chair may call a meeting subject to the public notification procedures of the Committee. The Chair will be responsible for collaboratively developing meeting agendas and reviewing draft meeting minutes and summaries for accuracy and completeness.

iii. The Chair shall have the authority to represent the scope and purpose of the Committee and convey the consensus decisions of the Committee to agencies, elected officials, and in public settings, but shall not act in a lobbying capacity.

iv. The Chair and Vice Chair will serve or be removed with the consensus of the Committee. The term of office of the Chair and Vice Chair will be one (1) year, with the opportunity for reappointment. Should a Committee member believe the Chair and/or Vice Chair are not performing in a fair and balanced manner, it is the responsibility of the member to raise his/her concerns to the Chair or to the full Committee for consideration.

v. The Vice-Chair will assume the duties of the Chair in her/his absence.

vi. The Chair and Vice-Chair shall be selected at the last meeting of the calendar year and assume office at the first meeting of each calendar year.

vii. The Chair and Vice-Chair shall not be employees of the federal government.

b) Member and Alternate Responsibilities

i. Members and alternates are expected to honor their commitment to seek consensus.

ii. All members and alternates will be accurate and respectful with regard to their communications with others.

iii. Members and their alternates will be responsible for representing the interests and concerns of the organizations, institutions, and constituencies they represent.

iv. It is the affirmative responsibility of members and alternates to voice dissent if they cannot support or live with a recommendation. If a member objects to a recommendation, it is also his/her affirmative responsibility to articulate the reasons behind the objections and to provide an alternate proposal if possible.

v. Members and alternates are free to abstain from a determination of consensus for whatever reasons. However, it is the responsibility of each member and alternate to affirmatively state his or her desire to abstain from participating in a determination of consensus if she/he so chooses. Abstentions will not affect the determination of a quorum.

vi. Members and alternates will adhere to the Committee's charter, operating procedures, and ground rules. They are expected to give due consideration to the procedural guidance and recommendations of the Chair.

c) Working Groups and Subcommittees

The Committee may create special work groups or sub-committees as necessary to accomplish its purposes. These may include individuals not on the Committee.

d) Written Directives and Scopes of Work

Prior to commencing work, the Committee will provide each working group or sub- committee written instructions that outline the purpose of the work and the tasks being requested, as well as specifying its members, their roles and responsibilities, the expected work products, and the specific time frames for reports and completion of the group's work.

e) Independent Panels

Lead and participating agencies may convene panels independent of the convening agencies as requested by the Committee to advise the Committee on substantive issues as identified by the Committee. The Committee will recommend panel members as established by its operating procedures.

VIII General Committee Operations

a) Operating Procedures and Guidelines

The Committee will develop a set of operating procedures and guidelines to set forth in detail how it shall conduct meetings and accomplish the requirements of this charter.

b) Meetings

i. Meeting frequency and location

1) The first meeting of the Committee will be convened by the Secretary on or before October 1, 2008.

2) The Committee will meet a minimum of two (2) times per year and will determine meeting dates and locations.

c) Communications, Record Keeping, Documents, and Reports

i. Open meetings

Except as provided herein, each Committee meeting will be open to the public. Interested persons shall be permitted to attend, offer public comment, or file statements with the Committee.

ii. Executive sessions

The Committee may call an executive session that is closed to the public upon the consensus of the members present. An executive session may only be called for legal, personnel, or property transfer issues directly pertaining to the Committee. Decision-making will be conducted during the open meetings.

iii. Notice of meetings

Public notice of each such meeting of the Committee will be given as provided for in the Operating Procedures.

iv. Minutes and approval of minutes

Detailed minutes of each Committee meeting will be kept by an independent, qualified note taker. These minutes and summaries of the minutes will be approved by the Committee in accordance with its decision making process.

v. Availability of records

Any records, reports, transcripts, minutes, appendices, working papers, drafts, studies, agenda, or other documents which were made available to or prepared for or by the Committee will be available for public inspection and copying, except as provided by law.

vi. Assessment and Self-Evaluation

The Committee will conduct a self-evaluation of its operations every year.

vii. Reports

The Committee will submit an annual report to the Secretary.

IX Consensus and Decision Making

a) Process

i. The Committee's goal is to reach consensus on all substantive issues brought before it. Federal Agency representatives may participate [per section 5(a)(ii)] in the discussion of all matters pending before the Committee and provide their opinions, input, and suggestions. The Committee will only make recommendations where there is a consensus. Federal agencies will not participate in the determination of the Committee's consensus recommendations.

ii. Consensus recommendations will be made using a two-step process with information, discussion, proposal development, and tentative consensus at the first meeting and actions no sooner than the next meeting to assure adequate notification of and deliberations by Committee members and the interests they represent. Upon consensus of the Committee, the two-step process may be waived except for recommendations to federal and/or other agencies and Charter amendments.

iii. If consensus cannot be reached, the Chair will designate a period of time to be set aside to address the issue during at least two different meetings. If consensus still cannot be reached, the meeting minutes will not characterize or quantify the level of support for the differing views.

iv. Once consensus is reached on any recommendation, the Chair will ask the Lead Federal Agency representatives involved with the issue being considered whether they can endorse the recommendation. The Lead Federal Agencies will be requested to respond immediately to the Committee, if possible, or by an agreed upon date. Lead Federal Agency endorsement is not necessary for a consensus recommendation to be submitted to the appropriate government entity.

v. Once recommendations and guidance are delivered by the Committee to the Secretary, it is requested that s/he, in coordination with other participating Federal Agencies, agrees to provide the official federal position on the issue and outline the steps to implement the recommendations by an agreed upon date or provide the reason(s) for

not implementing the recommendation.

vi. Committee members are free to abstain from a determination of consensus. Abstentions will be recorded in the meeting minutes when requested by the individual who wishes to abstain.

b) Reports, Work Plans, and Proposals

i. The U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, and other agencies as requested by the Committee will provide reports at least on an annual basis, related to Missouri River and tributaries recovery, mitigation, and restoration, which include the status of recovery activities for the pallid sturgeon, interior least tern, and piping plover. In addition to construction, monitoring, research, and propagation activities, the annual reports will address:

1) Number of pallid sturgeons, interior least terns, and piping plovers present over their entire ranges, where available
2) Downlisting and/or delisting criteria, including target numbers, for the pallid sturgeon, interior least tern, and piping plover for the Missouri River and their entire ranges
3) Comparison of numbers for the pallid sturgeon, interior least tern, and piping plover with previous years' reports
4) Progress and effectiveness of adaptive management toward the pallid sturgeon, interior least tern, and piping plover recovery
5) Other reports as requested by the Committee.

ii. Reporting agencies will be prepared to respond to specific questions from the Committee, by an agreed upon date, regarding recovery status and recovery activities.

iii. Federal agencies involved in recovery, mitigation, and restoration efforts in the basin will submit status reports, work plans, and cost estimates to the Committee at least annually.

iv. Other federal, tribal, and state agencies, as well as non-governmental organizations may also submit recovery and restoration proposals for review by the Committee.

c) Budget, Funding, and Support Services

i. General

1) Subject to the availability of appropriations and subject to the

limitations of the Secretary's authorities, the Secretary shall provide funding to achieve the purposes of the Committee as described in Section 5018.

2) Annual funding level recommendations for the Committee will be developed through annual coordination between the Committee and the Secretary.

X Interactions Outside The Committee

a) Web Site

The Secretary will maintain a Web site as a clearinghouse for Committee related information.

b) Annual Conference

The Committee may host an annual conference to provide information to the public on the Missouri River Recovery and Mitigation Program including plans and studies as referred to in Section 5018 and any other plans related thereto.

Attachment A.2 – MRRIC FINAL Operating Procedures and Ground Rules (May 23, 2013 Amended Version)

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Appendix A. Degrees of Collaboration **38**

Missouri River Recovery Implementation Committee (MRRIC) Operating Procedures and Ground Rules

The Secretary of the Army (Secretary) has established the Missouri River Recovery Implementation Committee (MRRIC) as provided by SECTION 5018 of the Water Resources Development Act of 2007. The operating procedures and ground rules established herein have been developed to support and facilitate the MRRIC process but do not alter or modify the MRRIC Charter.

1) Purpose for MRRIC:

As stated in the MRRIC Charter:

a) The Purpose and Scope of the Committee are to:

i) Provide recommendations and guidance on a study of the Missouri River and its tributaries to determine actions required to:

(1) Mitigate losses of aquatic and terrestrial habitat

(2) Recover federally listed species under the Endangered Species Act of 1973

(3) Restore the ecosystem to prevent further declines among other native species

ii) Provide guidance with respect to the existing Missouri River mitigation and recovery plan, including recommendations on:

(1) Changes to the implementation strategy as a result of adaptive management

(2) Coordination of the development of consistent policies, strategies, plans, programs, projects, activities, and priorities for the Missouri River recovery and mitigation plan

(3) Exchange of information regarding programs, projects, and activities of the agencies and entities represented on the Committee to promote the goals of the Missouri River recovery and mitigation plan

(4) Establishment of such working groups as the Committee determines to be necessary to assist in carrying out the duties of the Committee, including duties relating to public policy and scientific issues

(5) Facilitation of the resolution of interagency and intergovernmental conflicts between entities represented on the Committee associated with the Missouri River recovery and mitigation plan

(6) Coordination of scientific and other research associated with the Missouri River recovery and mitigation plan

(7) Preparation of an annual work plan and associated budget requests

iii) Provide recommendations and guidance that will include:

(1) Recognition of local stakeholders' social and economic, historical and cultural, flood control, irrigation, agriculture, internal drainage, water supply, water quality, navigation, hydropower, thermal power, science, natural resources, conservation, and recreation issues, and any other issues identified by the Committee.

(2) Identification of impacts to stakeholders.

(3) Identification of actions that will benefit multiple uses of the river.

(4) Avoidance, minimization, and/or mitigation of adverse impacts.

2) This Document

a) Definition of Words and Terms

Definitions listed here are in addition to those set out in the MRRIC Charter.

i) **Missouri River Basin Interagency Roundtable (MRBIR):** The established forum for federal agencies advocating a collaborative approach to solving issues within the Missouri River watershed.

ii) **MRRIC:** The Missouri River Recovery Implementation Committee.

iii) **Meeting:** A physical face-to-face gathering of the Committee lasting one or more, partial or full days.

iv) **Substantive Issue:** An issue for which the Committee is considering developing recommendations and guidance consistent with the Committee's purpose and scope as well as other issues identified as substantive by any member of the Committee.

b) Updates and Revisions

Revisions to these operating procedures and ground rules shall be made by the consensus of MRRIC using the decision process outlined in the MRRIC Charter.

3) Operating Procedures and Ground Rules

a) Individual Participants

i. Representation of Interests

MRRIC members and their alternates will be responsible for representing the interests and concerns of the organizations, institutions, and constituencies they represent.

ii. Conflict of Interest

All Committee members have the affirmative responsibility for representing the interests and concerns of the organizations, institutions, and constituencies they represent and the other interests set forth in the Charter and in the performance of such duties do not have any conflict of interest. Beyond Committee advocacy, Committee members are obligated to avoid and disclose any individual ethical, legal, financial, or other conflicts of interest involving MRRIC.

iii. Preparation and Attendance

(1) Members will make every effort to attend meetings, to participate actively, to be prepared to discuss information and issues, and to be available for work between formal meetings. Meeting agendas will not allocate time for recapping past discussions and decisions for the purpose of updating those members who have missed past meetings.

(2) Members will notify the facilitation team and Chair if they are unable to attend meetings.

iv. Sharing and Considering Information and Perspectives (*Items 3-7 Approved by MRRIC on October 25, 2012*)

(1) Members agree to respect each other. Members will avoid personal attacks and the use of intimidation.

(2) Meeting participants will silence their personal electronic devices

(e.g., cell phones and pagers) and will not talk on cell phones inside the meeting room during meetings to avoid interruption of group discussions and MRRIC work.

(3) MRRIC is a collaborative forum for the basin stakeholders, states, and Tribes to come together and develop a shared vision and comprehensive plan for Missouri River recovery.

(4) As such, MRRIC members acknowledge their responsibility to utilize MRRIC as the forum for raising and addressing concerns and issues related to the duties of the Committee.

(5) If a member raises an issue in MRRIC and does not feel their interests are sufficiently met in the course of deliberations, they should strive to make that as clear as possible to the rest of the Committee.

(6) If the member ultimately determines they need to explore other avenues beyond MRRIC to have their interests met on a MRRIC-related issue and that action could impact the full Committee, they have a "good faith" obligation to inform the group.

(7) The Charter defines "In Good Faith" as "the sincere intention to deal fairly and equitably with Tribes and others, without deception. The willingness of all Committee members to interact openly, honestly, and respectfully with all other members."

v. Members and Alternates

(1) The Chair will conduct a written roll call at the beginning of each meeting. Only the member or (in the member's absence) his/her alternate may participate in discussions and decision making.

(2) A MRRIC member may designate an alternate as provided in the MRRIC Charter.

b) Expectations for Chair

The Chair will act as provided for in the MRRIC Charter. Expectations include but are not limited to:

i. Presiding over, and leading meetings of MRRIC, including the opening and closing of all meetings.

ii. Collaboratively develop draft meeting agendas based on input from MRRIC and review draft meeting minutes and summaries for accuracy and completeness.

iii. Be responsible for protecting the deliberative process and act in a fair and balanced manner with respect to MRRIC's operation and the conduct of its meetings.

iv. Explore and incorporate the views of all MRRIC members in achieving consensus.

v. With the permission of MRRIC, have the responsibility and authority to represent and convey the views of MRRIC to agencies, elected officials, and the public.

c) Resolving Compliance with Ground Rules and Operating Procedures

i. Should a question or concern arise regarding the conduct of members of MRRIC or its staff, an individual is encouraged to discuss the issue directly with the person involved. There is no expectation that MRRIC members will be informed of this discussion unless it becomes the joint decision of the parties involved.

ii. Should a one-on-one conversation be inadequate to resolve the issue, the person raising the concern may request a conference call or in-person meeting with the Chair to discuss the issue and seek a satisfactory resolution. Part of the resolution of the issue at this level will be a decision as to whether MRRIC should be informed of the issue and its resolution.

iii. Should the issue remain without satisfactory resolution, the person raising the concern may bring the issue to MRRIC for discussion and resolution. The resolution of the issue at this level will be documented in the meeting summary.

iv. If resolution cannot be achieved through all of the means above, the issue will be forwarded to the Secretary of the Army for discussion and resolution.

d) Consensus and Decision-Making

i. Consensus decision making shall be as provided in the MRRIC Charter.

ii. Agenda items that involve actions or decisions will be clearly identified on meeting agendas and sent out with read-ahead materials.

e) Decision Making Roles and Responsibilities

i. Members of MRRIC are expected to honor their commitment to seek

consensus.

ii. It is the affirmative responsibility of each MRRIC member to voice dissent if they cannot support or accept a recommendation. If a member objects to a recommendation, it is also their affirmative responsibility to articulate the reasons behind the objection and to provide an alternate proposal, if possible.

iii. MRRIC members are free to abstain from a determination of consensus for whatever reasons. However, it is the responsibility of each MRRIC member to affirmatively state his or her desire to abstain from participating in a determination of consensus if they so choose. Abstentions will not affect the membership requirements for a quorum.

f) General MRRIC Operations

i. Use of Time

(1) MRRIC members and staff, and agency staff, will respect each other by being on time. Meetings and work group conference calls will begin and end as scheduled unless otherwise agreed to by consensus of the participants.

(2) When making comments, MRRIC members will be considerate of the time needed for others to share their perspectives.

ii. MRRIC Records, including Guidance

(1) MRRIC staff will maintain a written record that will accurately summarize decisions and recommendations made by MRRIC at its meetings. These written minutes and summaries will be prepared in draft form and will be clearly identified as draft documents. All MRRIC members will be provided an opportunity to suggest revisions to the draft meeting minutes and summaries before they are approved by MRRIC. Draft meeting notes will be provided to the Committee fifteen (15) working days after the meeting.

(2) All MRRIC guidance shall be documented in writing in meeting minutes and summaries.

(3) Public notice of each meeting of the Committee will be given as provided for in the Charter Definitions.

iii. Working Groups

(1) MRRIC may create special working groups to address specific issues directly related to MRRIC's purpose. Prior to commencing work,

each of these work groups will have a short, written directive that outlines their purpose and tasks, as well as specifying the membership, their roles and responsibilities, the expected products, and the specific time frame for completing the group's work.

(2) Agenda Work Group: The chair will collaborate with a rotating agenda working group. Stakeholder, tribe and state Committee members will volunteer each meeting for the next meeting. The work group will not exceed seven (7) stakeholders, tribe, and state members selected at the discretion of the Chair. No member will serve on this work group for more than two consecutive meetings. The Chair will ensure that the membership is balanced. The Chair will work with all appropriate entities necessary, including the facilitation team, to create the agenda.

(3) Process for Rotating Work Group Points of Contact (*approved by MRRIC July 22, 2010):*

Overview:

There are types of work groups (the process for operation of the agenda work group is contained in the Operating Procedures and Ground Rules, Section 3)f)iii)(2).

- Ad hoc - An ad hoc work group is formed to take care of a specific issue and then the work group dissolves. This type of work group would have one point of contact (POC) for the life of the work group.
- Standing - There should be co-points of contact for the standing work groups, such as but not limited to:
  - Communications/IT
  - Science and Adaptive Management

(i) Point of Contact Eligibility[1]

1 Clarification to the Process for Rotating Work Group POC's:

Following the July 2010 MRRIC meeting a few members had questions about the eligibility section of the process to rotate work group points of contact. The Nominating Work Group's intent behind the eligibility section is to encourage leadership among the stakeholder, Tribe, and state Committee members. Occasionally a work group may identify a Federal Committee member to serve as a co-POC for a work group. This is likely to be the exception

- A point of contact should be a Committee member or alternate and be a member of the work group.

(ii) Point of Contact Term

- The term for the POC should be two (2) years for the standing work groups and the life of an ad hoc work group, so long as the participant is a Committee member
- The terms between the co-points of contact will be staggered
- There are no term limits for a point of contact
- The terms will run with the calendar year

(iii) Selection Process

- The POCs for standing work groups;
  - In a work group meeting; volunteers for POC are requested from among the Committee, approved work group membership, and then endorsed by the work group
  - The POCs are selected by the full Committee at the last meeting of the year using the voting and consensus process steps 1–3 (stated in section iv).

(iv) The POC for ad hoc work groups:

The following steps take place before the full MRRIC;

- At the time the ad hoc work group is created, work group members are identified and approved by the MRRIC.
- From the work group members, volunteers are requested to serve as a POC.
- The proposed POCs are selected by the full Committee using the voting and consensus process steps 1–3 (section iv).

rather than the norm. Volunteers for work groups should be encouraged. The standing work groups are intended to have two POC's and at least one of the POC's must be a stakeholder, Tribe, or state Committee member.

1. Committee members vote for nominees on slips of paper in rounds until there is a majority. Each stakeholder, state, and tribal member present at the Committee meeting must vote or the ballot is spoiled. Between each round of voting, members may take a five (5) minute break. Questions may be asked of the candidates in front of the full Committee before each subsequent round of voting.

2. Once there is a majority preference, the Committee makes a consensus decision to select a POC by show of hands.

3. If there is no consensus, the process starts again.

(4) Process for Updating Work Group Members (approved by MRRIC October 21, 2010)

(i) Responsibilities of Work Group members
Individuals joining MRRIC work groups are expected to regularly engage in work group calls, be familiar with materials in advance of calls, and notify the work group POC and/or facilitator if they cannot participate in a work group call or meeting. When a work group member cannot be on a call, or attend a work group meeting, the member is expected to support the decisions of the work group. In accordance with the MRRIC Charter, it is the affirmative responsibility of a member to voice dissent if they cannot support, or live with a recommendation. If a member objects to a recommendation, it is also their affirmative responsibility to articulate the reasons behind the objections and to provide an alternative proposal if possible.

(ii) Annual Renewal of Ongoing Work Group Members (to take place at the second MRRIC meeting of the federal fiscal year)

a) Facilitator provides POC's with list of work group member participation for the year.

b) POC(s) ask work group members who in the work group wants to continue.

c) The POC(s) will present list of continuing work group members to MRRIC (provided as a read ahead to MRRIC)

d) MRRIC discusses and makes decisions

(iii) Addition of new work group members between plenary MRRIC meetings (Approved by MRRIC May 5, 2011)

a) New work group members who are current MRRIC members, alternates, or agency staff may participate in work group calls and discussions but not engage in work group decisions. The list of individuals who want to join a work group will be noticed and approved at the first available plenary MRRIC meeting (e.g., new work group members are noted on the agenda).

b) Individuals who are not MRRIC members, alternates or agency staff may participate in work group calls and discussions, but may not engage in work group decisions until approved by MRRIC. The list of individuals who want to join a work group will be noticed at the first available plenary MRRIC meeting (e.g., new work group members are noted on the agenda).

iv. Independent Panels

The Committee shall recommend panel membership to the convening agency as provided in the MRRIC Charter.

v. Annual Self-Evaluation

No later than ninety (90) days after the ending of the federal fiscal year, MRRIC will complete a self-evaluation that includes the following:

(1) Review of the efficiency of the MRRIC Charter and Operating Guidelines along with recommended changes, if necessary.

(2) Review the adequacy of membership as provided in the Charter and recommended changes, if necessary.

(3) Review of annual work plan, level of success in completing work plan tasks, and recommended changes to the work plan tasks, format, or process, if necessary.

vi. Annual Report to the Secretary

No later than ninety (90) days after the ending of the federal fiscal year, MRRIC will submit an annual report to the Secretary detailing MRRIC's accomplishments and failures of the previous fiscal year, as well as recommended Charter changes and membership appointments.

vii. MRRIC Work Plans, Agendas, or Goals

The Committee will develop work plans, agendas, or goals.

g) Expectations for Interactions Outside the Committee

Public input during meetings:

i. All meetings shall be open to the public. MRRIC staff will be responsible for collecting and documenting public input for MRRIC consideration. MRRIC will determine how best to incorporate public comment into its work.

ii. The public will be given the opportunity for at least one formal comment period during the course of each meeting day.

iii. Public comment periods are designated for the public. Seated members of MRRIC will not make statements during public comment periods.

iv. Members of the audience and other observers will be asked to refrain from making statements except during public comment periods.

h) Internal Communications

i. Meeting agendas and materials will be distributed not less than seven (7) days prior to each meeting by MRRIC staff. This will include an updated MRRIC contact list.

ii. When requested, individual communications from MRRIC members to

the entire group will be distributed by MRRIC staff.

i) External Communications and Activities

All members will be accurate and respectful with regard to communications with others.

j) Protocol for Informing MRRIC Members and Alternates About All Meetings, Webinars, and Conference Calls (*approved by MRRIC on February 4, 2010*)

i. Commencing immediately, the calendar section on MRRIC's WebEx home page will list the dates and times for upcoming work group conference calls or meetings, webinars, or other activities scheduled between MRRIC meetings. The entry will also list the point(s) of contact and facilitator, and the facilitator's phone number and email.

ii. The facilitator assigned to the call, meeting or other activity will post the event on WebEx in a timely fashion, with the understanding that some calls are scheduled with short notice.

iii. A non-member interested in joining a work group conference call or meeting will notify the appropriate facilitator, by e-mail or phone, at least three (3) days in advance of the scheduled call or meeting. This advance notice will allow the facilitator time to ensure sufficient phone lines are available; provide the member or alternate with an agenda, relevant documents and call-in information; and notify the point(s) of contact of the desired participation.

iv. The non-member should notify the facilitator, if there are any specific agenda topic(s) upon which he or she desires to be heard.

v. During the conference call or meeting, the non-member may listen in as an observer. Generally, non-members will be given an opportunity to ask questions at the end of a call unless they have let the facilitator or POC know that they have a comment they would like the work group to consider. Non-members may not participate in decision making.

If a non-member joins work group calls on a continuous basis, the non-member will be asked to consider joining the work group.

k) Meeting Frequency, Dates, and Locations (*approved by MRRIC October 21, 2010*)

The Committee shall meet four (4) times per year. The length of each meeting, date, and location shall be determined by the USIECR through collaboration with MRRIC, the Chair, the lead agencies, and others as necessary to make those arrangements which best meet the needs of MRRIC in conducting its business.

l) MRRIC Vice-Chair Responsibilities and Selection Process *(approved by MRRIC July 22, 2010)*

i. Description of Duties and Time Commitment Per Committee Charter: See section 5.b.i (1-7) "Roles, Responsibilities, and Leadership" (page 11) specifically paragraph 5 "The Vice-Chair will assume the duties of the Chair in her/his absence."

ii. Additional Duties:

1) Work with Facilitation team and Committee Chair in preparation for agenda work group calls and in preparation for Committee meetings. Work includes discussing the best use of Committee time, developing meeting agendas, reviewing draft documents.

2) Participate on agenda work group calls between MRRIC meetings.

3) Work with Chair on preparing communications in Committee's annual report

4) Conduit for Committee stakeholders

5) May continue to represent his/her stakeholder interest while serving in the capacity as Vice-Chair including participating on work groups as a representative of their interest category.

- The individual is expected to be clear when he/she is speaking on behalf of his/her interest category or as the Vice-Chair.
- It is recommended that the Vice-Chair not serve as a work group point of contact.

iii. Time Commitment: The Vice Chair requires a substantial time commitment above a person's time commitment as a Committee

member.

iv. Experience/Attributes of Vice Chair

Once the slate of nominees is established the following experience or attributes should be considered in the vice-chair nominees.

1) Understand the different interests on Committee.
2) Available to make this position your priority for scheduled meetings and between meeting work group activities.
3) Impartial approach.
4) Able to work with Committee Chair and Facilitation team.
5) Available, accessible.
6) Effective communication and listening skills.
7) Active involvement in a work group or served as a point of contact on a work group.

v. Nomination and Selection Process

1) Any stakeholder member interested in serving as Vice-Chair should notify Nominating Work Group Point of Contact (NWG-POC) about their interest in serving thirty (30) days before the last meeting of the calendar year.
2) Any stakeholder member may nominate a stakeholder member for Vice-Chair. Nominations should be sent to the NWG-POC. The NWG POC or his/her designee will contact nominees to confirm if they are interested in serving as Vice-Chair.
3) On the first day of the last MRRIC meeting of the calendar year, a slate of at least two (2) Vice-Chair nominees will be introduced. The Selection Process occurs on the second day of the MRRIC meeting.
4) Selection Process on Day Two
5) Each nominee shares why they are interested in serving as Vice-Chair. Members have a chance to ask questions of each nominee.
6) On slips of paper members are asked if there is any nominee they cannot live with serving as Vice-Chair and why? And to write down any questions they have of individual candidates. A comment/question box will be available to collect questions.
7) The questions and/or concerns are read before the full Committee. Nominees then answer questions in front of the Committee. Members may ask follow up questions
8) Committee members vote for nominees on slips of paper in

rounds until there is a majority. Each stakeholder, state, and tribal member present at the Committee meeting must vote or the ballot is spoiled. Between each round of voting, members may take a five (5) minute break. Questions may be asked of the candidates in front of the full Committee before each subsequent round of voting.

9) Once there is a majority preference, the Committee makes a consensus decision to select a Vice-Chair by show of hands.
10) If there is no consensus, the process starts again.

m) Establishing MRRIC Meeting Agendas (a*pproved by MRRIC October 20, 2011*)

The MRRIC meeting agendas are collaboratively developed by the MRRIC Chair and the Agenda Work Group (see sections 3(b)iii and 3 (f)iii(2)). MRRIC agenda items can originate in a number of ways by members:

i. Topics proposed by work groups and approved by MRRIC during the plenary meeting.
ii. Topics identified in the approved MRRIC work plan.
iii. New topics suggested by members, including lead agencies, at the conclusion of every meeting (during the Thursday morning plenary session)
iv. Emergent topics identified between meetings as suggested by members, Federal Working Group, lead agencies etc., and shared with Agenda Work Group and Chair
v. Discretion of Chair – often for topics in the Chair's hour

n) MRRIC Work Plan Development Process and Implementation *(approved by MRRIC October 20, 2011)*

<u>Overview</u>

There are two (2) documents that guide the annual work and product of MRRIC: the annual work plan and work group charges.

The purpose of the MRRIC work plan is to provide an overview of the Committee's work each year in fulfilling its duties as outlined in Section 5018 of the 2007 Water Resources Development Act (WRDA 2007). The work plan

guides the more detailed work of MRRIC that is developed through work group charges approved by MRRIC at its meetings.

The work group charge documents provide more detailed information about the tasks of the work groups, the expected product and the timeline for completing the tasks. The work group charge documents are updated and approved by MRRIC at each meeting. In addition, the work group charge documents provide a mechanism for the Committee to work on issues that emerge in the year that were not anticipated in the work plan. New tasks not listed in the work plan can be added to the work of MRRIC during the year using the work group charge documents.

Topics in the work plan could, with MRRIC concurrence, be tabled. The work plan is created annually based on the calendar year and updated during the year as necessary. The steps below outline the approach to creating the plan.

1. Work group points of contact (POCs), lead agency staff of the work group, and work group members identify ongoing work group tasks expected to carry into the next year. They also identify and propose anticipated new tasks. As a part of this discussion the lead agencies share their priority needs relative to each work group for the upcoming year. The product from this discussion can be a list of current and anticipated work group charges and products and approximate time frame (e.g., at the winter, spring, summer, or fall MRRIC meeting).

2. Work group POCs, lead agency staff, MRRIC leadership and facilitation team meet to discuss collective MRRIC tasks, their relative priorities, and assess the distribution of work across the calendar year. At this meeting, the lead agencies confirm their priority needs from MRRIC for the year. Competing priorities between work groups or between MRRIC and the lead agencies are identified and addressed if possible between the work groups and lead agencies. If conflicting priorities cannot be resolved among the work groups, the MRRIC leadership may be consulted and when necessary, discussed with the full committee in order to achieve a resolution.

3. Leadership and Facilitation Team (LFT) draft a proposed work plan identifying the work of MRRIC, by work group, across the calendar year based on inputs and priorities from Step 2. The LFT circulate the draft proposed plan to the work groups for their review and comment.

4. The LFT revise the draft proposed work plan based on work group comments and circulate the revised to MRRIC members for review.

5. MRRIC reviews proposed work plan and provides comments to Chair and Vice-Chair.

6. MRRIC Leadership and Facilitation Team revise proposed work plan.

7. MRRIC reviews the revised proposed work plan, as a tool to guide the work of the committee, and approves the work plan as a process decision at the first MRRIC meeting of the calendar year. If the work plan includes anticipated tasks these tasks must have a MRRIC approved work group charge before work commences on the task.

8. The work plan maybe up updated during the calendar year to reflect the MRRIC approved work group charges not listed in the work plan at the time of its approval.

o) **Work Group Decision Making** (approved by MRRIC February 9, 2012)

Consensus will be used as the decision making standard in MRRIC work groups. In work group discussions, all work group members (i.e., agency staff, MRRIC members, non- MRRIC work group members) participate in the discussion and in developing a work group product. The consensus decision-making during the development of work group proposals is made by the current MRRIC members (or their alternates) seated on the work group. See paragraph 3b of the MRRIC Charter for a definition of consensus. In situations where a primary and an alternate MRRIC member sit on the same work group the individuals should coordinate their perspectives and speak with one voice as consistent with MRRIC.

If a work group does not reach consensus on a MRRIC task, or is not making timely progress on a task, the work group should inform MRRIC of the full status of the task such as the varying opinions, objections and perspectives. MRRIC should weigh-in, give guidance and further direction to the work group.

p) **Stakeholder Membership** (Approved by MRRIC January 31, 2013)

MRRIC member terms run on the federal fiscal calendar from Oct 1 to Sept 30. If a stakeholder member is appointed after October 1, his or her term will complete the current fiscal year and two additional years ending on Sept 30. For example:

If a member is appointed at the August 2013 meeting his or her term would end Sept 30, 2015.

q) **Process for MRRIC Stakeholder Member Disclosure** (*Approved by MRRIC May 23, 2013*)

SECTION I. WHAT SHOULD BE DISCLOSED

If any of the following are applicable they should be disclosed to MRRIC:

1. If a current stakeholder member or applicant is directly employed by a federal, state or tribal government agency or program.

OR

2. If a current stakeholder member's employment status changes (to # 1 above) from when you applied to MRRIC.

SECTION II. HOW TO DISCLOSE

1. Current stakeholder members who are renewing their MRRIC membership: disclose items 1 or 2 in Section I above in their renewal letter.

2. Current stakeholder members whose status changes during their three year term on MRRIC should make the disclosure immediately by:

a. Preparing a letter to the MRRIC Chair that is included in the consent agenda of the next MRRIC meeting and the letter is posted to a folder for disclosures on the MRRIC Sharepoint site. (Goal is to ensure notice and transparency to MRRIC.)

b. If a MRRIC member has a concern about a disclosure then the consent agenda procedures are followed (i.e., item is removed from consent agenda; Chair and individuals with the concern and the individual who made the disclosure meet to clarify and seek resolution of concerns; report back to MRRIC to affirm disclosure.)

3. Applicants for stakeholder membership: disclose on their MRRIC application. USACE should include the following language in the MRRIC stakeholder application materials:

Committee members are obligated to avoid and disclose any individual ethical, legal, financial or other conflicts of interest involving MRRIC. (From MRRIC Operating Procedures). Applicants must disclose on their MRRIC

application if they are directly employed by a government agency or program (Note: "government" encompasses state, tribal, and federal agencies and/or programs).

The following question should be added to the stakeholder application to help the applicant understand what information is being sought:

"Are you currently directly employed by a government entity? If yes, please share the agency or program name, your position, and describe any decision-making roles or responsibilities that you have."

SECTION III. GUIDANCE FOR EVALUATING DISCLOSURES, ROLES of USACE and MRRIC

- Evaluate disclosures on a case-by-case basis.
- Preference will be given to stakeholder applicants who are not directly employed by state, tribal or federal government.

Scenarios that might not be acceptable for an individual to fill a stakeholder seat are:

- If stakeholder applicant/member is directly employed by a government and serves in a role appointed by a governor or executive branch (e.g., head of a state program or department).
- If stakeholder applicant/member is directly employed by a government and as a stakeholder member of MRRIC her/his decision making is influenced by his status as a government employee.

<u>Who Decides?</u>

Ultimately the ASA for Civil Works decides on stakeholder appointments to MRRIC.

<u>Role of MRRIC in evaluating disclosures;</u>

MRRIC members can weigh in on new and renewing stakeholder applicants through the online survey issued by USACE every summer. If a MRRIC member has a concern about stakeholder applicant, or members' disclosure,

they can raise it using the survey. The USACE evaluation panel must then evaluate it.

Can a MRRIC member stop a selection of a stakeholder member?

If a single member has a concern about a disclosure that concern alone should not force a decision about the applicant/renewing/current member's status as a stakeholder. It was also noted that the Committee has in place in the MRRIC operating procedures (Section 3c) a dispute resolution process. If a member has a concern about another members' disclosure they use this process to address the concern. If the concern cannot be sufficiently addressed at the lowest level the process allows for issues to ultimately be resolved by the ASA.

Attachment A.3 – Alternatives Considered in the MRRMP and EIS

Note: This attachment presents a summary of the alternatives evaluated in the MRRMP-EIS. For a more detailed discussion of the alternatives, see Chapter 2 of the DEIS.

Table A.3.1 summarizes the features of each plan alternative carried forward for detailed evaluation in this draft MRRMP-EIS. Six plan alternatives were identified (the No-Action Alternative and five action alternatives). The names of each alternative correspond to the concept or feature that distinguishes them from all other alternatives. Some of the alternatives share management actions and these are discussed in the sections describing common actions.

Actions Common to All Plan Alternatives

The following management actions would be implemented as part of all plan alternatives carried forward for detailed evaluation in this draft MRRMP-EIS including the No-Action Alternative. However, the actual scale and extent of a particular action may vary.

Least Tern and Piping Plover

Mechanical ESH Creation

All alternatives include mechanical ESH creation as a management action; however, the amounts of ESH that would be created mechanically vary by alternative and those differences are described in the respective section for each alternative. Mechanical construction amounts vary because this management action would be used to create enough ESH to meet bird habitat targets after accounting for the amount of ESH created by a habitat-forming flow release in several alternatives. Therefore, because the amount of ESH created by the habitat-forming flow release varies by alternative, so does the

amount of mechanical ESH construction needed to achieve targets. Methods to implement this action would occur as described in Section 2.5.1.6.

Vegetation Management, Predator Management, and Human Restriction Measures

Vegetation management, predator management, and human restrictions measures as described in Sections 2.5.1.8 through 2.5.1.10 would be implemented as part of all the plan alternatives including the No-Action Alternative.

TABLE A.3.1. SUMMARY OF FEATURES COMPRISING THE MRRMP-EIS ALTERNATIVES CARRIED FORWARD FOR DETAILED CONSIDERATION.

Management Actions	Alternative 1 No Action	Alternative 2 USFWS 2003 BiOp Projected Actions	Alternative 3 Mechanical Construction Only	Alternative 4 Spring Habitat-Forming Flow Release	Alternative 5 Fall Habitat-Forming Flow Release	Alternative 6 Pallid Sturgeon Spawning Cue
Least Tern and Piping Plover						
Mechanical ESH Creation	X	X	X	X	X	X
Vegetation Management	X	X	X	X	X	X
Predator Management	X	X	X	X	X	X
Human Restriction Measures	X	X	X	X	X	X
Flow Management to Reduce Take	X	X	X	X	X	X
Spring Habitat-Forming Flow Release				X		
Fall Habitat-Forming Flow Release					X	
Monitoring and Research	X	X	X	X	X	X
Pallid Sturgeon (both Upper and Lower River)						
Propagation and Augmentation	X	X	X	X	X	X
Pallid Sturgeon Population Assessment Project	X	X	X	X	X	X

Management Actions	Alternative 1 No Action	Alternative 2 USFWS 2003 BiOp Projected Actions	Alternative 3 Mechanical Construction Only	Alternative 4 Spring Habitat-Forming Flow Release	Alternative 5 Fall Habitat-Forming Flow Release	Alternative 6 Pallid Sturgeon Spawning Cue
Level 1 and 2[1] Studies			X	X	X	X
Upper River Pallid Sturgeon						
Monitoring and evaluation related to fish passage at Intake Diversion Dam	X	X	X	X	X	X
Lower River Pallid Sturgeon						
Spawning Habitat Construction			X	X	X	X
Early Life History Habitat Construction	X (SWH)	X (SWH)	X (IRC)	X (IRC)	X (IRC)	X (IRC)
Spawning Cue Flow	X	X				X
Low Summer Flow		X				
Floodplain Connectivity		X				
Habitat Development and Land Management	X	X	X	X	X	X

2003 BiOp (USFWS, 2003)

[1] Note that some level 2 studies would require additional NEPA compliance beyond the scope of this EIS.

Monitoring and Research

The USACE conducts annual productivity monitoring of least tern and piping plover populations on the reservoir and river reaches of the Missouri River mainstem. The monitoring focuses on an adult census, measurement of fledge ratios, and documentation of incidental take. The USACE also performs ESH habitat monitoring. Monitoring results are used to determine the effectiveness of management actions for least terns and piping plovers. In addition, the USACE funds focused research projects on various aspects of least tern and piping plover demographics and habitat use.

Pallid Sturgeon (Both Upper and Lower River)

Propagation and Augmentation

The pallid sturgeon propagation and augmentation program, as described in Section 2.5.2.2, would be implemented as part of all the plan alternatives including the No-Action Alternative. The Pallid Sturgeon Recovery Team and Basin Workgroups undertake annual reviews of data to ensure timely updates to stocking plans in the Upper and Lower River (e.g., USFWS 2007). A new Pallid Sturgeon Propagation Plan is being developed by the Pallid Sturgeon Recovery Team because of important concerns related to fish health/disease, genetics, stocking size, stocking practices, etc. This propagation plan examines hatchery practices and recommends changes to rearing practices that minimize disease occurrences and ensure appropriate levels of production. The plan will also address issues related to obtaining appropriate genetic representation in the stocked population. The USFWS plan will focus on hatchery practices, rather than the fate of fish after release from the hatchery. The authority and responsibility for hatchery management lie with the USFWS for those facilities operated by the USFWS; other entities (e.g., Montana Fish Wildlife and Parks) are responsible for the operation of their hatcheries.

Pallid Sturgeon Population Assessment Project

The Pallid Sturgeon Population Assessment Project (PSPAP) has been the primary fish monitoring element for the BiOp and the MRRP and would continue in some form under all plan alternatives including the No-Action Alternative. Data collected through the PSPAP are used to evaluate the Pallid Sturgeon Propagation and Population Augmentation management action and provide long-term assessment of fish metrics. The USACE is responsible for ensuring that these long-term assessment activities occur to meet BiOp required monitoring and evaluation. The USACE has developed partnerships with state and federal agencies already active on the Missouri and Kansas Rivers and has provided the funding, standardized protocols, and quality control

oversight necessary to implement the monitoring strategy of the PSPAP. Some level of redesign of the PSPAP is anticipated in the future in order to achieve efficiencies and align the PSPAP to assist with evaluating management hypotheses.

Upper River Pallid Sturgeon

Under all plan alternatives, the USACE would conduct the monitoring and assessment complimentary of that for which Reclamation has responsibility to determine if modifications for fish passage at Intake Diversion Dam are meeting pallid sturgeon objectives. Reclamation is responsible for monitoring whether fish passage occurs at Intake following implementation of fish passage measures. The USACE would be responsible for ensuring that MRRP monitoring and assessment can determine if successful fish passage at Intake is contributing to the Upper River pallid sturgeon population.

Lower River Pallid Sturgeon

Channel Reconfiguration for Creation of Early Life History Habitat

All plan alternatives include channel reconfiguration for the creation of early life history pallid sturgeon habitat; however, the amounts and types of habitat that would be created vary by alternative and those differences are described in the respective section for each alternative. Methods to implement this action are described in Section 2.5.3.3.

Habitat Development and Land Management on MRRP Lands

All plan alternatives include habitat development on MRRP lands; however, the amount of land acquisition varies by alternative and so would the magnitude of this action. Those differences are described in the respective section for each alternative. Methods to implement this action are described in Section 2.5.4.

Adaptive Management

Adaptive Management (AM) Framework for Alternatives 1 and 2

Under Alternatives 1 and 2, the USACE would continue to implement the AM approach that has been in place since 2009. Under Alternative 1, the AM approach consists of two primary components; the AM Plan for ESH (USACE, 2011) and the AM strategy developed for SWH creation (USACE, 2012c). The AM approach developed for the SWH and ESH sub-programs was developed in accordance with the 2000 BiOp and the 2003 amendment, which called for establishing an AM process to evaluate species and habitat responses to management actions within the river and to continually provide knowledge

for the decision-making process (USFWS 2000; 2003). Under Alternative 2, following the same AM approach as Alternative 1, AM strategies would be developed for additional specific management actions such as reservoir unbalancing and low nesting season reservoir releases. Under Alternatives 1 and 2, the individual AM strategies are driven by the management actions contained in the 2000 BiOp and its 2003 Amendment. Monitoring data would be compiled and analyzed on an annual basis to assess progress towards stated objectives for both ESH and SWH and to report results. These annual reports would include recommendations related to all or some of the following program decisions;

- Level of construction effort,
- Pilot projects,
- Site adjustments,
- Incorporation of new methodologies,
- Investigations.

Every five years, additional analyses would be conducted in order to assess whether the elements of the ESH AM Plan and SWH AM strategy are being met. If a decision is made to update the ESH AM Plan or SWH AM strategy document, a scope, schedule, and plan of action would be developed.

For additional detail regarding the Adaptive Management Framework that would be followed under Alternatives 1 and 2, see the MRRP Adaptive Management Framework, ESH AM Plan, and SWH AM Strategy which are public documents available on the MRRP website at www.moriverrecovery.org.

Adaptive Management Framework for Alternatives 3, 4, 5 and 6

Under Alternatives 3–6, the USACE would follow the Missouri River SAMP developed as part of this Management Plan process. The SAMP is rooted in the effects analysis (EA), which was an effort to synthesize and analyze existing scientific data and information that has accrued since the 2000 BiOp and its 2003 Amendment. The EA developed conceptual ecological models to facilitate visualization and organization of the current thinking about relationships between management actions and species response, developed hypotheses about the effects of different management actions, and assess the hypotheses with multiple lines of evidence. The AM Plan, based on this EA, includes elements of both active and passive adaptive management. Active AM emphasizes knowledge as an intermediate objective toward the fundamental objectives and uses experiments or alternative management strategies to better understand system behavior (i.e., it is typically hypothesis-driven). The knowledge gained is then fed back

into the decision-making process, improving performance toward the fundamental objectives. Passive AM is strictly objective-driven, and embraces learning gained through monitoring as secondary to the achievement of the fundamental objectives.

The role of AM in managing the birds under this MRRMP is to improve decision-making in light of an uncertain future system state; a type of uncertainty that can never fully be resolved, and through improved understanding of how the system functions and responds to various management actions. As the AM program is implemented, what is learned about the actions included within its scope will be applied to increase their effectiveness and may also result in the addition or removal of management actions from consideration. For pallid sturgeon, lingering uncertainties regarding the scope and scale of the management actions necessary to address recruitment failure has led to an Adaptive Management strategy reliant upon a progressive AM approach to manage risks to the pallid sturgeon. Under Alternatives 3–6, the Adaptive Management strategy is driven by the hypotheses generated by the EA effort. For additional detail about the AM Framework, see the SAMP.

Alternative 1 – No Action

Under the No-Action Alternative, the MRRP would continue to be implemented as it is currently. The current program does not implement all RPAs included in the 2003 Amended BiOp (USFWS 2003). The following sections describe the actions that would be taken towards BiOp compliance in addition to those common actions identified in Section 2.8.1 and their projected level of intensity as part of the No-Action Alternative.

Least Tern and Piping Plover

Under the No-Action Alternative, the following management actions would be implemented in compliance with the BiOp for least tern and piping plover on the Missouri River. The geographic scope of these management actions include the Missouri River from Fort Peck reservoir downstream to Ponca, Nebraska.

Mechanical Emergent Sandbar Habitat Construction

Under the No-Action alternative, the USACE would mechanically construct ESH annually at a rate of up to 107 acres per year across the entire system. This amount (107 acres/year) is based on past average annual ESH construction in the Gavins Point Dam and upper Lewis and Clark Lake segments from 2004 through 2010.

The No-Action Alternative includes only mechanical construction and maintenance of ESH using earth moving equipment and hydraulic dredges. Under the No-Action

Alternative, there are no flow actions specific to managing ESH for terns and plovers. Current operations under the Missouri River Mainstem Reservoir System Master Water Control Manual (USACE 2006) would constitute the underlying base flows. Consistent with the Master Manual, flow management to reduce take of least tern and piping plover would continue.

The results of ESH availability modeling indicate that under the No-Action Alternative, the 107-acre-maximum construction cap would occur in 82 percent of years modeled. In the remaining years, the model indicates there would be sufficient ESH on the System that construction would not be necessary. On average, the 107 acres would be divided between the Garrison reach (47 acres) and the Gavins Point reach (61 acres).

Pallid Sturgeon – Lower River

Under the No-Action Alternative, the following management actions would be implemented in compliance with the BiOp for pallid sturgeon in the lower Missouri River. The geographic scope of these management actions to benefit pallid sturgeon in the lower Missouri River is downstream of Gavins Point Dam to the confluence of the Missouri and Mississippi Rivers near St. Louis, Missouri.

Propagation and Augmentation

Under the No-Action Alternative, the USACE support of pallid sturgeon propagation and augmentation efforts would continue at current levels. The USACE primary method of support is through the provision of annual funding, which is anticipated to continue at approximately $455,000 annually.

Early Life History Habitat Construction

Under the No-Action Alternative, construction of habitat to support early life history requirements of pallid sturgeon would occur as part of the SWH program. The SWH restoration goal as outlined in the 2003 Amended BiOp (USFWS 2003) is to achieve an average of 20–30 acres of SWH per river mile. Under the No-Action Alternative, the USACE would achieve the low end of this acreage target (i.e., 20 acres per river mile between Ponca, Nebraska, and the mouth). This equates to a total of 15,060 acres of SWH. Existing habitat on the system combined with SWH projects have created a total of 11,832 acres, leaving 3,999 acres to be created (Table A.3.2). For purposes of evaluating potential impacts to the human environment, modeling assumed that the additional SWH acreage would be created as follows (Table A.3.3):

- Approximately 3,519 acres of in-channel SWH created through channel or top-width widening. A conceptual width of 250 feet was assumed for projects between Ponca and Rulo (20 projects encompassing 48 river miles) and 300 feet for projects downstream of Rulo (24 projects encompassing 57 river miles). Actual project width and size will vary by site.
- Approximately 480 acres of off-channel backwaters, assuming 8 new backwaters with each creating 60 acres of SWH.

Table A.3.4 summarizes the amount of land acquisition that was assumed to be required to implement the identified amount of SWH.

TABLE A.3.2. SUMMARY OF PROJECTED SHALLOW WATER HABITAT CREATION UNDER THE NO-ACTION ALTERNATIVE.

River Reach	River Mile Start	River Mile End	Miles in Reach	20 acres per mile of SWH	Existing acres of SWH	Target Acres of SWH
Ponca to Sioux City	753	735	18	360	120	240
Sioux City to Platte River	735	595	140	2,800	1,779	1,021
Platte River to Rulo	595	498	97	1,940	1,268	672
Rulo to Kansas River	498	367	131	2,620	1,491	1,129
Kansas River to Osage River	367	130	237	4,740	3,803	937
Osage River to Mouth	130	0	130	2,600	3,371	0
		Total	**753**	**15,060**	**11,832**	**3,999**

TABLE A.3.3. PROJECTED COMPOSITION OF SHALLOW WATER HABITAT CREATION TYPE UNDER THE NO-ACTION ALTERNATIVE.

River Reach	Target Acres of SWH	Channel Widening[1]			Backwaters[2]	
		Acres	Miles	# of Projects	Acres	# of Projects
Ponca to Sioux City	240	180	5.9	2	60	1
Sioux City to Platte River	1,021	601	19.8	9	420	7
Platte River to Rulo	672	672	22.2	9	0	0
Rulo to Kansas River	1,129	1,129	31.1	14	0	0
Kansas River to Osage River	937	937	25.8	10	0	0
Osage River to Mouth	0	0	0	0	0	0
Total	3,999	3,519	105	44	480	8

[1] Acreage amounts assume a top width of 250 feet for projects between Ponca and Rulo and 300 feet for projects downstream of Rulo.

[2] Assumes 60 acres of SWH are created by each project.

TABLE A.3.4. LAND ACQUISITION REQUIREMENTS TO IMPLEMENT EARLY LIFE HISTORY OF PALLID STURGEON HABITAT UNDER ALTERNATIVE 1.

River Reach	Target Acres of SWH	Additional Land Required – Habitat Only (acres)	Additional Land Required – Total (acres)*
Ponca to Sioux City	240	240	1,848
Sioux City to Platte River	1,021	0	0
Platte River to Rulo	672	0	0
Rulo to Kansas River	1,129	675	5,198
Kansas River to Osage River	937	0	0
Osage River to Mouth	0	0	0
Total	**3,999**	**915**	**7,046**

* For estimating purposes, it was assumed that 7.7 acres of land acquisition are required for every 1 acre of habitat needed. This is based on historic implementation data and accounts for factors such as parcel size and other real estate acquisition considerations.

Spawning Cue Release

For purposes of modeling the No-Action Alternative, the USACE assumed continued implementation of the plenary spring pulse as described in the Master Manual (USACE 2006). The bimodal Gavins Point spring pulse plan was developed based on the following; the provisions of the 2003 Amended BiOp (USFWS 2003) including the Integrated Science Program (ISP), input from the 2005 spring pulse Plenary Group, and its associated technical working groups, Tribal consultations/meetings, and public comments received on the draft spring pulse plan presented in the fall of 2005. A description of the detailed features of the plan follows.

Gavins Point Spring Pulse Downstream Flows Limits

The magnitude of both the March and May Gavins Point spring pulses would be constrained by the Gavins Point spring pulse downstream flow limits. These downstream flow limits are established at the same locations as the current flood control constraint flow targets discussed in the Master Manual (USACE 2006) and shown in Table A.3.5. The downstream flow limits shown in Table 2-15 are the same values as the most conservative flood control constraint flow targets and therefore, would provide similar downstream flood control during the spring pulse periods. As an additional precaution, radar detected precipitation and National Weather Service quantitative precipitation forecasted (QPF) precipitation would continue to be used in forecasting the resultant downstream flows. Gavins Point releases would be adjusted as required during the spring pulse periods based on this forecast.

TABLE A.3.5. DOWNSTREAM FLOW LIMITS DURING THE SPRING PULSE UNDER THE NO-ACTION ALTERNATIVE.

Location	Flow Limit (cfs)
Omaha	41,000
Nebraska City	47,000
Kansas City	71,000

cfs = cubic feet per second

March Spring Pulse from Gavins Point

The March spring pulse below Gavins Point is a preclude based on System storage. If the actual System storage as computed on 1 March is at or below 36.5 MAF, a March pulse would not be implemented. After the first occurrence of a March pulse, the preclude would change to 40.0 MAF. The magnitude of the March pulse is defined as the combination of the Gavins Point release increase and the contribution of the James River. Assuming that System storage is above the March pulse preclude, the magnitude of the March pulse would be 5,000 cfs and would be implemented the day after System releases reach the level necessary to provide downstream flow support for the beginning of the navigation season. More specifically, the magnitude of the Gavins Point release at the peak of the March pulse would be 5,000 cfs minus the contribution of the James River measured at the Scotland, South Dakota, stream gage. Actual releases from Gavins Point dam would be set to the nearest 500 cfs increment. Also, the total Gavins Point release during the March pulse would not be set any higher than the Gavins Point powerplant capacity (35,000 cfs). The duration of the peak of the March pulse would be 2 days. Following the 2-day peak, the March pulse flows would be reduced each day over the next 5 days until non-spring pulse downstream flow support rates are achieved.

May Spring Pulse from Gavins Point

The May spring pulse from Gavins Point would also have a preclude based on actual System storage as computed on 1 May. If the actual System storage as computed on 1 May is at or below 36.5 MAF, a May pulse would not be implemented. The May pulse preclude would also initially be 36.5 MAF until the first time the May spring pulse is implemented. As with the March pulse, once the first May spring pulse has been implemented the May spring pulse preclude would change to 40.0 MAF.

The magnitude of the May pulse, as is the case for the March pulse, is defined as the combination of Gavins Point release increase and the contribution of the James River. Therefore, the magnitude of the Gavins Point release at the peak of the May pulse would be the result of the two-step proration computation described below, minus the contribution of the James River measured at the Scotland, South Dakota, stream gage. The total Gavins Point release during the May pulse would not be constrained to the

Gavins Point powerplant capacity, as is case for the March pulse. The two-step proration computation to determine the magnitude of the May pulse is as follows:

1. **First Step**: The May pulse magnitude is first computed based on 1 May System storage. The May pulse magnitude is prorated in a straight-line interpolation between 16,000 cfs and 12,000 cfs based on a System storage range between 54.5 and 40 MAF. The May pulse magnitude in this step is limited to 16,000 cfs if System storage is greater than 54.5 MAF. For the initial occurrence of the May pulse, if System storage is between 36.5 and 40 MAF, the resultant magnitude from this step is 12,000 cfs.
2. **Second Step**: The resultant May pulse magnitude from the first step is then further prorated based on the USACE 1 May data, Mainstem Calendar Year Runoff Forecast for the Missouri River basin above Sioux City, Iowa. The May pulse magnitude computed in the first step could be decreased or increased by as much as 25 percent in this step. The May pulse magnitude resulting from the first step is increased in a straight line interpolation from 0 to 25 percent for a calendar year runoff forecast that ranges from median to upper quartile. The May pulse magnitude from the first step is decreased in a straight line interpolation from 0 to 25 percent for a 1 May calendar year runoff forecast that ranges from median to lower quartile runoff. Use of both steps in this computational process produces a potential range of May pulse magnitudes from 9,000 cfs to 20,000 cfs. Actual releases from Gavins Point Dam would be set to the nearest 500 cfs increment.

The initiation of the May pulse would be between 1 May and 19 May, depending on Missouri River water temperature. The May pulse would be initiated after the second daily occurrence of a 16°C or higher Missouri River water temperature measured immediately below Gavins Point Dam. However, the final decision on the date of the initiation of the May pulse would take into account the potential for “take” of threatened and endangered bird species during the pulse period and downstream flow conditions.

Gavins Point releases would be increased at a rate of approximately 6,000 cfs per day from normal downstream flow support releases until the full May pulse magnitude (as calculated above), is achieved. The May pulse magnitude would be maintained for 2 days, after which releases would be decreased by 30 percent over the following 2 days. The remaining release reductions would be prorated over an additional 8 days until non-spring pulse downstream flow support rates are achieved. This would result in a recession length of 10 days from the peak of the May pulse. The length and magnitude of the recession may also be constrained by the downstream flow limits shown in Table A.3.5.

Monitoring and Research

Pallid sturgeon science efforts require a comprehensive approach when providing information to decision-makers. The USACE management actions require riverine monitoring to determine the species response, effectiveness of the action, and/or any

unintended effects. These assessments are further developed through research activities that clarify critical uncertainties and focus on factors limiting recruitment. These elements, in combination with propagation and augmentation, seek to identify and remove bottlenecks to pallid sturgeon recruitment. Under the No-Action Alternative, the following monitoring and research activities would continue, in addition to the PSPAP, which is common to all plan alternatives.

- **Habitat Assessment and Monitoring Program (HAMP)**: The HAMP began in 2004 and was developed by representatives of state and federal agencies and academia that collectively possess knowledge and expertise on the Missouri River, pallid sturgeon, and other native Missouri River fishes, research, experimental design, and statistical analysis. The HAMP focuses on the endangered pallid sturgeon, other big river native fishes, and their habitats as recommended by the BiOp. The goal of the HAMP is to assess the physical and biological responses to habitat creation actions that are expected to benefit pallid sturgeon and related fish communities.
- **Focused Pallid Sturgeon Research**: The USACE annually funds focused research to address remaining critical pallid sturgeon information gaps including the identification and better understanding of key pallid sturgeon life history transitions and development of explicit pallid sturgeon objectives and prioritized hypotheses.

Alternative-Specific Adaptive Management Considerations

Under Alternative 1, the USACE would continue to implement the AM approach that has been in place since 2009. It consists of two primary components; the AM Plan for ESH (USACE 2011) and the AM strategy developed for SWH creation (USACE 2012c). The AM approach developed for the SWH and ESH sub-programs was developed in accordance with the 2000 BiOp and its 2003 amendment. These two documents called for establishing an AM process to evaluate species and habitat responses to management actions within the river and to continually provide knowledge for the decision-making process (USFWS 2000; 2003). In addition, the USACE released a technical memorandum describing implementation guidance for Section 2039 of the WRDA 2007 which called for monitoring and AM of ecosystem restoration projects and provided some specific direction on what should be addressed within AM plans. Finally, the National Research Council (NRC) called for AM efforts in their 2002 report *The Missouri River Ecosystem: Exploring the Prospects for Recovery* (NRC 2002). In 2008, a multi-agency team consisting of representatives from the USACE, USFWS, National Park Service (NPS), and experts in structured decision-making and model development initiated strategy development. In 2009, the strategy was updated by the MRRP Adaptive Management Work Group and the ESH Programmatic Environmental Impact Statement PDT, in coordination with cooperating agencies on the Programmatic Environmental Impact Statement (i.e., USFWS and NPS) before finalization and implementation in 2010.

Monitoring data would be compiled and analyzed on an annual basis to assess progress towards stated objectives for both ESH and SWH, and to report results. These annual reports would include recommendations related to all or some of the following program decisions; 1) level of construction effort, 2) pilot projects, 3) site adjustments, 4) incorporation of new methodologies, and 5) investigations. Every five years, additional analyses would be conducted in order to assess whether the elements of the ESH AM Plan and SWH AM strategy are being met. If a decision is made to update the ESH AM Plan or SWH AM strategy document, a scope, schedule, and plan of action would be developed.

MRRIC and other groups may choose to provide comments or recommend adjustments to AM strategies at any time during the implementation process. This could include changes to AM objectives, incorporation of additional management actions, input on anticipated benefits and tradeoffs, and other pertinent elements of the AM Plans.

Alternative 2 – U.S. Fish and Wildlife Service 2003 Biological Opinion Projected Actions

Alternative 2 represents the USFWS interpretation of the management actions that would be implemented as part of the USFWS 2003 Amended Biological Opinion (USFWS 2003). Whereas the No-Action Alternative only includes the continuation of management actions the USACE has implemented to date for BiOp compliance, Alternative 2 includes additional iterative actions and expected actions that the USFWS anticipates would ultimately be implemented through AM and as such, impediments to implementation were removed. This section describes the actions that would be taken towards BiOp compliance and their projected level of intensity as part of the Projected Actions alternative under the USFWS 2003 Amended Biological Opinion. The USFWS input on this alternative was formalized in a planning aid letter submitted to the USACE on 5 November 2015.

Least Tern and Piping Plover

Under Alternative 2, the following management actions would be implemented in compliance with the 2003 Amended BiOp (USFWS 2003) for least tern and piping plover on the Missouri River. The geographic scope of these management actions would include the Missouri River from Fort Peck reservoir downstream to Ponca, Nebraska. The Planning Aid Letter submitted to the USACE on 5 November 2015 reiterated the ESH goals included in the BiOp, which include a goal of 11,886 acres of ESH on the System subdivided as follows:

- Below Gavins Point Dam – 80 acres of ESH per river mile
- Below Garrison Dam – 50 acres of ESH per river mile

- Below Fort Randall Dam – 20 acres of ESH per river mile
- Lewis and Clark Lake – 80 acres per river mile

The USACE would have management discretion as to how those acreage goals are achieved (i.e., mechanical construction vs. flows) as using construction alone to reach acreage goals under this alternative would be cost prohibitive. The USACE would approach the acreage goals under this alternative incrementally; beginning with lower acreages, monitoring the bird response, and moving to higher acreages if birds are not achieving the desired biological metrics.set forth in the 2003 Amended BiOp (USFWS 2003).

Mechanical Emergent Sandbar Habitat Construction

Under Alternative 2, the USACE would mechanically construct ESH annually at an average rate of 191 acres per year across the entire system. This amount represents the acreage necessary to meet the 2003 Amended BiOp acreage goal after accounting for available ESH on the system resulting from system operations (including the spawning cue flows for pallid sturgeon). The average annual construction amount includes replacing ESH lost to erosion and vegetative growth, and constructing new ESH. As with Alternative 1, ESH would be constructed using earth moving equipment and hydraulic dredges.

The results of ESH availability modeling indicate that under Alternative 2, ESH construction would occur in 69 percent of the years modeled. In the remaining years, the model indicates there would be sufficient ESH on the system that construction would not be necessary.

Spring Habitat-Forming Flow Release

A spring reservoir release for the purposes of ESH creation is not included in Alternative 2. However, the timing and magnitude of the pallid sturgeon spawning cue release would provide ESH creating benefits. These benefits are accounted for in the habitat availability modeling that determined the amount of ESH that would be mechanically created.

Lowered Nesting Season Flows

The low summer flow described for pallid sturgeon would also serve as a lowered nesting season flow for the benefit of least terns and piping plovers under Alternative 2. The criteria for the flow implementation would be the same as described in Section 2.8.3.2 of the AMP.

Pallid Sturgeon – Lower River

Under Alternative 2, the following management actions would be implemented in compliance with the BiOp for pallid sturgeon in the lower Missouri River. The geographic scope of these management actions to benefit pallid sturgeon in the lower Missouri River is downstream of Gavins Point Dam to the confluence of the Missouri and Mississippi rivers near St. Louis, Missouri.

Propagation and Stocking

Under Alternative 2, the USACE' support of pallid sturgeon propagation and augmentation efforts would continue at current levels. The USACE primary method of support is through the provision of annual funding, which is anticipated to continue at approximately $455,000 annually.

Early Life History Habitat Construction

Under Alternative 2, construction of habitat to support early life history requirements of pallid sturgeon would occur as part of the SWH program. The SWH restoration goal as outlined in the 2003 Amended BiOp (USFWS 2003) is to achieve an average of 20–30 acres of SWH per river mile. Under Alternative 2, the USACE would achieve the upper end of this acreage target (i.e., 30 acres per river mile between Ponca, Nebraska, and the mouth). This equates to a total of 22,590 acres of SWH. Existing SWH projects have created a total of 11,832 acres, leaving 10,758 acres to be created (Table A.3.2). For the purposes of evaluating potential impacts to the human environment, modeling assumed that the additional SWH acreage would be created as follows (Table A.3.3):

- Approximately 9,858 acres of in-channel SWH would be created through channel widening. A conceptual width of 250 feet was assumed for projects between Ponca, Nebraska, and Rulo, Nebraska (60 projects encompassing 118.2 river miles) and 450 feet for projects downstream of Rulo (48 projects encompassing 115 river miles). Actual project width and size will vary by site.
- Approximately 900 acres of off-channel backwaters, assuming 15 new backwaters with each creating 60 acres of SWH.

Land acquisition to implement the SWH requirements described is summarized in Table A.3.4.

TABLE A.3.6. SUMMARY OF PROJECTED SHALLOW WATER HABITAT CREATION UNDER ALTERNATIVE 2

River Reach	River Mile Start	River Mile End	Miles in Reach	30 acres per mile of SWH	Existing acres of SWH	Target Acres of SWH
Ponca to Sioux City	753	735	18	540	120	420

Sioux City to Platte River	735	595	140	4,200	1,779	2,421
Platte River to Rulo	595	498	97	2,910	1,268	1,642
Rulo to Kansas River	498	367	131	3,930	1,491	2,439
Kansas River to Osage River	367	130	237	7,110	3,803	3,307
Osage River to Mouth	130	0	130	3,900	3,371	529
		Total	**753**	**22,590**	**11,832**	**10,758**

TABLE A.3.7. PROJECTED COMPOSITION OF SHALLOW WATER HABITAT CREATION TYPE UNDER ALTERNATIVE 2

River Reach	Target Acres of SWH	Channel Widening[1]			Backwaters[2]	
		Acres	Miles	# of Projects	Acres	# of Projects
Ponca to Sioux City	420	240	7.9	4	180	3
Sioux City to Platte River	2,421	1,761	58.1	32	660	11
Platte River to Rulo	1,642	1,582	52.2	24	60	1
Rulo to Kansas River	2,439	2,439	44.7	19	0	0
Kansas River to Osage River	3,307	3,307	60.6	25	0	0
Osage River to Mouth	529	529	9.7	4	0	0
Total	**10,758**	**9,858**	**233**	**108**	**900**	**15**

[1] Acreage amounts assume a top width of 250 feet for projects between Ponca and Rulo and 450 feet for projects downstream of Rulo.

[4] Assumes 60 acres of SWH are created by each project.

TABLE A.3.8. LAND ACQUISITION REQUIREMENTS TO IMPLEMENT EARLY LIFE HISTORY PALLID STURGEON HABITAT UNDER ALTERNATIVE 2

River Reach	Target Acres of SWH	Additional Land Required – Habitat Only (acres)	Additional Land Required – Total (acres)*
Ponca to Sioux City	420	420	3,234
Sioux City to Platte River	2,421	925	7,123
Platte River to Rulo	1,642	675	5,198
Rulo to Kansas River	2,439	1,985	15,285
Kansas River to Osage River	3,307	1,932	14,876
Osage River to Mouth	529	0	0
Total	**10,758**	**5,937**	**45,716**

* For estimating purposes, it was assumed that 7.7 acres of land acquisition are required for every 1 acre of habitat needed. This is based on historic implementation data and accounts for factors such as parcel size and other real estate acquisition considerations.

Spawning Cue Release

The USFWS determined in the 2003 Amended BiOp (USFWS 2003) that restoration of a normalized river hydrograph below Gavins Point Dam was necessary to avoid jeopardizing the continued existence of the pallid sturgeon. Several biologically relevant features were identified for a flow action below Gavins Point Dam including; 1) flows to cue spawning that are sufficiently high for an adequate duration, and 2) flows that provide for connection of low-lying lands adjacent to the channel.

The spawning cue release from Gavins Point Dam would be bimodal (i.e., consisting of two separate flow pulses) and would be implemented in every year if conditions are met. If System storage on 15 March is 31.0 MAF or less, equating to a "no service" navigation year, the spawning cue release would not be implemented. In addition, if downstream flood control targets are exceeded, the spawning cue release would not be initiated or it would be terminated if these targets are exceeded during implementation. The results of preliminary reservoir simulation modeling, based on an 82-year period of record, indicate that in practice the bimodal spawning cue flows would likely only meet the conditions for implementation once every eight years. The conditions and characteristics of the two pulses would include:

- In advance of the first pulse, the maximum winter Gavins Point release would be maintained at 16 kcfs.
- First pulse from Gavins Point Dam.
  - Implementation would occur if the conditions described previously are met; system storage on 1 March is at least 40.0 MAF and the System is not at storage evacuation service level on 15 March.
  - Implementation would begin with the typical increase in flow to provide for navigation around 15 March.
  - The rate of flow increase (i.e., the ascending limb of the pulse) would last 7 days until a peak of 31 kcfs is reached.
  - Once reached, the peak flow would be maintained for 7 days. After that, the rate of decrease (i.e., the descending limb of the pulse) would last 7 days and then return to FTT operations based on service level from the 15 March storage check.
- Second pulse from Gavins Point Dam.
  - Implementation would occur if the conditions described previously are met and system storage on 1 May is at least 40.0 MAF. Flood control constraints would be determined by adding the pulse magnitude to the existing flood control constraints as shown in Table VII-7 and VII-8 in Master Manual (USACE 2006). For example, if the pulse magnitude is 16 kcfs and the flood targets are 41 kcfs, 47 kcfs, and 71 kcfs at Omaha, Nebraska City, and Kansas City, respectively, the new flood targets would be 57 kcfs at Omaha (16 kcfs + 41 kcfs), 62 kcfs at Nebraska City (16 kcfs + 47 kcfs), and 87 kcfs at Kansas City (16 kcfs + 71 kcfs). The pulse would be terminated any time flood control constraints are exceeded.
  - Implementation would begin on 1 May.
  - The rate of flow increase (i.e., the ascending limb of the pulse) would last 7–10 days.
  - The pulse peak would be based on the 1 March forecast as follows but would never exceed a total Gavins Point Dam release of 60 kcfs:
    - Lower quartile or lower runoff = 12 kcfs rise over 1 May release and maintained for 14 days
    - Median = 16 kcfs rise over 1 May release and maintained for 25 days

        - Upper quartile or higher runoff = 20 kcfs rise over 1 May release and maintained for 35 days
    - The rate of decrease (i.e., the descending limb of the pulse) would last not less than 7 days until a return to "steady release" scenario is reached.

Low Summer Flow

The USFWS 2003 Amended BiOp (USFWS 2003) also called for modification to System operations to allow for flows that are sufficiently low to provide for SWH as rearing, refugia, and foraging areas for larval, juvenile, and adult pallid sturgeon. Alternative 2 includes a low summer flow that would be implemented as follows:

- Summer low flow would only be implemented in the two years following implementation of a complete bimodal spawning cue flow, meaning that both the first and second pulses as described in Attachment A.3 (Alternative 6) are implemented completely.
- From 23 June to 1 July, Gavins Point Dam release would be set to 25 kcfs
- On 1 July, the USACE would assess the navigation season length and operate as follows:
    - If there is a shortened navigation season as determined by the existing Master Manual (USACE 2006):
        - Gavins Point Dam releases would be determined based on meeting water supply targets (open channel non-navigation season).
        - The duration of those releases would be equivalent to that of the number of days the season is shortened less the 8 days in June (e.g., if season is shortened 30 days).
        - Following that duration, flows would be set to 25 kcfs until 15 July at which time release would be dropped to 21 kcfs until 15 August. As of 15 August, releases would return to 25 kcfs until 1 September.
        - FTT operations would resume from 1 September until 1 December.
    - If there is not a shortened navigation season:
        - Releases of 25 kcfs would continue from 1 July to 15 July then drop to 21 kcfs until 15 August. After 15 August, releases would return to 25 kcfs until 1 September.
        - FTT operations would resume from 1 September until 1 December or 10 December if a ten-day navigation season extension is determined.

Floodplain Connectivity

The USFWS 2003 Amended BiOp (USFWS 2003) stated the following in regard to floodplain connectivity: "*Floodplain inundation and connectivity is essential in order to maximize the production of the forage base for pallid sturgeon. The forage base production must occur at a time that coincides with larval sturgeon becoming active, free-swimming feeders. Floodplains are highly productive habitat in the late spring*

and early summer when warm, shallow water floods over the area and produces a bloom of forage that is of appropriate size for larval fish to eat. Additionally, low-lying lands are an extremely important source for floodplain spawning fish which subsequently support the forage base for adult pallid sturgeon. Highly productive floodplains are necessary on a frequent annual basis to provide necessary life requisites for pallid sturgeon survival."

The USACE coordinated with the USFWS during alternatives development to identify criteria for clarification of the floodplain connectivity management action for Alternative 2. These criteria were included in a Planning Aid Letter submitted to the USACE on 5 November 2015. The criteria stated that this management action should maximize floodplain habitat by ensuring that 77,410 acres of connected floodplain are inundated at a 20 percent annual chance exceedance. The USACE conducted HEC-GeoRAS mapping to determine the acres of existing floodplain connectivity in the lower Missouri River. The mapping results indicated that 156,480 acres of floodplain connectivity are currently present, not including the area of the main channel. Under Alternative 2, the USACE would continue management of the System for a minimum of 77,410 acres of floodplain connectivity.

Monitoring and Research

Monitoring and research efforts under Alternative 2 would be the same as described for Alternative 1.

Alternative-Specific Adaptive Management Considerations

The AM approach for Alternative 2, is similar to the AM approach that the USACE has been implementing since 2009 and described for Alternative 1. The AM approach for Alternative 2 would be the same as for Alternative 1 but would be modified to address specific alterations in proposed management actions as described in the 5 November 2015 Planning Aid Letter from the USFWS. Management actions implemented by the USACE as part of Alternative 2 would be modified and continually improved upon through AM and in cooperation with the USFWS. Due to changing river conditions, methods of implementing management actions may vary over time, and modifications to management actions would be based on an evaluation of habitat, flow, climate, species response, and any other new information available each year. Under Alternative 2, monitoring would remain a key component to the AM approach to document how management actions were implemented and their effects within the river and on the listed species. The USACE and USFWS would jointly define what is considered to be sufficient progress for each management action within specified timeframes to avoid jeopardy.

Actions Common to Alternatives 3–6

Active Adaptive Management

Under alternatives 3–6, the USACE would implement an AM program. AM promotes collaboration and flexible decision-making through deliberately designing and implementing management actions to test hypotheses and maximize learning about critical uncertainties that better inform management decisions (Williams et al. 2009). The AM Plan, based on the EA, includes elements of both active and passive adaptive management. Active AM emphasizes knowledge as an intermediate objective toward the fundamental objectives and uses experiments or alternative management strategies to better understand system behavior (i.e., it is typically hypothesis-driven). The knowledge gained is then fed back into the decision-making process, improving performance toward the fundamental objectives. Passive AM is strictly objective-driven and embraces learning gained through monitoring as secondary to the achievement of the fundamental objectives. Alternatives 3–6 would implement the active form of adaptive management, which employs management actions in an experimental design aimed primarily at learning to reduce uncertainty; near-term benefits to the resource are secondary. Specific AM actions would be implemented focused on understanding limiting factors associated with least terns and piping plovers, as well as pallid sturgeon.

Level 1 and 2 Studies

As part of the AM program described above, the USACE would implement level 1 and 2 studies under Alternatives 3–6 for better understanding limiting factors associated with pallid sturgeon. Level 1 studies are research focused and do not change the system (Laboratory studies or field studies under ambient conditions). Level 2 studies would focus on in-river testing of actions at a level sufficient to expect a measurable biological, behavioral, or physiological response in pallid sturgeon, surrogate species, or related habitat response. Some level 2 studies would be outside the scope of this EIS and require additional compliance with NEPA. For additional information on the types of studies that could be implemented under alternatives 3–6 see Section 4.2.4 of the SAMP.

Spawning Habitat

Under Alternatives 3–6, the USACE would create three, high-quality spawning habitat sites. Monitoring the effectiveness of these actions in terms of the relative use of these sites compared to other control areas, and the relative spawning success, as determined by hatch rate, catch per unit effort of free embryos and other indicators will be conducted. Sufficient understanding to characterize the necessary features of high quality pallid sturgeon spawning habitats does not exist. These sites would be

constructed following initial studies that further clarify habitat specifications. An early emphasis would use information from the Yellowstone River as the best natural reference condition to inform the design of these pilot projects on the Lower Missouri River, while also continuing to examine the habitat characteristics of spawning sites on the Lower Missouri River.

Channel Reconfiguration for Interception and Rearing Complexes

Under Alternatives 3–6, construction of habitat to support early life history requirements of pallid sturgeon would occur following the IRC (interception and rearing complexes) concept. Best available science indicates that future acreage required to construct IRCs would most likely be achieved through channel widening. For the purposes of evaluating potential impacts to the human environment, modeling assumed that about 3,380 acres of channel widening would be implemented to create IRCs under Alternatives 3–6 (Table A.3.9). A conceptual width of 250 feet was assumed for projects between Ponca and Rulo and 300 feet for projects downstream of Rulo. Land acquisition to implement the requirements described is summarized in Table A.3.10.

TABLE A.3.9. SUMMARY OF PROJECTED IRC CREATION UNDER ALTERNATIVES 3–6

River Reach	River Mile Start	River Mile End	Miles in Reach	Target Acres of IRC habitat[1]
Ponca to Sioux City	753	735	18	0
Sioux City to Platte River	735	595	140	276
Platte River to Rulo	595	498	97	585
Rulo to Kansas River	498	367	131	670
Kansas River to Osage River	367	130	237	1,389
Osage River to Mouth	130	0	130	460
			Total	**3,380**

[1] All acreage achieved through channel widening. Acreage amounts assume a top width of 250 feet for projects between Ponca and Rulo and 300 feet for projects downstream of Rulo.

TABLE A.3.10. LAND ACQUISITION REQUIREMENTS TO IMPLEMENT IRC UNDER ALTERNATIVES 3–6

River Reach	Target Acres of SWH	Existing Public Lands Available for Habitat Development (acres)[1]	Additional Land Required – Habitat Only (acres)	Additional Land Required – Total (acres)[2]
Ponca to Sioux City	0	420	0	0
Sioux City to Platte River	276	276	0	0
Platte River to Rulo	585	585	0	0
Rulo to Kansas River	670	454	216	1,664

Kansas River to Osage River	1,389	1,375	14	108
Osage River to Mouth	460	460	0	0
Total	**3,380**	**3,150**	**230**	**1,772**

[1] Existing public lands includes USACE, USFWS, and state conservation owned lands. Acreage was based on identifying government owned lands that may be appropriate for habitat development; however, these areas do not necessarily represent actual locations of future habitat development.

[2] For estimating purposes, it was assumed that 7.7 acres of land acquisition are required for every 1 acre of habitat needed. This is based on historic implementation data and accounts for factors such as parcel size and other real estate acquisition considerations.

Alternative 3 – Mechanical Construction Only

Mechanical Emergent Sandbar Habitat Creation

Under Alternative 3, the USACE would only create ESH habitat through mechanical means at an average rate of 391 acres per year across the entire system. This amount represents the acreage necessary to meet bird habitat targets after accounting for available ESH resulting from system operations. The average annual construction amount includes replacing ESH lost to erosion and vegetative growth, as well as constructing new ESH.

The results of ESH availability modeling indicate that under Alternative 3, ESH construction would occur in 75 percent of the 50 years modeled. In the remaining years, the model indicates there would be sufficient ESH on the system that construction would not be necessary.

Alternative 4 – Spring Habitat-Forming Flow Release

Mechanical Emergent Sandbar Habitat Creation

Under Alternative 4, the USACE would mechanically construct ESH annually at an average rate of 240 acres per year across the entire system. This amount represents the acreage necessary to meet the bird habitat targets after accounting for available ESH resulting from implementation of a Spring ESH-creating reservoir release. The average annual construction amount includes replacing ESH lost to erosion and vegetative growth, as well as constructing new ESH.

The results of ESH availability modeling indicate that under Alternative 4, ESH construction would occur in 49 percent of the 50 years modeled. In the remaining years, the model indicates there would be sufficient ESH on the system that construction would not be necessary.

Spring Habitat-Forming Flow Release

Alternative 4 reservoir operations would be similar to Alternative 1 (current operations), with the addition of a high spring release designed to create ESH for the least tern and piping plover. In any year, the implementation of this habitat-forming flow release would occur if System storage is at 42 MAF or greater on 1 April. Natural flows creating 250 acres of ESH have not occurred in the previous four years and downstream flow is below identified flood control constraints specific to this alternative (Table A.3.11). If those conditions are met, the habitat-forming flow release would be implemented on 1 April with a release of up to 60 kcfs out of Gavins Point Dam, and occur as often as every four years. To achieve the Gavins Point Dam release, Fort Randall Dam releases would be increased a similar amount as Gavins Point and releases from Garrison Dam would be approximately 17.5 kcfs less than the Gavins Point release.

TABLE A.3.11: FLOOD TARGETS.

Location	Kilo Cubic Feet Per Second (kcfs)
Omaha	71
Nebraska City	82
Kansas City	126

The duration of the release would increase as release magnitude is decreased. Table A.3.12 shows the duration (number of days) required for the habitat-forming flow release at various discharges.

TABLE A.3.12: ESTIMATED DURATIONS OF HABITAT-FORMING FLOW RELEASE.

Kilo Cubic Feet Per Second (kcfs)	Required Number of Days
60	35
55	49
50	77
45	175

If flood targets are exceeded, the Gavins Point release would be reduced by 5 kcfs until flood targets are no longer exceeded. In instances where the Gavins Point release falls below 45 kcfs, the release would be terminated. Modeling indicates that over the 82-year period of record, the spring habitat-forming flow release as defined here would have been implemented 10 times and would have been partially implemented 5 times. Partial implementation means that the criteria were met in that year to initiate the flow release but it was terminated before completion.

Under current operations, navigation releases are computed based on the current service level prior to flood targets being assessed. Flow support for navigation and other downstream purposes is defined based on service level. A “full-service” level of 35,000 cfs results in target flows of 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City and 41,000 cfs at Kansas City. Similarly, a “minimum-service” level of 29,000 cfs results in target flow values of 6,000 cfs less than the full-service levels. If system storage is high enough to warrant evacuation of flood storage, the service level will be greater than 35,000 cfs.

The following example assumes a service level of 40,000 cfs is the operations target. Navigation discharges for each of the target locations are computed based on Table A.3.13 (Table VII-1 in the Master Manual [USACE 2006]). These navigation discharges are the required discharges at the four target locations to support navigation. For a 40,000 cfs service level, the required navigation discharges at Sioux City, Omaha, Nebraska City, and Kansas City are; 36,000 cfs (40,000 - 4,000); 36,000 cfs (40,000 - 4,000); 42,000 cfs (40,000 + 2,000); and 46,000 cfs (40,000 + 6,000), respectively.

TABLE A.3.13. RELATION OF TARGET DISCHARGES TO SERVICE LEVEL.

Control Point Location	Flow Target Discharge Deviation from Service Level
Sioux City	-4,000 cfs
Omaha	-4,000 cfs
Nebraska City	+2,000 cfs
Kansas City	+6,000 cfs

Source: Master Manual, Table VII-1 (USACE 2006)

cfs = cubic feet per second

Once navigation discharges are calculated, two tiers of flood target discharges are calculated and forecasted discharges are checked against the flood discharges. The first tier is based on the criteria in Table A.3.14 (Table VII-7 in the Master Manual [USACE 2006]) and represents a full-service flood target. The second tier is based on the criteria in Table A.3.15 (Table VII-8 in the Master Manual [USACE 2006)] and represents a minimum-service flood target.

TABLE A.3.14. CRITERIA FOR MODIFYING TARGET FLOWS – FULL SERVICE.

Target flows will be reduced to those consistent with full-service level of 35,000 cfs when one or more of the anticipated downstream flows exceed the current service level flow values by more than:

6,000 cfs at Omaha	(target flow + 10,000 cfs)
12,000 cfs at Nebraska City	(target flow + 10,000 cfs)
36,000 cfs at Kansas City	(target flow + 30,000 cfs)

Source: Master Manual, Table VII-7 (USACE 2006)

cfs = cubic feet per second

TABLE A.3.15. CRITERIA FOR MODIFYING TARGET FLOWS – MINIMUM SERVICE.

Target flows will be reduced to those consistent with minimum-service level of 29,000 cfs when one or more of the anticipated downstream flows exceed the current service level flow values by more than:	
11,000 cfs at Omaha	(target flow + 15,000 cfs)
22,000 cfs at Nebraska City	(target flow + 20,000 cfs)
66,000 cfs at Kansas City	(target flow + 60,000 cfs)

Source: Master Manual, Table VII-8 (USACE 2006)

cfs = cubic feet per second

Using Table A.3.16 for a 40,000 cfs service level, full-service flood target discharges at Omaha, Nebraska City, and Kansas City are 46,000 cfs (36,000 + 10,000); 52,000 cfs (42,000 + 10,000); and 76,000 cfs (46,000 + 30,000), respectively. When downstream discharges are forecasted, if discharges at Omaha, Nebraska City, or Kansas City exceed their full-service flood targets, the system is operated as if at full-service. Navigation discharges become; 31,000 cfs (35,000 - 4,000); 31,000 cfs (35,000 - 4,000); 37,000 cfs (35,000 + 2,000); and 41,000 cfs (35,000 + 6,000). Gavins Point releases are then decreased until the full-service flood targets of 46,000 cfs, 52,000 cfs, and 76,000 cfs are no longer exceeded while still maintaining at least full-service discharges at each of the target locations.

Using Table A.3.16 for a 40,000 cfs service level, minimum-service flood target discharges at Omaha, Nebraska City, and Kansas City are 51,000 cfs (36,000 + 15,000); 62,000 cfs (42,000 + 20,000); and 106,000 cfs (46,000 + 60,000), respectively. When downstream discharges are forecasted, if discharges at Omaha, Nebraska City, or Kansas City exceed their minimum-service flood targets, the system is operated as if at minimum service. Navigation discharges become 25,000 cfs (29,000 - 4,000); 25,000 cfs (29,000 - 4,000); 31,000 cfs (29,000 + 2,000); and 35,000 cfs (29,000 + 6,000). Gavins Point releases are then decreased until the minimum-service flood targets of 51,000 cfs, 62,000 cfs, and 106,000 cfs are no longer exceeded while still maintaining at

least minimum-service discharges at each of the target locations. These calculations are summarized in Table A.3.16.

The habitat-forming flow release of 60 kcfs from Gavins Point could not occur under current operations because of how the flood target criteria are operationally applied. If 60,000 cfs were released from Gavins Point and it was assumed that all tributaries between Gavins Point and Omaha were dry, there would still be 60,000 cfs at Omaha due to releases from Gavins Point. A 60,000 cfs discharge at Omaha exceeds both the full-service flood target of 46,000 cfs and the minimum-service flood target of 51,000 cfs for a 40,000 service level. If the current flood target operations were used, the habitat-forming flow release would never have a chance to occur until the service level exceeded 49,000 cfs; therefore, in order to allow this high release from Gavins Point, it was necessary to modify how the flood target criteria are applied during times when a habitat-forming flow release is attempted. This revision results in the flood targets presented in Table A.3.16.

TABLE A.3.16 EXAMPLE NAVIGATION AND FLOOD TARGET DISCHARGES FOR A 40 KCFS SERVICE LEVEL UNDER CURRENT OPERATIONS.

Location	Navigation Discharge for 35,000 Service Level (Full-service) (cfs)	Navigation Discharge for 29,000 Service Level (Minimum-service) (cfs)	Navigation Discharge for Example 40,000 Service Level (cfs)	Full-service Flood Target (cfs)	Minimum-service Flood Target (cfs)
Sioux City	31,000	25,000	36,000	--	--
Omaha	31,000	25,000	36,000	46,000	51,000
Nebraska City	37,000	31,000	42,000	52,000	62,000
Kansas City	41,000	35,000	46,000	76,000	106,000

cfs = cubic feet per second

Alternative 5 – Fall Habitat-Forming Flow Release

Mechanical Emergent Sandbar Habitat Creation

Under Alternative 5, the USACE would mechanically construct ESH annually at an average rate of 309 acres per year across the entire system. This amount represents the acreage necessary to meet the bird habitat targets after accounting for available ESH resulting from implementation of a Fall ESH-creating reservoir release. The average annual construction amount includes replacing ESH lost to erosion and vegetative growth, as well as constructing new ESH.

The results of ESH availability modeling indicate that under Alternative 5, ESH construction would occur in 63 percent of the 50 years modeled. In the remaining years, the model indicates there would be sufficient ESH on the system that construction would not be necessary.

Fall Habitat-Forming Flow Release

Alternative 5 reservoir operations would be similar to Alternative 1 (current operations), with the addition of a high fall release designed to create ESH for the least tern and piping plover. In any year, the implementation of this habitat-forming flow release would occur if the service level is at 35 kcfs or greater (54.5 MAF System storage) on 17 October. Natural flows creating 250 acres of ESH have not occurred in the previous four years and downstream flow is below identified flood control constraints. Downstream flood control constraints for Alternative 5 would be the same as that for Alternative 4 (Table A.3.11). If those conditions are met, the habitat-forming flow release would be implemented on 17 October with a release of up to 60 kcfs out of Gavins Point Dam, and as often as every four years. To achieve the Gavins Point Dam release, Fort Randall Dam releases would be increased a similar amount as Gavins Point and releases from Garrison Dam would be approximately 17.5 kcfs less than the Gavins Point release. As with Alternative 4, the duration of the release would increase as release magnitude is decreased (Table A.3.12).

If flood targets are exceeded, the Gavins Point release would be reduced by 5 kcfs until flood targets are no longer exceeded. In instances where the Gavins Point release falls below 45 kcfs, the release would be terminated. Modeling indicates that over the 82-year period of record, the fall habitat-forming flow release as defined here would have been implemented 7 times and would have been partially implemented 2 times.

Alternative 6 – Pallid Sturgeon Spawning Cue

Mechanical Emergent Sandbar Habitat Creation

Under Alternative 6, the USACE would mechanically construct ESH annually at an average rate of 303 acres per year across the entire system. This amount represents the acreage necessary to meet the bird habitat targets after accounting for available ESH resulting from System operations, which includes a spawning cue flow for pallid sturgeon. The average annual construction amount includes replacing ESH lost to erosion and vegetative growth, as well as constructing new ESH.

The results of ESH availability modeling indicate that under Alternative 6, ESH construction would occur in 71 percent of the 50 years modeled. In the remaining years,

the model indicates there would be sufficient ESH on the system such that construction would not be necessary.

Spawning Cue Release

Under Alternative 6, the USACE would attempt a spawning cue release every 3 years consisting of a bimodal pulse in March and May. These spawning cue releases would not be started or would be terminated whenever flood targets are exceeded. ResSim modeling indicates that over the 82-year period of record, the spawning cue release as defined here would have been implemented 11 times and would have been partially implemented 33 times.

March Pulse

The USACE would initiate a March pulse once navigation releases were met at downstream target locations. This could result in increases of 2,200 cfs per day until the pulse magnitude is achieved. Peak pulse magnitude is equal to the navigation release that occurs on the day the pulse is initiated. In the case of Gavins Point, the peak release is double the navigation release that occurs on the day the pulse is initiated. The peak would be maintained for two days. Once peak duration is met, the USACE would reduce the pulse by 1,700 cfs per day until flow-to-target navigation releases are reached. Table 2-27 below provides flood targets associated with a March pulse. After the first occurrence of a March pulse, the preclude for System storage would change to 40.0 MAF. Based on ResSim POR simulations, Gavins Point releases during the March spawning cue would be 39-61 kcfs.

TABLE A.3.17: FLOOD TARGETS

Location	Kilo Cubic Feet Per Second (kcfs)
Omaha	41 + Pulse Magnitude
Nebraska City	47 + Pulse Magnitude
Kansas City	71 + Pulse Magnitude

May Pulse

The USACE would initiate the pulse on 18 May each year. A varied initiation date based on water temperature was specified by the USFWS; however, 18 May was used for modeling purposes. The USACE would increase the pulse by 2,200 cfs per day until the pulse magnitude is achieved. The peak pulse magnitude would be equal to the steady

release on 18 May. The peak Gavins Point release would be double the steady release that occurs on the day the pulse is initiated (18 May). The USACE would maintain the peak for two days, and then reduce the pulse by 1,900 cfs per day until steady release is reached. Table A.3.17 provides flood targets associated with a May pulse. Based on ResSim POR simulations, Gavins Point releases during the May spawning cue would range from 50-67 kcfs.

TABLE A.3.18: FLOOD TARGETS

Location	Kilo Cubic Feet Per Second (kcfs)
Omaha	41 + Pulse Magnitude
Nebraska City	47 + Pulse Magnitude
Kansas City	71 + Pulse Magnitude

Preferred Alternative

Alternative 3 has been identified as the preferred alternative in this MRRMP-EIS. Alternative 3 is a complete plan in that it meets the USFWS probability of persistence targets for piping plover and least terns. Alternative 3 would continue ongoing pallid propagation activities, build spawning habitats (as in-river test projects will learn if this action is effective), and build IRC habitats thru structure modification and channel widening. It would also provide (in common with Alternatives 4, 5, and 6) a foundational active AM program.

Although Alternative 3 would not be the most efficient alternative from an overall National Economic Development (NED) standpoint; when compared to alternative 1, the lack of adverse NED impacts is a good balance between overall efficiency and impacts to specific NED resources. Although there are uncertainties associated with the effectiveness in meeting the species objectives (in common with Alternative 4, 5, and 6), Alternative 3 would be the least impactful means of meeting species objectives across the full range of interests.

Attachment A.4 – Water Management Technical Criteria

Note: This attachment reflects the current Water Management Technical Criteria as presented by the USACE in the Missouri River Mainstem Reservoir System - System Description and Regulation (USACE 2007). Future updates to the criteria should be reflected in this attachment and the appropriate reference.

Summary of Master Manual Technical Criteria

Missouri River Mainstem Reservoir System - System Description and Regulation (USACE 2007)

NAVIGATION TARGET FLOWS

Location	Minimum Service (kcfs)	Full Service (kcfs)
Sioux City	25	31
Omaha	25	31
Nebraska City	31	37
Kansas City	35	41

RELATION OF SYSTEM STORAGE TO NAVIGATION SERVICE LEVEL

Date	System Storage (MAF)	Navigation Service Level
March 15	54.5 or more	35,000 cfs (full-service)
March 15	49.0 to 31	29,000 cfs (minimum-service)
March 15	31.0 or less	No navigation service
July 1	57.0 or more	35,000 cfs (full-service)
July 1	50.5 or less	29,000 cfs (minimum-service)

RELATION OF SYSTEM STORAGE TO NAVIGATION SEASON LENGTH

Date	System Storage (MAF)	Final Day of Navigation Support at Mouth of the Missouri River
July 1	51.5 or more	November 30 (8-month season)
July 1	46.8 through 41.0	October 31 (7-month season)
July 1	36.5 or less	September 30 (6-month season)

RELATION OF SYSTEM WINTER RELEASE TO SYSTEM STORAGE

September 1 System Storage (MAF)	Average Winter Release for Gavins Point
58.0 or more	17,000 cfs
55.0 or less	12,000 cfs

GAVINS POINT RELEASES NEEDED TO MEET TARGET FLOWS

1950 to 1996 Data (kcfs)

Median, Upper Quartile, Upper Decile Runoff

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Full Service	26.7	28.0	27.9	31.6	33.2	32.6	32.0	31.1
Minimum Service	20.7	22.0	21.9	25.6	27.2	26.6	26.0	25.1

Lower Quartile, Lower Decile Runoff

	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Full Service	29.8	31.3	31.2	34.3	34.0	33.5	33.1	31.2
Minimum Service	23.8	25.3	25.2	28.3	28.0	27.5	27.1	25.2

RESERVOIR UNBALANCING SCHEDULE

	Fort Peck		Garrison		Oahe	
Year	*March 1*	*Rest of Year*	*March 1*	*Rest of Year*	*March 1*	*Rest of Year*
1	High	Float	Low	Hold Peak	Raise & hold during spawn	Float
2	Raise & hold during spawn	Float	High	Float	Low	Hold peak
3	Low	Hold peak	Raise & hold during spawn	Float	High	Float

Notes: Float year: Normal regulation, then unbalance 1 foot during low pool years or 3 feet when System storage is near 57.0 MAF on March 1.

Low year: Begin low, then hold peak the remainder of the year.

High year: Begin high, raise and hold pool during spawn, then float.

MRNRC RECOMMENDED RESERVOIR ELEVATION GUIDELINES FOR UNBALANCING

	Fort Peck	Garrison	Oahe
Implement unbalancing if March 1 pool is above this level.	2234 feet msl	1837.5 feet msl	1607.5 feet msl
Implement unbalancing if March 1 pool level is in this range **and** the pool is expected to raise more than 3 feet after March 1.	2227-2234 feet msl	1827-1837.5 feet msl	1600-1607.5 feet msl
Scheduling Criteria	Avoid pool level decline during spawn period which ranges from April 15 – May 30	Schedule after spawn period of April 20 – May 20	Schedule after spawn period of April 8 – May 15

TECHNICAL CRITERIA FOR SPRING PULSES FROM GAVINS POINT DAM

Criteria Applicable to Both the March and May Spring Pulses

Flood Control Constraints	No change from current levels

Criteria Applicable to the March Spring Pulse

Drought Preclude	40.0 MAF or below measured on March 1.
Drought Proration of Pulse Magnitude*	None, 5 kcfs added to navigation releases, but no greater than 35 kcfs.
Initiation of Pulse	Extend the stepped System release increases that precede the beginning of the navigation season.
Rate of Rise before Peak	Approximately 5 kcfs for 1 day.
Duration of Peak	Two days.
Rate of Fall after Peak	Drop over 5 days to navigation target release.

Criteria Applicable to Time Period Between the Bimodal Pulses

Release	Existing Master Manual Criteria

Criteria Applicable to the May Spring Pulse

Drought Preclude	40.0 MAF or below measured on May 1.
Proration of Pulse Magnitude Based On System Storage*	Prorated from 16 kcfs based on a May 1 System Storage check; 100% at 54.5 MAF; straight line interpolation to 75% at 40.0 MAF.

Proration of Pulse Magnitude Based On Projected Runoff*	After the proration of the spring pulse magnitude for System Storage, the resultant magnitude would be further adjusted either up or down based on the May CY runoff forecast; 100% for Median; straight-line interpolation to 125% at Upper Quartile runoff; 125% for runoff above Upper Quartile; straight-line interpolation to 75% at Lower Quartile runoff; 75% for runoff below Lower Quartile.
Initiation of Pulse	Between May 1 to May 19, depending on Missouri River water temperature immediately below Gavins Point Dam. If possible, pulse will be initiated after the second daily occurrence of a 16 degree Celsius water temperature; however, the decision will be informed by the potential for 'take' of Threatened and Endangered bird species.
Rate of Rise before Peak	Approximately 6 kcfs per day.
Duration of Peak	Two days.
Rate of Fall after Peak	Approximately 30% drop over 2 days followed by a proportional reduction in releases back to the existing Master Manual criteria over an 8-day period.

<u>Spring Pulse Downstream Flow Limits</u>

Omaha	41,000 cfs
Nebraska City	47,000 cfs
Kansas City	71,000 cfs

* Spring pulse magnitudes will be determined by taking the difference between pre-pulse Gavins Point releases and the peak pulse Missouri River flows measured just downstream of the mouth of the James River.

Attachment A.5 – Procedures to Adjust Water Management Technical Criteria

Note: This attachment will be prepared by Water Management. Materials below are summary points already made in presentations to MRRIC.

The water control plan and technical criteria that guide the operation of the six mainstem reservoirs on the Missouri River, as well as their operation as a system are presented in a set of seven Water Control Manuals, one for each of the individual reservoir projects and the Missouri River Basin Mainstem Reservoir System Master Water Control Manual (Master Manual) for the entire system.

Policies and procedures for the preparation, review, update, and adjustment of water control manuals, including "master" water control manuals, are provided in the following USACE Engineer Regulations and Engineer Manuals:

- ER 1110-2-240 WATER CONTROL MANAGEMENT
- ER 1110-2-8156 PREPARATION OF WATER CONTROL MANUALS
- ER 1110-2-1400 RESERVOIR/WATER CONTROL CENTERS
- EM 1110-2-3600 MANAGEMENT OF WATER CONTROL SYSTEMS

Periodic updates and adjustments to the manuals are encouraged as a policy of the Chief of Engineers to ensure that the best use is made of available water resources. Actions are taken to keep approved water control plans up-to-date and plans are subject to continuing study. Consequently, water control manuals are revised as necessary to conform with changing requirements resulting from developments in the project area and downstream, improvements in technology, new legislation and other relevant factors provided such revisions comply with existing Federal regulations and established USACE policy.

Updates to the Master Manual or any of the Water Control Manuals for the individual projects that might be required as a consequence of the MRRP would be undertaken following the policies and practices outlined in the above references. These include requirements for public engagement in the process. Revisions to water control manuals that are administrative or informational in nature and that do not change the water control plan do not require public meetings (ER 1110-2-240). Conditions that require

public involvement and public meetings include revision or update of a water control manual that changes the water control plan. These changes would also involve coordination with MRRIC as described in the sections below.

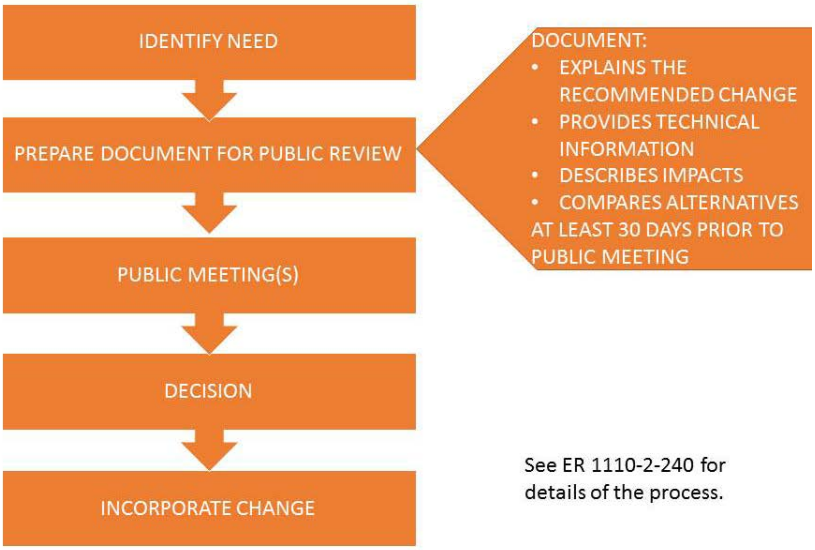

Figure A 1. Process for modifying the Master Manual.

Changes to the plan or manual would be prepared only after the associated public involvement process is complete. The USACE will provide information to the public concerning proposed changes at least 30 days in advance of a public meeting. A separate document(s) should be prepared that a) explains the recommended water control plan or change, b) provides technical information explaining the basis for the recommendation, c) includes a description of its impacts (both monetary and nonmonetary) for various purposes, and d) includes the comparisons with alternative plans or changes and their effects.

[Note: Remaining text under development.]

Attachment A.6 – Procedures for Adjustments to Significant Components of the AM Plan

Note: This attachment has not yet been prepared. It will address the process for adjustments to the MRRP AM Plan, including interactions with MRRIC.

Attachment A.7 – Agendas for Annual AM Workshop and the Fall Science Meeting

Note: This section is subject to change as plans for the Fall Science Meeting and AM Workshop are under development in collaboration with the AM ad Hoc.

Draft Agenda

MRRP Annual AM Workshop

XX-XX February, 20XX

Location

Day 1 (date)

I. Introduction and Purpose (Facilitator)
   a. Logistics and schedule
   b. Introductions
   c. Role of meeting within MRRP Process
   d. Purpose and expected outcomes

II. Status Updates
   a. MRRP – Multi-year and Annual Work Plan status; Current FY appropriations and President's Budget for FY+1 (MRRP PM)
   b. MR system –AOP; past & projected storage, run-off (WM)
   c. Updates to the Effects Analysis (EA Team Lead)
   d. Birds – existing conditions (ISP)
   e. Fish – existing conditions (ISP)
   f. Summary of major action items/lessons from Fall Science Meeting

III. Bird Session I – Status and Trends; What's happening?
   a. Context- Conceptual model
   b. Species monitoring, modelling and population trends
      i. Advances in monitoring
      ii. Advances in modelling and decision criteria

iii. Estimates of Trends in Recruitment, Abundance, Survival, Other Demographic Parameters, Population Growth
iv. Performance towards objectives
v. Model predictions of trend

IV. Bird Session II – What are we doing, might do, shouldn't do?
a. Context- Conceptual model and hypotheses
b. Constructed Habitat Actions
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments
c. Flow Management Actions
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments
d. Other Actions (e.g. predator control; vegetation management; etc.,)
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments

V. Bird Session III - Research findings and new information
a. Report on Bird Research Activities
i. Research effort #1
ii. Research effort #2
iii. Etc.,
b. New Information
c. Needs Assessment, Research Prioritizations, Calls for Proposals

VI. Bird Session III - Synthesis: Progress Towards Objectives and Learning (ISP)
a. New Insights on Habitat
b. Learning About Actions; Answers to Original Big Questions and Hypotheses
c. Updates to Big Questions, Hypotheses, and CEMs

Day 2 (date)

VII. Pallid Sturgeon Session I – Status and Trends; What's happening?
   a. Context- Conceptual model
   b. Species monitoring, modelling and population trends
      i. Advances in monitoring
      ii. Advances in modelling and decision criteria
      iii. Estimates of Trends in Recruitment, Abundance, Survival, Other Demographic Parameters, Population Growth
      iv. Performance towards objectives
      v. Model predictions of trend

VIII. Pallid Sturgeon Session II – Upper Missouri; What are we doing, might do, shouldn't do?
   a. Upper Missouri Big Questions, and Hypotheses
      i. Propagation Program Status of Implementation
      ii. Performance monitoring and evaluation
      iii. Possible adjustments
   b. Intake Dam
      i. Planning, Analysis and Design (Level 1 and Level 2)
      ii. Status of Implementation of Level 3 Actions
      iii. Performance monitoring and evaluation (including HCs)
      iv. Possible adjustments
   c. Other Actions (e.g. temperature control at Fort Peck; flow management; Lake Sakakawea drawdown, etc.,)
      i. Planning, Analysis and Design (Level 1 and Level 2)
      ii. Next Steps

IX. Pallid Sturgeon Session III – Lower Missouri; What are we doing, might do, shouldn't do?
   a. Lower Missouri Big Questions, and Hypotheses
   b. Propagation Program
      i. Status of Implementation
      ii. Performance monitoring and evaluation
      iii. Possible adjustments
   c. Channel Reconfiguration Actions (IRCs, Spawning Habitat)
      i. Planning, Analysis and Design (Level 2 and 3)
      ii. Status of Implementation of Level 3 Actions
      iii. Performance monitoring and evaluation (including HCs)

iv. Possible adjustments

d. Other Actions (e.g. Temperature control at Gavins Point; Flow releases; sediment management, etc.,)

i. Planning, Analysis and Design (Level 1 and Level 2)

ii. Next Steps

X. Pallid Sturgeon Session IV – Research and New Information (ISP)

a. Report on Pallid Sturgeon Research Activities

i. Research effort #1

ii. Research effort #2

iii. Etc.,

b. New Information

c. Needs Assessment, Research Prioritizations, Calls for Proposals

XI. Pallid Sturgeon Session V - Synthesis: Progress Towards Objectives and Learning (ISP)

a. New Insights on Habitat

b. Learning About Actions; Answers to Original Big Questions and Hypotheses

c. Updates to Big Questions, Hypotheses, and CEMs

Day 3 (date)

XII. Program Summary Results and Discussion (Facilitator)

a. Bringing it all together- actions

b. Bringing it all together- monitoring and research

c. Bringing it all together- species

XIII. Breakout Meetings (Team Leads)

a. Bird Team

i. Results in Context of system status and 5 year trajectory

1. Habitat

2. Flow

3. Monitoring- habitat, species, HC

ii. Concerns, learning, or new information

iii. Review of prioritized proposed actions and research

iv. Review of AWP and 5 year plan

v. Conclusions:

1. Action- up, down, same

2. Flow- yes/no
3. Research- continue/end, new start, rankings

b. Fish Team
   i. Results in Context of system status and 5 year trajectory
      1. Habitat
      2. Flow
      3. Monitoring- habitat, species, HC
      4. Modelling
   ii. Concerns, learning, or new information
   iii. Review of prioritized proposed actions and research
   iv. Review of AWP and 5 year plan
   v. Conclusions:
      1. Action- up, down, same
      2. Flow- yes/no
      3. Research- continue/end, new start, rankings

Day 4 (date)

XIV. Close out Session (Facilitator)
   a. Bird Team Report out
   b. Fish Team Report out
   c. System Considerations
   d. Recommendations
   e. Next Steps

Draft Agenda

MRRP Annual Fall Science Meting

XX-XX October, 20XX

Day 1 (date)

I. Research Program IPR (ISP Manager)
   a. Report on Bird Research Activities
      i. Research effort #1
      ii. Research effort #2
      iii. Etc.,
   b. Report on Fish Research Activities
      i. Research effort #1
      ii. Research effort #2
      iii. Etc.,
   c. Report on System Research Activities
      i. Research effort #1
      ii. Research effort #2
      iii. Etc.,
   d. New Information

II. Day 2 (date)

III. Introduction and Purpose (Facilitator)
   a. Logistics and Introductions
   b. Role of meeting within MRRP Process
   c. Expected outcomes

IV. Status Updates
   a. MR system –AOP; past & projected storage, run-off (WM)
   b. Updates to the Effects Analysis (EA Team Lead)
   c. Review of scheduled activities in AWP

V. Bird Session I – Status and Trends; What's happening?
   a. Species monitoring, modelling and population trends
      i. Advances in monitoring

ii. Advances in modelling and decision criteria
iii. Estimates of Trends in Recruitment, Abundance, Survival, Other Demographic Parameters, Population Growth
iv. Performance towards objectives
v. Model predictions of trend

VI. Bird Session II – What are we doing, might do, shouldn't do?
a. Context- Conceptual model and hypotheses
b. Constructed Habitat Actions
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments
c. Flow Management Actions
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments
d. Other Actions (e.g. predator control; vegetation management; etc.,)
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments

Day 3 (date)

VII. Pallid Sturgeon Session I – Status and Trends; What's happening?
a. Context- Conceptual model
b. Species monitoring, modelling and population trends
i. Advances in monitoring
ii. Advances in modelling and decision criteria
iii. Estimates of Trends in Recruitment, Abundance, Survival, Other Demographic Parameters, Population Growth
iv. Performance towards objectives
v. Model predictions of trend

VIII. Pallid Sturgeon Session II – Upper Missouri; What are we doing, might do, shouldn't do?
a. Upper Missouri Big Questions, and Hypotheses

i. Propagation Program Status of Implementation
ii. Performance monitoring and evaluation
iii. Possible adjustments

b. Intake Dam
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments

c. Other Actions (e.g. temperature control at Fort Peck; flow management; Lake Sakakawea drawdown, etc.,)
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Next Steps

IX. Pallid Sturgeon Session III – Lower Missouri; What are we doing, might do, shouldn't do?

a. Lower Missouri Big Questions, and Hypotheses

b. Propagation Program
i. Status of Implementation
ii. Performance monitoring and evaluation
iii. Possible adjustments

c. Channel Reconfiguration Actions (IRCs, Spawning Habitat)
i. Planning, Analysis and Design (Level 2 and 3)
ii. Status of Implementation of Level 3 Actions
iii. Performance monitoring and evaluation (including HCs)
iv. Possible adjustments

d. Other Actions (e.g. Temperature control at Gavins Point; Flow releases; sediment management, etc.,)
i. Planning, Analysis and Design (Level 1 and Level 2)
ii. Next Steps

Day 4 (date)

X. Close out Session (Facilitator)

a. Bird Team Report out

b. Fish Team Report out

c. System Considerations

d. Recommendations

e. Next Steps

Attachment A.8 – Fact Sheet Requirements/Template

Attachment A.9 – Requirements and Procedures for the Independent Science Advisory Committee

Attachment A.10 – Requirements and Procedures for External Peer Review

The objectives and general requirements for peer review are presented in Section 2.6.5 of the AMP. Quality Assurance and Quality Control (QA/QC) requirements are outlined in Section 6.5 of the AMP. This attachment specifies the requirements and procedures for Type I and Type II Independent External Peer Review (IEPR) not involving the use of the ISAP. Details regarding the use of the ISAP are presented in Attachment 12. The following references apply:

- ER 1105-2-100, Planning Guidance Notebook, 22 April 2000
- ER 1110-1-12, Engineering and Design Quality Management, 30 September 2006
- REF8008G, Quality Management Plan, 15 October 2002
- EC 1105-2-408, Peer Review of Decision Documents, 31 May 2005
- EC 1165-2-209 Change 1, Civil Work Review Policy, 31 January 2012
- Memorandum signed MG Don Riley, Peer Review Process, 30 March 2007
- 08502-CENWD-RBT EC 1165-2-209 Civil Works Review Policy Guidance, 29 September 2011

A.10.1. Requirements and Procedures for assembling an IEPR Panel

A.10.2. Requirements and procedures for conducting an IEPR

A.10.3. Reporting on an IEPR

[Note: Section to be completed]

Attachment A.11 – MRRP Health and Safety Requirements for Contractor Activities

Safety Requirements

Safety is the primary concern for all on-site activities. A government representative is required to monitor contractor activities from a QA viewpoint, including the contractor's safety program. Under the terms of the contract, Federal Acquisition Regulations (FAR) 52-212-3 Stop-Work Order clause of the basic contract, the contracting officer has full authority to require the contractor to take any steps deemed necessary for maintaining safe operating conditions.

The contractor is obligated by the terms of the contract to protect the lives and health of persons exposed to their operations and to safeguard property and equipment from accidental loss or destruction. All work must be performed in accordance with the safety and health provisions of the contract, Engineering Manual (EM) 385-1-1 (U.S. Army Corps of Engineers Safety and Health Requirements Manual), and federal, state, and local codes and standards. When a difference in standards exists, the most stringent standard applies.

In addition to being a contract requirement, a well-planned and conscientiously applied accident prevention program is essential to the efficiency, quality, and scheduling of work and the minimization of costs. The prime contractor is responsible for informing their subcontractors of the safety provisions under the terms of the contract and the penalties for noncompliance. The prime contractor is responsible for coordinating the work to prevent one craft from interfering with, or creating hazardous working conditions for other crafts, and inspecting subcontractor operations to ensure that accident prevention responsibilities are being fulfilled. Public safety is paramount, all sites must be secured from public access.

Unsafe practices will not be tolerated. Reckless behavior or disregard of safety and health requirements will not be tolerated on USACE projects. If any contractor employee endangers his own life, the lives of others or property by disregard of safety and health requirements, the contractor shall be informed of the employee and their unacceptable attitude/performance towards accident prevention. The contractor will be reminded of the contract requirements and be instructed to immediately resolve the problem.

Should a USACE employee identify an immediate endangerment to life or health, a Stop-Work Order may be issued. Situations in this category include, but are not be limited to, workers being crushed, buried, electrocuted, suffocated, thrown from moving equipment, falling, drowning, and being blown up. If any of the aforementioned safety concerns should arise, the following steps shall be taken; the PM or USACE employee(s) on-site will instruct the contractor to immediately remove workers from the area of danger or to desist from the dangerous operation or practice. If a representative of the contractor is not at the site, the PM or USACE employee(s) on-site will order the workers to remove themselves from the dangerous location or to cease the dangerous operation or practice. The PM or USACE employee(s) onsite will ensure that the work would not be resumed in the area of danger and that workers would not be involved in the operations or practices until recommendations for corrections had been complied with fully. Defective equipment will not be operated until all deficiencies are corrected and the equipment meets inspection and testing requirements.

Safety Reporting

It is necessary that the safety offices of both the NWO and NWK receive monthly contractor man-hours in order to determine the lost time frequency rates. This data will be required to be received telephonically, electronically, or by mail by the fifth of every month. The information needed will be the number of man-hours worked by the prime and subcontractors at any particular project for the previous month. The Safety Office of the Omaha District (CENWO-SO) will only need the total labor hours (not separated by contracts). The existing office safety plan will be used. Onsite personnel safety plans will be developed for each subprogram and included in the PMP. The Implementation PM for each USACE district will be responsible for ensuring these reports are completed in a timely manner.

Attachment A.12 – Cultural Resources Plan

Note: This attachment will reference appropriate policies, agreements, etc. (e.g., the 2004 Programmatic Agreement for operation and management of the Missouri river mainstem system for compliance with the national historic preservation act, as amended). It will also summarize key provisions as they pertain to implementation of the MRRP AMP.

Attachment A.13 – MRRP Program Management Plan

To be developed/provided by the USACE

Attachment A.14 - ISP Program Management Plan

Important components of an ISP Program Management Plan have been developed, at least in part, throughout the AMP. The AMP will now be used as a guide to revise the ISP PMP to ensure the ISP is structured to best serve the many adaptive management, agency, and stakeholder needs. Due to time constraints, other priorities, and need to develop AMP components first, this task has yet to be completed but will be completed in coming months by ISP staff with additional input from outside experts, agency leadership, and partners as appropriate.

Attachment A.15 the TPSN and the Independent Advisory Panel process

Third Party Science Neutral Support to Establish an Independent Science Advisory Panel for the Missouri River Recovery Program

Approved by MRRIC on July 21, 2010

Attachment A

ISP WG Involvement in ISAP Information/Presentation Requests

Approved by MRRIC on February 17, 2011

I. BACKGROUND AND INTRODUCTION

The US Army Corps of Engineers (Corps) - Missouri River Recovery Program (MRRP) are engaged in large scale ecosystem management on the Missouri River, with significant efforts to restore ecosystem functions and recover threatened and endangered species. This effort relies on collaborations with a wide range of governmental, academic, and private organizations that are working to deliver products, including extensive scientific analyses and syntheses. The Missouri River Recovery Implementation Committee (MRRIC), a group of 69 members representing various interests, tribes, and agencies, assists these efforts by developing recommendations for the agencies implementing the ecosystem management efforts.

The desire and need for well thought out science and independent scientific advice and recommendations to support decisions and directions taken by the Corps has increased, and is also desired by the MRRIC. As a result, the MRRP Integrated Science Program (ISP) is working to ensure the quality, completeness, and application of scientific information in use, and is following the Office of Management and Budget's "Final Information Quality Bulletin for Peer Review" (2005). This approach is also consistent with Corps civil works review policy guidance EC 1165-2-209.

This document describes the Corps' intent to establish a standing independent Science Advisory Panel for the MRRP and the MRRIC, utilizing the Third Party Science Neutral (TPSN) contracted by the US Institute for Environmental Conflict Resolution (USIECR), as a lead advisor for the management of scientific advisor selection, panel processes, and panel products.

General support tasks of the independent Science Advisory Panel could include but are not limited to the following:

- Synthesis of all available information on a specific topic which may include meetings with scientists, agency personnel and stakeholders and culminates in a written report providing independent advice and recommendations to the Corps or MRRIC.
- Scientific or technical services to gather, evaluate, and synthesize the best available information/data on a scientific topic resulting in a report to the Corps. Providing independent opinion and recommendations on the topics presented.
- Evaluation of scientific proposals and making recommendations on how to proceed.
- A standing program of independent opinions and recommendations for the overall MRRP-ISP.
- Assessment of documents (models, data, monitoring plans, management plans, and recovery actions) for contextual clarity and their application to a specific project planning effort, resulting in a letter report to the Corps.
- Responding to scientific questions from the Corps, USFWS, or MRRIC.

II. MRRP SCIENCE ADVISORY PANEL

1. A standing panel of up to 6 science advisors who will meet at least annually (and more often in the initial stages of setting up the panel and as required by specific scope of tasks). This panel will be charged with overall independent science support and technical oversight of the ISP program. In addition, the panel will be charged to provide advice on specific topics as needed. The general disciplines of expertise desired on the standing panel will be from the following areas of science including:
    a. Aquatic/Riverine Ecologist: Expertise in energy flow dynamics; flora and fauna community assembleges; river/floodplain dynamics; and knowledge of biological/physical drivers and processes.
    b. River Hydrologist/Geomorphologist: Expertise in dynamics of river and associated landforms; sediment dynamics/transport; large dryland river physical processes; and flow modeling.
    c. Least Tern/Piping Plover Specialist: Ornithological expertise in least tern and piping plover population dynamics; ecological threats; habitat, energy, and security requirements; and status of population and productivity within the interior population of least tern and Great Plaines population of piping plovers.
    d. Sturgeon Specialist: ichthyological expertise in scaphirhynchus sturgeon population dynamics; ecological threats; habitat, energy, and security requirements; knowledge of the current understanding of life history needs; and status of population and productivity within the pallid sturgeon range.
    e. Quantitative Ecologist/Statistician: Expertise in biostatistical methods, analytical tools, and the interpretation of ecological data sets; mathematical modeling; and presentation of complex analysis.

f. Conservation Biologist: Expertise in ecological community interations with emphasis on large river form and function; restoration and recovery at the population/ landscape scale.

2. Ad hoc specialists may be added to the standing panel, as needed, to provide expertise not represented by standing panel members for a particular topic. These individuals would serve only for the duration of the topical study for which they are selected. The type of expertise needed may be identified by the Corps or MRRIC as they develop questions to be considered by the standing panel, or by the standing panel itself if it convenes around a topic and determines additional expertise is needed. In either case, the TPSN would select a candidate and potential alternates qualified in that expertise for the panel following the criteria and selection process for the standing panel.

3. Standing panel members are expected to commit to a three year term, renewable upon review by the TPSN.

III. SELECTION OF SCIENCE ADVISORS

1. When selecting science advisors, the TPSN shall comply with the National Academy of Science's "Policy and Procedures on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports" (2003) and the Office of Management and Budget's "Final Information Quality Bulletin for Peer Review" (2005). The TPSN shall strive to establish a panel of science advisors that demonstrates:
    a. Expertise. Varied knowledge, experience and skill.
    b. Balance. A diversity of scientific perspectives.
    c. No Conflict of Interest. No financial or other interest that impairs the panel's objectivity or gives an unfair competitive advantage to a person or organization.

2. The TPSN shall undertake a structured search process whereby they shall select science advisors that represent a broad spectrum of scientific expertise within their discipline and that have established high-caliber scientific credentials including:
    a. Widely recognized by peers for expertise in their field
    b. Strong publication record or record of scientific leadership
    c. Willingness to participate with objectivity and professionalism
    d. Track record of fair and unbiased, yet constructive, criticism
    e. Ability to function within a team and an interdisciplinary setting
    f. High standard of scientific integrity, independence, and objectivity
    g. Demonstrated ability to forge creative solutions to address identified topics or problems
    h. Knowledge and understanding of adaptive management process and application (represented in at least some members)

3. The TPSN will provide a proposed list of panelists for each position to the full MRRIC. The ISP Work Group (and any other MRRIC members who choose to participate), Corps, and USIECR will have the opportunity to review and collaboratively provide input (through a joint facilitated conference call or meeting) on the proposed panelists. All MRRIC members will also have the opportunity to provide comments to the ISP Work Group Points of Contact to bring into the conversations. The TPSN will select the standing panel members representing the general disciplines using the criteria identified above.

4. The TPSN shall recognize and provide clear direction to prospective panel members that the independent science advice/reviews required are scientific in nature and that decision making and policy interpretation are left to the Corps after consideration of any consensus recommendations from MRRIC.

IV. HOW THE INDEPENDENT SCIENCE ADVISORY PANEL WORKS

1. Task Orders/Charge Questions: Topics for the Science Advisory Panel may originate from either the Corps or MRRIC (or collectively). For each topic, initial charge questions will be drafted by the proposing entity for review and discussion. If the Corps develops the initial questions, MRRIC members will have an opportunity to provide questions they would like

addressed through the ISP WG for consideration as part of the initial questions to be presented to the Science Advisory Panel for their evaluation. Ideally, the ISP WG and the Corps will agree on the questions to be delivered to the TPSN. Where there is not agreement, both the ISP WG and Corps have the option to provide questions to the TPSN.

2. Charge Description: The description of the charge to the Science Advisory Panel shall be developed as follows:
    a. The TPSN shall expeditiously develop a proposal containing specific instructions to the science advisors including:
        i. Description of topic.
        ii. Expected products and ground rules for operation.
        iii. How panel deliberations will be conducted, either sessions open to the general public and/or restricted to only the panel; and how findings will be presented.
            1. The TPSN shall make the science advisors aware that key agency staff and members of MRRIC are available to provide input as necessary when requested by the panel.
            2. A panel chair (and/or the full panel if desired) shall present findings to MRRIC via video teleconference or at a regularly scheduled meeting.
        iv. Schedule/timeline.
    b. The ISP WG, USACE, and USIECR will review and collaboratively provide input on the TPSN proposed description of the charge.
    c. The TPSN will provide the final charge description to the MRRIC, USACE, and USIECR.

3. Implementation: In coordination with the Corps and the ISP WG, the TPSN shall schedule the review and coordinate all logistical issues associated with carrying out the panels' charge including, but not limited to, travel, facilities, equipment, facilitators, panelists, arranging for transcription of panel discussions (if necessary), and public access (as necessary). Also see Attachment A for additional information on ISP WG involvement in information and presentation requests from the ISAP.

4. Panel Chair: A panel chair will be chosen to ensure consideration of all technical matters amongst panelists and coalesce a final report. The method for choosing the chair will be determined by the panel members with the assistance of the TPSN. Possible options include, but are not limited to, a different chair for each topic, a chair for the full period of time, and a rotating chair.

5. Facilitation: The TPSN will facilitate selection of panel chair, all panel deliberations, external panel interaction, and report preparation and dissemination. The TPSN will also provide other project management duties including ensuring product completion per schedule and budget.

6. Standing Ground Rules: To facilitate consideration of multiple perspectives on the issues, a structured process has been developed to avoid bias and guide communications between Science Advisory Panel members and the Corps, MRRIC, and other interested parties including the public. The TPSN may add to or refine these in certain situations as necessary (see How the Independent Science Advisory Panel Works, 2.a.ii. above).
    - The TPSN will coordinate all contact between candidate or selected panelists and interested parties.
    - There will be no direct communication between interested parties and candidate or selected panelists, except as invited by the Science Advisory Panel through the TPSN.
    - All communication regarding the topics under consideration, between the Corps, MRRIC members, and candidate or selected panelists, will be coordinated through the TPSN. Communications between the Corps and/or MRRIC members and the candidate or selected panelists outside of the MRRIC process are inappropriate.
    - Questions or information received after the initial questions have been delivered to the Science Advisory Panel (including from the Institute's Independent Science Advisory Panel web site) will be routed to the Institute and TPSN. The Institute and TPSN will assess the information/ questions received. The TPSN will forward to the panel information and questions determined pertinent to the proceedings. To ensure the transparency of the process the Institute and TPSN will inform the Corps and ISP Work Group and MRRIC of any information/questions received and the disposition of these items.
    - During their deliberations, science advisors may access and reference any peer reviewed literature in their review deliberations and report(s). They also may reference other information that the panel deems credible, and include a copy of the other information with their report(s).
    - The panel may make on-site visits to gain understandings in topics being addressed and to see, first-hand, the challenges and successes.
    - During their deliberations science advisors may (through the TPSN) invite presentations and/or request information through the Institute from MRRIC including member agencies, Corps, or any source that they believe may be of value to their deliberations. The presenters and content of the presentations or information received will be included with their report(s).
    - Science advisors may recommend the need for ISR.
    - It is anticipated that the Science Advisory Panel will meet with the ISP WG and the Corps periodically during the advisory process and in some cases the MRRIC. These meetings will be open to MRRIC members and the public. Additional questions may be agreed to by the ISP WG/MRRIC and the agencies as the process iterates.

7. Interaction with MRRIC: The Science Advisory Panel will interact directly with the MRRIC at the beginning (soon after the charge is given to the Advisory Panel) of their work on a particular topic and when they are ready to present their draft report and recommendations.

The presentations and panel interaction with MRRIC will occur at a regular MRRIC meeting.

8. MRRIC Input/Recommendations: Once the Advisory Panel recommendations are final MRRIC will have the opportunity to develop recommendations on: 1) implementation of the Advisory Panel recommendations; and 2) the socio/economic and Tribal impacts from implementing the recommendations/alternatives presented by the Advisory Panel.

The MRRIC, Corps, the public, the Institute, TPSN, and candidate and selected advisory panelists will follow the above ground rules and communication protocols. The Institute and TPSN should be alerted to possible violations of the protocols, or to other undue biases or influences immediately. When the violations are related to a panel member's conduct, the Institute and TPSN will assess the situation and act accordingly and then the report back to MRRIC on disposition of the issue. If the violations are related to the MRRIC, the Charter and Operating Procedures will be used to address the situation.

V. FINAL REPORT

The Panel Chair shall be responsible for writing and editing any initial, draft, and/or final reports that are required under the task order. The TPSN should ensure that the report addresses all task order requirements, is thorough, and is understandable.

The TPSN shall deliver a final report. In general, the final report for each task order shall:

1. Summarize the goals and objectives of the charge to the panel, the process undertaken to select any additional advisory panel participants, the participants selected, a brief summary of their qualifications, the information considered by the panel, the exercises completed as part of the process, summary of panel discussion and the results.

2. Include an analysis of the findings including observations of the strengths and weaknesses of the findings and any dissenting opinions.

3. Provide independent opinions and recommendations regarding each task request or question as assigned.

4. Accurately present the views of the entire panel.

5. Be delivered in electronic format as a text selectable "pdf" file (portable document format created with Adobe Acrobat) within the dates established in the task order schedule.

VI. LITERATURE CITED

National Academy of Sciences. 2003. Policy and Procedures on Committee Composition and Balance and Conflicts of Interest for Committees Used in the Development of Reports. May 2003. Available online at: http://www.nationalacademies.org/coi/index.html

Office of Management and Budget. 2005. Final Information Quality Bulletin for Peer Review. December 16, 2004. Available online at: http://www.whitehouse.gov/omb/memoranda/fy2005/m05-03.pdf

Attachment A.15. Examples of decisions required for the MRRP

Examples of decisions needed for the MRRP, sorted by category or action type. For each decision, the step in the AM cycle in which it occurs is identified, and the typical recommending entity and primary decision level is indicated[1].

Category/ Action	Decision	Step in AM Cycle	Recommendi Entity
Plan design	What are the objectives?	Plan/design	USFWS
	What are the targets?	Plan/design	USFWS
	How will decisions be made?	Plan/design	Management
	What actions are included?	Plan/design	Management
	What are the criteria for implementing the actions?	Plan/design	Bird or Fish Tea
	What monitoring will be conducted?	Plan/design	Bird or Fish Tea
	How will research be prioritized?	Plan/design	Bird or Fish Tea
	How will learning be incorporated into decisions?	Plan/design	Bird or Fish Tea
	How will status and decisions be reported and communicated?	Plan/design	Bird or Fish Tea
	How will conflicts be resolved?	Plan/design	Management
Program-scale	How will resources be allocated to program components?	Adjust/continue	Bird or Fish Tea
	If objectives cannot be met, what are the implications for compliance?	Adjust/continue	Management
	How will flows be managed to meet objectives for both species?	Adjust/continue	Management/ Water Mgt.
Habitat construction	What are the criteria for implementing habitat construction?	Plan/design	Bird or Fish Tea
	How much new habitat should be constructed?	Adjust/continue	Bird or Fish Tea
	Where and how should it be constructed?	Adjust/continue	Bird or Fish Tea
	Should ESH be created using construction or flows?	Adjust/continue	Bird or Fish Tea
	Should construction be implemented with experimental design and/or additional monitoring to increase understanding?	Adjust/continue	Technical Team
	Should adjustments be made to project design due to unanticipated field conditions?	Implement	Bird or Fish Tea
	Should construction methods or design be changed to improve effectiveness?	Adjust/continue	Bird or Fish Tea

[1] Entities in the columns at the right are described in Section 2.3. The indicated entity/decision level is provisional – discussions are underway regarding these issues.

Category/ Action	Decision	Step in AM Cycle	Recommendi Entity
Non-routine flow modification[1]	What are the criteria for implementing non-routine flows?	Plan/design	Technical Team Water Mgt.
	If ESH is to be created using flows, what should the duration, magnitude, and timing be?	Adjust/continue	Technical Team Water Mgt.
	Will flows be implemented in a way to increase understanding?	Adjust/continue	Technical Team
	What additional monitoring and/or research will accompany a non-routine flow action?	Adjust/continue	Technical Team
	Should non-routine flows be changed or terminated during implementation?	Implement	Water Management
	Should non-routine flow releases be implemented in the same way (magnitude, duration, timing) in the future, or should they be adjusted to reduce impacts, increase effectiveness or improve learning?	Adjust/continue	Water Management; Technical Team
	Should non-routine flow releases be attempted more or less often as a result of past outcomes?	Adjust/continue	Technical Team Management
	Are there additional ways to improve the effectiveness of non-routine flow actions within the current constraints?	Adjust/continue	Technical Team Water Mgt.
	Should constraints on non-routine flow releases be increased or decreased?	Adjust/continue	Technical Team Water Mgt.
Routine flow management[1]	What are the criteria for implementing routine flow management?	Plan/design	Water Mgt.
	How will flows be managed during the nesting season to reduce incidental take (inundation of nests or chicks)?	Adjust/continue	Technical Team USFWS
	Will flows be implemented in a way to increase understanding?	Adjust/continue	Technical Team
	Should routine flow management be changed during implementation because of HC or species impacts?	Implement	Bird or Fish Tea Management
	Should routine flow management be implemented in the same way (magnitude, duration, timing, etc.) in the future, or should they be adjusted to reduce impacts or increase effectiveness?	Adjust/continue	Bird or Fish Tea
	Are there additional ways to improve the effectiveness of routine flow management within the current constraints?	Adjust/continue	Bird or Fish Tea Technical Team

[1] Decisions regarding reservoir releases are made by the USACE Northwest Division Water Management, and does so in accordance with guidance and criteria in the Master Manual and consistent with relevant policies, laws, and court decisions. Recommendations and/or analytical support from the Technical or Management Teams and public/stakeholder input are typical for non-routine flows, which are subject to Oversight approval.

Category/ Action	Decision	Step in AM Cycle	Recommendi Entity
	Do constraints on routine flow management needed to be increased or decreased?	Adjust/continue	Bird or Fish Tea Management
Habitat modification	What are the criteria for implementing habitat modification?	Plan/design	Technical Team
	Should current habitat be modified?	Adjust/continue	Bird or Fish Tea
	What habitat should be modified, and how?	Adjust/continue	Bird or Fish Tea
	Should modification be implemented with experimental design and/or additional monitoring to increase understanding?	Adjust/continue	Technical Team
	Should adjustments be made to project design due to unanticipated field conditions?	Implement	Bird or Fish Tea
	Should modification methods be changed to improve effectiveness?	Adjust/continue	Bird or Fish Tea
Population intervention[1]	What are the criteria for implementing population interventions?	Plan/design	Bird or Fish Tea Technical Team
	Should population interventions be implemented? Where?	Adjust/continue	Bird or Fish Tea
	Should population interventions include experimental design and/or additional monitoring to increase understanding?	Adjust/continue	Bird or Fish Tea Technical Team
	Should population interventions be made to implementation due to unanticipated field conditions?	Implement	Bird or Fish Tea
	Should population interventions methods be changed to improve effectiveness?	Adjust/continue	Bird or Fish Tea
Research	Should an active hypothesis be rejected?	Adjust/continue	Technical Team
	Should a reserve hypothesis be activated?	Adjust/continue	Technical Team
	Is additional basic research (demographics, behavior, habitat quality, etc.) needed?	Adjust/continue	Technical Team
	Should existing research programs be continued or should resources be used elsewhere?	Adjust/continue	Technical Team
Monitoring	Should the level of effort and/or protocols of the current monitoring program be changed?	Adjust/continue	Bird or Fish Tea
	Should additional monitoring be conducted beyond the existing program in the long term (current metrics are insufficient)?	Adjust/continue	Bird or Fish Tea
	Should additional monitoring be conducted in the short- or moderate-term because of unusual conditions or natural events?	Adjust/continue	Bird or Fish Tea

[1] i.e.., stocking, predator control, etc. See Sections 3.2.4.1.5 and 4.2.6.2 for additional descriptions.

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Appendix B. Conceptual Ecological Models, Hypotheses, and Key Findings of the Effects Analysis

B.1. Overview

This appendix presents the Conceptual Ecological Models (CEMs) from the Effects Analysis (EA) for the MRRP and includes requirements for updates to the initial products. Updated information is presented in the first section of each chapter in the appendix. All updates are noted in the header. Note that only the diagrams for the CEMs are presented in this Appendix, the accompanying narratives in the EA reports provide important contextual information and the full suite of EA Products describe how the CEMs apply to other aspects of the science underpinning this AMP.

Buenau, K.E., C.J. Huber, V. Cullinan, and C.R. Vernon. In review. Draft Interim Effects Analysis Integrated Report; Piping Plovers and Least Terns. Pacific Northwest National Laboratory. Richmond, WA. October 2014 Draft.

Buenau, K.E., C.J. Huber, V. Cullinan, C.R. Vernon, and C. Huber. In review. Missouri River Effects Analysis Deliverable 2: Compilation of existing data, literature, and models for plovers and terns Pacific Northwest National Laboratory. Richmond, WA. October 2014 Draft.

Buenau, K.E., C. Aron, C.J. Huber, V. Cullinan, C.R. Vernon, C. Huber, J. Ledwin and T. Swannack. In review. Conceptual Ecological Models for Interior Least Terns And Piping Plovers on the Missouri River. Pacific Northwest National Laboratory. Richmond, WA. January 2014 Draft.

Fischenich, J.C., in review, Hydrologic, hydraulic, and geomorphic models and analyses to support the Missouri River Effects Analysis. ERDC Technical Report TR-16-X. Engineer Research and Development Center Environmental Laboratory. Vicksburg, MS. (In Review)

Fischenich, J.C., R. McComas, D. Meier, J. Tripe, D. Pridal, P. Boyd, S. Gibson, J. Hickey, T. Econopouly, and L. Strong. In Review. Habitat Analyses for the Missouri River Effects Analysis – Geomorphic Team Integrative Report. ERDC Technical Report TR-16-X. Engineer Research and Development Center Environmental Laboratory. Vicksburg, MS. (In Review)

Jacobson, R.B., Annis, M.L., Colvin, M.E., James, D., Welker, T.L., and Parsley, M.J., 2016, Missouri River *Scaphirhynchus albus* (Pallid Sturgeon) Effects Analysis—Integrative Report 2016: U.S. Geological Survey, Scientific Investigations Report 2016-5064, 154 p. 10.3133/sir20165064.

Jacobson, R.B., Parsley, M.J., Annis, M.L., Colvin, M.E., Welker, T.L., and James, D.A., 2016, Development of working hypotheses linking management of the Missouri River to population dynamics of

Scaphirhynchus albus (pallid sturgeon): U.S. Geological Survey, Open-file Report 2015-1236, 33 p. 10.3133/ofr20151236.

Jacobson, R.B., Annis, M.L., Parsley, M.J., James, D.A., Colvin, M.E., and Welker, T.L., 2015, Science information to support Missouri River Scaphirhychus albus (pallid sturgeon) effects analysis: U.S. Geological Survey, Open-file Report 2015-1226, 78 p. 10.3133/ofr20151226.

Jacobson, R.B., Parsley, M.J., Annis, M.L., Colvin, M.E., Welker, T.L., and James, D.A., 2015, Development of conceptual ecological models linking management of the Missouri River to pallid sturgeon population dynamics: U.S. Geological Survey, Open-File Report 2015-1038, 47 p. 10.3133/ofr20151038.

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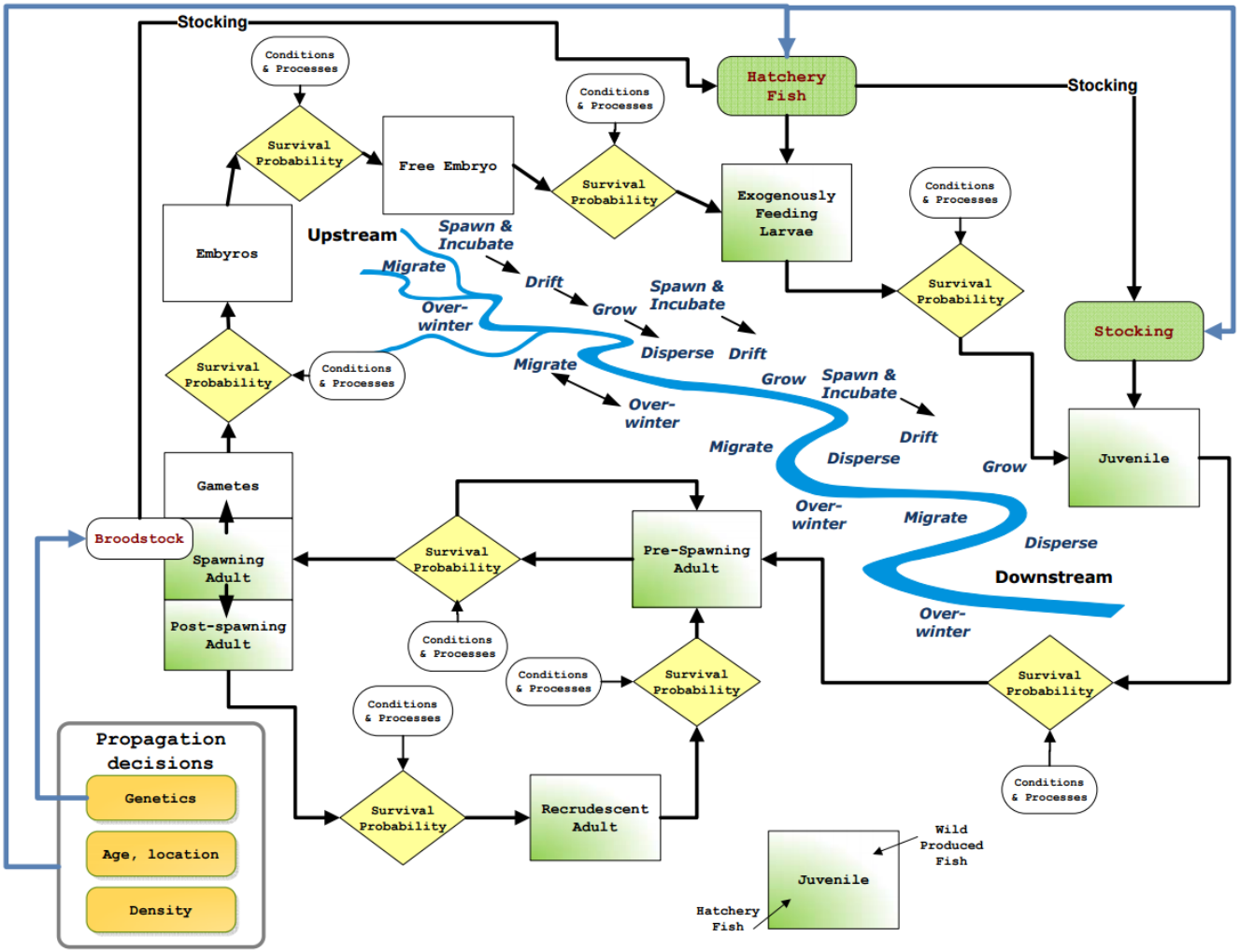
B.1 Pallid Sturgeon

Figure B 1. Population-level conceptual ecological model for pallid sturgeon. From Wildhaber et al (2007; 2011).



Upper River

Figure B 2. Upper River Pallid Sturgeon CEM – developing embryos.

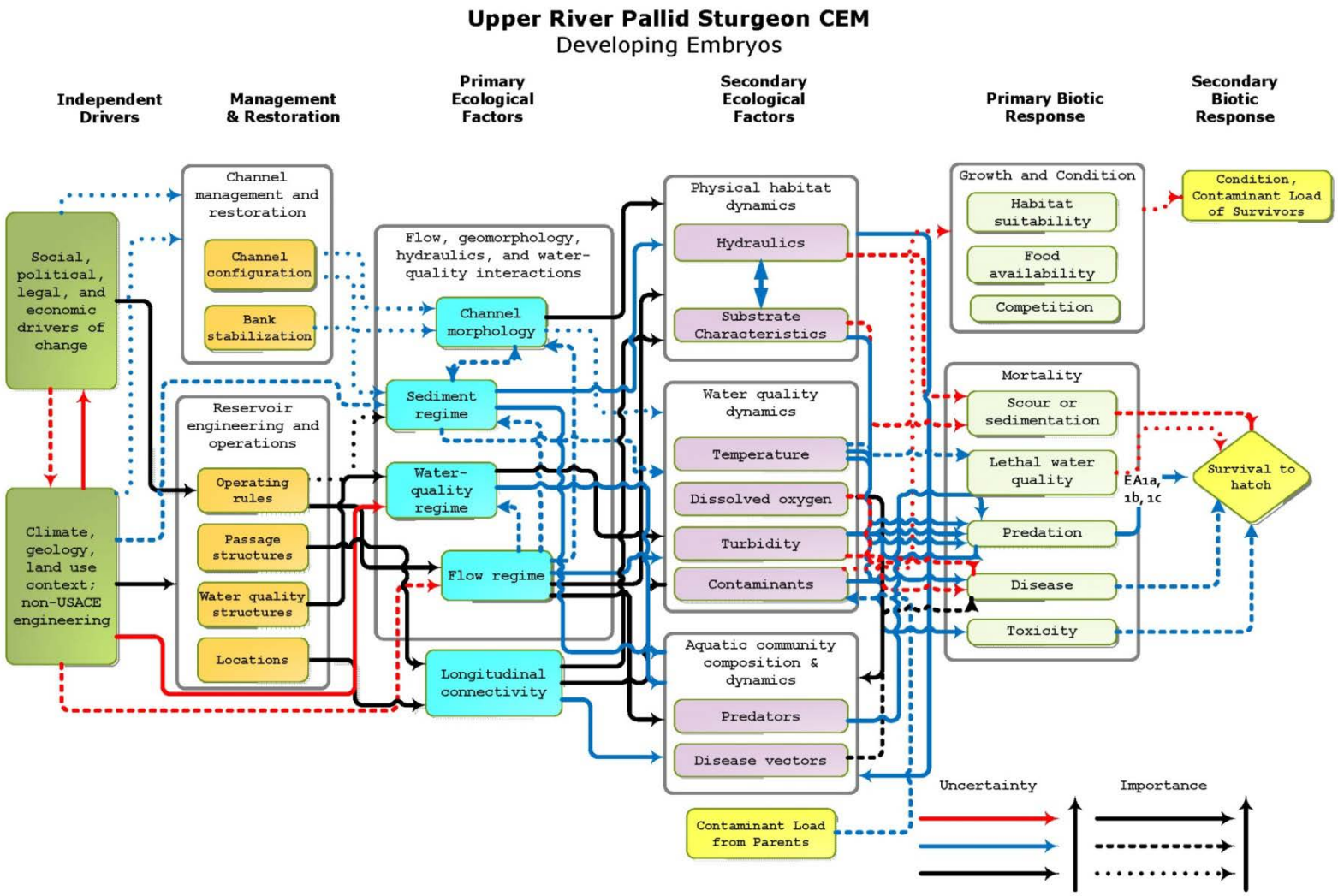


Figure B 3. Upper river pallid sturgeon CEM – free embryo.

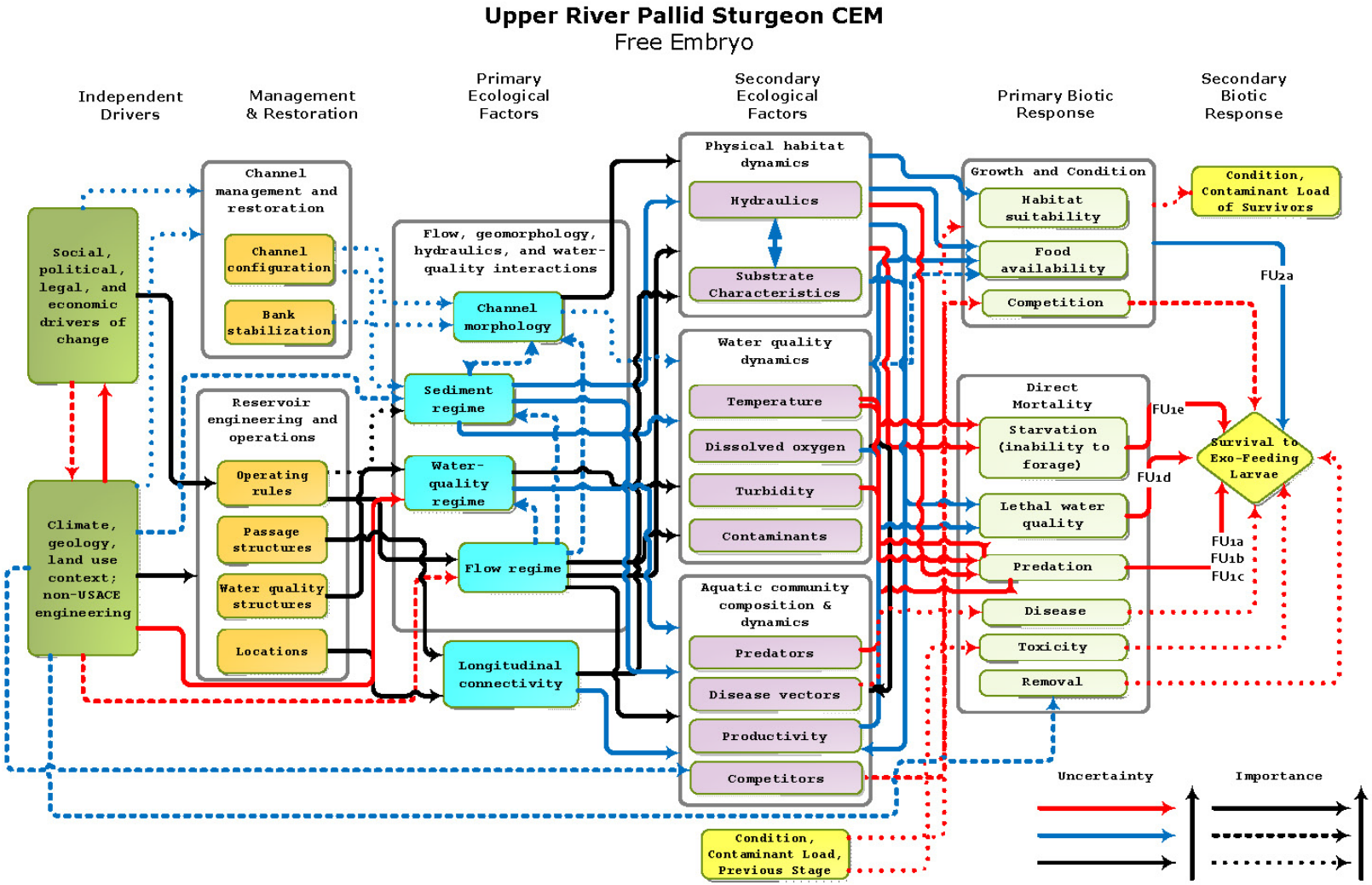


Figure B 4. Upper river pallid sturgeon CEM – exogenously-feeding larvae.

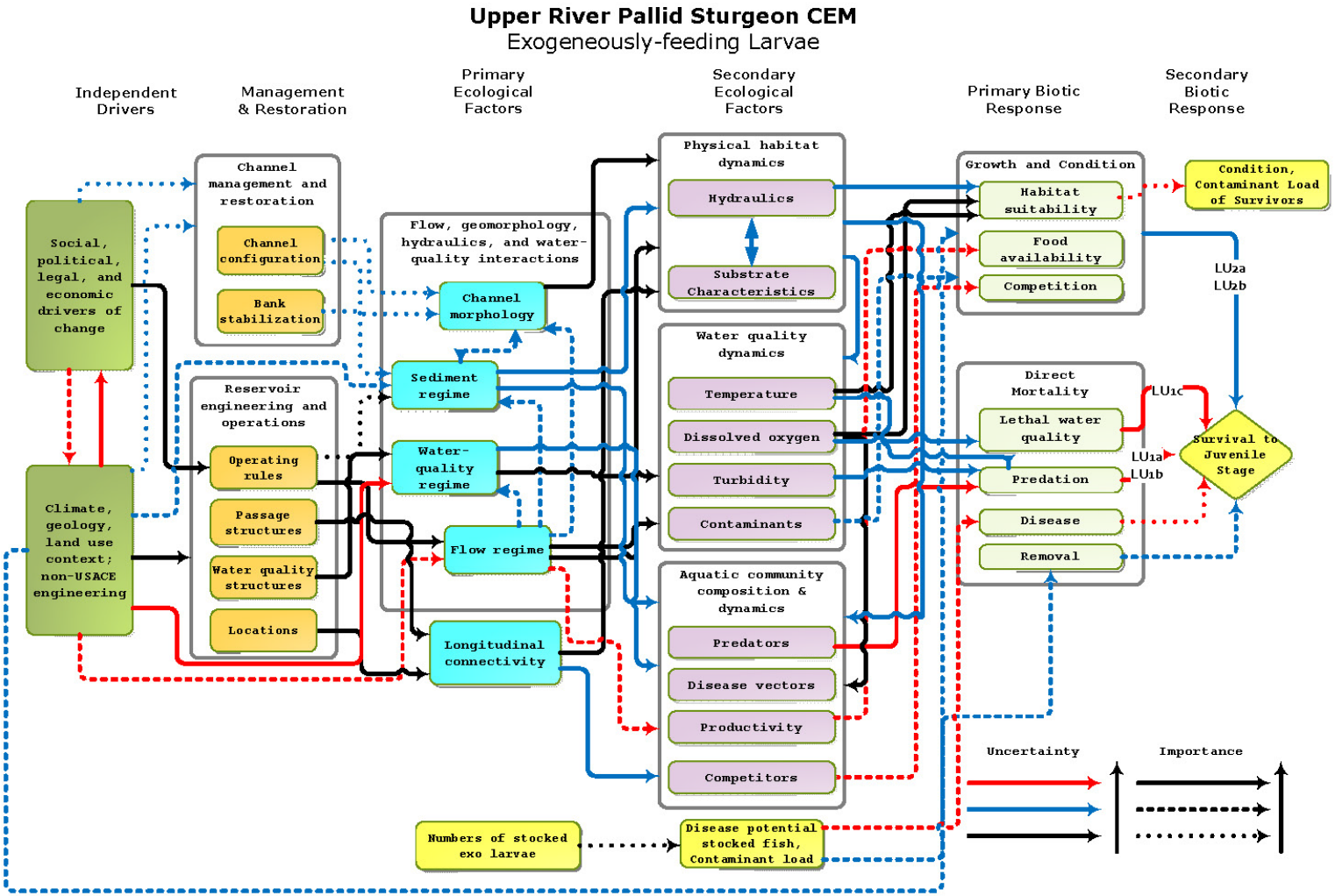


Figure B 5. Upper river pallid sturgeon CEM – juvenile.

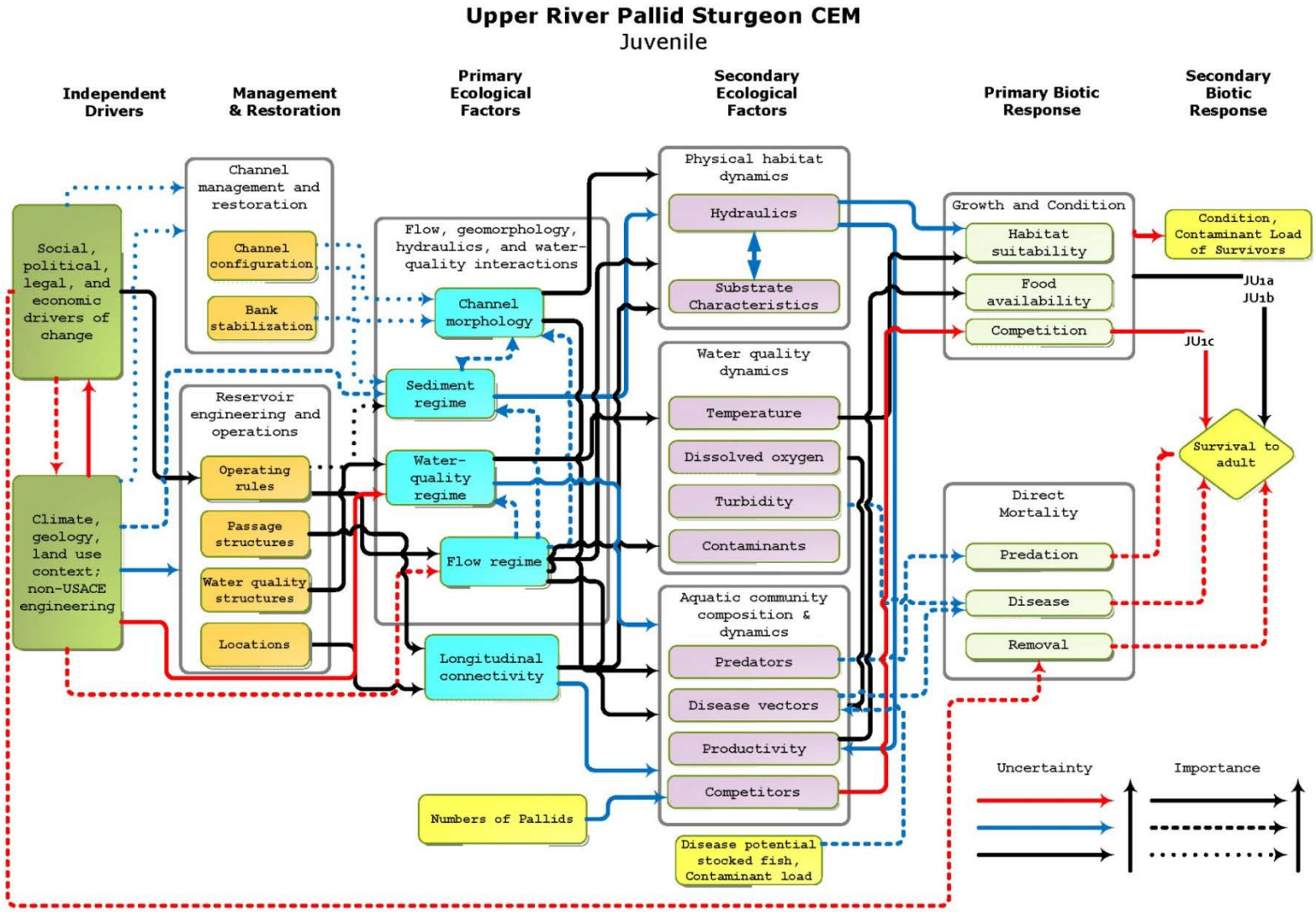
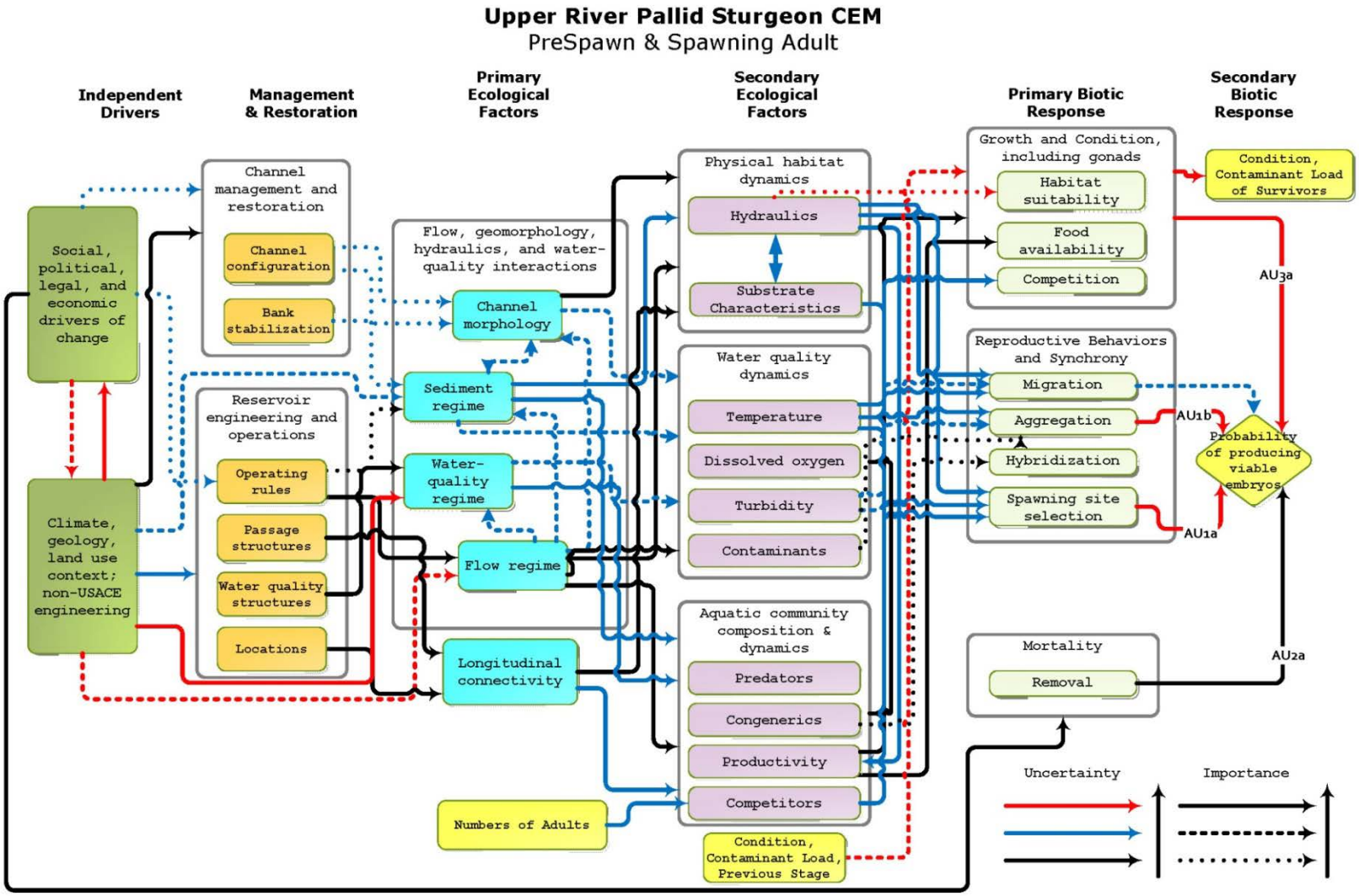


Figure B 6. Upper river pallid sturgeon CEM – pre-spawn and spawning adult.



Lower River

Figure B 7. Lower river pallid sturgeon CEM – developing embryos.

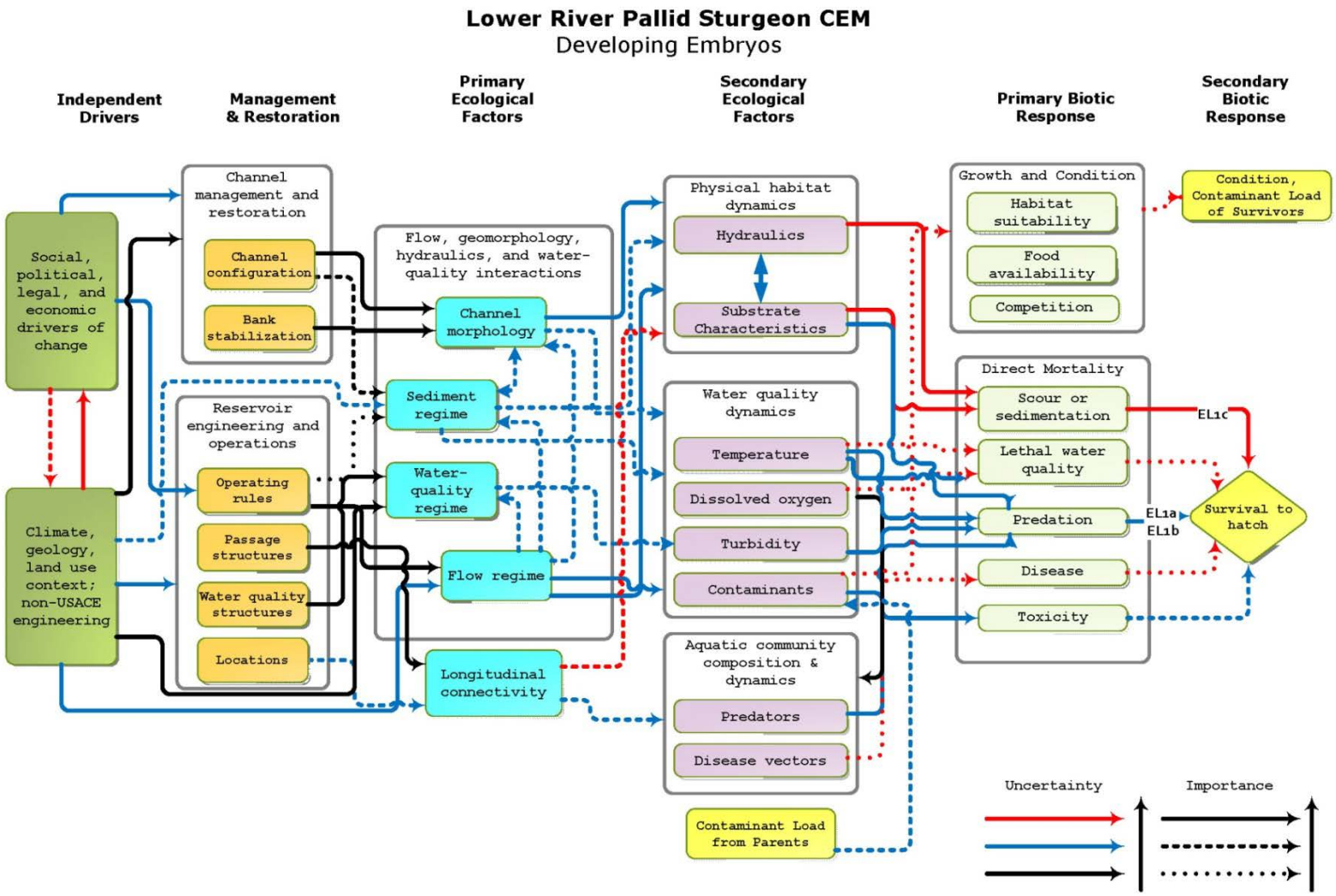


Figure B 8. Lower river pallid sturgeon CEM – free embryo.

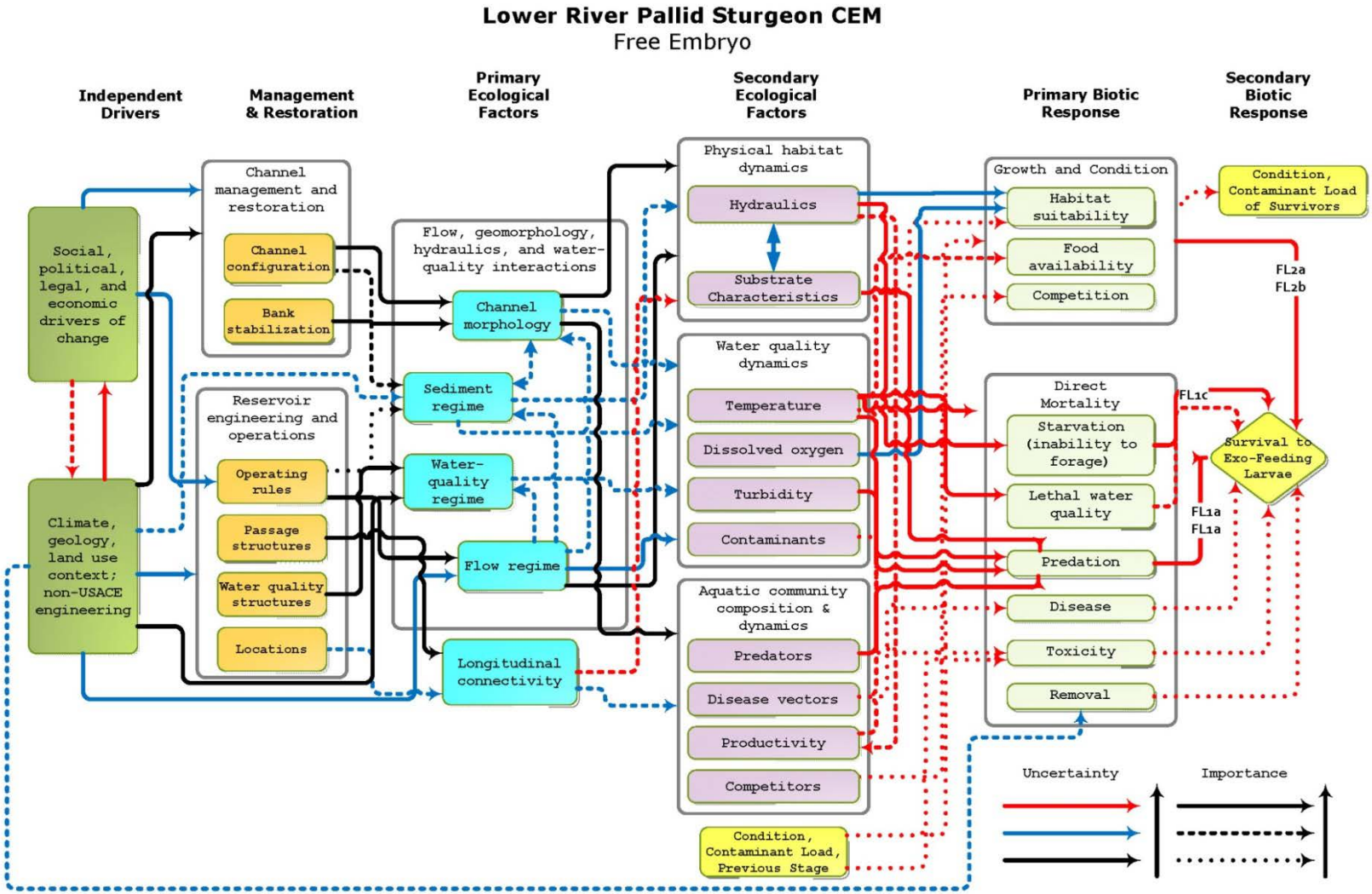


Figure B 9. Lower river pallid sturgeon CEM – exogenously-feeding larvae.

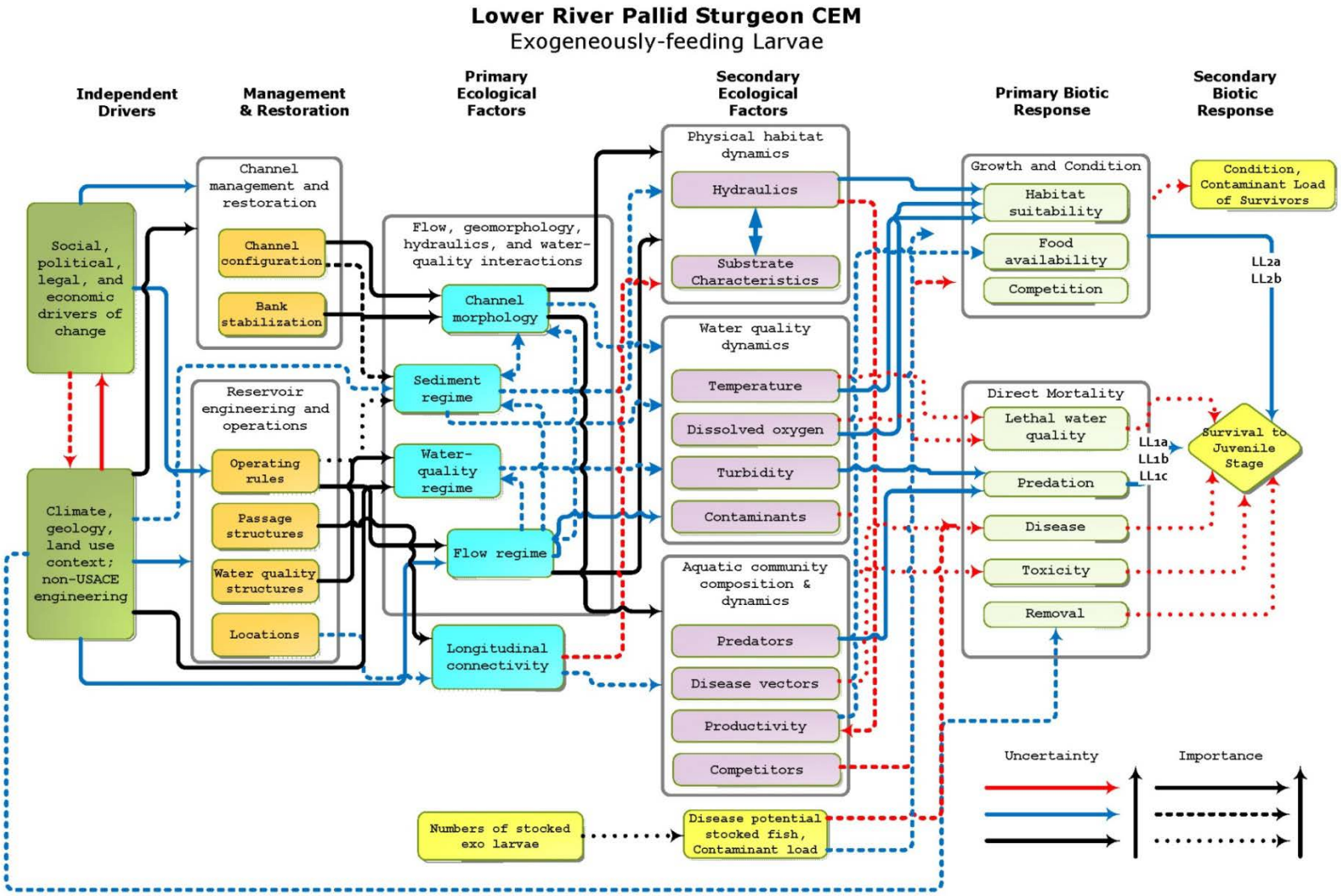


Figure B 10. Lower river pallid sturgeon CEM – juvenile.

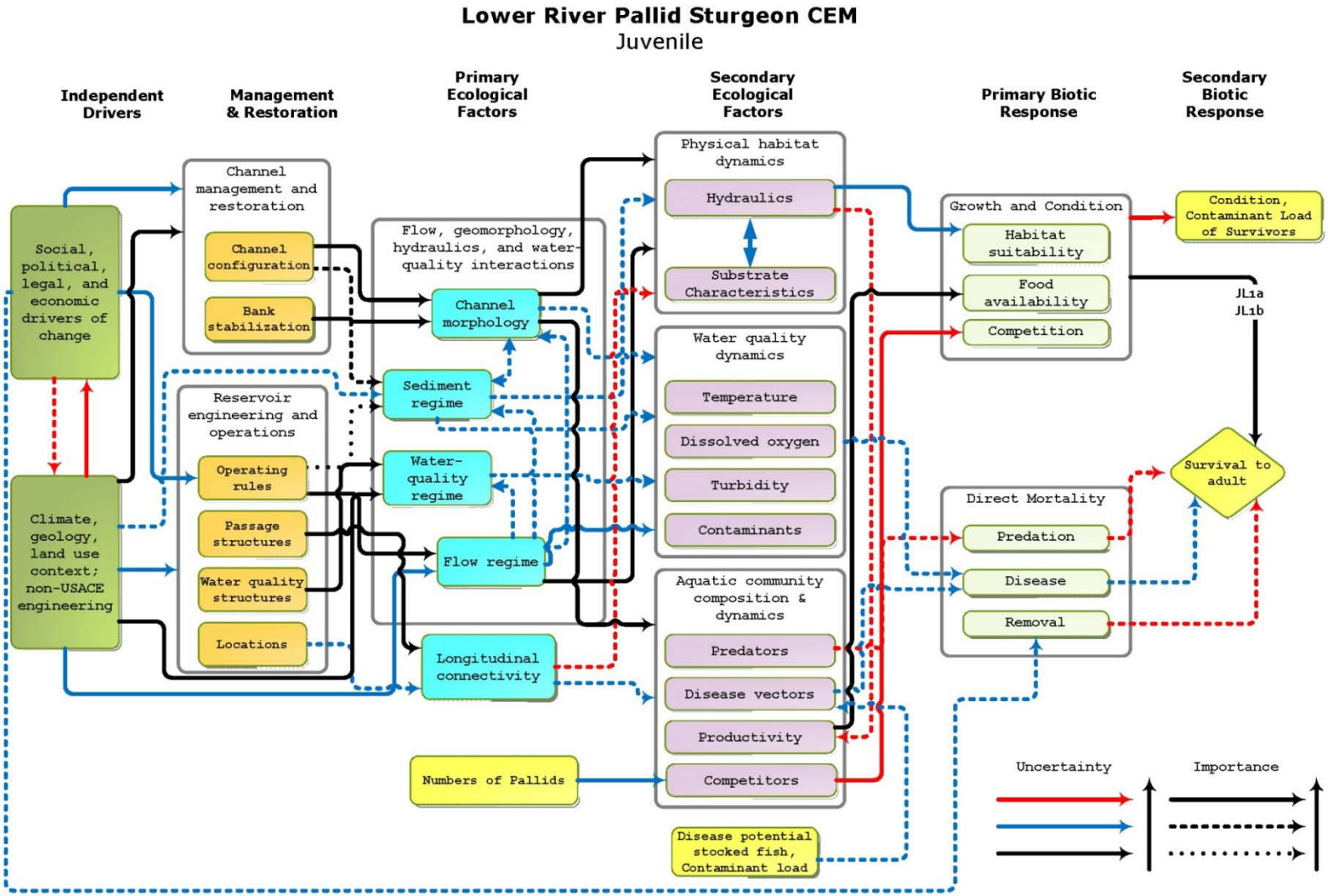
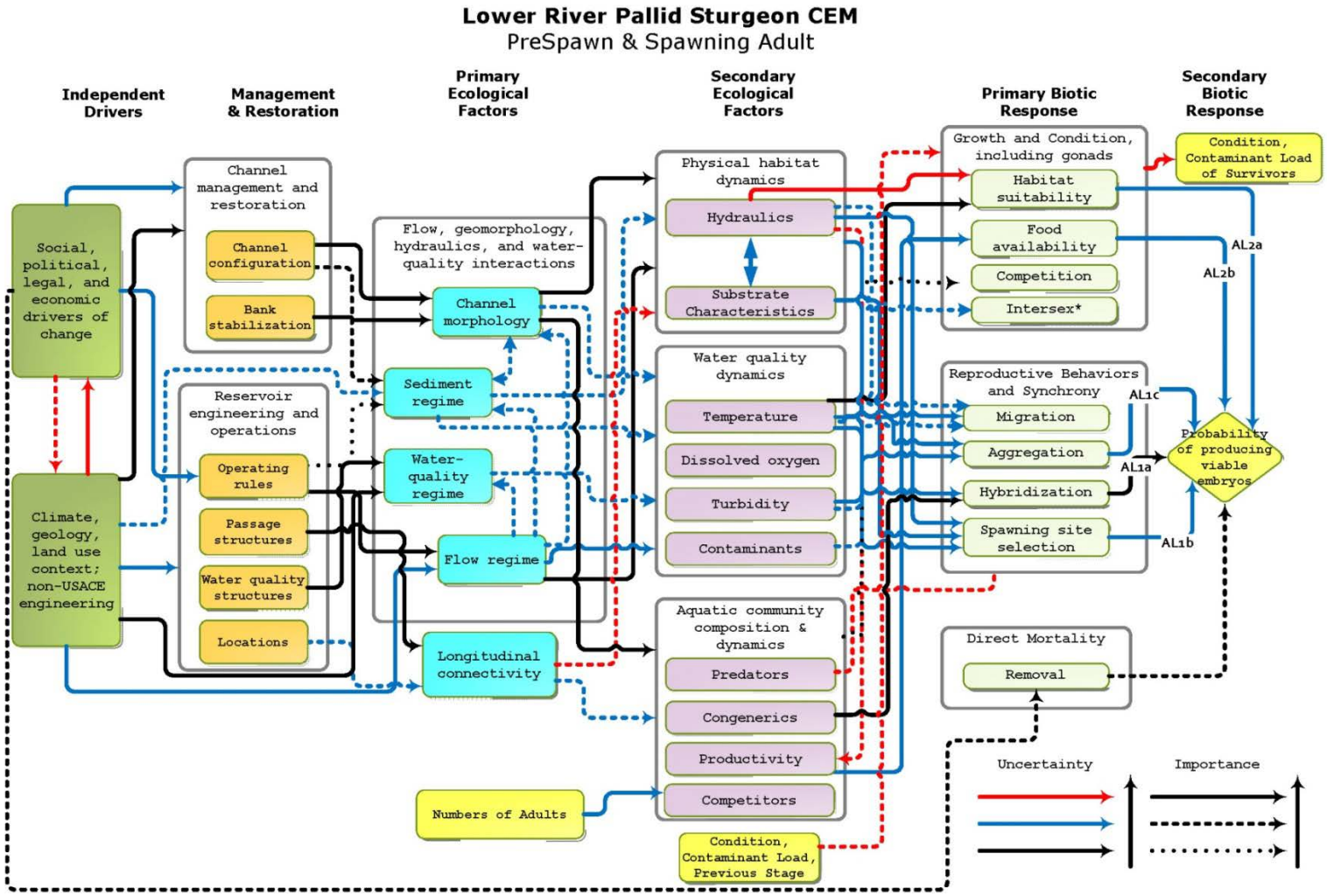


Figure B 11. Lower river pallid sturgeon CEM – pre-spawn and spawning adult.



B.2 Piping Plover CEMs

Without Management Action

Figure B 12. Piping plover ecological effects model (drivers → habitat) without management action.

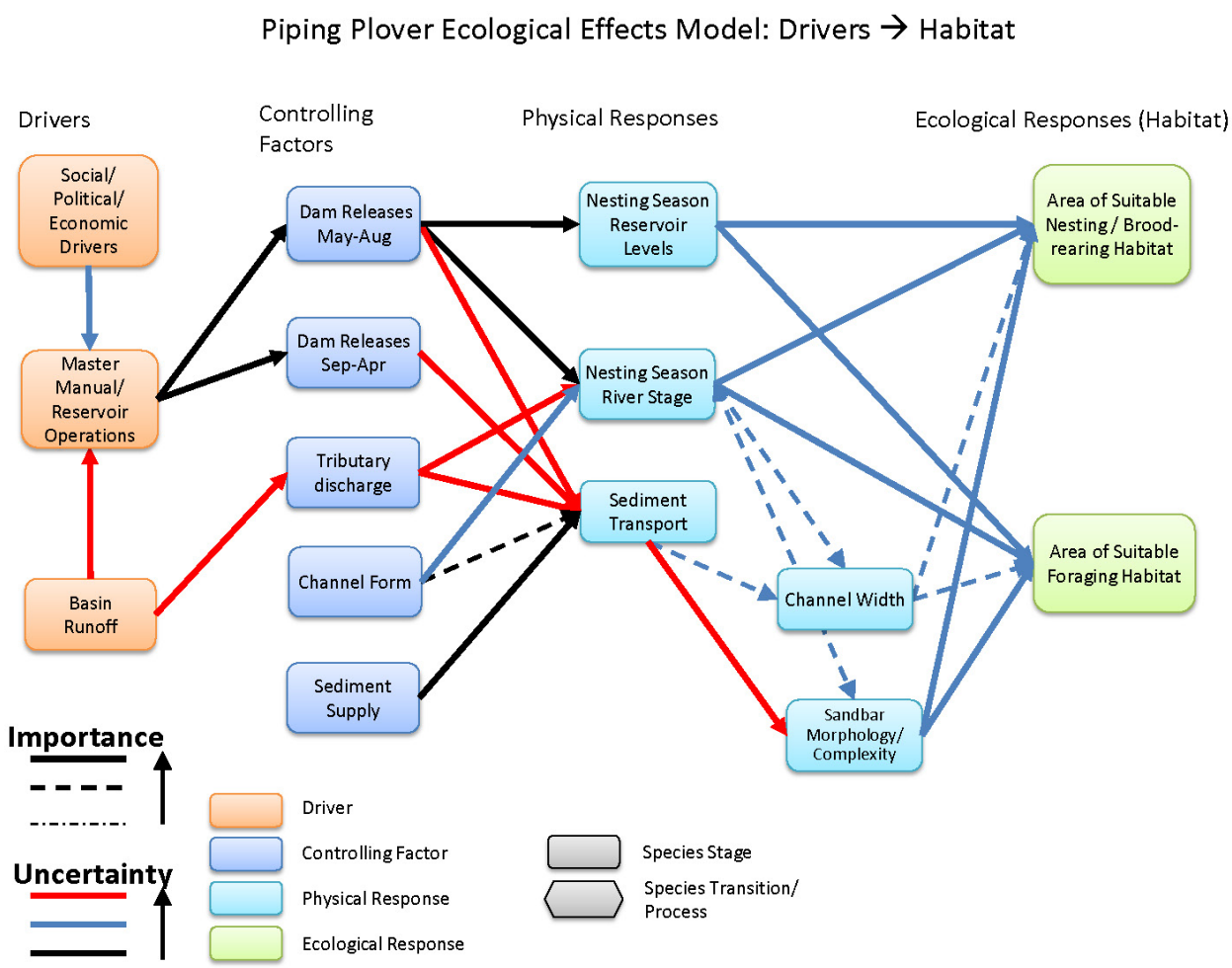
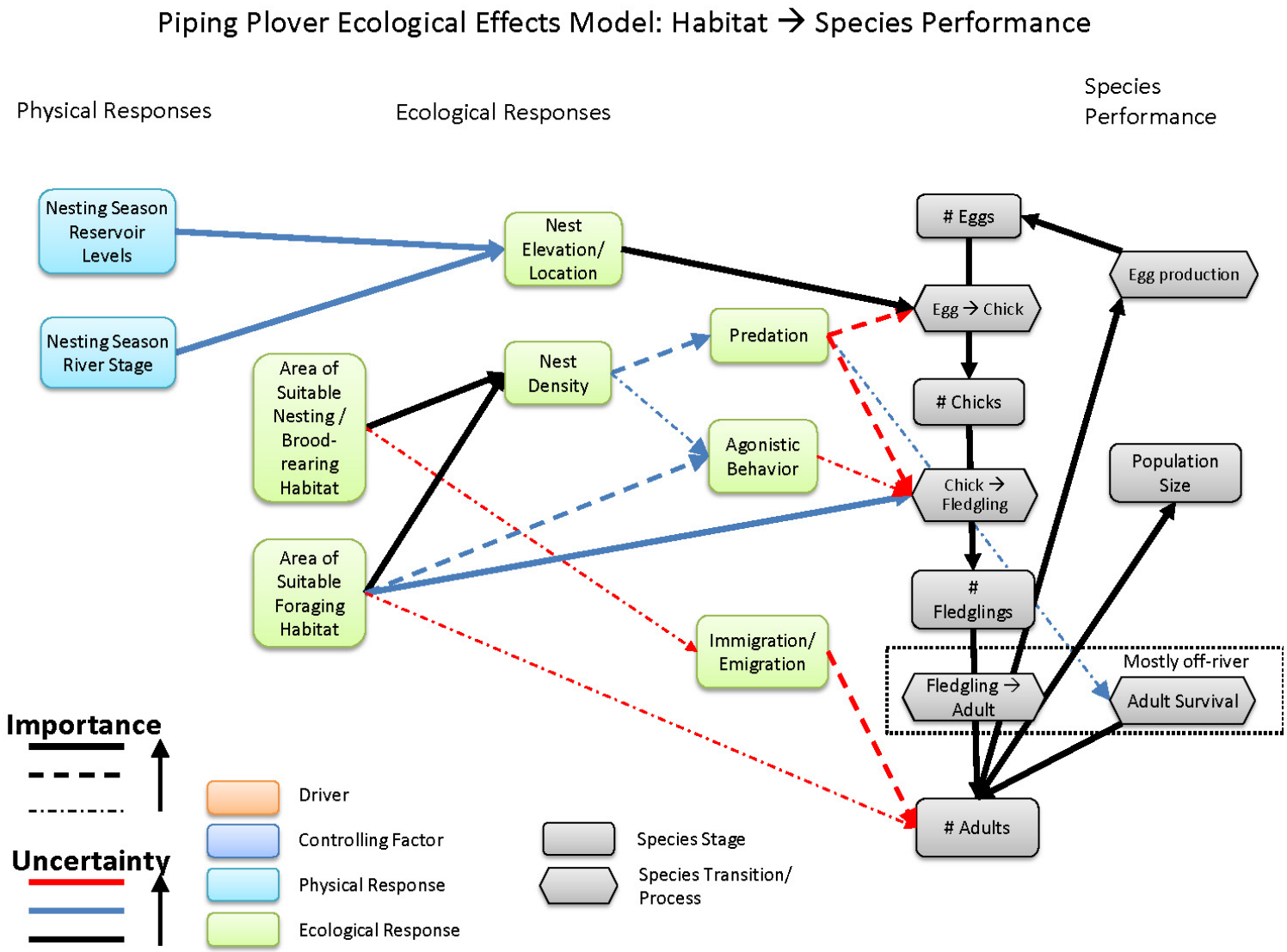


Figure B 13. Piping plover ecological effects model (habitat → species performance) without management action.



With Management Action

Figure B 14. Piping plover ecological effects model (drivers → habitat) with management action.

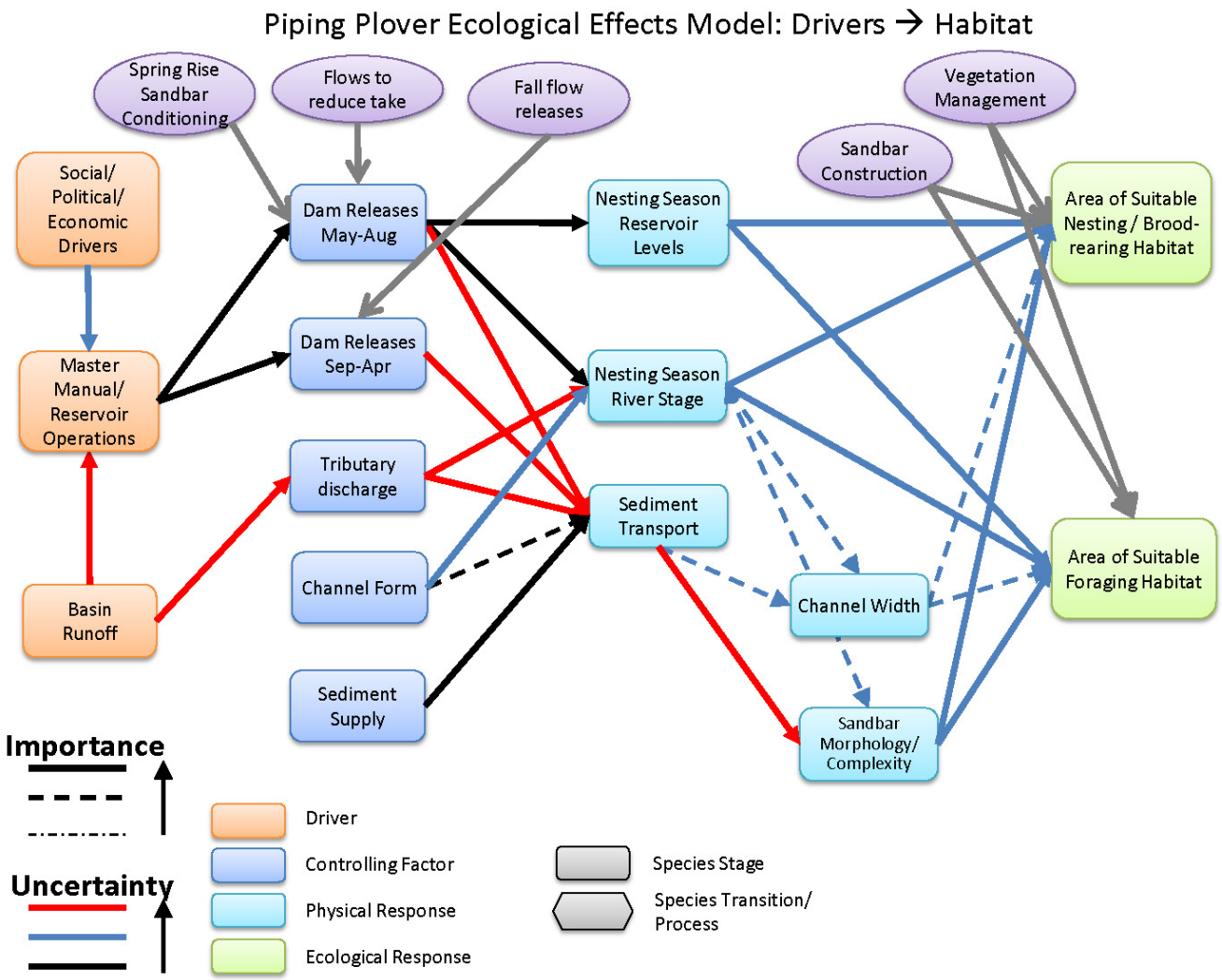
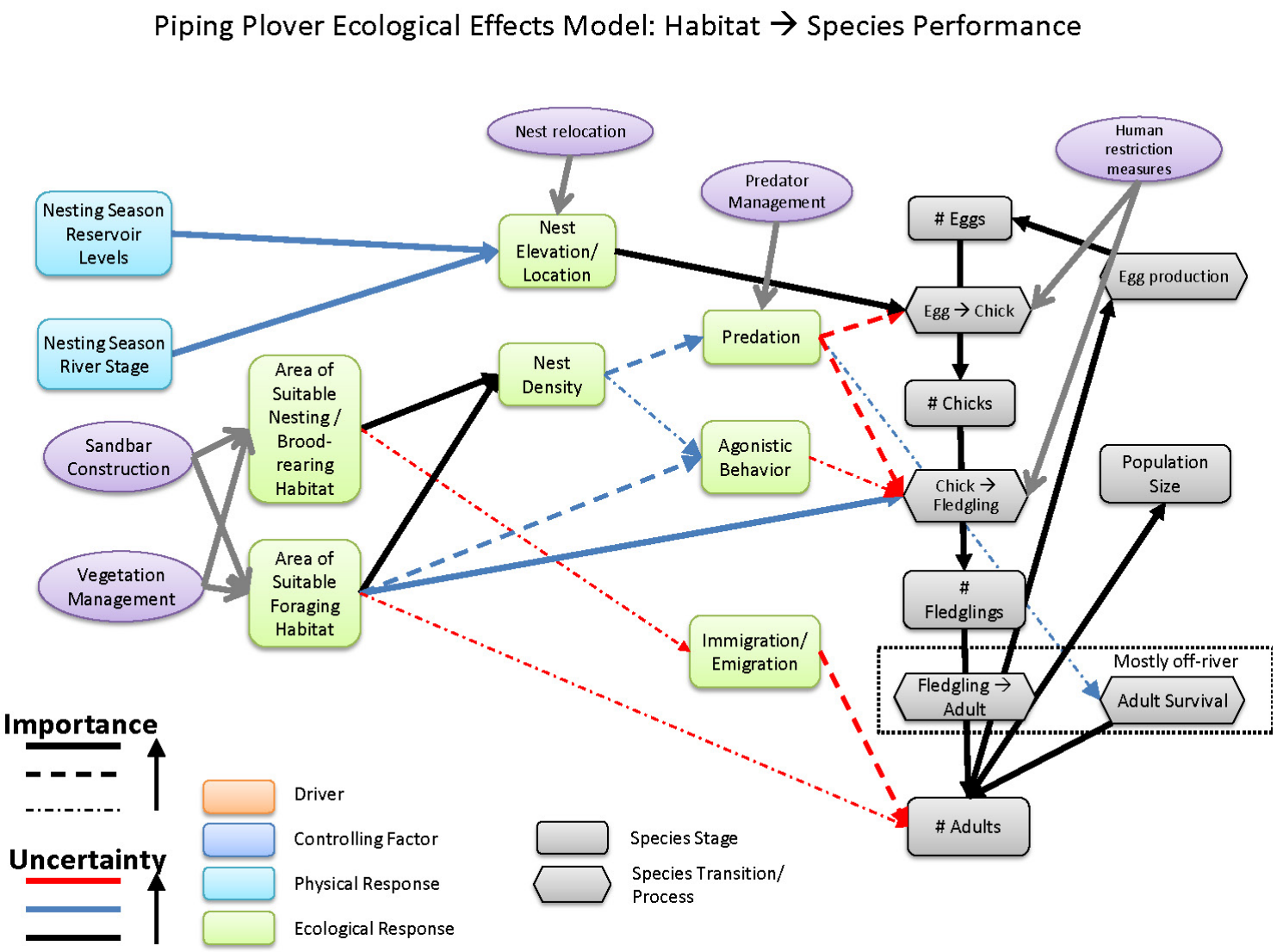


Figure B 15. Piping plover ecological effects model (habitat → species performance) with management action.



B.3 Least Tern CEMs

Without Management Action

Figure B 16. Least tern ecological effects model (drivers → habitat) without management action.

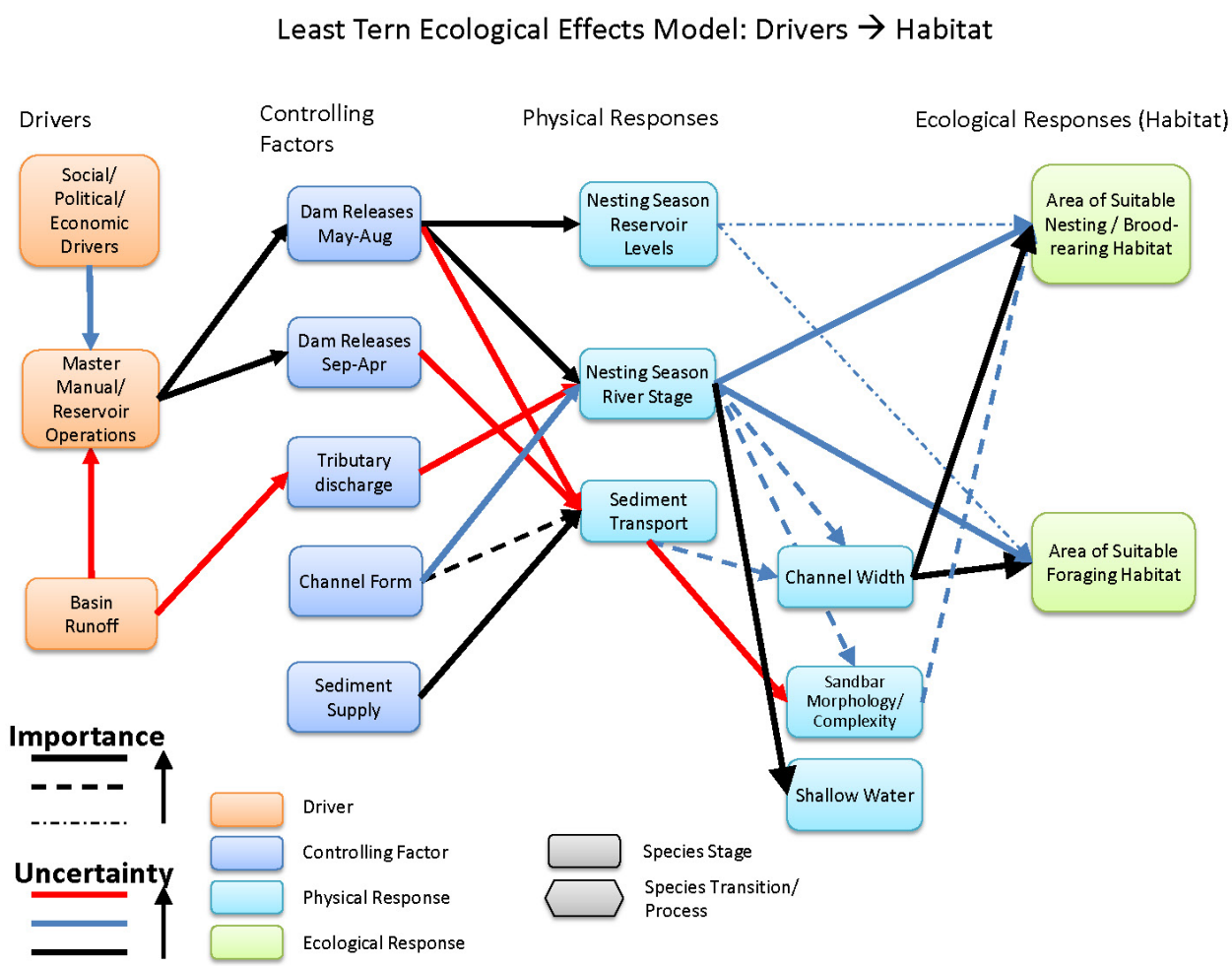
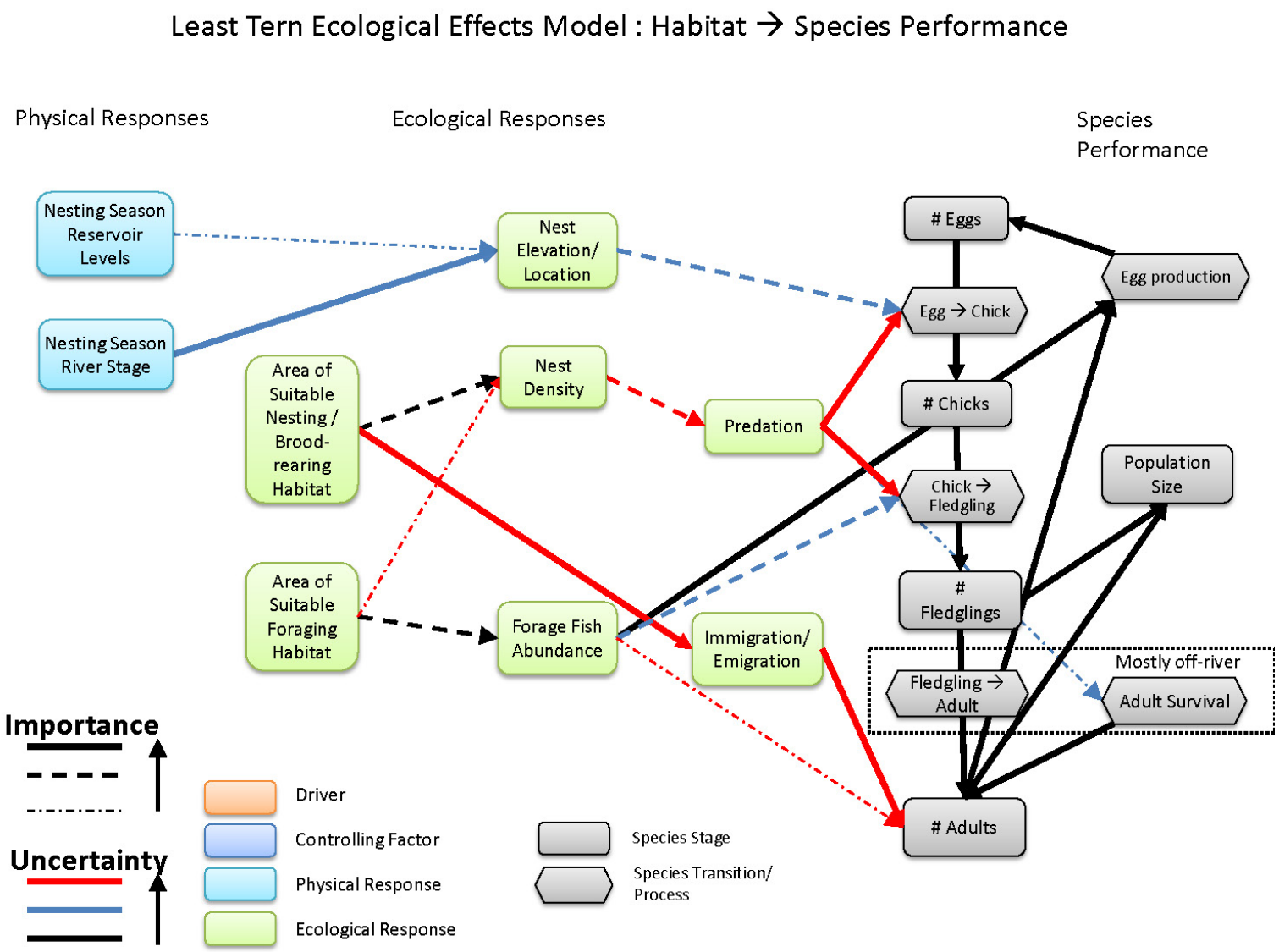


Figure B 17. Least tern ecological effects model (habitat → species performance) without management action.



With Management Action

Figure B 18. Least tern ecological effects model (drivers → habitat) with management action.

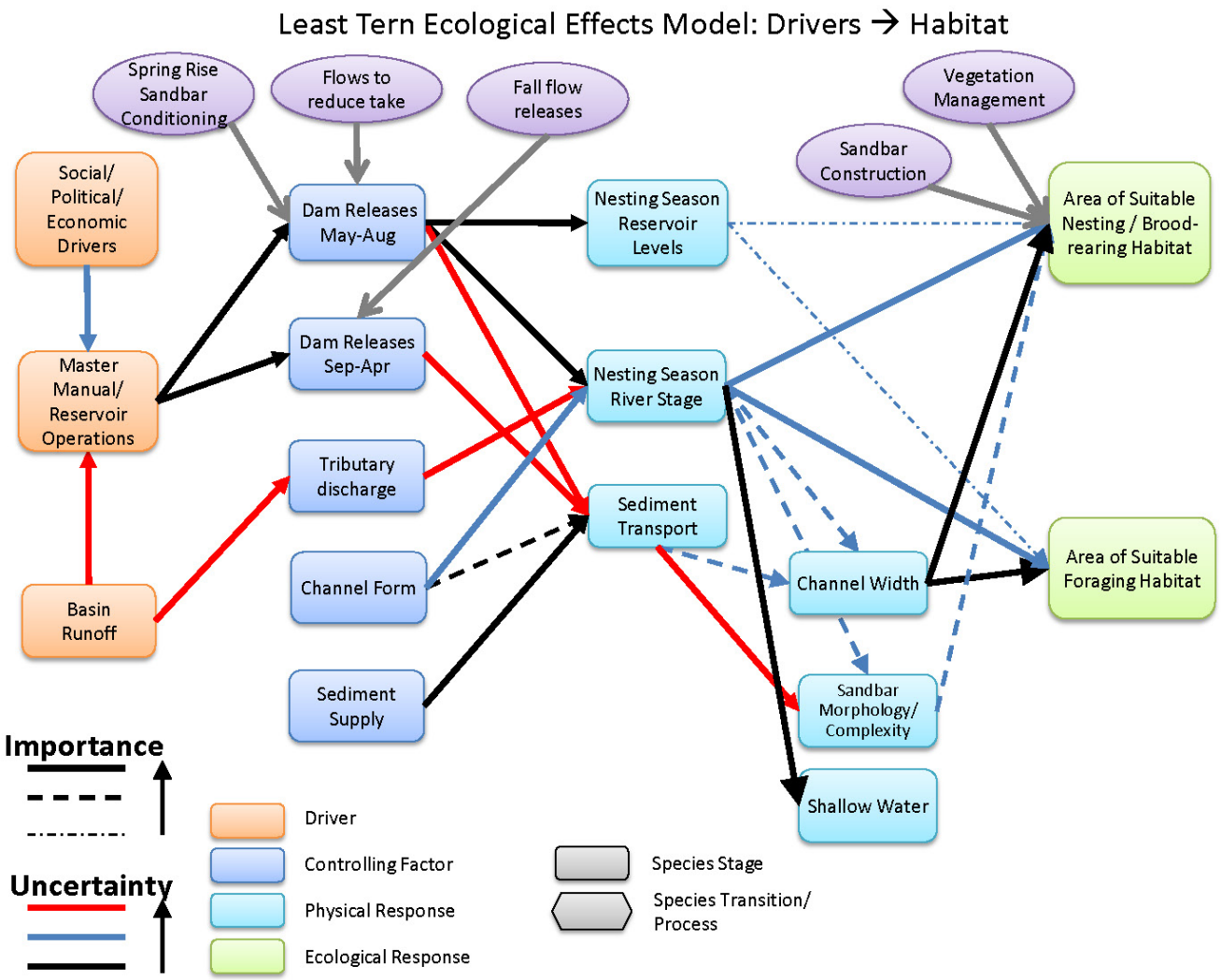
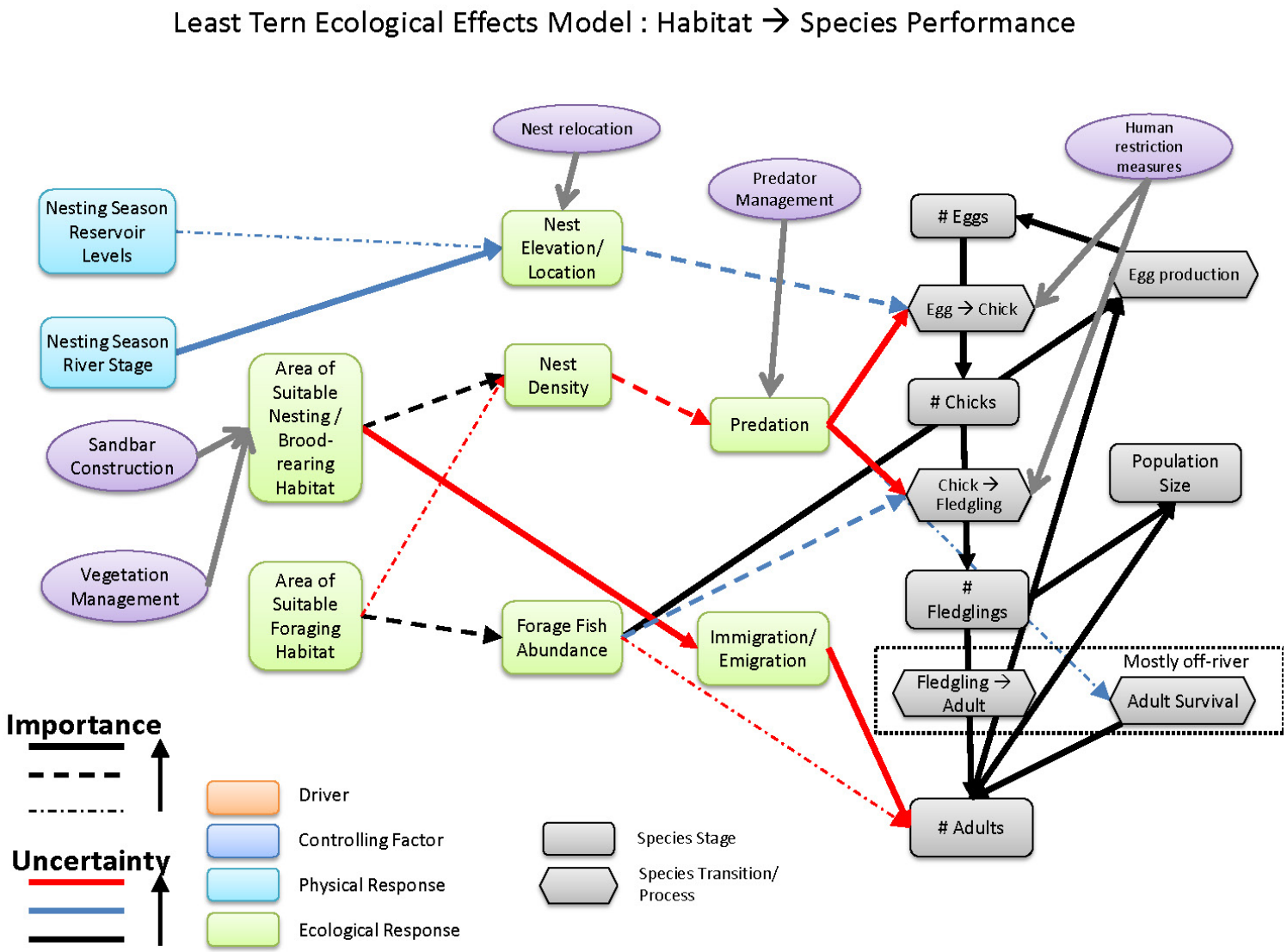


Figure B 19. Least tern ecological effects model (habitat → species performance) without management action.



B.2. Updating the CEMs

The CEMs are reviewed annually by the technical team and updates made as warranted. Updated CEMs are presented to the appropriate implementation team (i.e., bird team or fish team) and other attendees at the Fall Science Meeting or the AM Workshop. Reviews of any proposed changes are required from the ISAP. Pending the ISAP review and comments/recommendations from the appropriate implementation team, the proposed changes are presented to the MRRIC and the Agency senior leadership (USACE and USFWS) and discussed at the next MRRIC meeting. If approved at the Oversight level, the proposed changes are implemented and the revised CEMs are placed in this appendix, labeled as Updated and contain the approval date for reference.

Appendix C. Detailed Description of Level 1 and 2 Science Components for Pallid Sturgeon

C.1 Introduction

This appendix presents a series of scientific components intended to provide a foundation for the Adaptive Management (AM) of pallid sturgeon in the Missouri River. The components address the 21-hypotheses generated in the pallid sturgeon effects analysis (EA) (Jacobson et al. 2016a). These components provide an initial understanding of how management actions may affect pallid sturgeon recruitment and population dynamics.

The study components are broadly defined to address key information needs; however, the decision to pursue certain components, in certain sequences, will be based on evolving understanding, progress on competing hypotheses, trade-offs with socio-economic values, relevance to pending decisions, and estimated costs and benefits. Therefore, the components should be viewed as a set from which pieces can be selected as needed. The big questions and associated study components are not prioritized in this appendix and numbering does not reflect a priority or preference. A discussion about criteria for prioritization, a potential initial set of science components, and associated costs are provided in Appendix F.

This appendix is organized first by geography, separating the upper river and lower river, and then by *big questions*. For each big question, science components are provided for level 1 and level 2 (where level 1 is defined as *foundational research* needed to understand how pallid sturgeon populations will respond to a management action, and level 2 is defined as *field experimentation* to test efficacy of a management action). Additionally, study components are classified as:

- **Engineering/technology:** studies needed to a) develop technology to measure pallid sturgeon responses to a management action (e.g., new telemetry technology, new population modeling approaches) or b) develop engineering approaches to achieve the management action (e.g., engineering designs capable of increasing interception of drifting free embryos).

- **Biological screening:** studies to screen a management hypothesis for biological relevance (e.g., biological screening could describe a study to determine whether growth or survival of age-0 pallid sturgeon is food limited). These studies would proceed to quantify functional relationships

between the management action and the population response; if not applicable, the management hypothesis might be placed in reserve until the biological relevance was established. Screening studies may include mining of existing data or establishing new studies to address whether limitations exist.

- **Level of biological effect:** studies to quantify the functional relationships between the levels of management action and biological responses (e.g., determine the level of change in survival per increment of food-producing habitat). Understanding the level of biological effect that a management action produces is critical to modeling and projecting the effects of management actions on the species.

In addition, biological-screening and biological-effect studies are classified by approach. Because the sturgeon life cycle is complex and critical parts of it involve very small fish in a fast, deep, and turbid river, improvements in scientific understanding are likely to require a combination of approaches. Approaches range from laboratory studies which provide highly controlled, but unrealistic conditions to field-gradient studies, which typically lack experimental controls and replication, but take place under realistic conditions.

- **Laboratory experiment** – a controlled experiment at the laboratory scale typically involves randomization and replication for statistical rigor and may include experiments to determine fundamental biological rates (e.g., rate of embryo development as a function of temperature) and behavioral experiments (e.g., drift studies in racetrack flumes).

- **Mesocosm experiment** – experiments outside of the strict controls of laboratories, but at less than field scale. Examples include experiments in controlled flume, stream, or pond environments. These conditions are incrementally closer to field conditions when compared to laboratory experiments; however, they lack the full dynamism of the field example and typically involve somewhat less statistical rigor and precision of measurements when compared to laboratory experiments.

- **Field-gradient experiment** - using existing measured gradients of hydrologic, geomorphic, and biotic conditions to identify and/or quantify biological effects. These experiments often substitute space for time, or for treatment level. Field gradient experiments take advantage of existing conditions and offer to provide results under realistic conditions; however,

they often lack replication and statistical rigor. Gradient studies require care to reduce or eliminate effects of interacting variates.

- **Monitoring/assessment** – as used in this document, monitoring/assessment denotes data collection of physical and/or biological data, but not necessarily in a hypothesis-testing or adaptive-management framework (field experiments include hypothesis-driven monitoring/assessment in an adaptive management framework). Monitoring often provides critical contextual or covariate information, (e.g., water quality or discharge, or population indices or metrics).

- **Modeling** – numerical experiments with computational models to test sensitivity of habitats or population dynamics to changing parameter values and to explore system dynamics (e.g., using a well-calibrated population model to test population responses to variable stocking levels).

- **Field experiment** – manipulative field experiment to quantify responses to management actions and to test hypotheses (e.g., pulsed-flow experiments to elucidate effects of spawning cues, or controlled experiments on varied channel reconfigurations to document effects on foraging habitat availability). Although these are planned experiments, they fit the definition of quasi-experiment because they typically lack randomization, replication, and/or independence of treatments.

It is important to understand that biological-effect science components are designed ultimately to provide survival probabilities at critical life-stage transitions. Quantitative estimates of survival probabilities will be challenging to derive, but they are critical numbers needed to link management actions to population responses through the collaborative population model (Appendix D). Field-gradient studies and field-based experiments may provide useful information to evaluate aspects of performance of management actions, but laboratory and mesocosm experiments will likely be necessary to estimate associated survival probabilities.

Study components in the following sections are arranged by big questions that serve to group management hypotheses that require similar scientific approaches. Individual components (or discrete studies) are presented for level 1 and level 2 efforts for the upper river and lower river. The description of each component includes metrics, timelines and contingencies, and decision criteria for application of information from the component. For each big question, information is provided on critical uncertainties, utility of the component, risks, and associated adaptive actions.

The objective of this listing is to provide a general framework for the types and sequences of scientific studies that are envisioned for level 1 and 2 phases for the Lower Missouri River pallid sturgeon alternatives. The intent is for these studies, in aggregate, to provide the scientific foundation needed to implement an action, or actions, at level 3, which would be intended to create a positive population response. Information developed during level 1 and level 2 studies may indicate that some hypotheses are invalid and associated management actions should be dropped from consideration, or that new hypotheses and actions need to be developed to address pallid sturgeon population needs.

Level 3 monitoring and assessment are not included in this appendix; specific monitoring and assessment protocols for level 3 implementations will be included with descriptions of those implementations (e.g., in IRCs monitoring design in Appendix E). However, it is clear that knowledge gained in level 1 and 2 components will be useful in design of monitoring for many level 3 assessments by providing technical insights and by directing monitoring efforts toward the most effective metrics for evaluating process- and population-level responses. There will also be complementarity between population-level monitoring/modeling (Appendix D) and some efforts at levels 1–3. Metrics used at levels 1–3 should ultimately provide information to estimate critical population parameters (particularly survival of early life stages). Age-0 CPUE monitoring, envisioned as part of population-level monitoring, may also be designed to complement level 1 and 2 science components related to dispersal and retention of larval pallid sturgeon.

C.1.1 Decisions about quality of science information

As information is developed during implementation of level 1 and level 2 efforts, decision points will be reached where the AM program will need to determine whether to pursue alternate paths. Decisions might be:

- accept that the scientific information supports the hypothesized action and:
  - move to the next most important science question pending for each big question; or
  - move to implementation of level 3 actions intended to promote a measurable, positive biological response to the species;
- determine that the scientific information does not support the hypothesized action; and
  - refine the hypothesis and continue scientific investigations; or

- reject the hypothesis and promote an alternative hypothesis that better explains observed information.

In some science components, rigorous hypothesis testing may be possible, especially in well-constrained laboratory or mesocosm experiments. In this case, specific and quantitative decision criteria can be applied. When results are investigated in the field under realistic conditions, it is likely that statistically robust results will not be produced because of the inherent challenges in designing field experiments with sufficient randomization and replication. Under these conditions, a lines-of-evidence approach may be necessary in which multiple types of information are evaluated and judged. A lines-of-evidence approach may require a specific process for using experts to provide judgments in these decisions as well as independent review (e.g., ISAP).

C.1.2 Geographic areas

The geographic scope of the pallid sturgeon framework is the Upper Missouri River mainstem from Fort Peck Dam to the headwaters of Lake Sakakawea, the Yellowstone River upstream of the confluence with the Upper Missouri River for an unspecified distance (Figure C 1, Figure C 2), the Lower Missouri River mainstem from Gavins Point Dam to confluence with the Mississippi River at St. Louis, tributaries used by pallid sturgeon, and an unspecified distance downstream in the Mississippi River (Figure C 2). The geographic scope is constrained, in part, by decision-making authority of the USACE and in part, by present understanding of the geographic distribution of pallid sturgeon. The reservoirs and inter-reservoir reaches (from Lake Sakakawea to Lewis and Clark Lake) presently are excluded from the analysis based on the assumption that these habitats are unlikely to sustain reproductive populations of pallid sturgeon. The upstream distance on the Yellowstone River is unspecific because of limited knowledge about how far pallid sturgeon might migrate and whether they may use tributaries for spawning. The distance in the Mississippi River is unspecified because presently available information (2016) is ambiguous about the extent to which Missouri and Mississippi river populations mix through migrations and dispersal.

Figure C 1. Location of Upper Missouri and Yellowstone River segments.

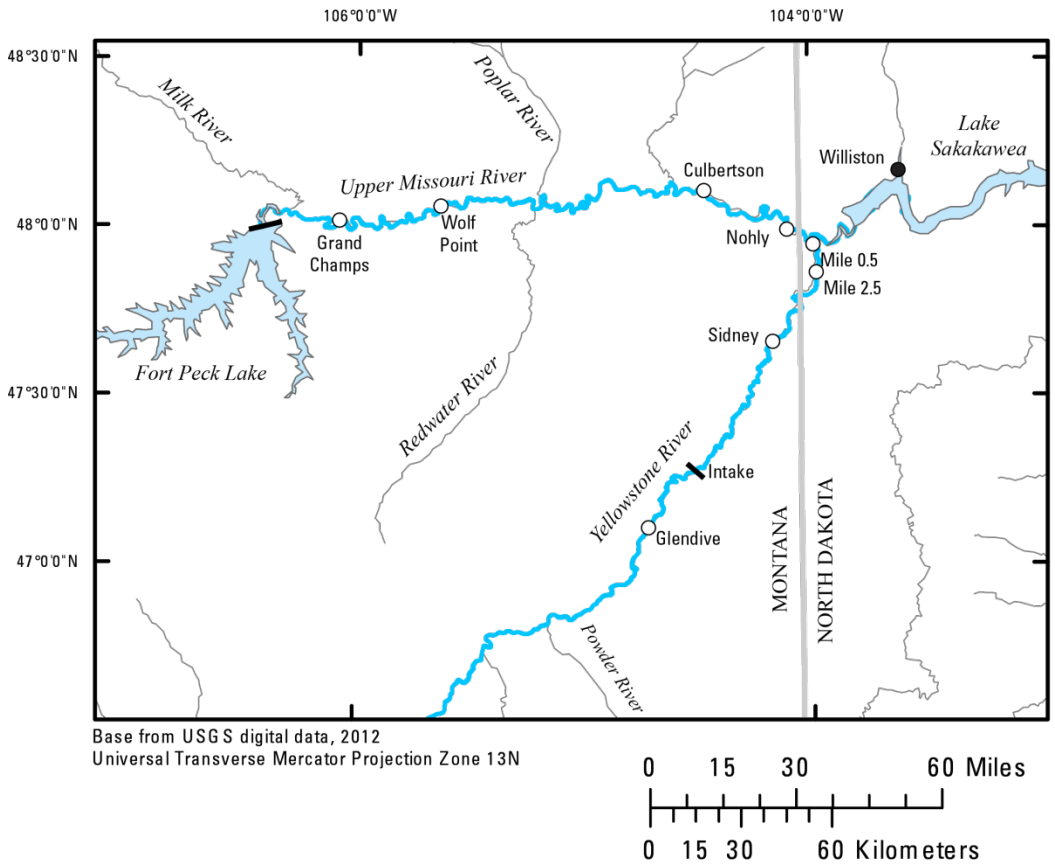
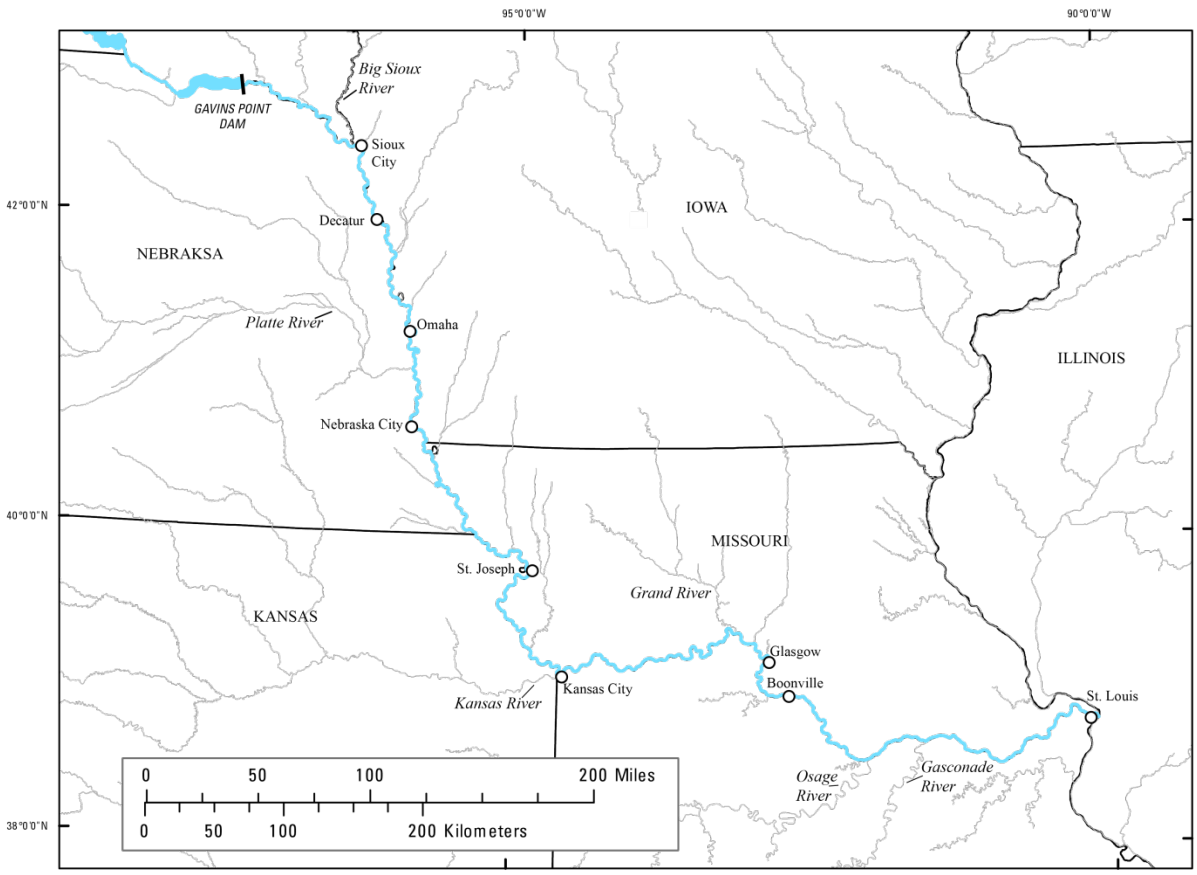


Figure C 2. Location map for the Lower Missouri River.



C.1.3 Breadth and staging of science components

The large breadth of components presented here represents a view of the information content necessary to inform management decisions. The components are designed to be decision-critical, cost effective, and flexible. In addition, the components are intended to develop sufficient understanding of cause and effect to support adaptive management of the river and the species. The selection of components is not prioritized in this appendix, but is instead presented as a superset of components from which prioritized components can be selected as required. An initial set of prioritized science components is presented in Appendix F.

The staging (sequence) of components and cost estimates, based on current priorities, are presented in Appendix F. This staging assumes that all level 1 components can be pursued effectively in parallel and level 2 components can be substantially overlapped in time, although level 2 components generally follow the completion of level 1.

The staging of science components has implications for costs and how information is developed to support decision making. In a purely sequential approach, science components would be staged and prioritized so the next component is only addressed when the previous ones have been completed with satisfactory results; that is, with results providing relevant information to frame the next component. In a parallel approach, multiple science components may be pursued simultaneously. The parallel approach involves more financial risk compared to the sequential approach in that it may expend resources on science components whose relevance could be negated by other components. Hence, the parallel approach would have higher annual budget needs than the sequential and could potentially be less cost effective. The parallel approach is less risky to the species, however, in that relevant information will be developed more rapidly and the more definitive field experiments of level 2 (and potential implementation of level 3) would occur sooner.

In general, the parallel staging scenario presented maintains a sequential approach to moving from level 1 to level 2. This recognizes the considerable cost that may be incurred with level 2 implementation of field experiments and the perceived need to justify that cost with strong support for hypotheses that are developed during level 1.

It should be noted that time frames estimated for the science components are highly contingent on what is learned and how rapidly. Some components that would require long time-intervals may be dropped from consideration if information indicates that the hypotheses should be rejected, whereas others may expand in time if the logistics of carrying out the science require it. Moreover, estimated total time required varies considerably among the hypotheses. Importantly, the decision criteria for ending science components are subject to considerable judgement concerning how reliable the information needs to be to either proceed or abandon a hypothesis. The need for judgement should provide ongoing flexibility for the management team to adjust the times devoted to these components.

Several significant management actions on the Missouri River are in progress or are near the completion of the planning process. These actions include some aspects of the shallow-water habitat program that correspond closely to the IRC concept, population augmentation, and the Yellowstone River Intake Diversion Dam Passage Project. This document assumes that although decisions have already been made to move forward with these actions (essentially at level 3), additional level 1 and level 2 science components are needed to backfill the scientific foundation of the actions. Although performance of these ongoing level 3 actions may be assessed using various monitoring metrics, the level 1 and 2 components are designed to impart more controlled, quantitative analysis of ecological processes than will be possible with monitoring of

level 3 actions alone. The level 1 and 2 components will provide important cause/effect understanding to explain performance; such understanding is essential to design adaptive responses if performance is not as expected.

The Intake Passage Project presents a special challenge to staging and adaptive management because of the legal and multi-agency framework. The Intake Project is at least a level 3 implementation that was pursued with incomplete implementation of level 1 and level 2 components. For the purposes of this appendix, level 1 and level 2 components are presented that address fundamental, underlying science questions to help guide decisions related to the Intake Project. Chapter 4 of the main document presents a level 3 monitoring plan for the Intake Project that is intended to complement the Bureau of Reclamation Adaptive Management Plan (U.S. Bureau of Reclamation 2014) and extend relevance to decision making for the Upper Missouri River.

C.2 Upper River

The upper river refers to the Upper Missouri River mainstem from the headwaters of Lake Sakakawea to Fort Peck Dam, major tributaries to the Upper Missouri River, and the Yellowstone River and its tributaries for an undetermined distance upstream from the Yellowstone/Missouri confluence (Figure C 1). The level 1 and level 2 adaptive management actions are referred to below by upper big questions.

Upper big questions 1–6 relate mostly, or in part, to management actions on the Upper Missouri River that would be intended to increase natural recruitment of pallid sturgeon. At the same time, significant Federal action is underway on the Yellowstone River to increase fish passage at Intake Diversion Dam near Glendive, Montana. As documented in the EA, the prospect of successful passage around Intake Diversion Dam, combined with upstream migration of sufficient numbers of reproductive fish to suitable spawning habitat in the Yellowstone River or tributaries, is related to Upper Missouri management actions. If spawning occurs at locations in the Yellowstone that allow free embryos sufficient distance for transition to first feeding upstream of Lake Sakakawea, actions on the Upper Missouri River may not be necessary to recover the subpopulation. However, if passage on the Yellowstone is not documented to result in sufficient successful recruitment, there is a logical need to evaluate whether actions on the Upper Missouri River could increase probability for recruitment. These could include decreases in flows from Fort Peck Dam to decrease downstream transport rates, increases in water temperatures from Fort Peck Dam to increase developmental rates, drawdown of Lake Sakakawea to increase available dispersal distance, or some combination thereof.

Although contingencies based on evolving information might dictate a sequential approach to science components and eventual management actions, the staging

assumed here (Appendix F) infers all level 1 components are simultaneous and will be followed by appropriate level 2 field experiments. Appendix F presents additional discussion of prioritization.

C.2.1 Upper big question 1; can spring pulsed flows from Fort Peck synchronize reproductive fish, increasing chances of reproduction and recruitment?

C.2.1.1 Objective of study components

The objective of these study components is to determine if water flow, or changes in flow, from Fort Peck Dam during the spring influences spawning behavior and successful reproduction of pallid sturgeon in the Upper Missouri River. The value of these study components would accrue in the event that recruitment from spawning on the Yellowstone River is not sufficient to sustain population size.

C.2.1.2 Description of study components

Water discharge is thought to influence pallid sturgeon migration behavior, reproductive readiness, and possibly spawning site selection prior to spawning. By providing attractant flows from the dam during the spring, reproductive pallid sturgeon may be cued to migrate in synchrony, leading to increased aggregations at spawning locations. This could increase the chances of successful reproduction.

C.2.1.3 Relation to Effects Analysis

These study components directly support EA hypothesis 2; attractant flow releases at Fort Peck will result in increased reproductive success through increased aggregation and spawning success of adults.

C.2.1.4 Approaches

Two levels could be implemented to test this hypothesis. Level 1 includes opportunistic field testing in the river and experiments in a constructed mesocosm in order to evaluate behavioral responses under more controlled conditions. Level 2 includes an engineering study to determine the associated effects of flow pulses and implementation of experimental flow releases to test fish reproductive behaviors.

C.2.1.5 Level 1

C.2.1.5.1 Component 1

This component is a technology development study to design, optimize, and implement a passive, fixed-station telemetry receiver network to complement intensive, boat-based

tracking through the Upper Missouri and Yellowstone study area. The study is intended to support component 2 and upper big question 5 (drift/dispersal). This is delineated separately because of the potential challenges in design and implementation in the dynamic Missouri River system.

Metrics

Metrics for this technology development study will be; performance metrics for detectability of tags, variation of detectability with discharge-related characteristics, cost, and reliability.

Timelines and contingencies

The technology developed and tested in this component would contribute to the success and cost effectiveness of subsequent components (components 2 and 5) and will be especially useful in upper big question 5 (evaluate spawning locations). Development and testing could be accomplished in one year. It is expected to begin in 2017 under the parallel staging scenario.

Decision criteria for application of component

If testing proves successful, the decision may be made to deploy passive telemetry receivers in a network that will contribute to sample designs for evaluating sturgeon responses to flow pulses. Success will be determined by the ability to detect fish movements past strategic locations.

C.2.1.5.2 Component 2

This study component involves opportunistic monitoring of water discharge, pallid sturgeon movement, and pallid sturgeon location data. Flows would need to be measured continuously at multiple locations downriver from Fort Peck Dam and on the lower Yellowstone River. A range of opportunistic flows (low to high) would be needed to bracket ecologically ineffective and effective flows. Without intentional flow releases, variation between the Upper Missouri River and the Yellowstone River will still provide a strong experimental contrast. Pallid sturgeon in reproductive condition would need to be tracked via telemetry methods to determine movement patterns. Telemetry would include documenting reproductive behavior (aggregation, spawning) and spawning success as measured by production of free embryos. Statistical relationships of flow-regime components (e.g., mean discharge, change in discharge) and covariates (e.g., turbidity and temperature) to pallid sturgeon behavior would be evaluated.

Metrics

Metrics for this component will include the degree of association of reproductive migrations and successful spawning with monitored hydrologic characteristics (magnitude, duration, timing, rate of change of discharge, temperature, and water quality). Extensive tracking by way of the passive telemetry network (component 1) will be complemented with intensive, boat-based tracking. Tracking information for reproductive adults (males and females) will be evaluated against time series of hydrologic characteristics and will be analyzed for degree of association. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes.

Timelines and contingencies

This component is an extension of existing research. This 8-year effort in understanding reproductive ecology of the pallid sturgeon has not been sufficient to associate reproductive success with hydrologic characteristics with confidence. More tagged fish, a longer record, more-intensive manual tracking, and a denser passive telemetry network will contribute to a significantly improved understanding of whether hydrologic links exist and are important to the pallid sturgeon population. It is anticipated that an additional 8 years of data collection will be necessary. Success of the study will depend in part on the development of passive receiver networks (component 1) and on maintenance of a tagged research population of reproductive fish that are not subject to being selected for use in the population augmentation program. This component would progress in parallel with component 1 and the mesocosm experiments in component 3.

Information on spawning locations collected in this component will be essential for evaluations of drift and dispersal under upper big question 5, as the spawning locations determine the upstream extent of dispersal. Tracking of reproductive pallid sturgeon on the Yellowstone River would be highly complementary to the monitoring and assessment of Intake Project performance.

Decision criteria for application of component

Based on past research, it is unlikely that this component will result in a statistically rigorous decision. Instead, a decision to accept information as useful to decision making will most likely be based on the judgement of multiple lines-of-evidence from components 1, 2, and 3.

C.2.1.5.3 Component 3

Many of the same aspects of component 2 would be measured in component 3 except at a smaller scale in a controlled environment. The objective is to develop a precise understanding of what characteristics of flow are instrumental in producing a fish response and how can those characteristics be optimized in flow releases from Fort Peck to draw fish up the Missouri River for successful reproduction. Possibilities for mesocosm experiments include very large circulating tanks, circulating ponds, or constructed side channels to the Missouri River. Mesocosm experiments would ideally vary water velocity, temperature, and turbidity (and rates of change) to evaluate behavioral responses of reproductive adults. Acoustic video and 3-dimensional telemetry arrays would allow for detailed characterization of behaviors.

Metrics

Metrics for this component will include the degree of association of reproductive behaviors with manipulated hydrologic characteristics (magnitude, duration, timing, rate of change of discharge, temperature, and water quality). Intensive, fine-scale telemetry tracking data of reproductive adults (males and females) will be evaluated in trials with varying discharge, temperature, and turbidity. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes. The ultimate metric will be probability of successful spawning as a function of abiotic variables.

Timelines and contingencies

This component is anticipated to progress in parallel with field-scale telemetry in component 2, indicating that neither component is contingent on completing the other. The two types of information are considered mutually supporting.

Implementation of this component will require construction of a mesocosm (large flume or pond facility) that is capable of a creating a wide range of hydrologic and water-quality conditions; in addition, the facility will need to be large enough to accommodate multiple full-sized adult fish (see discussion of lower big question 2, component 3). This facility could be a semi-controlled side channel of the Missouri River or a highly controlled experimental flume similar to the USACE-ERDC cognitive fish flume (http://el.erdc.usace.army.mil/emrrp/nfs/facilities.html). The mesocosm studies are identical with those discussed under lower big question 1, component 3.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to accept information as being useful in decision making and moving forward to level 2. Controlled mesocosm studies may provide statistically rigorous results indicating the presence or absence of hydrologic effects on reproductive success and the strength of any association that exists. Such information would likely be an incomplete assessment of field-scale conditions; and therefore, would be evaluated in a lines-of-evidence approach along with component 2 information.

C.2.1.5.4 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement that there is, or is not, a likely relation between actionable hydrologic characteristics and reproductive success. The judgement should be based on the strength and replicability of relations between flow pulses (and associated water quality characteristics) and reproductive migrations, spawning, and spawning success demonstrated by capture of free embryos.

C.2.1.6 Level 2

Although level 2 components are included in this compilation, they are not currently planned for implementation (Appendix F). The timeline is likely beyond the current MRRMP planning process and contingent decisions will likely focus on achieving recruitment on the Yellowstone River first.

C.2.1.6.1 Component 4

In anticipation of intentional experimental flow releases in component 5, an engineering study may be implemented to evaluate effects of experimental flow releases for other impacts such as bank stability and flood control. This study would also be used to design monitoring of ancillary effects during intentional flow releases.

Metrics

Metrics for this component will include measures of the effects of flow pulses on other authorized purposes. Some of the elements of these studies will have been developed in earlier planning efforts, such as human consideration proxies and metrics in the MRRMP-EIS. New studies on the specific effects of the experimental releases will provide similar metrics (e.g., days above flood stage), but specific to the planned experiments.

Timelines and contingencies

This component is expected to take 2 years and is contingent on completing all of the level 1 analyses so the results of the experimental design parameters can be evaluated. Although this experiment is included in this compilation, it is not currently planned for implementation (the timeline is likely beyond the current MRRMP planning process and contingent decisions will likely focus on achieving recruitment on the Yellowstone River first).

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to component 5. That decision will be based on development of functional relations between experimental flow pulses, effects on reproductive behaviors, and other authorized purposes. If experimental flow pulse characteristics thought to be biologically significant (magnitude, duration, frequency, timing, rate of change) reach a threshold wherein impacts to other authorized purposes are a concern and/or are beyond levels previously given NEPA coverage, then additional analysis and approval may be needed to move to component 5. If experimental flow pulse hydrologic characteristics are within previously approved levels, then the decision to move to component 5 field experimentation would be based on anticipated biological results.

C.2.1.6.2 Component 5

This study, while similar to level 1, component 2, also uses experimental flow releases from Fort Peck Dam to exert more experimental control. Flows from Fort Peck Dam would be deliberately manipulated over a range of magnitude, duration, timing, and rate of change to evaluate the reproductive behavior of pallid sturgeon. Parameter values for the experiments would be developed from preceding opportunistic and mesocosm experiments. Years with flow pulses should also be tested against control years without flow pulses.

Metrics

Metrics for this component will be very similar to component 2 and will include the degree of association of reproductive migrations and successful spawning with monitored experimental flow pulses. Intensive and passive network telemetry tracking data of reproductive adults (males and females) will be evaluated against time series of hydrologic characteristics and will be analyzed for degree of association. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if

they have released gametes and through capture of genetically identified free embryos. The experiment will be a series of experimental releases over several years; the series will result in a functional relationship between flow-pulse characteristics, migrations, and probability of producing viable gametes.

Timelines and contingencies

For the experiment to be successful there will need to be a substantial number (12 or more) of tagged, reproductive adult fish identified and tracked each experimental year. Assuming a minimum of four pulse levels, one replicate year, and two control years, seven years will be necessary for completion of this component. Success of the study will depend in part on development of passive receiver networks (component 1) and on maintenance of a tagged research population of reproductive fish that are not subject to being selected for use in the population augmentation program. Success will also depend on experimental parameters thought to elicit a biologically useful result while minimizing negative effects on other authorized purposes. These flow releases would need to be coordinated with upper big questions 2 and 3; releases under this big question would likely be accommodated with naturalization under big question 2; however, if temperature treatments are added, then accommodation of temperature/flow combinations may require additional experimental years.

Although this experiment is included in the compilation, it is not currently planned for implementation. The timeline is likely beyond the current MRRMP planning process and contingent decisions will likely focus on achieving recruitment on the Yellowstone River first.

Decision criteria for application of component

Experimental control imposed in this component will add to the ability to detect and quantify reproductive behavioral changes related to flow pulses; however, the experiments will still take place within a system where many sources of variability are not controlled (e.g., weather systems and tributary inputs). It is therefore unlikely that these experiments will result in a statistically rigorous result. Instead, a decision to accept the value of manipulated flow pulses in increasing pallid sturgeon reproductive success, or to reject it, will probably be based on judgement of multiple lines of evidence, including consideration of whether there is evidence of sufficient drift/dispersal distance.

C.2.1.7 Critical scientific uncertainties and constraints

Several components under this big question require the ability to tag and monitor a large population of pallid sturgeon in the Upper Missouri River and Yellowstone River; therefore, reproductive condition and history of subject fish will be known. Implementation of mesocosm studies will require a facility that can culture reproductive adult fish for experiments and construction of a mesocosm large enough to accommodate ecologically significant velocity, temperature, and turbidity pulses. Locations of fish in the field and mesocosms must be established with high spatial and temporal frequency during spawning season in order to infer with confidence that behaviors are relatable (or not) to flow pulses. Data on flow-related covariates (water temperature and turbidity) are also necessary to discriminate cause and effect. Implementation of field experiments will require buy-in from agencies and stakeholders to accept risks from providing flow pulses of a magnitude that are likely to be measurable and effective. Evaluation of spawning success will require additional investment in technology to image spawning behaviors, egg release, and fertilization in challenging environments.

C.2.1.8 Utility of study components

These study components will provide critical information to determine if pallid sturgeon in the upper river require flow cues that ultimately lead to successful reproduction. If flow cues are apparently successful, the study component will provide guidance about flow thresholds, changes in flow, or other aspects of flow influencing spawning behavior.

C.2.1.9 Ancillary information benefit

The results of the study components will provide ancillary information applicable to habitat use, spawning locations, reproductive ecology, and migration routes of pallid sturgeon.

C.2.1.10 Risks

Manipulating discharge from Fort Peck Dam (component 5) imposes the greatest risk for this big question. Impacts on stakeholders could be considered high, depending on the magnitude of flow changes. Manipulated flows that are too low or too high could lead to problems with bank stability, irrigation, or flooding. Little risk to stakeholders is associated with other components. Risk to pallid sturgeon is minimal as telemetry on the species has been practiced for many years without issue.

C.2.1.11 Adaptive actions

Results of these study components could provide information to optimize releases from Fort Peck Dam in the spring, or potentially to indicate that flow manipulations are not necessary to elicit a reproductive behavioral response from pallid sturgeon. The hydrologic characteristics of the flow pulses (magnitude, duration, frequency, timing, rate of change) can be adaptively managed to elicit an optimal biological response while minimizing effects on other authorized purposes.

C.2.1.12 Estimated costs

The estimated cost of these study components is medium to high. Maintenance of a telemetry tagged population, enhancement of the passive telemetry array, intensive telemetry tracking, and construction of a large-scale mesocosm would all require substantive investments on the order of several million dollars per year.

C.2.2 Upper big question 2: Can naturalization of the flow regime from Fort Peck contribute to increased food production, foraging habitat, and survival of age-0 sturgeon?

C.2.2.1 Objective of study components

This big question addresses the hypothesis that naturalization of the flow regime from Fort Peck would result in increased productivity, foraging habitat, and survival of age-0 pallid sturgeon. Naturalization refers to the process of using characteristics of the natural ecosystem to guide elements of river restoration, but constrained by social and economic values (Rhoads et al. 1999; Jacobson and Galat 2008). The study components are intended to provide the scientific basis for understanding how flow regime and channel reconfiguration can interact to provide food-producing and foraging habitats supportive of increased growth and survival. The value of these study components would accrue mainly in the event that recruitment from spawning on the Yellowstone River is not sufficient to sustain population size and free embryos are successfully retained in the Upper Missouri River.

C.2.2.2 Description of study components

The hypothesis states naturalized flow releases at Fort Peck will result in increased productivity through increased hydrologic connections with low-lying land and floodplains in the spring, and decreased velocities and bioenergetic demands on exogenously feeding larvae and juveniles during low flows in summer and fall. Hence, naturalization may include elements of both high and low flows. Unlike the lower river, the assumption is made that the channel morphology is near natural so channel

configuration would not be an interacting management action. Study components at level 1 will focus on engineering, technology development, and field-gradient/mesocosm studies that would establish whether habitats are limiting and how habitats vary within the Upper Missouri River. Contingent on results of level 1 components, study components at level 2 will involve design and implementation of field-scale experiments to quantify linkages from flow naturalization to habitat availability, growth, and survival.

Productivity may relate to pallid sturgeon population dynamics in two different ways. Under a scenario of population augmentation, with or without natural reproduction and recruitment, increased productivity may be necessary to maintain growth of juveniles and adults. When stocked fish reach reproductive age, their reproductive potential (fecundity) may then also depend on increased productivity (carrying capacity) in the river. However, productivity may also be limiting in terms of food production for age-0 fish that could be naturally produced in the system. In the latter case, the importance of productivity is contingent on adequate drift/dispersal distance as discussed in upper big question 5 and hypotheses 3, 7, and 10. Although productivity for all life stages may be important for population growth, the immediate emphasis is on survival of age-0 sturgeon, if they are provided adequate dispersal distance.

C.2.2.3 Relation to effects analysis

Study components address hypothesis 2 from the EA. This hypothesis includes both food productivity and bioenergetic demands of foraging habitats.

C.2.2.4 Approaches

Two levels with six different components could be implemented to evaluate the hypothesis. Level 1 is proposed to include methods development and engineering studies to understand how flow naturalization would interact with other authorized purposes. Level 1 will also include screening studies to determine whether food or foraging habitats are limiting to age-0 pallid sturgeon, field-gradient studies to quantify relations between flow naturalization and habitat and food availability, and mesocosm studies to attempt to develop quantitative relations between abiotic variables and growth and survival. If level 1 results are supportive, level 2 components would include design and implementation of controlled, field-scale experiments to validate quantitative relations from flow naturalization to growth and survival. This level 1 experiment is not currently planned for implementation (Appendix F). This is because the timeline is likely beyond the current MRRMP planning process and because contingent decisions will likely focus on achieving recruitment on the Yellowstone River first.

C.2.2.5 Level 1

D.1.1.1.1 Component 1

Engineering studies are anticipated to address how ranges of flow naturalization, provision of high and low flows mimicking timing of natural flows, will interact with other authorized purposes. Some of this data will have been completed by other NEPA study components; however, some will likely require testing of new ranges of high and low flows that have not been previously addressed. In the Fort Peck reach there is likely to be some emphasis on how high flows will affect agricultural production, groundwater levels, and bank stability. Modeling may include 1-, 2-, and 3-dimensional models, including groundwater effects, to address these concerns.

Metrics

Metrics for this group of studies includes measures of costs or foregone services as a result of flow naturalization. Some emphasis will be placed on effects of floodplain connectivity with agricultural production, groundwater effects, and bank stability. The studies are expected to illustrate a cost function associated with the attainment of different levels of naturalized flow.

Timelines and contingencies

The measurements and models anticipated in this component would require three years for development. Under a parallel staging, this work could proceed simultaneously with components 1 and 3 to provide mutually supportive information. The time for this component depends as well on the need for more or less complex models; models involving groundwater and bank stability may require longer times.

Decision criteria for application of component

Results of the measurement and modeling should help in understanding the functional relationships between levels of naturalized flows and effects on authorized purposes. This information will be fundamental for deciding whether to proceed to components 5 and 6. If measurement and modeling demonstrate acute costs to other authorized purposes there may be need for additional NEPA coverage before moving to subsequent levels.

D.1.1.1.2 Component 2

Component 2 studies are biological screening studies to determine, if possible, whether food production or foraging habitats are likely to be limiting to pallid sturgeon. These studies may be very powerful in determining whether flow naturalization is necessary for survival of the pallid sturgeon in the upper river. These studies could be based on sampling a gradient of assumed habitat quality or as a randomized design and would involve assessing age-0 sturgeon for indications of starvation or growth. Because of dietary overlap between shovelnose and pallid sturgeon at this life stage, shovelnose sturgeon may be used to some extent as a surrogate.

Metrics

The metrics for this study are indicators of starvation or impending death of age-0 sturgeon in conjunction with possible explanatory abiotic variables. Such indicators may be based on stomach contents (percentages of empty/full stomachs) or physiological indicators (lipid content). Because it is extremely rare to catch dead age-0 fish, these metrics are useful to characterize the surviving population but may fail to address actual mortality rates, that is, sampling will be biased toward live fish. Because these metrics are likely to measure the net bioenergetic effects of a combination of food availability (food-producing habitat) and energy expenditures (foraging habitats), additional studies may be needed to address cause and effect.

Timelines and contingencies

Similar studies started in 2013 in the lower river and are likely to provide useful comparative results by 2017. In addition, some ongoing studies concerning carrying capacity of the upper river are under way, and results should address productivity of food items for juveniles and adults, and spatial gradients in productivity. The question of whether bioenergetic conditions are limiting to age-0 survival is contingent on avoidance of mortality by other sources, and so this science component could be delayed until adequate drift/dispersal distance is documented. Component 2 will occur simultaneously or with substantial overlap with components 1, 3, and 4.

Decision criteria for application of component

Results from this component may be indicative of bioenergetic constraints, but may not be statistically robust. Most of the age-0 sturgeon evaluated will be shovelnose, and although there is evidence to support the notion that the pallid and shovelnose diets and bioenergetic demands are very similar at this life stage,

there is residual uncertainty about how well the surrogate species represents pallid sturgeon. If results indicate that age-0 sturgeon have full stomachs and healthy lipid content, it indicates that current bioenergetic conditions are not limiting, but additional science components may still be justified in order to evaluate future conditions when the population is larger and either food or forage could become limiting. If results indicate that stomachs are not full and/or lipid content is not healthy, it will not necessarily be clear whether this is attributable to food availability or energetic demands. Therefore, a decision to proceed or continue with level 2 science components may require multiple lines of evidence.

D.1.1.1.3 Component 3

The information value of this study component is closely tied to component 2 regarding limitations of food, forage habitat, or both, on survival of age-0 pallid sturgeon. The objective will be to develop quantitative links from flow manipulation actions to the amount and quality of food-producing and foraging habitat. The study will incorporate information from component 2 to improve definition of food-producing habitats through understanding of spatial linkages and geometries. It can be pursued on a field-gradient design by evaluating food and forage habitat conditions along existing ranges of habitat conditions (flow variability and channel complexity) along the river. For food, the study would include repeated measures sampling of biota judged to be food items for larval and juvenile pallid sturgeon. For foraging habitat, the study would include habitat selection based on catch rates from trawling for age-0 sturgeon in comparison to well-characterized habitat conditions. Habitat characterization at the scale of age-0 sturgeon will be challenging and may require innovative applications of acoustic Doppler current profilers, acoustic velocity meters, and/or benthic imaging technologies to establish bioenergetic conditions experienced by larval fish.

Metrics

Habitat metrics (potential explanatory variables) will be statistical measures of depths, velocities, and substrate, including means and variances, potentially complemented with metrics of spatial complexity like patch dimensions and spatial relations. Metrics for this study would include measures of habitat selection for food items (chironomids) and foraging (age-0 sturgeon), based on habitats occupied and unoccupied.

Timelines and contingencies

The measurements and models anticipated in this component would require four years for development, although some of this work is already underway. This

component may proceed simultaneously with components 1, 2, and 4 to provide mutually supportive information.

Decision criteria for application of component

Results of the measurement and modeling should help develop quantitative statistical associations between habitat characteristics and selection by food sources and age-0 fish. The statistical analysis is likely to include substantial uncertainty and a lines-of-evidence approach that includes data from mesocosm experiments in component 4. This will further refine understanding of functionality of these habitats and help determine if evidence supports moving to level 2 experiments.

D.1.1.1.4 Component 4

This study component would attempt to develop quantitative relations between the range of habitat conditions identified in component 3 with quantitative productivity rates and growth and survival of pallid sturgeon, using mesocosms. This component would provide parameter values for integrated bioenergetic and population models that could be used to predict results of flow naturalization.

Metrics

Habitat metrics (potential explanatory variables) will be statistical measures of depths, velocities, and substrate, including means and variances, potentially complemented with metrics of spatial complexity like patch dimensions and spatial relations. Metrics for this study would be relative growth rates and survival as a function of habitat characteristics.

Timelines and contingencies

The measurements and models anticipated in this component would require four years for development. It would be most effective to wait for completion of component 3 so the range of conditions needed in mesocosm experiments would be known and hypotheses would be rigorously formulated.

Decision criteria for application of component

Results of the mesocosm experiments will quantify relations between abiotic variables and growth and survival. These are likely to be relations that show a peak of growth and survival at some interval, with decreasing growth/survival at higher and lower values. If growth/survival does not show a systematic relation

to abiotic variables, the concept of flow naturalization would need to be substantially refined or abandoned. If there is a systematic relation, the supportive range of abiotic variables would be used to justify and to design field experiments in components 5 and 6.

C.2.2.5.1 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement that there is, or is not, a systematic relation between flow naturalization and increases in growth and survival of age-0 sturgeon. The judgement should be based on the strength and replicability of relations between abiotic habitat variables describing food and forage habitats, and growth and survival of age-0 sturgeon. Movement to level 2 would not be recommended if drift/dispersal continues to be limiting.

C.2.2.6 Level 2

Level 2 components are included in this section, but they are not currently planned for implementation (Appendix F). The timeline is likely beyond the current MRRMP planning process and contingent decisions will likely focus on achieving recruitment on the Yellowstone River first

C.2.2.6.1 Component 5

Components 5 and 6 will be contingent on the type and quality of information provided from previous components. The objective of component 5 will be to use quantitative relations gleaned from the gradient and mesocosm studies (components 3 and 4) to design flow naturalization experiments and to assess associated effects. This component would make use of the integrative hydrodynamic-bioenergetic models to test alternative flow regimes for the ability to provide effective amounts of both food-producing and foraging habitats.

Metrics

Metrics for this component will be relative performance of designs, measured as areas of functional habitat, flux of food items, predicted growth, and survival.

Timelines and contingencies

This component is expected to take two years under the assumption that hydrodynamic modeling reaches will already be established. If this is not the case, additional time would be required and an earlier start might be anticipated,

especially if the spatial variability in the Upper Missouri is not adequately represented in the existing models.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to component 6. That decision will be based on lines of evidence from components 1–4 and success in developing designs in component 5. The decision to proceed with component 6 would be based on the demonstrated ability to predict increases in productivity, growth, and survival from naturalization of the flow regime without unacceptable risk to other authorized purposes.

C.2.2.6.2 Component 6

The objective of component 6 will be to evaluate the functions of food-producing and foraging habitats under controlled, experimental conditions. It will involve a sample design that will evaluate specific metrics of productivity over a range of flow regimes. Responses can be measured in terms of hydraulic conditions, functional habitat area, and food production; responses in terms of growth and survival of age-0 sturgeon would need to be calculated from mesocosm results and bioenergetic models because of the difficulties in assessing these metrics in the field. The role of flow manipulations can be evaluated against interspersed, non-manipulated years.

Metrics

The study design will incorporate a gradient of flow regimes with varying amounts of naturalization of the flow regime, indicated by quantiles of ecological flow components (for example, 25th, 50th, and 75th percentiles of flow pulses, low flows). Because growth and survival probably cannot be measured reliably under field conditions, the metrics will need to be indirect and may include area of food-producing habitat, area of foraging habitat, catch per unit effort of age-0 sturgeon, stomach contents, and lipid content.

Timelines and contingencies

This component is expected to take seven years to complete, assuming four treatment years, one treatment replicate year, and two control years. The component is contingent on results from component 5. This component has a high degree of interaction with science components or implementations that alter the flow and temperature regimes (e.g., components under upper big questions 1, 3, and 5). Although the component does not directly relate to productivity to support juveniles and adults, the hydrodynamic modeling results will be useful

for inferring general productivity (carrying capacity) of the river system as a function of flow regime.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move forward to level 3 implementation. Statistical relations will likely not be robust, and the decision will therefore require a judgement based on lines of evidence presented in components 1–6. If experimental results in component 6 fail to support systematic increase in habitat and fish condition, then the hypothesis may need to be refined or abandoned. If the experimental results support the hypothesis that flow naturalization can provide increased food-producing and foraging functional habitats, and if evidence from level 1 and 2 studies under upper big question 5 indicates that there is adequate drift / dispersal distance, then the decision would be to move toward level 3 implementation.

C.2.2.7 Critical scientific uncertainties and constraints

Critical scientific uncertainties include the food base for age-0, exogenously feeding pallid sturgeon, and relation of that food base to habitat conditions. Additional critical uncertainty relates to foraging behaviors of age-0 sturgeon and the extent to which foraging habitat can be measured and modeled at appropriate scale. In addition, the linkage from habitat variables to survival is critical to link management actions to population-level responses. Finally, the uncertainty about whether free embryos have adequate drift/dispersal distance is a fundamental uncertainty that could overwhelm the importance of this big question.

C.2.2.8 Utility of study components

These study components will provide scientific information bearing on whether flow manipulation will be effective in increasing survival and recruitment of age-0 pallid sturgeon. If successful, the study components will provide functional relations indicating how much flow naturalization is needed to increase survival, which can then be accommodated in population models.

C.2.2.9 Risks

Level 1 components present little risk to stakeholders, authorized purposes, or pallid sturgeon. At level 2, field experimentation would require flow manipulations that could be perceived as risks to flood control, power generation, water supply, navigation, and floodplain farming.

C.2.2.10 Adaptive actions

The results of these will have a bearing on decisions regarding extent of flow-management at Fort Peck Dam. The relations provided in component 6 will allow for incremental naturalization of flows toward greater survival.

C.2.2.11 Estimated costs:

Estimated costs of level 1 components are relatively small. Field-gradient studies will rely on existing gradients of flow regime and channel reconfiguration. Mesocosm studies may require some investment in laboratory facilities to provide ecologically meaningful conditions, but much of the culture and laboratory investment already exists. Level 2 studies with field experiments will be more costly, and may involve substantial investments in land and construction.

C.2.3 Upper big question 3; can water-temperature manipulations at Fort Peck contribute significantly to increased chance of reproduction and recruitment?

C.2.3.1 Objective of study components

The objective of these study components is to determine if increased water temperature from Fort Peck Dam during the spring can significantly increase productivity and developmental rates. These two aspects were combined in this big question because both depend on the same action, implementation of increased water temperatures at Fort Peck. The productivity components relate strongly to upper big question 2 and the development rates components relate strongly to upper big question 5. Aspects of scientific approaches presented here may be accommodated in close coordination with those questions.

C.2.3.2 Description of study components

Water temperature may influence productivity of the river system downstream from Fort Peck as well as increasing the development rate of free embryos. The first of these hypotheses relates water temperature to productivity of food which will eventually be consumed by the pallid sturgeon; this hypothesis is highly correlated with flow naturalization under upper big question 2. The second of these hypotheses is highly related to drift/dispersal hypotheses under upper big question 5, but is included here because of the relation to temperature controls at the dam. Water temperature may also interact with flow pulses (upper big question 1) to influence spawning cues.

C.2.3.3 Relation to Effects Analysis

The study components directly address action hypotheses 4 and 5 in that increased temperatures may increase productivity and development rates. These hypotheses are interrelated with hypotheses 1, 3, and 10, which also involve changes in flow regime.

C.2.3.4 Approaches

Two levels with six different components could be implemented to evaluate these hypotheses. For some components, it is convenient to separate sub components related to temperature-mediated productivity ('a' components) and those related to temperature-mediated development during drift/dispersal ('b' components). Level 1, component 1 includes feasibility studies and modeling temperature elevations as a function of water releases from Fort Peck. Component 2a is a biological screening component that will document whether temperature-mediated productivity is limiting to population growth (similar to upper big question 2, component 2). Component 2b will similarly document whether the temperature-mediated developmental rate is relevant given other constraints on drift/dispersal and survival. Component 3a is a field-gradient study to document whether productivity varies significantly across existing gradients of water temperature along the Upper Missouri River and in comparison between the Upper Missouri and the Yellowstone. Component 3b is a field experiment to validate simple advection/dispersion models for drift of free embryos, with emphasis on including temperature-mediated development rates to add biological realism. Component 3b is essentially identical to upper big question 5, component 3 and these would be coordinated. Components 4a and 4b depend on controlled mesocosm studies to develop quantitative relations between water temperature and productivity and developmental rate. Component 5 is an engineering study to test temperature control structures and validate downstream variation in water temperature. Component 6a is a series of field experiments to test sensitivity of productivity to water temperature whereas component 6b does the same to test sensitivity of development rate and survival to water temperature.

C.2.3.5 Level 1

C.2.3.5.1 Component 1

This component includes an engineering study to investigate the feasibility of temperature mediation at Fort Peck and a technology development study that would merge a temperature-mediated development model with advection/dispersion modeling of free embryo drift/dispersal. The feasibility study would update previous study results on costs, practicality, and reliability of different approaches to mediating temperature of releases at Fort Peck (modification to the existing intake, new intake and tunnel,

pumped discharge over spillway, or submerged weir), and determine the range of water temperatures that could be attained. The developmental drift/dispersal model would indicate whether the resultant temperature increase would likely increase developmental rate sufficient to retain larvae in the free-flowing river. Previously completed feasibility studies will provide a useful foundation for this component.

Metrics

Metrics for this component will be costs, temperature increases, achieved development stages, increased productivity, and length of the river that would be needed to attain retention of larvae before transport into Lake Sakakawea. These metrics may be analyzed to reach conclusions about the cost effectiveness of alternative designs.

Timelines and contingencies

The models developed in this component will provide; 1) quantitative understanding of need and efficacy for water temperature control and 2) an estimate of costs. As such, this component will provide foundational information to determine whether the hypothesized action is necessary and practical. Components 1, 2, and 3 would start at the same time (as early as 2017).

Decision criteria for application of component

Results of the modeling will demonstrate whether operations of temperature mediation strategies at Fort Peck may increase water temperatures in the Upper Missouri River to the point where sufficient development can take place before larvae are dispersed into Lake Sakakawea, and whether such manipulations would be expected to significantly increase productivity. If the models indicate that water temperatures will contribute significantly to recruitment or productivity, alone or in combination with manipulated flows and drawdown of Lake Sakakawea, this will support moving to level 2 science components related to temperature management.

C.2.3.5.2 Component 2

The science component includes two subcomponents related to biological screening to determine whether water temperatures may be limiting in recruitment. Component 2a addresses the fundamental question of whether food is limiting to recruitment of age-1 pallid sturgeon and component 2b addresses whether conditions in Lake Sakakawea are necessarily fatal to age-0 sturgeon. Studies currently (2017) underway to address food limitation on the lower river will provide some framework for 2a; in this component

randomized sampling for age-0 sturgeon (presumed to be shovelnose in this case) will indicate whether young fish are starving through stomach content and whole body lipid analyses. For component 2b, studies currently (2017) underway to assess anoxia in the headwaters of Lake Sakakawea may provide substantive results by 2017; additional study may be needed to refine understanding of the spatial and temporal patterns of anoxia.

Metrics

Metrics for component 2a will be numbers of age-0 sturgeon with full or empty stomachs, plus an inventory of stomach contents to define where food items originate. Whole-body lipid content of the age-0 sturgeon should also provide a metric for the extent to which food availability limits fish health and potential for survival. For component 2b, metrics will be the spatial extent and temporal persistence/variability of anoxic conditions that would be fatal to benthic dwelling larval fish.

Timelines and contingencies

Components 1 and 2 can be pursued simultaneously. Component 2a is expected to require three years to complete starting in 2017 and component 2b is shown starting in 2015 and extending four years to 2019. Because the temperature mediation advection/dispersion modeling is central to Upper Big Question 5, these science components would be highly coordinated. Note that essential validation of the advection/dispersion modeling approach is addressed in component 3b and is identical to component 3 for Upper Big Question 5.

Decision criteria for application of component

It is unlikely that component 2a will result in a statistically rigorous result due to interactions with uncontrolled variables, and the dependence on shovelnose sturgeon as a surrogate species. The decision to accept or reject results may need to be based on judgement of multiple lines of evidence. This determination will depend a great deal of the strength of the results and may be complicated by spatial variability in productivity (productivity may not be limiting downstream of the Yellowstone confluence, but may also be much less amenable to management). Results from component 2b may indicate a continuum from presence of a persistent, spatially homogeneous area of anoxia with no potential for supportive habitats to presence of little area or patchy areas of anoxia among non-anoxic patches that may retain potential for supportive habitats. If the result is more like the former, it will document a fundamental constraint on pallid

sturgeon recruitment as it will validate the assumption that transport into the headwaters of Lake Sakakawea is fatal. If lethality of Lake Sakakawea is validated, decisions could still be made to move forward with level 2 science components under this big question if advection/dispersion modeling presents positive or equivocal results that temperature, flow, passage, and or drawdown may be sufficient to keep free embryos from dispersing into the anoxic zone. Component 3b addresses the essential need to validate the advection/dispersion model on the Upper Missouri.

C.2.3.5.3 Component 3

Similar to the previous component, component 3 is split into 3a, a field gradient study of the association between productivity and water temperature and 3b, a field study to validate advection/dispersion models as a predictive tool for dispersal of free-embryos. Component 3a will assess food (indexed by chironomid larvae) availability along temperature gradients on the Upper Missouri and in comparison between the Upper Missouri and Yellowstone River. The relevance of this study depends on; a) whether age-0 pallid sturgeon can be expected to be retained in the Upper Missouri River and b) whether water temperatures can be practically managed at Fort Peck. Component 3b is envisioned as a field experiment using tracking of dispersal of free embryos and surrogate tracers, combined with robust characterization of flow fields and dispersion coefficients, to test/validate/refine the advection/dispersion model developed as part of the EA process. Because of the importance placed on advection/dispersion modeling in the EA process for both the upper and lower river, validation of the model is presented as a high priority and initial experimentation began in 2016.

Metrics

Metrics for component 3a will be densities of chironomid larvae and associated abiotic habitat variables (depth, velocity, temperature, and derivatives). The abiotic variables will quantify relations between flow conditions, channel configurations, and food availability that will be useful to parameterize predictive models. Metrics for component 3b will be space and time distributions of larvae and surrogate tracers developed through Eulerian sampling during the experiment. Free embryos will have known genetics to allow for discrimination from wild-produced sturgeon. Metrics will include Lagrangian evaluation of the flow fields experienced by the tracers to characterize mean velocities, variance, and longitudinal dispersion coefficients; these data will be collected by acoustic Doppler current profile mapping from boats floating with the tracers. Areas identified with increased loss of tracers will be identified for subsequent, high-

resolution measurement and modeling of the flow field to determine conditions that retard or retain drifting larvae.

Timelines and contingencies

Carrying capacity studies are already underway in the Upper Missouri River; therefore, component 3a is shown beginning in 2014 and extends to 2018. Component 3b is fundamental to acceptance of information from advection/dispersion modeling in the decision making process. Component 3b is shown starting in 2017 in parallel with components 1, 2, and 4. A minimum of two experiments are anticipated to establish some confidence in replicability (additional controlled experimentation would occur under level 2). To allow for variability in years and availability of sufficient numbers of free embryos, four years are indicated for the component. It should be noted that availability of a large number of free embryos and agreement about prevailing releases from Fort Peck during the experiments are necessary conditions for success.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to accept the science information as useful to decision making. The quality of information developed in these components will depend to a large extent on how well the field studies control ancillary variables. The cumulative results from components 1–3 are likely to be less than statistically rigorous and the decision to accept the information may require judgement from multiple lines of evidence.

C.2.3.5.4 Component 4

Component 4 is similarly divided into 4a and 4b. Component 4a is a mesocosm-based study of water temperature, food production, and growth intended to develop the quantitative relations that will indicate how much additional food production will result in how much growth of exogenously feeding larvae, assuming they have been retained before entering Lake Sakakawea. These relations would be essential to parameterize bioenergetics and population models to link temperature manipulations and recruitment to age-1. Component 4b is a laboratory study that will document developmental rates of embryos, free embryos, and exogenously feeding larvae as a function of water temperature. Some of these relations already exist, but they need to be confirmed and expanded to a wider temperature range to apply to Yellowstone River temperatures. Component 4b is placed here logically because it is a laboratory/mesocosm study that is critical to understanding the role of temperature in development and dispersal.

Metrics

Metrics for component 4a will be densities of chironomid larvae as a function of water temperature and associated growth rates of exogenously feeding pallid sturgeon larvae. These experiments will be most useful if carried out in mesocosms that can vary abiotic variables (velocities, bed configurations) so they will include behavioral (foraging) metrics associated with those variables. Metrics for 4b will be descriptions of developmental stages of embryos through exogenously feeding larvae as functions of water temperature (parameterized as cumulative thermal units). Because shovelnose sturgeon are used in many related science components as surrogates, it will be valuable to have parallel information on shovelnose sturgeon development rates for comparative purposes. This information applies to the upper and lower river, so temperature ranges and genetic diversity associated with the two river sections should also be represented.

Timelines and contingencies

Mesocosm studies could start in 2017 and progress concurrently with other level 1 studies in order to minimize total time frame. Construction of mesocosms and supportive propagation facilities may require some lead time depending on complexity of the experiment.

The fundamental nature of component 4b supports an earlier staging; as some of this work has already been published (Kappenman et al. 2013), it is shown as starting in 2014 and concluding in 2017.

Decision criteria for application of component

The decision at this stage for component 4a and 4b is whether to accept information as valuable to decision making. Results from mesocosm experiments are likely to be statistically rigorous, but their relevance to decision making depends on how the experimental results apply to the capacity of the river system and the ability to manage it. Hence, decisions to move forward with level 2 may require judgements based on multiple lines of evidence (more in next section). Results from the developmental rate experiments are likely to be statistically rigorous and the data will contribute critical context to results of advection/dispersion modeling. Based on existing data, these new information on developmental rates will not likely influence the decision to level 2 alone; rather, it is the context of management capacity (temperatures, flows, drawdown) and

the accuracy of the advection/dispersion models that will likely influence this decision.

C.2.3.5.5 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement that there is a likely relation between feasible temperature mitigation and recruitment, whether constrained by productivity or dispersal distance. The experiments envisioned in component 6 are highly interdependent with experiments envisioned under Upper Big question 5. These are related to other questions about drift/dispersal and therefore, the decision to move forward to level 2 may not be based solely on information developed in this Big Question. The decision to move to level 2 would be based on the strength and replicability of relations between temperature variation (and associated abiotic characteristics) and productivity, growth, and survival, assuming the survival of dispersing free embryos has been shown to be sufficient to sustain population targets and assuming there is sufficient drift/dispersal distance. Because of the high cost anticipated for construction of many of the mechanisms to manipulate water temperature ($10's–$100's of millions), the decision to invest in temperature management is likely to require a very high level of confidence of success, thereby placing high reliance on the quality of information developed in components 1–4.

C.2.3.6 Level 2

Although level 2 components are included in the staging, they are not currently planned for implementation. The timeline is likely beyond the current MRRMP planning process and contingent decisions will likely focus on achieving recruitment on the Yellowstone River first.

C.2.3.6.1 Component 5

This study component would consist of field tests of water temperature manipulation structures or managed water releases to determine if expected river water temperatures are realized downstream. Water temperature would be controlled by one or more of the mechanisms determined during the feasibility study in component 1a. Controlled releases of warm water into the river would be measured and monitored. A longitudinal series of temperature monitors would need to be placed downstream to evaluate the effectiveness of water temperature manipulations.

Metrics

Metrics for this component will be increase of water temperatures above those that would have prevailed without the temperature mitigation. This will necessitate well-calibrated water-temperature models to be able to simulate what temperatures would have been in the absence of the mitigation. Field tests may include a range of implementations that would have a range of temperature effects. Field tests would also evaluate whether water temperature effects were adverse for other authorized purposes.

Timelines and contingencies

Construction would likely require four years, and the study part of the component is expected to take four additional years after construction to address climatic variability. It is contingent primarily on component 1a results that will indicate feasibility but also on components 2, 3, and 4 which will together indicate the expected biological benefits of water temperature manipulations. If results for components 1–4 are negative, components 5 and 6 would be abandoned.

This component is highly related to Upper Big Question 5 experiments because water temperature, velocities, fish passage at Yellowstone, and drawdown of Lake Sakakawea may all contribute in some proportion to recruitment.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to component 6. That decision will be based on lines of evidence from components 1–4 and information developed during component 5 that temperature mitigations can be effective. The decision to proceed with component 6 would be based on the demonstrated ability to raise water temperature by an increment thought to be biologically significant.

C.2.3.6.2 Component 6

This component is a field-based experiment based on manipulated water temperatures. The primary goal of the experiment is to validate that increased water temperature contributes substantially to free-embryo survival and recruitment under real-world conditions. It would require free-embryo tracer experiments similar to component 3b, but with alternating years of cold (normal operations) and a series of elevated water temperatures. The developmental rate of tracer free embryos placed in the river at suitable locations would be determined at sampling sites along the river and would be compared to model predictions and among years. Results for altered productivity could

also be evaluated in these experiments by repeated sampling of chironomid-producing habitats (identified in component 2a) during the experiments to evaluate effects of temperature. Multiple experimental events in time would be necessary to establish replicability, and the role of covariates of discharge, turbidity, and genotype (of tracer free embryos).

Metrics

Metrics for this component will be primarily the developmental rate of free embryos as a function of water temperature achieved on the river and the location of developmental stages relative to Lake Sakakawea headwaters. Metrics could also include costs of the experimental operations and impacts to other authorized purposes. Secondary metrics would be densities or fluxes (productivity) of chironomid larvae in parts of the river where free embryos may be retained.

Timelines and contingencies

These experiments are contingent on successful validation tests (component 5). For the experiment to be successful there will need to be a substantial number of free embryos available and strong agreement to an experimental release schedule. Assuming a minimum of four temperature manipulations and the risk that experimental logistics may fail 1 year in 2, or 50 percent of the time, at least eight years of evaluation will be necessary for this component. Time for this experiment may be increased depending on how the temperature manipulations are carried out in coordination with flow and drawdown experiments under Upper Big Questions 1, 2, 4, and 5. If combinations of temperature, flow, sediment, and drawdown are considered, the number of years of experiments could extend farther in time than indicated.

Decision criteria for application of component

Experimental control imposed in this component will add to the ability to quantify effects of water temperature manipulations on pallid sturgeon recruitment in the Upper Missouri River. However, the experiments will still take place within a system where many sources of variability are not controlled, such as weather systems and tributary inputs. Moreover, the number of true replicates of the experiment will be low or zero. It is therefore unlikely that these experiments will result in statistically rigorous results. Instead, a decision to accept the value of manipulated water temperatures in increasing pallid sturgeon recruitment, or to reject it, will probably be based on judgement of multiple lines

of evidence including the risk to other authorized purposes. This may require consideration of the cumulative level 1 and level 2 information.

C.2.3.7 Critical scientific uncertainties and constraints

The overarching critical uncertainty for this Big Question is whether actions to manipulate water temperature on the Upper Missouri River are justified if increased fish passage at Intake Dam results in recruitment to the population on the Yellowstone River side. The next critical uncertainty is whether feasible water temperature infrastructure can increase water temperatures on the Upper Missouri River to a biologically significant point, that is, temperatures that would increase recruitment by increasing development rate or increasing food productivity. Implicit in these uncertainties are the accuracy of advection/dispersal models presently being used to evaluate drift/disperal, and uncertainties in the developemental rates of embryos and free embryos as a function of water temperature and genotype and whether reproductive adults can be attracted sufficiently far upstream on the Upper Missouri River. The staging of science components addresses the implicit uncertainties by staging them early in the process.

C.2.3.8 Utility of study component

This study component will provide critical information to determine if pallid sturgeon recruitment can be increased by temperature manipulation at Fort Peck Dam. Given the high estimated costs of mechanisms to accomplish increased temperatures ($10's–$100's of millions), the information developed in these studies is critical to substantive decisions. In particular, if temperature is an over-riding variable determining recruitment success, and temperature manipulation is not feasible, that knowledge will determine future decisions. If temperature changes are shown to be possible and influential, the study components will provide guidance about temperature management in relation to other management actions.

C.2.3.9 Ancillary information benefit

The results of the assessment will provide ancillary information applicable to the river system productivity and response of other organisms in the river to temperature management.

C.2.3.10 Risks

Manipulating water temperature from the dam imposes little risk but substantial cost. Risk to pallid sturgeon is minimal as temperatures would not be increased to a level

harmful to the fish. Impacts on stakeholders would be minimal because temperature increases would be in spring before other temperature constraints would apply.

C.2.3.11 Adaptive actions

Based on the results of these study components, the information would be used to optimize water temperature (and discharge) during the spring to increase recruitment probability. This might mean combinations of increased water temperature, decreased releases (to minimize velocity), and drawdown of Lake Sakakawea.

C.2.3.12 Estimated costs

Estimated costs of components 1–4 are relatively low and would provide a high return on investment, both in relation to management of the Upper Missouri River but also by providing fundamental, highly transferable information to managing the Lower Missouri River. Extension of this Big Question to level 2 would be very costly because of the investment needed to increase water temperature at the river scale.

C.2.4 Upper Big Question 4; can sediment bypass at Fort Peck contribute significantly to increased chance of reproduction and recruitment?

C.2.4.1 Objective of study components

The objective of this study component is to evaluate capability and biological value of sediment augmentation at Fort Peck Dam to increase turbidity and decrease predation on embryos, free embryos, and exogenously feeding larvae. This objective includes a feasibility study to address whether sediment bypass is viable, and field and laboratory studies to determine rates of predation related to turbidity. The relevance of these study components depends on ability of the Fort Peck segment to retain free embryos; if recruitment is demonstrated on the Yellowstone these components may not be a high priority.

C.2.4.2 Description of study components

Two levels of study components are presented. Level 1 includes a feasibility study for mechanisms to bypass sediment around Fort Peck Dam and a biological screening study in the laboratory to document whether turbidity-mitigated predation is likely to be a limiting factor. In contrast to other Big Questions, the biological screening study is pursued in the laboratory because of the challenges of measuring predation under field conditions. If screening studies demonstrate that predation may be a limiting factor, additional mesocosm studies will be designed to develop quantitative relations of predation risk as a function of turbidity. Follow-on level 2 components include an

engineering study to pilot test the sediment bypass mechanism and validate with turbidity measures downstream. The manipulated field experiment is intended to validate mesocosm models in the real world. Because validation of mortality of age-0 and age-1 fish due to predation is practically impossible in the field, biological metrics will not be addressed; instead, biological performance will be inferred from physical variables.

C.2.4.3 Relation to Effects Analysis

This Big Question informs the EA hypothesis: installing sediment bypass at Fort Peck will increase and naturalize turbidity levels, resulting in decreased predation on embryos, free embryos, and exogenously feeding larvae.

C.2.4.4 Approaches

Two levels and five total components are presented to address sediment bypass. Level 1 includes an engineering feasibility study to determine practicality of sediment by pass at Fort Peck dam, costs, and effects on other authorized purposes. Level 1 also includes a biological screening study using laboratory mesocosms to establish whether it is likely that predation of embryos, free embryos, or larvae is limiting to the population and whether predation is affected by turbidity. If the previous study indicates a measurable turbidity effect, a follow-on mesocosm study will attempt to develop quantitative relations between survival of predation-susceptible life stages and turbidity. Level 2 components would be pursued if level 1 components provide sufficient support for the hypotheses. Level 2 components would include an engineering test of a constructed sediment bypass (or procedure) and a manipulated field experiment to quantify how much of the river would have significantly increased turbidity.

C.2.4.5 Level 1

C.2.4.5.1 Component 1

Component 1 is a feasibility study of various mechanisms, structures, and procedures that could be used to bypass sediment around Fort Peck Dam. Because the dam was not designed to process annual sediment loads, a mechanism to transport sediment from areas of accumulation in the headwaters to the base of the dam will probably involve extensive engineering. This study will establish alternative engineering approaches to bypass and associated costs, as well as providing predictive models for how much turbidity may be increased as a result.

Sediment augmentation may target various particle-size ranges, and costs will vary depending on the targeted size classes. Although long-term sustainability of the Upper

Missouri River may be enhanced by augmenting to restore natural fluxes and particle sizes, the emphasis here is on turbidity (and washload) as the effective abiotic variable.

Metrics

Metrics for this study will be predicted cost (including environmental, construction, and operations) and predictions of the extent of the Upper Missouri River that will have turbidity raised on average, and by how much.

Timelines and contingencies

We anticipate that the feasibility study would require two years. Relevance of the feasibility study to pallid sturgeon population dynamics would only accrue if free embryo drift conditions are such that free embryos do not disperse into Lake Sakakawea. This component will be pursued simultaneously with the start of mesocosm studies under component 2.

Decision criteria for application of component

The relevant decision after this component would be to accept the information as relevant to decision making, in particular whether the determination of whether sediment bypass was practical or would significantly increase turbidity.

C.2.4.5.2 Component 2

Component 2 is a mesocosm-based experiment to determine whether turbidity is possibly a limiting factor in predation of pallid sturgeon embryos, free embryos, and larvae. The experiment would subject these three life stages to varying levels of turbidity in the presence of different prospective predators. Mesocosm conditions should include variable velocity and bed complexity as co-variates. Survival will be enumerated after set time intervals.

Metrics

The primary metric for this component will be survival by life stage and predator species, as a function of turbidity.

Timelines and contingencies

The study is anticipated to take three years, including mesocosm construction and running experiments over two spawning seasons. Additional replicates of the

experiment may be possible using shovelnose sturgeon early life stages are a surrogate.

Decision criteria for application of component

Decisions at this stage are primarily whether to accept the information as useful in decision making. Statistical results for these mesocosm studies should be quite rigorous in establishing whether turbidity has a significant effect on survival.

C.2.4.5.3 Component 3

This component is an extension of component 2. Component 2 will establish whether a relation exists between turbidity and survival whereas component 3 will establish quantitative functional relations. For component 3 it may also be possible to focus on one or two of the life stages and perhaps a limited number of predators, instead of all considered in component 2. The experiments would involve evaluating predation effectiveness for a range of turbidity conditions; those relations would provide a quantitative model (with appropriate covariates) for linking sediment bypass to survival.

Metrics

The primary metric for this component will be survival by life stage and predator species, as a function of turbidity.

Timelines and contingencies

The study is anticipated to take two years to run refined experiments. Additional replicates of the experiment may be possible using shovelnose sturgeon early life stages as a surrogate. This component may be pursued in parallel with components 1 and 2, or sequentially after feasibility and screening have been established in components 1 and 2.

Decision criteria for application of component

The decision at this stage is whether the information is useful in decision making and supports moving to level 2. Statistical results for these mesocosm studies should be quite rigorous in establishing functional relations between turbidity and survival. The decision to move to level 2 may depend more on feasibility determined in component 1 and identification of effect determined in component 2; component 3 results will help define the experiments in component 5.

C.2.4.5.4 Criteria to move to level 2

The decision to move to field experimentation is likely to depend mostly on the feasibility study in component 1 because sediment bypass may be impractical or the costs may be prohibitive. Decisions based on cost are policy decisions, not scientific, and the appropriate decision making steps would be invoked. After feasibility, the next level of criteria would be whether an effect of turbidity could be established. If not, the hypothesis would be abandoned. If an effect is evident and the action feasible, the decision could be made to proceed to level 2 experimentation. In the event that turbidity is shown to be an over-riding variable determining recruitment success, and increasing turbidity is not a viable option, the information would indicate a fundamental constraint on recovering pallid sturgeon in the Upper Missouri River.

C.2.4.6 Level 2

Although level 2 components are included in this compilation, they are not currently planned for implementation (Appendix F). The timeline is likely beyond the current MRRMP planning process and contingent decisions will likely focus on achieving recruitment on the Yellowstone River first.

C.2.4.6.1 Component 4

Component 4 is a field-scale test of the mechanism or procedure selected to bypass sediment around Fort Peck Dam and to increase turbidity.

Metrics

The primary metrics for this study will be operational costs and extent of downstream increases in turbidity, and compared relative to predictive models. Additional metrics may be related to negative effects on socioeconomic values like public water supply.

Timelines and contingencies

This component would occur after all Level 1 components and before the field experiment, component 5. Depending on the bypass mechanism, testing may require specific hydrologic conditions. Several tests may be practical in a particular year; we anticipate two years of tests after an estimated four years of design and construction.

Decision criteria for application of component

The decision to move forward with component 5 would be based on demonstrable success in raising turbidity with the field test to biologically meaningful levels.

C.2.4.6.2 Component 5

Component 5 is a field-scale experiment of sediment bypass, resulting in downstream increases in turbidity sufficient to decrease predation on embryos, free embryos, and larvae. Because it is impractical and impossible to document survival/mortality of these life stages in the field, the experiment will rely on turbidity levels achieved and results of mesocosm experiments (components 2, 3) to indicate biological effect. It is anticipated that a suite of three experiments with varying magnitude of sediment bypass is needed.

Metrics

In addition to turbidity values and length of river affected, metrics will include implementation costs and effects on other authorized purposes.

Timelines and contingencies

The experiments are anticipated to require three years to provide a suite of three treatments, or magnitudes of sediment bypass. The experiments would follow the field test in component 5.

Decision criteria for application of component

Although the physical metrics (turbidity and length of river) should provide strong statistical evidence for whether the sediment bypass mechanism has a significant effect on the system, the lack of biological endpoints may detract from the value of the experiment. The decision to move to level 3 implementation may require expert judgement based on combined effects of the field experiments, including effects on other authorized purposes and mesocosm lines of evidence.

C.2.4.7 Critical scientific uncertainties and constraints

The central scientific uncertainty addressed in this Big Question is the extent to which predators cause significant mortality of embryos, free embryos, and larvae. Previous laboratory studies have documented that older, age-0 sturgeon are not susceptible to predation (French 2010), whereas one anecdotal study documented predation of age-0 larvae by flathead catfish (Steffensen et al. 2015a). No studies have looked at predation

of the early life stages (free embryos and new feeding larvae). A key engineering uncertainty for this Big Question is whether any practical means of sediment bypass exists; to move sediment from headwaters to the Fort Peck Dam or spillway could be a considerable engineering challenge. A technical uncertainty for this Big Question relates to methods to measure predation in turbid mesocosms where behaviors cannot be observed. Overcoming this challenge may require innovative approaches to imaging in turbid water or procedures to drain and count survivors.

C.2.4.8 Utility of study components

The study components are designed to address whether turbidity is limiting to survival of very early life stages, and if so, whether sediment bypass can be used to increase turbidity and decrease predation. Components 1–3 will be of particular utility in documenting whether the significant investment in sediment bypass would be practical or needed.

C.2.4.9 Ancillary information benefit

Information on pallid sturgeon predation and turbidity may be generalizable to other turbid-adapted species. Feasibility studies and engineering designs for sediment bypass (if implemented) may be transferable to other dams.

C.2.4.10 Risks

Risks of components 1–3 are low. Risks implicit in components 4 and 5 would be considered high because of the potential high cost and uncertainty about biological responses. Increased turbidity may present a risk to other authorized purposes like water supply and recreation, or to recreational fish species.

C.2.4.11 Adaptive actions

Adaptive actions are possible in components 1–3, decisions to go ahead with bypass construction or not. The degree of adaptive action available after construction will depend on the mechanism used for bypass and whether it is adjustable. Because it will probably be an active transport procedure, available actions may include abandoning sediment bypass or adjusting for a range of fluxes or sediment sizes.

C.2.4.12 Estimated costs:

Estimated costs of components 1–3 are relatively low. Cost at construction (component 4) may be substantial, and costs of operations (component 5) may also be considerable due to energy demands.

C.2.5 Upper Big Question 5; can combinations of flow manipulation from Fort Peck, drawdown of Lake Sakakawea, and fish passage at Intake Dam on the Yellowstone River increase probability of successful dispersal of free embryos and retention of exogenously feeding larvae?

C.2.5.1 Objective of study components

The objectives of these study components are to improve understanding of the variables affecting drift/dispersal of free embryos, with application to management actions downstream from Fort Peck. The utility of the components will increase to the extent that recruitment does not occur on the Yellowstone River.

C.2.5.2 Description of study components

Multiple study components are included in this Big Question because of the interactions of mechanisms that are hypothesized to affect drift and dispersal. Some of the components have been previously discussed under Big Question 3 and would be identical because they address fundamental science related to drift/dispersal and development. Level 1 components include development of integrated development and drift/dispersal models and an engineering study to evaluate spatial and temporal variation of anoxia in the headwaters of Lake Sakakawea. Biological screening components include the study already proposed in Upper Big Question 3, component 2 to evaluate mortality in Lake Sakakawea and an additional component to evaluate the distribution of suitable spawning habitats upstream of Intake Dam. The latter is considered a screening study as it will document whether spawning potential exists to take advantage of increased passage. Assessment of biological effects relies on opportunistic field experiments of free embryo drift identical to Upper Big Question 3, component 3b. These experiments are intended to validate and refine advection/dispersion models and understand factors that might retard free embryo drift and whether those factors can be managed. Compared to Upper Big Question 3, component 3b, the drift experiments described here would emphasize velocity and available drift distance, but because they are opportunistic the range of conditions sampled may not be large. Complementary mesocosm studies are proposed to provide additional experimental control, in particular to investigate abiotic and biotic factors that affect mechanics of drift and dispersal of free embryos and first-feeding larvae, and reproductive behaviors of adults that determine selection of spawning habitat and hydraulic conditions under which drift begins. Level 2 components include engineering studies to determine experimental effects on authorized purposes, validation of passage hydraulics at Intake Dam, and evaluation of sediment and water-quality effects in the headwaters of Lake Sakakawea. Finally level 2 includes manipulated field experiments to investigate effects of low flows from Fort Peck and drawdowns of Lake Sakakawea,

coupled with monitoring of passage and upstream migration of reproductive adults upstream of Intake Dam.

C.2.5.3 Relation to Effects Analysis

These study components address hypotheses 3, 7, and 10 from the effects analysis:

- Reduction of mainstem Missouri flows from Fort Peck Dam during free-embryo dispersal will decrease mainstem velocities and drift distance; thereby, decreasing mortality by decreasing numbers of free embryos transported into headwaters of Lake Sakakawea.

- Fish passage at Intake Diversion Dam on the Yellowstone River will allow access to additional functional spawning sites, increasing spawning success and effective drift distance, and decreasing downstream mortality of free embryos and exogenously feeding larvae.

- Drawdown of Lake Sakakawea will increase effective drift distance, decreasing downstream mortality of free embryos and exogenously feeding larvae.

C.2.5.4 Approaches

The approaches include technology development studies in level 1 to improve ability to integrate advection/dispersion and developmental models, field-based biological screening studies, and mesocosm biological effects studies to quantify relations between abiotic and biotic variables. For level 2 field experiments, engineering studies are proposed to refine experimental designs and document ancillary effects. Finally, manipulative field experiments are proposed to evaluate spawning and drift performance under realistic conditions. Monitoring and assessment of passage, spawning, dispersal, and contribution to recruitment at Intake Dam are included under level 3 in Chapter 4 of the AMP.

C.2.5.5 Level 1

C.2.5.5.1 Component 1

Component 1a develops modeling technology to merge hydrodynamics, water temperature, and developmental rate models, to predict population dynamics. It is identical to Upper Big Question 3, component 1. Component 1b is an engineering study to evaluate temporal and spatial variation of anoxia in the headwaters of Lake Sakakawea. This study would be complementary to ongoing studies of the anoxia zone

but would extend results through modeling effects of flows and drawdowns. The following sections apply only to component 1b.

Metrics

Metrics for this engineering study will be number of years and how much free-flowing length of the Upper Missouri will occur with drawdown and flow scenarios. Some of this modeling has already been completed by the effects analysis but it is anticipated that additional runs will be required to explore a greater range of options.

Timelines and contingencies

These studies will be useful to inform what management options may be practical on the Upper Missouri River. Component 1a is contingent on ongoing developmental series studies (also Big Question 3, component 4b) that are expected to provide data 2017. Model integration would require one year. Modeling of the location of the headwaters of Lake Sakakawea has been partially accomplished by the effects analysis and expansion is likely to require one year. These components are not contingent upon one another.

Decision criteria for application of component

Component 2 will proceed regardless of the outcomes from component 1a or 1b. Components 1a and 1b, along with components 2, 3 and 4, will be done in parallel and will together inform a decision to move to level 2. The results of the engineering study will provide information on how the anoxic zone might move over time depending on interaction of flows from Fort Peck and drawdown of Lake Sakakawea. If these results show that biologically sufficient movement of the anoxic zone (extension of free flowing river) is sufficiently rare under management scenarios, a decision may be made to abandon drawdown as a potential management action.

C.2.5.5.2 Component 2

These study components include two screening studies based on abiotic variables. The first of these is to document anoxia related mortality in Lake Sakakawea; this component is already underway by a research group from Montana State University and is included here as Big Question 3, component 2b. The second is to document presence of suitable spawning habitat on Yellowstone upstream from Intake, tributaries, and on the Upper Missouri and tributaries.

Metrics

For component 2a, the metrics are measures of spatial and temporal distribution (extent and variability) of anoxia, much of which may come from the ongoing study. The spatial and temporal scope of this component will be expected to be more fine-grained than models in component 1b. For component 2b, the metrics will be spatial distributions of suitable spawning habitat and ancillary physical variables upstream from Intake Diversion Dam, at least to the Cartersville Diversion Dam, and for some distance up larger tributaries. Determination of suitability will be based on ongoing documentation of spawning habitats that are selected by reproductive pallid sturgeon.

Timelines and contingencies

The ongoing study of anoxia (Upper Big Question 3, component 2b) will be completed in 2017 and it is anticipated that two additional years of fine-scale complementary assessment is needed. Component 2a may occur simultaneous with component 1. Component 2b can be completed in two years, but is highly dependent on reliable definition of spawning habitat. Current studies at spawning habitats on the Yellowstone River will provide useful definitions but these definitions may be updated as additional spawning sites are identified. Component 2b results will have substantial leverage on the prospects of successful recruitment on the Yellowstone River.

Decision criteria for application of component

The decisions at this stage relate to how useful information is to inform decision making and whether to move to level 2 science components. Results from component 2a are fundamental to assumptions about sources of mortality and recruitment failure, and evidence needed from this component supporting level 2 drawdown studies also includes suitable habitat to take advantage of the increased distance. If the results indicate that the anoxia zone is patchy in time and space, or does not develop as intensively as has been assumed, many management options will open up because dispersal into the headwaters of Lake Sakakawea would not necessarily be fatal. If instead, the studies confirm that anoxia is pervasive and fatal, management options are limited and studies are unlikely to proceed to level 2. If the results of component 2b document a lack of spawning habitat upstream of Intake Diversion Dam a major assumption of the Intake project will be challenged. This information would inform expectations of the role of the Yellowstone River in recruitment and would possibly increase the level of interest in Upper Missouri River management actions.

C.2.5.5.3 Component 3

Component 3 is a series of opportunistic field experiments using drifting free embryos and other potential tracers in an attempt to improve understanding of the joint effects of temperature, velocity, drawdowns, and developmental rates in controlling fates of dispersing free embryos. These experiments are intended to refine basic understanding on physical and biological processes governing dispersal, and to validate and refine advection/dispersion models. Because the experiments are not controlled, temperature, velocity, and drawdowns are not controlled, so the experiments in Upper Big Question 3, component 3b, and components 3a and 3b are essentially the same; the substantive differences would be attempts to emphasize opportunities with varying velocity and drawdown for these components. Because of the importance placed on advection/dispersion modeling in the effects analysis process for both the upper and lower river, validation of the model is presented as a high priority; current plans are to begin with an experiment in 2017.

Metrics

Metrics for these components will be space and time distributions of larvae and surrogate tracers developed through Eulerian sampling during the experiment. Free embryos will have known genetics to allow for discrimination from wild-produced sturgeon. Metrics will include Lagrangian evaluation of the flow fields experienced by the tracers to characterize mean velocities, variance, and longitudinal dispersion coefficients; these data will be collected by acoustic Doppler current profile mapping from boats floating with the tracers. Areas identified with increased loss of tracers will be identified for subsequent, high-resolution measurement and modeling of the flow field to determine conditions that retard or retain drifting larvae.

Timelines and contingencies

Component 3 is fundamental to acceptance of information from advection/dispersion modeling in the decision making process, supporting the argument that it should be prioritized among the Upper River Big Questions. Component 3 is anticipated to start in 2017 in parallel with components 1 and 2. A minimum of two experiments is anticipated to establish some confidence in replicability (additional controlled experimentation would occur under level 2). To allow for variability in years and availability of sufficient numbers of free embryos, four years are indicated for the component. It should be noted that prerequisites for these experiments are availability of a large number of free embryos and agreement among the pallid sturgeon recovery team that release of

free embryos would not skew desired genetics of stocked fish. In addition, experiments will require coordination with USACE reservoir control to manage releases from Fort Peck during the experiments.

Decision criteria for application of component

Decision criteria at this stage apply to the value of information in decision making and the decision to move to level 2. In particular, the results of drift/dispersal experiments will likely document the probability distribution for free embryos to be retained upstream of the headwaters of Lake Sakakawea, and therefore the probability for successful recruitment. Results could be definitive (for example, a vanishingly small probability of retention in the free-flowing river) or equivocal (for example, 2% probability of retention in the free-flowing river). If equivocal, other science components may be useful in determining how survival could be maximized.

C.2.5.5.4 Component 4

Component 4 is a mesocosm study designed to quantify how and why free embryos velocities depart from passive transport assumptions. The study will take place in racetrack flume mesocosms, or similar facility, to quantify the factors that may operate to alter transport conditions from purely passive assumptions. If component 3 information is definitive, these studies may not be necessary, although the staging (Appendix F) shows them taking place in parallel.

Metrics

Metrics for component 4 will be virtual velocity of the free embryo as a function of time, cumulative temperature units, and developmental stage. These metrics will be evaluated for different levels of channel complexity in constructed in racetrack flumes (e.g., varying substrate and varying bedforms). Qualitative observations will also be important for direct insight into if and how actual dispersal mechanisms depart from purely passive assumptions.

Timelines and contingencies

This study is likely to take three years in order to test useful ranges of velocity, bed configurations, substrate, and perhaps genotype. Quantification of processes responsible for departures from passive transport assumptions will be important to the extent that experiments in component 3 indicate that departures exist. From previous studies we expect biological processes to become an increasing influence on lowering dispersal rates after about 8 days

post hatch (Braaten et al. 2012); these components will quantify these processes. This study is anticipated to begin in 2017 simultaneous with components 1, 2, and 3.

Decision criteria for application of component

Results from this study component will contribute to understanding of probabilities of free embryo retention and to the decision to move to level 2 experimentation. The mesocosm experiments are likely to provide robust statistical evaluation of relations among abiotic variables, development stages, and dispersal rates. However, because the mesocosms cannot be expected to capture the range of velocities, hydraulics, and macroturbulence of the real river, substantial uncertainty will exist about whether all factors potentially influencing drift will be captured. The information will contribute useful information, however in design of level 2 experiments.

C.2.5.5.5 Criteria to move to level 2

The decision to move to level 2 field experimentation, component 5, will be based on judgement from multiple lines of evidence. If anoxia is documented to be pervasive and fatal and advection/dispersion models (component 1a) and field experimentation (component 3) indicate that dispersal from likely spawning locations (component 2b) indicate that retention in free-flowing parts of the Upper Missouri and Yellowstone has an extremely low probability, then level 2 experiments would not provide useful information. On the other hand, if the anoxic zone is patchy (component 2a, 1b) and/or retardation mechanisms can be identified and quantified (components 3, 4), then some reasonable probability may exist that slowly dispersing free embryos could be retained and thrive in free-flowing reaches. In this case, field experimentation to quantify survival rates under controlled conditions would be useful.

C.2.5.6 Level 2

C.2.5.6.1 Component 5

Component 5 is in anticipation of field experimentation and consists of experimental determination of effects on authorized purposes of reduced flows and velocities from Fort Peck intended to slow dispersal.

Metrics

Metrics will be velocities, water-surface elevations, and potential dispersal distances for an appropriate range of low-flow releases during dispersal season,

compared to potential authorized purposes like public- and irrigation water supply and recreation.

Timelines and contingencies

This study component would be highly contingent on results from components 1–4 indicating reasonable probabilities for survival and recruitment. While it is expected that much of the effect of a low-flow release experiment is already captured in existing 1-d models, it is anticipated that a pilot experiment of one or more releases to evaluate velocities achieved and to assess any negative influences on other authorized purposes. A series of low-flow releases could be completed in one year.

Decision criteria for application of component

Decisions related to this science component will be whether pilot results are sufficiently satisfactory to move onto field experimentation. If low-flow pulses provide anticipated decreases in mean velocities and do not substantially diminish attainment of other authorized purposes, results would support moving to field experimentation in component 6.

C.2.5.6.2 Component 6

The final science components in this Big Question are two inter-related efforts. Component 6a is a series of controlled field experiments in which combinations of flow releases from Fort Peck Dam and drawdown of Lake Sakakawea are tested to determine whether management actions can provide for first feeding within the supportive, free-flowing reach of the Upper Missouri River. These experiments will use day-1 free embryos and other tracers injected into the Upper Missouri River at likely spawning locations near Fort Peck, and downstream transport and survival will be monitored using the same protocols described in component 3. Survival estimates from these studies will be directly applied to population models to assess effects of these management actions on population dynamics. The form of the experiment will be very similar to component 3, only with manipulated releases and drawdowns.

Component 6b is an experiment to address a fundamental uncertainty associated with passage at Intake Dam. The experiment will translocate and release a dozen or more tagged, reproductive male and female pallid sturgeon upstream of the dam during June when temperatures rise above 16C. Upstream migration of the fish will be monitored through active and passive telemetry to determine where they select for spawning habitat. That habitat will then be extensively characterized to quantify the physical

environment, and free-embryo collection will be implemented downstream to attempt to confirm successful spawning, fertilization, hatch, and recruitment to the drift. Whether this experiment takes place before or after construction of the passage at Intake, the results will provide a clearer view of spawning habitat selection, without the requirement to first pass by the dam. If spawning occurs, the spawning site will allow for calculation and assessment of adequate drift distance using advection/dispersion models.

Metrics

Metrics for component 6a will be very similar to component 3; space and time distributions of larvae and surrogate tracers developed through Eulerian sampling during the experiment. Free embryos will have known genetics to allow for discrimination from wild-produced sturgeon. Metrics will also include Lagrangian evaluation of the flow fields experienced by the tracers to characterize mean velocities, variance, and longitudinal dispersion coefficients; these data will be collected by acoustic Doppler current profile mapping from boats floating with the tracers. Depending on the location of the headwaters and the presumptive anoxic zone, survival will be calculated as the proportion of free embryos that remains in the free flowing river at first feeding. The advection/dispersion models and sampling will indicate what section of the lower river will likely retain exogenously feeding larvae, and those sections will be targeted for aggressive capture of larvae to establish survival.

Metrics for component 6b will be similar to Big Question 1, components 2 and 5, and will include intensive and passive network telemetry tracking data of reproductive adults (males and females) to determine spawning locations. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes, combined with sampling for free embryos. Spawning sites will be extensively characterized with hydroacoustic instruments to quantify depth, velocity, velocity profiles, basal shear stress, and substrate. Based on spawning location, survival probability of free embryos will be calculated using the refined advection/dispersion models.

Timelines and contingencies

Components 6a and 6b will occur contingent upon results from components 5a and 5b. Component 6a may require a series of low flows combined with a series of drawdown events. Without replication, assuming 4 treatment levels of each, 16 years would be required; however, the experiments could be implemented to

minimize the numbers of treatment combinations based on results acquired from some of the extreme combinations. Anticipating the ability to accomplish some optimization, eight years are estimated for these experiments. Larval drift sampling for this component would also be supportive of larval drift sampling from component 6b. The Intake translocation experiment is contingent on deployment of the passive telemetry network and availability of reproductive adults, but is otherwise not contingent on other science components. This experiment could occur as early as spring 2017 (Appendix F). The experiment should be replicated at least four times, during four years, to characterize reproducibility.

Decision criteria for application of component

For component 6a, decision criteria at this stage apply to the decision to move to level 3 on the Upper Missouri, to implement flow changes, or drawdowns, or both. For component 6b, the information will contribute to understanding the potential for the Intake Passage Project to result in successful recruitment. If the translocated fish spawn sufficiently far upstream to allow for settling before hitting Lake Sakakawea, then a significant assumption will be validated and focus can be applied to level 3 monitoring of passage at the project. Conversely, if the fish do not spawn far enough upstream, then management options on the Upper Missouri River may be worthy of reconsideration.

C.2.5.7 Critical scientific uncertainties and constraints

The fundamental scientific uncertainty for component 6a is whether spawning locations on the Upper Missouri, flow management to minimize advection, and drawdown to maximize drift distance can combine to result in recruitment. The fundamental uncertainty for component 6b is whether reproductive adults who find passage around or over Intake Dam will migrate sufficient distance to find suitable spawning habitat, and spawn in sufficient numbers to recruit to the population. Resolution of these uncertainties will have a profound effect on the ability to predict whether recruitment is possible in the upper river. In the event that spawning upstream of Intake is not successful, other uncertainties become more important. One of those relates to biological departures from purely passive transport of free embryos. If free embryos progressively develop the ability to move themselves out of the current or to slow dispersal by interacting with benthic bedforms, then advection/dispersion calculations will overestimate dispersal distance. In such a case, management actions on the Upper Missouri River may have the potential to support recruitment. Components 3, 4, and 6 address this uncertainty and will contribute to refinement of the advection/dispersion model.

C.2.5.8 Utility of study components

These components directly address the foremost decisions on the upper river: whether passage at Intake Diversion Dam is sufficient to support recruitment, or instead whether recruitment can be accomplished through management actions on the Upper Missouri River.

C.2.5.9 Ancillary information benefit

Ancillary information collected during these science components will include detailed characterization of channel morphology, flow fields, transport rates, and ecological complexity, all of which may provide useful insights into ecosystem health. Captures of free embryos of species other than pallid sturgeon will provide insights into how spawning, drift, and dispersal affect recruitment of those species.

C.2.5.10 Risks

Level 1 science components present few risks, except possibly to the population augmentation program because of changes in genetic diversity and increased mortality of very young free embryos in field experiments. Parentage will need to be carefully selected so under-represented genetics are not potentially wasted in the experiments, or if survival is high, that over-represented parents are not used. Level 2 risks may be substantial because low flows and drawdowns on Lake Sakakawea may have implications for a wide range of authorized purposes. Risk involved with the translocation experiment include potentially wasting opportunities to use the fish in the propagation program, or to apply the tagged fish to other science components.

C.2.5.11 Adaptive actions

Results of these science components will establish important decision space for adaptive actions in the upper river. Knowing whether or not the Intake Project is likely to work as planned will indicate whether the Yellowstone River can be relied on for future recruitment, or if instead, an action should be taken to improve recruitment on the Upper Missouri River. The information developed in these science components will show what combination of Fort Peck low releases and Lake Sakakawea drawdowns may produce recruitment.

C.2.5.12 Estimated costs:

Estimated costs for components 1–4 are relatively low. Costs for components 5a and 6a could be substantial depending on how many test flows and drawdowns are needed, and how costs to authorized purposes accrue. The cost for robust monitoring and

assessment of the Intake Project to support Missouri River decisions is estimated at about $500,000 per year.

C.2.6 Upper Big Question 6: Can population augmentation (stocking) processes be enhanced to increase survival and genetic fitness of stocked fish?

C.2.6.1 Objective of study components

The science components for this Big Question are nearly identical to those for the lower river (Lower Big Question 6), with differences limited to geographic location. The objective of these study components is to provide the understanding needed to optimize population augmentation in recovery of the pallid sturgeon. While population augmentation is thought to be necessary for recovery of the pallid sturgeon, by itself it is not sufficient as the Endangered Species Act requires a self-sustaining population objective. Nevertheless, augmentation can help severely depleted populations recover numbers of individuals needed to evaluate what works and what doesn't in recovering the population.

The study components listed here will provide information to improve population augmentation methods and hopefully achieve higher survival at lower cost, while maintaining needed genetic diversity. Population augmentation is already taking place at the level where it has a measurable effect on the population (level 3), and it is assumed that population augmentation is presently following best management practices, to the extent possible, to maintain genetic diversity. The study components described here are not considered necessary steps before implementing level 3. Instead, the level 1 and level 2 components will develop information to improve on the level 3 implementation. The USFWS is preparing an update of the Pallid Sturgeon Rangewide Stocking Plan that, in combination with the collaborative decision making process of the Pallid Sturgeon Recovery Team and basin workgroups, may determine specific population-augmentation policies and information needs. The study components outlined here can be considered indicative of the types of studies that may be needed, rather than definitive.

Study components include an engineering study to investigate facility-design options for the pallid sturgeon hatchery system to determine if it might be possible to increase and maintain consistent production with appropriate, size, health, and genetics; some of this work may be accomplished or preempted by the drafting of a new propagation plan by the USFWS. Field monitoring components are proposed to evaluate how size, health, and genetics have affected survival of previously stocked fish. To develop quantitative relations between propagation decisions and survival probabilities, a modeling study is proposed to evaluate population sensitivity to typical ranges of differential survival that

might be affected by size, health, and parentage, and varied stocking rates that might arise from year to year variability in available broodstock or hatchery survival. A similar modeling study is proposed to investigate sensitivity of population genetics to variability in available parents, variable survival of family lots. Finally, a series of field experiments can be envisioned to provide a systematic evaluation of costs and population benefits associated with stocking at a range of sizes (ages).

C.2.6.2 Relation to Effects Analysis

These study components provide information to support EA hypotheses 8 and 9. Since the EA integrative report was written, new information has become available indicating that incidence of disease in hatchery origin fish has substantially constrained stocking levels in recent years. New information has also indicated that fish may have been overstocked in the upper river and that some genetics are over represented among the stocked population. Although disease was not identified as a priority working hypothesis in the EA, the issue is intimately connected to the two issues that were identified, genetic parentage and size. In the case of parentage, population augmentation best-management practices generally do not support culling populations based on genetic makeup, as doing so would apply an unnatural selective pressure. Hence, management actions related to genetics (hypothesis 21) are actually quite limited aside from existing best management practices that seek to manage for diversity. Size at stocking, however, is a variable that can be managed, and doing so has implications for costs, numbers available to stock, and disease exposure. While survival nominally increases with size at stocking, the longer a fish is maintained in the hatchery the greater the cost (including opportunity cost for other fish species that are not propagated) and the greater the opportunity for disease. Consideration of hypothesis 8 therefore, implicitly involves consideration of facilities capacity and disease risk.

C.2.6.3 Approaches

Approaches to these study components at level 1 include an engineering design study, field-based monitoring of differential survival rates, and sensitivity assessments using population and population genetics models. At level 2, a series of field-based experiments can be envisioned for a systematic evaluation of size at stocking effects on differential survival.

C.2.6.4 Level 1

C.2.6.4.1 Component 1

This component would be an engineering feasibility design study to address costs and presumed population benefits for propagation facilities of different designs and

capabilities. The selection of design and capability would be based on costs relative to results of component studies 2–4, which would indicate benefits of stocking size, and related disease risk. Much of the work may be accomplished by the USFWS revised propagation plan currently (2016) under development.

Metrics

Metrics for this study would be costs and measures of likely survival for a range of facilities designs, including distribution of risk based on numbers of hatcheries. Measures of survival would be based on existing data for differential survival for stocked age-0, age-1, and juvenile fish, plus an estimate of the relations among designs, operations, size at stocking, and risk of disease.

Timelines and contingencies

Although this study would benefit from new information that evolves from components 2–4, the immediacy of the issue and likely time lag between a study and changes in facilities and operations indicates that the feasibility study should start soon, perhaps as early as October, 2017. The study is estimated to take two years for completion and would be done concurrently with components 2 and 3.

Decision criteria for application of component

The results of the feasibility study would presumably indicate a range of options in facilities and operations, with attendant costs, and benefits to the propagation program in terms of probable increased survival. Indications from this component of benefits from alternative designs, and at a reasonable cost, will provide evidence to move to level 2. The decision of what improvements to implement (a level 3 or 4 action) would be based this information as well as information from components 2, 3, and4.

C.2.6.4.2 Component 2

This study will use monitoring data on growth and survival of hatchery-origin fish to assess how factors such as size at stocking, health history, and parentage may have affected survival. The study assumes that genetic and propagation records for hatchery-origin fish are complete and accurate. Appropriate monitoring could be a stand-alone operation or it could be incorporated within a population-trends monitoring program (see population monitoring project discussion, Appendix D). Monitoring would need to include both the Upper Missouri and the lower Yellowstone Rivers. A Cormack Jolly Seber (CJS) model will then be used to estimate apparent survival using the multiple recapture occasions. Data of this nature can be fit using traditional mark recapture

software such as Program MARK and hierarchical Bayesian approaches can provide increased flexibility.

Metrics

The metrics for this component are estimates of the number and survival rates for stocked pallid sturgeon by stocked size, hatchery of origin, location of release, and health history.

Timelines and contingencies

The timing for this component would be most efficient if coordinated with the population trends monitoring described in Appendix D. It is estimated that 3 years of sampling would be necessary, at a minimum, to provide useful data on differential survival. Sampling could be coordinated and coincident with population trends sampling.

Decision criteria for application of component

Information developed in this component will illustrate the scope of differential survival and whether a need exists for fundamental changes to the propagation facilities and operations. The statistical rigor of the analysis is difficult to anticipate and decisions may need to be made based on judgements informed by multiple lines of evidence, including results from components 1 and 3.

C.2.6.4.3 Component 3

These study components are model simulation studies intended to test sensitivity of population dynamics and population genetic structure to variability in augmentation. The first of these would assess how population dynamics would be affected by typical variation in survival related to size at stocking, results of which would indicate if there is value to the population to develop hatchery capabilities to optimize size, with implications for hatchery capacity and number of hatcheries. The model would also be used to assess effects of variable stocking rates (due to year-to-year variability in broodstock availability), health history, and parentage. The second of these models would investigate sensitivity of population genetics to mating decisions made in the hatchery and other factors like year to year variation in availability of wild broodstock. Results will provide a quantitative basis for assessing risks of genetic swamping and insights into effort needed to collect and keep broodstock.

Metrics

Metrics from these modeling studies will include probability of quasi extinction, instantaneous growth rates, and sensitivity measures under various scenarios and parameterizations of the models.

Timelines and contingencies

Ideally, some of the parameters for the models would be informed with data from the mark/recapture survival data from component 2, although useful assessments of sensitivity do not necessarily need high-precision parameter estimates. The time for completion of the study is estimated to be 3 years and would occur in parallel with components 1 and 2.

Decision criteria for application of component

The information developed in this component will have a bearing on decisions about hatchery facilities and operations and stocking. The mix of empirically derived differential survival data and modeled extrapolations of those data will not necessarily provide a statistically defensible decision criterion. The decision will likely be based on judgement informed from multiple lines of evidence.

C.2.6.4.4 Criteria to move to level 2

Level 2 components are field based experiments that will vary size at stocking and release location, and assess differential survival. These level 2 activities may not be necessary to decide among facilities/operations options if the retrospective evidence is sufficiently robust. Moving to level 2 would be indicated if models show a high sensitivity of cost and survival to size at stocking, and more precise parameters for the relationships are needed, and if information from components 1 and 2 also show a need for level 2 studies.

C.2.6.5 Level 2

C.2.6.5.1 Component 4

If results of component 2 are equivocal about relations between size at stocking and differential survival, this component will provide a systematic, field-based experiment to assess the effect. The study would involve stocking fish at variable sizes (representing variable hatchery costs) keeping all other factors as constant as possible. Monitoring over several years would provide information on mortality and provide guidance on tradeoffs between survival and cost. The experiment would require that fish are

identifiable from year to year based on tags or genetics, and that genetic and propagation records for the fish are complete and accurate. A CJS model will then be used to estimate apparent survival using the multiple recapture occasions. Data of this nature can be fit using traditional mark recapture software such as Program MARK and hierarchical Bayesian approaches can provide increased flexibility.

Metrics

Metrics from these experiments will be estimated number of stocked pallid sturgeon and survival rates by stocked age, size and hatchery of origin, fish condition, location of release, and water-year conditions.

Timelines and contingencies

This component would only be pursued if deemed necessary to make decision regarding facilities and operations. The monitoring approach would be a subset of the previously described population trends assessment; we estimate a minimum of five years to provide useful information on survival based on two years of stocking of 4 size ranges and 4 years of monitoring.

Decision criteria for application of component

The information developed in this component will have a bearing on decisions about hatchery facilities, operations, and stocking. The mix of empirically derived differential survival data and modeled extrapolations of those data will not necessarily provide a statistically defensible decision criterion. The decision will likely be based on judgement informed from multiple lines of evidence.

C.2.6.6 Critical scientific uncertainties and constraints

One critical uncertainty for these components is the geographic scope that needs to be sampled to assess survival. Another uncertainty is how co-variates – environmental conditions, genetics, and health history – will interact to determine actual survival. A critical constraint in implementing field-based experiments with stocking is the availability of fish with appropriate genetics from the hatchery system.

C.2.6.7 Utility of study components

The study components under this Big Question address information that may be useful in improving effectiveness of the population augmentation program, which is in turn, a critical part of the recovery program. The information developed will be useful in cost: benefit decisions about investments in hatchery facilities and capabilities.

Monitoring proposed as parts of components 2 and 4 will be consistent with monitoring efforts envisioned for drift/dispersal studies and may contribute to population-trends monitoring.

C.2.6.8 Risks

Risks to pallid sturgeon populations presented by these components are low as long as best management practices for conserving appropriate genetics are practiced. Risks to stakeholders appear also to be low.

C.2.6.9 Decision criteria

The information gained in these studies will inform investments in hatchery facilities and capabilities, and perhaps contribute to refinement of some propagation decisions.

C.2.6.10 Adaptive actions

Information provided through these components would be useful in incremental changes to hatchery facilities and procedures.

C.2.6.11 Estimated costs

Costs of development of new facilities or expansion of existing facilities could be high. The intent of this set of components is to provide a cost: benefit basis for understanding the value of that investment.

C.3 Lower River

The lower river refers to the Missouri River mainstem downstream of Gavins Point Dam, the influences (to the extent they are relevant) from upstream reservoirs like Fort Randall and Lewis and Clark Lake, influences of major tributaries, and some distance downstream in the Middle Mississippi River (Figure C2). The level 1 and level 2 adaptive management actions are referred to below by Big Questions.

Although contingencies based on evolving information might dictate a sequential approach to science components and eventual management actions, the staging discussed here assumes all level 1 components are simultaneous, followed by appropriate level 2 field experiments. Appendix F presents more detail on prioritization, staging, and costs.

C.3.1 Lower Big Question 1: Can spring pulsed flows synchronize reproductive fish,

increase chances of reproduction and recruitment?

C.3.1.1 Objective of study components

The objective is to determine if water flow, or changes in flow, from Gavins Point Dam during the spring influences spawning behavior and successful reproduction of pallid sturgeon in the Lower Missouri River.

C.3.1.2 Description of study components

Water discharge is thought to influence pallid sturgeon migration behavior, reproductive readiness, and possibly spawning site selection prior to spawning. By naturalizing the flow regime from the dam during spring, reproductive pallid sturgeon may be cued to migrate in synchrony and lead to increased aggregations at spawning locations. This could increase the chances of successful reproduction.

C.3.1.3 Relation to Effects Analysis

These study components directly support EA hypothesis 11: Naturalization of the flow regime at Gavins Point will improve flow cues in spring for aggregation and spawning of reproductive adults, increased reproductive success.

C.3.1.4 Approaches

Two levels could be implemented to test this hypothesis. Level 1 includes opportunistic field testing in the river and experiments in a constructed mesocosm in order to evaluate behavioral responses under more controlled conditions. Level 2 includes an engineering study to determine the associated effects of flow pulses and implementation of experimental flow releases to test fish reproductive behaviors.

C.3.1.5 Level 1

C.3.1.5.1 Component 1

This component consists of two sub-components, 1a and 1b. Component 1a is a technology-development study to design and implement a passive, fixed-station telemetry receiver network to complement intensive, boat-based tracking. The study is intended to support component 2, but is delineated separately because of the potential challenges in design and implementation in the dynamic Missouri River system. Component 1b is a power analysis of the ability to associate reproductive behaviors with flow pulses. Component 1b will indicate whether existing or future levels of effort will be able to provide statistical rigor to the hypothesis that flow pulses cue spawning and recruitment.

Metrics

Component 1a, telemetry network. Metrics for this technology development study will be performance metrics for detectability of tags and variation of detectability with discharge and sediment load. Cost and reliability will be additional metrics.

Component 1b, power analysis. Power analysis will be used to determine the number of tagged adults required to detect differences in the level of spawning or other reproductive response.

Timelines and contingencies

The technology developed and tested under component 1a would contribute to success and cost effectiveness of subsequent components (components 2 and 5), as well as being a substantive contributor to assessing immigration and emigration for population-level monitoring (see Appendix D). Development and testing could be accomplished in one year, and may begin as early as 2017. Components 1a and 1b would proceed at the same time, and would also be concurrent with the other level 1 studies under components 2 and 3.

Decision criteria for application of component

If testing of a passive telemetry network design proves successful, the decision may be made to deploy passive telemetry receivers in a network that will contribute to sample designs for evaluating sturgeon responses to flow pulses. Success will be determined by the ability to detect fish movements past strategic locations. Power analysis under component 1b will indicate numbers of fish and level of effort that will be necessary to develop statistically significant relations between flow pulses and reproductive responses, either to accept or reject the hypothesis. The results may indicate that statistical rigor is feasible or infeasible.

C.3.1.5.2 Component 2

This study component would involve monitoring of water discharge, pallid sturgeon movement, and pallid sturgeon location data. Flows would need to be measured continuously across numerous locations longitudinally downriver from Gavins Point Dam. A range of opportunistic flows (low to high) would be needed to bracket ecologically ineffective and effective flows. Variation in flow regimes from upstream to downstream provide dynamic range in discharges, without requiring intentional flow releases. Pallid sturgeon in reproductive condition would need to be tracked via telemetry methods to determine movement patterns. Telemetry would include

documenting reproductive behavior (aggregation, spawning) and spawning success as measured by production of free embryos and/or age-0 catch rates. Statistical relationships of flow-regime components (mean discharge, change in discharge, e.g.), and covariates (turbidity and temperature) to pallid sturgeon behavior would be evaluated.

Metrics

Metrics for this component will include the degree of association of reproductive migrations and successful spawning with monitored hydrologic characteristics (magnitude, duration, timing, rate of change of discharge, temperature, water quality). Intensive telemetry tracking data of reproductive adults (males and females) will be evaluated against time series of hydrologic characteristics and will be analyzed for degree of association. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes. Catch of free embryos and/or age-0 pallid sturgeon can also be used as an indicator of reproductive success as demonstrated in 2014 and may be collected as part of other science activities.

Timelines and contingencies

This component is an extension of existing research efforts in understanding reproductive ecology of the pallid sturgeon. A collaboration among agencies has collected 8 years of reproductive movement data based on telemetry, and those data have not been sufficient to associate reproductive success with hydrologic characteristics. More tagged fish and a longer record will be required to reach a significantly improved understanding if hydrologic links exist and are important to the pallid sturgeon population. We anticipate an additional 8 years of data collection will be necessary. Success of the study will depend in part on development of passive receiver networks (component 1) and on maintenance of a tagged research population of reproductive fish that are not subject to being selected for use in the population augmentation program.

Information on spawning habitat selection generated in this science component will also be used in Big Question 5, component 2, related to identifying and quantifying functional spawning habitat.

This component may progress in parallel with mesocosm experiments in component 3, indicating that neither component is contingent on completing the other. The two types of information are considered mutually supporting.

Decision criteria for application of component

Based on research experience, it is unlikely that this component will result in a statistically rigorous decision. Instead, a decision to use the information in decision making will probably be based on judgement of multiple lines of evidence, probably combined with results of mesocosm experiments in component 3.

C.3.1.5.3 Component 3

Many of the same aspects of component 2 would be measured in component 3, however at a small scale in a controlled environment. Possibilities for mesocosm experiments include very large circulating tanks, circulating ponds, or constructed side channels to the Missouri River. Mesocosm experiments would vary water velocity, temperature, and turbidity (and rates of change) to evaluate behavioral responses of reproductive adults. Acoustic video and 3-d telemetry arrays would allow for detailed characterization of behaviors.

Metrics

Metrics for this component will include the degree of association of reproductive behaviors with manipulated hydrologic characteristics (magnitude, duration, timing, rate of change of discharge, temperature, water quality). Intensive, fine-scale telemetry tracking data of reproductive adults (males and females) will be evaluated in trials with varying discharge, temperature, and turbidity. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes, complemented with targeted sampling of free embryos. The ultimate metric will be probability of successful spawning as a function of abiotic variables.

Timelines and contingencies

This component may progress in parallel with field-scale telemetry in component 2, indicating that neither component is contingent on completing the other. The two types of information are considered mutually supporting.

Implementation of this component will require construction of a mesocosm (large flume facility) that is capable of creating a wide range of hydrologic and water-quality conditions; in addition, the facility will need to be large enough to accommodate multiple full-sized adult fish (see discussion of Lower Big Question 2, component 3). This facility could be semi-controlled side channel of the

Missouri River or a highly controlled experimental flume such as the USACE-ERDC cognitive fish flume (http://el.erdc.usace.army.mil/emrrp/nfs/facilities.html). Mesocosms for this science component would presumably be the same as those used in the upper river for Big Question 1, component 3.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to level 2 implementation or possibly to decisions about rejecting the hypothesis that flows can be managed to optimize spawning and recruitment. Controlled mesocosm studies may provide statistically rigorous results indicating the presence or absence of hydrologic effects on reproductive success, and the strength of any association that exists. Such information would likely be an incomplete assessment of field-scale conditions, and so would be evaluated in a lines-of-evidence approach along with information from components 1 and 2.

C.3.1.5.4 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement that there is or is not a likely relation between actionable hydrologic characteristics and reproductive success. The judgement should be based on the strength and replicability of relations between flow pulses (and associated water quality characteristics) and reproductive migrations, spawning, and spawning success demonstrated by capture of free embryos. In addition, movement to level 2 should entail development of design parameters for a series of pulsed-flow experiments.

C.3.1.6 Level 2

C.3.1.6.1 Component 4

In anticipation of intentional experimental flow releases in approach 4, an engineering study may be conducted to evaluate effects of experimental flow releases on other authorized purposes such as interior drainage and tern/plover nesting habitat. This study would also be used to design monitoring of ancillary effects during intentional flow releases.

Metrics

Metrics for this component will include measures of the effects of flow pulses on other authorized purposes. Some of the elements of these studies will have been developed in earlier planning efforts, such as human consideration proxies and metrics in the MRRMP. New studies on the specific effects of the experimental

releases will provide similar metrics, such as days above flood stage or days above flap-gate elevations, but specific to the planned experiments.

Timelines and contingencies

This component is expected to take 2 years and is contingent on completing all of the level 1 analyses so the results of the experimental design parameters can be evaluated.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to component 5. That decision will be based on development of functional relations between experimental flow pulses and effects on other authorized purposes. If experimental flow-pulse characteristics thought to be biologically significant (magnitude, duration, frequency, timing, rate of change) reach a threshold wherein impacts to other authorized purposes are a concern and/or are beyond levels previously given NEPA coverage, then additional analysis and approval may be needed to move to level 2. If experimental flow pulse hydrologic characteristics are within previously approved levels, then the decision to be made to move to level 2 field experimentation would be based on anticipated biological results.

C.3.1.6.2 Component 5

This study is similar to Level 1, component 2, but uses experimental flow releases from Gavins Point to exert additional experimental control. Flows from Gavins Point dam would be deliberately manipulated over a range of magnitude, duration, timing, and rate of change to evaluate reproductive behavior of pallid sturgeon. Years with flow pulses should also be tested against control years without flow pulses. Implementation of Component 5 depends on the outcome of Level 1, Component 2, and the decision criteria describe in the evidentiary framework, Table 49 in section 4.2.6.6 of AM Plan).

Metrics

Metrics for this component will be very similar to component 2 and will include the degree of association of reproductive migrations and successful spawning with monitored experimental flow pulses. Intensive telemetry tracking data of reproductive adults (males and females) will be evaluated against time series of hydrologic characteristics and will be analyzed for degree of association. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released

gametes. The experiment will be a series of pulsed-flow releases over several years; the series will result in a functional relationship between flow-pulse characteristics and probability of producing viable gametes.

Timelines and contingencies

For the experiment to be successful there will need to be a substantial number (50 or more) of tagged, reproductive adult fish identified and tracked each experimental year in the river segments upstream from the Platte River. The number will be determined by the power analysis in component 1b. Assuming a minimum of 4 pulse levels and the risk that experimental logistics may fail 1 year in 2, at least 8 years will be necessary for this component. Success of the study will depend in part on development of passive receiver networks (component 1a) and on maintenance of a tagged research population of reproductive fish that are not subject to being selected for use in the population augmentation program.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to level 3. Experimental control imposed in this component will add to the ability to detect and quantify reproductive behavioral changes related to flow pulses; however, the experiments will still take place within a system where many sources of variability are not controlled, such as weather systems and tributary inputs. It is therefore unlikely that these experiments will result in a statistically rigorous result. Instead, a decision to accept the value of manipulated flow pulses in increasing pallid sturgeon reproductive success, or to reject it, will probably be based on judgement of multiple lines of evidence.

C.3.1.7 Critical scientific uncertainties and constraints

Several science components require the ability to tag and monitor a large population of pallid sturgeon in the Lower Missouri River so reproductive condition and history of subject fish are known. A tagged population will also aid a population monitoring program by quantifying reproductive home ranges and immigration and emigration. Implementation of mesocosm studies will require a facility that can culture reproductive adult fish for experiments and construction of a mesocosm large enough to accommodate ecologically significant velocity, temperature, and turbidity pulses. Locations of fish in the field and mesocosms must be established with high spatial and temporal frequency during spawning season in order to infer with confidence that behaviors are relatable (or not) to flow pulses. Data on flow-related covariates (water temperature and turbidity) are also necessary to discriminate cause and effect.

Implementation of field experiments will require buy-in from agencies and stakeholders to accept risks from providing flow pulses of a magnitude that are likely to be measurable and effective. Improved evaluation of spawning success will require additional investment in technology to image spawning behaviors, egg release, and fertilization in challenging hydraulic environments.

C.3.1.8 Utility of study components

These study components will provide critical information to determine if pallid sturgeon require flow cues that ultimately lead to successful reproduction. If flow cues are apparent, the study component will provide guidance about flow thresholds, changes in flow, or other aspects of flow influencing spawning behavior.

C.3.1.9 Ancillary information benefit

The results of the assessment will provide ancillary information applicable to habitat use, spawning locations, reproductive ecology, and migration routes of pallid sturgeon.

C.3.1.10 Risks

Manipulating discharge from Gavins Point Dam (component 5) imposes the greatest risk for this Big Question. Impacts on stakeholders could be considered high, depending on the magnitude of flow changes. Manipulated flows that are too low or too high could lead to problems with navigation, water supply, or flooding, for example. Little risk to stakeholders is associated with level 1 components. Risk to pallid sturgeon is minimal as telemetry on the species has been practiced for a decade without issue.

C.3.1.11 Adaptive actions

Results of these study components could provide information to optimize releases from Gavins Point Dam in the spring, or potentially to indicate that flow manipulations are not necessary to elicit a reproductive behavioral response from pallid sturgeon. The hydrologic characteristics of the flow pulses (magnitude, duration, frequency, timing, rate of change) can be adaptively managed to elicit an optimal biological response while minimizing effects on other authorized purposes.

C.3.1.12 Estimated costs

Estimated cost of this study component is medium to high. Maintenance of a telemetry tagged population, construction of a passive telemetry array, intensive telemetry tracking, and construction of a large-scale mesocosm would all require substantive investments on the order of several million dollars per year.

C.3.2 Lower Big Question 2: Can water-temperature manipulations at Fort Randall and/or Gavins Point contribute significantly to increased chance of reproduction and recruitment?

C.3.2.1 Objective of study components

The objective of these study components is to determine if increased water temperature from Ft. Randall and/or Gavins Point dams during the spring influences spawning behavior and successful reproduction of pallid sturgeon in the Lower Missouri River.

C.3.2.2 Description of study components

Water temperature could influence the timing of pallid sturgeon migration behavior and spawning activity. By increasing water temperature in the Lower Missouri River during spring, reproductive pallid sturgeon may be cued to migrate in synchrony, leading to increased aggregations at spawning locations. This could increase the chances of successful reproduction.

C.3.2.3 Relation to Effects Analysis

This study component directly supports EA hypothesis 15: Operation of a temperature management system at Fort Randall and/or Gavins Point dams will increase water temperature downstream of Gavins Point dam, providing improved spawning cues for reproductive adults. The EA presented data indicating that the effects of flows out of Fort Randall on water temperatures downstream of Gavins Point were uncertain, as was the net cooling effect from joint Fort Randall and Gavins Point operations (Jacobson et al., 2016a).

C.3.2.4 Approaches

Two levels with five different components could be implemented to evaluate this hypothesis. Level 1 includes modeling temperature increases as a function of water releases from the dams (component 1), relating temperature differences to fish behavior using surrogates (component 2), and relating water temperature to fish behavior in mesocosms (component 3). Level 2 includes pilot engineering tests to measure temperature increases in the Lower Missouri River as result of temperature manipulation from either of the two dams (component 4) and field experiments of pallid sturgeon reproductive behavior related to temperature increases (component 5).

C.3.2.5 Level 1

C.3.2.5.1 Component 1

This engineering study component would investigate, through modeling, alternate water release geometries or mechanisms at Ft. Randall and/or Gavins Point dams to determine if operations of the dams substantively decrease water temperatures downstream of Gavins Point Dam, and by extension, whether operations could mitigate this effect. Historical water temperature data from the Ft. Randall reach and downstream from Gavins Point Dam could be used in a modeling approach to predict the requirements for an ecologically significant increase in river water temperature downstream from Gavins Point Dam. Modeling should include scenarios where temperatures are increased from Ft. Randall Dam, Gavins Point Dam, and both dams. Modeling should also include the longitudinal extent of increased temperatures and include a seasonal component (early spring to summer).

Metrics

Metrics for this technology development study will include absolute water temperatures and changes relative to existing and unregulated water temperatures, by river mile downstream of Gavins Point Dam for various temperature control implementations. In addition, costs and performance metrics for the temperature control scenarios will be used to evaluate cost effectiveness.

Timelines and contingencies

The models developed in this component will provide 1) quantitative understanding of need and efficacy for water temperature control and 2) an estimate of costs. As such, this component will provide foundational information to determine whether the hypothesized action is necessary and realizable. Components 1, 2, and 3 would start at the same time, possibly as early as 2017. If models indicate a significant lowering of water temperature, additional models will be run to address feasibility of mitigating water temperature effects; results of these models will be used as a foundation for component 4.

Decision criteria for application of component

Results of the modeling will demonstrate whether operations of Ft. Randall and Gavins Point dams create a significant decrease in water temperature relative to historical, and if so, how much of the river is affected. If the change in water temperature is within prediction error, there will be no need to continue with

other science components of this management action. However, if results show a significant decrease, then results from additional models will be used to decide on feasible methods to mitigate dam operations on temperatures. Moreover, if water temperature decreases are significant relative to the unregulated river, then there will be support to continue with components 2 and 3 to develop biological significance.

C.3.2.5.2 Component 2

This study would examine how reproductive behaviors of surrogate species (other sturgeon species) respond to water temperature variations in other rivers. This could be accomplished by combining a literature search for existing information with targeted telemetry studies of shovelnose sturgeon behaviors on tributary rivers to the Missouri (Big Sioux, Kansas, and Platte) where seasonal water temperature variation occurs. This component would serve to evaluate the extent of temperature response expected in pallid sturgeon. The impetus to use surrogate species is based on the rarity of the pallid sturgeon and the value of developing larger, more statistically robust datasets.

Metrics

Metrics for this component will include the degree of association of reproductive migrations and successful spawning with monitored water temperatures, discharge, and other ancillary water quality parameters. Intensive telemetry tracking data of reproductive adult sturgeon (males and females, pallid sturgeon and shovelnose sturgeon) on the Missouri River and selected tributaries will be evaluated against time series of water temperatures and will be analyzed for degree of association. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes.

Timelines and contingencies

This component is highly related to Lower Big Question 1, component 2, so there would be some economies of scale in carrying out both components. Working with shovelnose as a surrogate (or comparative) species, a larger number of fish can be tagged than can be accomplished with pallid sturgeon alone. In addition, shovelnose use of tributaries will allow for a wider range of environmental effects (temperature, discharge, turbidity) than would result from working in the mainstem Missouri River. This work is not necessarily contingent on other components, but would provide information that would be mutually supportive

with component 3. Component 2 may proceed simultaneously with components 1 and 3.

Decision criteria for application of component

It is unlikely that this component will result in a statistically rigorous result due to interactions with uncontrolled variables, and the dependence on surrogate species. Instead, a decision to use the information in decision making will probably be based on judgement of multiple lines of evidence.

C.3.2.5.3 Component 3

This study would evaluate reproductive behavior of pallid sturgeon in relation to water temperatures in mesocosms. The experiment is intended to evaluate fish activity and indicators of reproductive behavior across a temperature gradient to determine the influence of temperature on pallid sturgeon reproductive ecology. Temperatures would need to replicate those in the current system and simulate hypothesized temperature increases from component 1. Mesocosm studies could make use of the facilities and study design used for Lower Big Question 1 (spawning cues).

Metrics

Metrics for this component will include the degree of association of reproductive behaviors with manipulated water-temperature characteristics (magnitude, duration, timing, rate of change of discharge, water quality). Intensive, fine-scale telemetry tracking data of reproductive adults (males and females) will be evaluated in trials with emphasis on varying water temperature, but also considering covarying discharge, and turbidity. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes. The ultimate metric will be probability of successful spawning as a function of water temperature, with or without other interacting abiotic variables.

Timelines and contingencies

This component is shown in the accompanying schedule (Appendix F) as progressing in parallel with field-scale telemetry in component 2, indicating that neither component is contingent on completing the other. The two types of information are considered mutually supporting.

Implementation of this component could be coordinated with Lower Big Question 1, component 3 because a mesocosm facility for addressing discharge

characteristics could also accommodate temperature and other related variables. The same experimental fish populations could be used for both. The mesocosm (large flume facility) would need to be is capable of a creating a wide range of hydrologic and water-quality conditions, and it would have to be big enough to have multiple adult fish. This facility could be semi-controlled side channel of the Missouri River or a highly controlled experimental flume similar to the USACE-ERDC cognitive fish flume (http://el.erdc.usace.army.mil/emrrp/nfs/facilities.html). Presumably, the same mesocosm facility would be used for the upper river, Big Question 1 component 3 and Big Question 3, component 4a.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to level 2 implementation or, if results are very convincing, to use the information to reject or embrace the hypothesis. Controlled mesocosm studies may provide statistically rigorous results indicating the presence or absence of water-temperature effects on reproductive success, and the strength of any association that exists. Such information would likely be an incomplete assessment of field-scale conditions, and so would be evaluated in a lines-of-evidence approach along with information from component 2.

C.3.2.5.4 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement that there is or is not a likely relation between feasible temperature mitigation and reproductive success. The judgement should be based on the strength and replicability of relations between temperature variation (and associated abiotic characteristics) and reproductive migrations, spawning, and spawning success demonstrated by capture of free embryos. In addition, movement to level 2 should entail development of design parameters for a series of temperature experiments.

C.3.2.6 Level 2

Although level 2 components are included in this compilation, they are not currently planned for implementation (Appendix F). The timeline is likely beyond the current MRRMP planning process and costs of experimental implementation may be untenable.

C.3.2.6.1 Component 4

This study component would be field tests of water temperature manipulation structures or managed water releases to determine if anticipated river water temperatures are realized downstream. Water temperature could be increased by water

heating devices, variable depth release structures, or by releasing/pumping surface water from the reservoir into the river. A controlled release of heated water into the river would be measured and monitored. A longitudinal series of temperature monitors would need to be placed downstream to evaluate the effectiveness of water temperature manipulations.

Metrics

Metrics for this component will be increase of water temperatures above those that would have prevailed without the temperature mitigation. This will necessitate well-calibrated water-temperature models to be able to simulate what temperatures would have been in the absence of the mitigation. Field tests may include a range of implementations that would have a range of temperature effects. Field tests would also check to see that water temperature effects were not adverse for other users of the river, e.g. power-plant cooling.

Timelines and contingencies

This component is expected to take 4 years to address climatic variability. It is contingent primarily on component 1 results that will indicate whether water temperatures have been adversely affected by system operations, and components 2 and 3 which will address whether the temperature effects are biologically significant. If results for components 1-3 are negative, components 4 and 5 would be abandoned.

This component is highly related to Lower Big Question 1, components 2, 4, and 5 as studies of flow pulses would need to be coordinated with studies on water temperature manipulations. Empirical data may emerge that both flow and temperature are significant in reproductive success, which would indicate the need for experimental manipulations combining water temperature and flow pulses. Conversely, it may emerge that one or the other, or neither, is significant in increasing reproductive success.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to component 5. That decision will be based on lines of evidence from components 1-3 and information developed during component 4 that temperature mitigations can be effective. The decision to proceed with component 5 would be based on the demonstrated ability to raise water temperature by an increment thought to be biologically significant.

C.3.2.6.2 Component 5

This component would be a field-based experiment parallel to that of Lower Big Question 1, component 5 in which behaviors of tagged reproductive pallid sturgeon are used as response variables. Temperatures associated with releases from Gavins Point Dam or Fort Randall Dam, or both, would be deliberately manipulated over a range of magnitude, duration, timing, and rate of change to evaluate reproductive behaviors. The experiment would include discharge and turbidity as covariates.

Metrics

Metrics for this component will be very similar to component 2 and will include the degree of association of reproductive migrations and successful spawning with monitored temperature manipulations. Intensive telemetry tracking data of reproductive adults (males and females) will be evaluated against time series of water temperature characteristics and will be analyzed for degree of association. Reproductive success or failure will be determined by recapturing reproductive fish soon after expected spawning events to determine if they have released gametes, and complemented by capture of free embryos. The experiment will be a series of experimental temperature manipulations, likely interspersed with and combined with flow-pulse releases over several years; the series will result in a functional relationship between water temperature characteristics and probability of producing viable gametes.

Timelines and contingencies

For the experiment to be successful there will need to be a substantial number (12 or more) of tagged, reproductive adult fish identified and tracked each experimental year in the river segments upstream from the Platte River. Assuming a minimum of 4 temperature manipulations and the risk that experimental logistics may fail 1 year in 2, at least 8 years will be necessary for this component. Success of the study will depend in part on development of passive receiver networks (Lower Big Question 1, component 1) and on maintenance of a tagged research population of reproductive fish that are not subject to being selected for use in the population augmentation program. Time for this experiment may be increased depending on how the temperature manipulations are carried out with in coordination with flow-pulse experiments. If combinations of temperature and flow pulses are considered, the number of years of experiments could extend farther in time than indicated.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to level 3. Experimental control imposed in this component will add to the ability to detect and quantify reproductive behavioral changes related to temperature manipulations; however, the experiments will still take place within a system where many sources of variability are not controlled, such as weather systems and tributary inputs. It is therefore unlikely that these experiments will result in a statistically rigorous result. Instead, a decision to accept the value of manipulated water temperatures in increasing pallid sturgeon reproductive success, or to reject it, will probably be based on judgement of multiple lines of evidence.

C.3.2.7 Critical scientific uncertainties and constraints

A critical uncertainty is whether water temperatures downstream from Gavins Point Dam have been significantly decreased due to reservoir operations, and if so, whether engineering designs are feasible to increase temperatures. Intentional field experiments will require that water temperature can be increased in an ecologically meaningful manner, probably several degrees Celsius over several hundred km of the river. In addition, comprehensive movement and location data of pallid sturgeon must be obtained in order to make valid inferences about reproductive behavior. Confounding factors that may also influence reproductive behavior, such as discharge and turbidity, must also be taken into consideration. The potential for channel reconfigurations (e.g., IRCs) to increaase water temperatures is discussed in section C.3.3.5.3.

C.3.2.8 Utility of study components

This study component will provide critical information to determine if pallid sturgeon respond to increased temperature cues that ultimately lead to successful reproduction. If temperature cues are apparent, the study component will provide guidance about temperature management and its influence on spawning behavior.

C.3.2.9 Ancillary information benefit

The results of the assessment will provide ancillary information applicable to the river system productivity and response of other organisms in the river to temperature management.

C.3.2.10 Risks

Manipulating water temperature from the dam imposes little risk except cost. Risk to pallid sturgeon is minimal as temperatures would not be increased to a level harmful to the fish. Impacts on stakeholders would be minimal because temperature increases would be in spring before other temperature constraints would apply.

C.3.2.11 Adaptive actions

Based on the results of this study component, the information would be used to optimize water temperature (and discharge) during the spring to increase reproductive success.

C.3.2.12 Estimated costs

The estimated cost of component 1 is relatively low, requiring perhaps one year of engineering modeling study. Components 2 and 3 would incur moderate costs over 2-4 years. Implementation of a field experiment would be extremely costly because of the infrastructure investment ($10's to $100's of millions) needed to increase water temperature at the river scale.

C.3.3 Lower Big Question 3: Can naturalization of the flow regime or channel reconfiguration (alone or in combination) contribute to increased food production, foraging habitat, and survival of age-0 sturgeon?

C.3.3.1 Objective of study components

This Big Question includes 4 inter-related hypotheses from the EA process. The study components are intended to provide the scientific basis for understanding how flow regime and channel reconfiguration can interact to provide food-producing and foraging habitats supportive of increased growth and survival.

C.3.3.2 Description of study components

The hypothesis states that increases in food and foraging habitats, through a combination of channel reconfiguration and flow management, will increase growth and survival of age-0 pallid sturgeon. In this context, flow naturalization refers to using elements of the natural hydrograph to design a more supportive flow regime, but one that is socially and economically acceptable. Channel reconfiguration refers to reconstruction of some combination of main-channel geometry, channel margin geometry, river-training structures, and construction of off-channel water bodies like backwaters and flow-through side channels (chutes). The underlying assumption is that

engineering latitude exists in the present channel and channel reconfigurations can be designed to be compatible with other authorized purposes.

Under these hypotheses, food-producing and foraging habitats would be developed in Interception-Rearing Complexes (IRCs) where channel geometry would create conditions conducive to secondary currents that would contribute to advection of free embryos into the complex. Study components at level 1 will focus on engineering, technology development, and field-gradient/mesocosm studies that would establish whether habitats are limiting and how habitats vary within existing IRCs. Contingent on results of level 1 components, study components at level 2 will involve design and implementation of field-scale experiments to quantify linkages from management actions to habitat availability, growth, and survival.

C.3.3.3 Relation to Effects Analysis

Study components address 4 inter-related hypotheses (12, 13, 17, and 18) of the EA. They are treated together in one Big Question because of recognition that flow regime and channel configuration interact in creating habitat, and because of the assumption that both food-producing and foraging habitats will be needed, either in close proximity or linked by transport vectors, to promote age-0 survival.

C.3.3.4 Approaches

Two levels with 6 different components could be implemented to evaluate the 4 management hypotheses. Level 1 is proposed to include methods development and engineering studies to understand spatial characteristics such as IRC size and location. Level 1 will also include screening studies to determine whether food or foraging habitats are limiting to pallid sturgeon, field-gradient studies to quantify relations between management actions (flow and form) and habitat and food availability, and mesocosm studies to attempt to develop quantitative relations between abiotic variables and growth and survival. If level 1 results are supportive, level 2 components would include design and implementation of controlled, field-scale experiments to validate quantitative relations from actions to growth and survival.

C.3.3.5 Level 1

C.3.3.5.1 Component 1

Component 1 studies are biological screening studies to determine, if possible, whether food production or foraging habitats are likely to be limiting to pallid sturgeon. These studies may be very powerful in determining whether these components of IRC are necessary to survival of the pallid sturgeon. These studies could be based on sampling a

gradient of assumed habitat quality or as a randomized design and would involve assessing age-0 sturgeon for indications of starvation or growth. Because of dietary overlap between shovelnose and pallid sturgeon at this life stage, shovelnose sturgeon may be used to some extent as a surrogate to contribute comparative information.

Metrics

The metrics for this study are indicators of starvation or impending death of age-0 sturgeon. Such indicators may be based on stomach contents (percentages of empty/full stomachs) or physiological indicators (lipid content). Because it is extremely rare to catch dead age-0 fish, these metrics are useful to characterize the surviving population but may fail to address actual mortality rates – that is, sampling will be biased toward live fish. This bias can at least be partially overcome base on the fish that are sampled. If, for example, the distribution is skewed toward the food-limited end of the spectrum, then it is likely that results are biased due to mortality of starved fish which couldn't be sampled. If, however, the distribution is skewed toward full stomachs and relatively high lipid contents then there would be no reason to believe that a significant bias exists due to presence of starved fish which could not be sampled. Because these metrics are likely to measure the net bioenergetic effects of a combination of food availability (food-producing habitat) and energy expenditures (foraging habitats), additional studies may be needed to address cause and effect.

Timelines and contingencies

These studies started in 2013 and are likely to provide results by 2017. The question of whether bioenergetic conditions are limiting to age-0 survival is fundamental to decisions to pursue further components, hence subsequent components are largely contingent on these results. Component 1 may occur simultaneously with components 2-4.

Decision criteria for application of component

Decision criteria from this component apply to the decision to move to level 2, in concert with evidence from the other level 1 components under this Big Question. Results from this component may be indicative of bioenergetic constraints, but will likely not be authoritative. Most of the age-0 sturgeon evaluated will be shovelnose, and although there is evidence to support the notion that the pallid and shovelnose diets and bioenergetic demands are very similar at this life stage, there is residual uncertainty about how well the surrogate species represents pallid sturgeon. If results indicate that age-0 sturgeon have full stomachs and

healthy lipid content, it indicates that current bioenergetic conditions are unlikely to be limiting. Nevertheless, food could become limiting under future conditions of increased population. Therefore, understanding the processes of food production, transport, and foraging would be valuable. If results indicate that stomachs are not full and/or lipid content is not healthy, it will not necessarily be clear whether this is attributable to food availability or energetic demands. Therefore, information developed in this science component may contribute to decision making, but is unlikely to be sufficient.

C.3.3.5.2 Component 2

Technology development studies will be needed to develop a) sampling technology for relating food production to pallid sturgeon growth and survival and b) modeling strategies to integrate hydrodynamic models with bioenergetics models to inform population models. The first would involve techniques for understanding age-0 diet dependence on other elements of the river's food-web. This may include detailed diet studies or stable isotope approaches to defining food sources. The second would involve developing an integrated modeling approach for calculating survival from hydrodynamic and bioenergetic inputs, including methods to trace food origin to foraging.

Concurrent with studies to quantify biological functioning of IRCs, we envision a need for development of engineering modeling studies to provide predictive understanding of effective channel geometries, river locations, and spatial extent of IRCs and how IRCs may interact with other authorized purposes.

Metrics

Metrics for this group of studies includes measures of density of food items (chironomid larvae) in prospective IRCs, and measurement and model results that indicate pathways for those food items to drift to foraging areas. Models will provide flux of food items that will then be used to parameterize bioenergetics models. Modeling will be coordinated with engineering studies which will produce optimized designs to connect food and foraging habitats in IRCs.

Timelines and contingencies

The measurements and models anticipated in this component would require 3 years for development, although some of this work is already underway. This work could proceed simultaneously with components 1, 3, and 4 to provide mutually supportive information.

Decision criteria for application of component

Results of the measurement and modeling should help in understanding of spatial relations between food and forage habitats within and among IRCs, and whether flux of food to foraging habitats is a significant factor in growth and survival. This information would inform subsequent design of IRCs and to inform sampling efforts in component 3. If measurement and modeling revealed no spatial linkage between local (bend-scale) food production and foraging locations, the concept of IRC would need to be substantially refined.

C.3.3.5.3 Component 3

The information value of this study component depends in part on support from component 1 that food, forage habitat, or both, are presently limiting survival of age-0 pallid sturgeon. The objective will be to develop quantitative links from actions (flow manipulation and channel reconfiguration) to amount and quality of food-producing and foraging habitat. The study will incorporate component 2 information to improve definition of food-producing habitats through understanding of spatial linkages and geometries. It can be pursued on a field-gradient design by evaluating food and forage habitat conditions along existing ranges of habitat conditions (flow variability and channel complexity) along the river. For food, the study would include repeated measures sampling of biota judged to be food items for larval and juvenile pallid sturgeon. For foraging habitat, the study would include habitat selection based on catch rates from trawling for age-0 sturgeon in comparison to well-characterized habitat conditions. Habitat characterization at the scale of age-0 sturgeon will be challenging and may require innovative applications of acoustic Doppler current profilers, acoustic velocity meters, and/or benthic imaging technologies to establish bioenergetic conditions experienced by age-0 fish. Co-variates such as dissolved oxygen (DO) and water temperature will be measured to address how water quality may interact with productivity and the quality of food producing habitats in IRCs. As well, it is possible IRCs will provide conditions that would increase water temperatures (increased top width, shallow depths, low velocities). Thus, IRC development may interact with the temperature hypothesis in Big Question 2.

Metrics

Habitat metrics (potential explanatory variables) will be measures of depths, velocities, and substrate, including means and variances, potentially complemented with metrics of spatial complexity, such as patch sizes and orientations. Metrics for this study would include measures of habitat selection

for food items (chironomids) and foraging (age-0 sturgeon), based habitats occupied and unoccupied.

Timelines and contingencies

The measurements and models anticipated in this component would require 4 years for development, although some of this work is already underway. This work could proceed simultaneously with components 1, 2, and 4 to provide mutually supportive information.

Decision criteria for application of component

Results of the measurement and modeling should help develop quantitative statistical associations between habitat characteristics and selection by food sources and age-0 fish. The statistical analysis is unlikely to be robust (i.e., it is likely to have relatively low confidence), and a lines-of-evidence approach may be necessary to decide on next steps. If the data indicate systematic relations, the information can be used to define mesocosm experiments in component 4 that would further refine understanding of functionality of these habitats. If the data do not indicate systematic relationships, the decision could be made, based on cumulative lines of evidence from components 1, 2, and 3, that the hypothesis that channels can be reconfigured to increase growth and survival is not supported. In this case, the concept of IRCs would need to be substantially refined or abandoned.

C.3.3.5.4 Component 4

This study component would attempt to develop quantitative relations between a range of habitat conditions identified in component 3 and quantitative productivity rates and growth and survival of pallid sturgeon, using mesocosms. This component would provide the parameter values for the integrated bioenergetic model described in component 1a.

Metrics

Habitat metrics (potential explanatory variables) will be measures of depths, velocities, and substrate, including central tendency and variance, potentially complemented with metrics of spatial complexity. Metrics for this study would be relative growth rates and survival as a function of habitat characteristics.

Timelines and contingencies

The measurements and models anticipated in this component would require 4 years for development and could be pursued concurrently with components 1, 2, and 3. It would be most effective to wait for completion of part of component 3 so the range of conditions needed in mesocosm experiments would be known and hypotheses would be rigorously formulated. The mesocosms used in this study would presumably be the same as those used in Upper Big Question 2, component 4, Upper Big Question 3, component 4a, and Upper Big Question 5, component 4.

Decision criteria for application of component

Decision criteria from this component apply to the decision to move to level 2, in concert with evidence from components 1-3. Results of the mesocosm experiments will quantify relations between abiotic variables and growth and survival. These are likely to be relations that show a peak of growth and survival at some interval, with decreasing growth/survival at higher and lower values. If growth/survival does not show a systematic relation to abiotic variables, the concept of IRCs would need to be substantially refined or abandoned. If there is a systematic relation, this would provide more support moving to level 2, and the supportive range of abiotic variables would be used to design field experiments in components 5 and 6.

C.3.3.5.5 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement across component 1-4 results that there is or is not a systematic relation between channel reconfigurations to build IRCs and increases in growth and survival of age-0 sturgeon. The judgement should be based on the strength and replicability of relations between abiotic habitat variables describing food and forage habitats, and growth and survival of age-0 sturgeon. In addition, movement to level 2 should be contingent on development of design parameters for IRC experiments in component 6.

C.3.3.6 Level 2

C.3.3.6.1 Component 5

Components 5 and 6 be related to the type and quality of information provided from previous components; however, because existing shallow-water habitat projects can be used for the experimental structure, components 5 and 6 may proceed effectively in

parallel with level 1 components. The objective of component 5 will be to use habitat information gleaned from the gradient studies (components 3, 4) and supporting quantitative data from component 5, to design IRC configurations for field experiments. This component would make use of the integrative hydrodynamic-bioenergetic model to test alternative channel designs and flow regimes for the ability to provide effective amounts of both food-producing and foraging habitats. It will be an iterative design process varying channel width and wing-dike characteristics

Metrics

Metrics for this component will be relative performance of designs, measured as areas of functional habitat, using linked hydraulic and biological models.

Timelines and contingencies

We recognize benefits could accrue from starting this component early, especially if some aspects of the field experimentation are expected to have long time lags associated with them and experimental units already exist. The staging scenario (Appendix F) indicates 6 years for this component from recognition that designs for IRC complexes may be developed in the near term under existing shallow water habitat projects, and that the geomorphic form of the complexes may take several years to reach an equilibrium.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to continue with IRC experiments in component 6. That decision will be based on lines of evidence from components 1-4 and success in developing designs in component 6. The decision to proceed with component 6 would be based on the demonstrated ability to increase those habitat components that have been shown to increase growth and survival of age-0 sturgeon, and to do so without unacceptable risk to other authorized purposes.

C.3.3.6.2 Component 6

The objective of component 6 will be to evaluate the functions of food-producing and foraging habitats under controlled, experimental conditions. A control-impact (CI) sample design comparing a channelized reach to one or more levels of experimentally reconfigured IRCs would provide evaluation of the functional response of habitats to reconfiguration. A before-after-control-impact (BACI) design would provide additional confidence because it would establish the spatial variability among treatments; time-variant implementations of IRCs can be evaluated in a staircase design as documented

in Appendix E. Responses can be measured in terms of hydraulic conditions, functional habitat area, and food production; response in terms of growth and survival would need to be calculated from mesocosm results. The role of flow manipulations can be evaluated based on measured variation from year to year and/or through hydrodynamic modeling of a flow time series through the IRCs.

Metrics

The study design will incorporate a gradient of IRCs with varying amounts of channel reconfiguration and varying amounts of flow regime naturalization. Because growth and survival cannot be measured reliably under field conditions, the metrics will need to be indirect and may include area of food-producing habitat, area of foraging habitat, catch per unit effort of age-0 sturgeon, stomach contents, and lipid content.

Timelines and contingencies

This component is expected to take 5 years to complete. It is contingent on some progress under component 5. Habitat quality and quantity in experimental IRCs will vary with both channel configuration and hydrologic characteristics. Therefore, the experimental design should include a range of channel reconfigurations as well as a range of flow naturalization; flow naturalization may be provided, in part, through utilization of reaches downstream of the Platte River where unregulated tributary influence increases flow variability. This component has a high degree of interaction with science components or implementations that alter the flow and temperature regimes (e.g., components under Lower Big Questions 1, 2, and 4).

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move forward to level 3 implementation. Statistical relations are likely to have high uncertainty, and the decision may therefore require a judgement based on lines-of-evidence presented in components 1-6. If experimental results in component 6 fail to support systematic increase in habitat and fish condition, then the hypothesis may need to be refined or abandoned. If the experimental results support the hypothesis that channel reconfigurations can provide increased food-producing and foraging functional habitats, then the decision would be to move toward level 3 implementation.

C.3.3.7 Critical scientific uncertainties and constraints

Critical scientific uncertainties include the food base for age-0 exogenously feeding pallid sturgeon, and relation of that food base to habitat conditions in IRCs. Additional critical uncertainty relates to foraging behaviors of age-0 sturgeon and the extent to which foraging habitat can be measured and modeled at appropriate scale. Finally, the linkage from habitat variables to survival is critical to link management actions to population-level responses; it is unlikely that this linkage will be measurable in the field and so inferences will need to be borrowed from laboratory and mesocosm results.

C.3.3.8 Utility of study components

These study components will provide scientific information bearing on whether flow manipulation, channel reconfiguration, or a combination of the two, will be effective in increasing survival and recruitment of age-0 pallid sturgeon. If successful, the study components will provide functional relations indicating how much habitat and what proportions are needed to increase survival, and the tradeoff between flow management and channel reconfiguration in achieving increased survival.

C.3.3.9 Risks

Level 1 components present little risk to stakeholders, authorized purposes, or pallid sturgeon. At level 2, field experimentation would require flow manipulations and/or channel reconfigurations that could be perceived as risks to flood control, power generation, water supply, navigation, and floodplain farming. An underlying assumption is that channel reconfigurations for IRCs will not interfere with other authorized purposes.

C.3.3.10 Adaptive actions

The results of these will have a bearing on decisions regarding extent of flow-management at Gavins Point Dam and extent and nature of channel reconfiguration on the Lower Missouri River.

C.3.3.11 Estimated costs

Estimated costs of level 1 components are relatively small. Field-gradient studies will rely on existing gradients of flow regime and channel reconfigurations. Mesocosm studies may require some investment in laboratory facilities to provide ecologically meaningful conditions, but much of the culture and laboratory investment already exists and the same mesocosm facilities can be used for multiple science components. Level 2 studies with field experiments will be more costly, and may involve substantial

investments in land and construction although the experiments could capitalize to some extent on the significant investments in shallow-water habitat that have already been made.

C.3.4 Lower Big Question 4: Can naturalization of the flow regime or channel reconfiguration (alone or in combination) contribute to decreased direct mortality and increased interception of free embryos into supporting habitats?

C.3.4.1 Objective of study components

The objective of these study components are to understand the role of flow regime and channel configuration in mediating drift, dispersal, and survival of pallid sturgeon free embryos. The information developed in these components is intended to help in management decisions that will increase survival of free embryos to exogenously feeding larvae.

C.3.4.2 Description of study components

Early pallid sturgeon life stages are believed to be dependent on downstream transport. Once hatched, free embryos are transported downstream as they derive nutrition from a yolk sac. After 9-15 days of drift and ontogenetic development, free embryos transition to benthic orientation ("settling") and must begin feeding. The ultimate fate of embryos in terms of river location and habitat is dependent on spawning location and instream conditions. For example, embryos fertilized in the upper reaches of the Lower Missouri River can be transported 100's of km downstream. These study components are intended to answer decision-critical questions about how flow regime (and resultant velocities) and channel configuration (and resultant hydraulic complexity) may be manipulated to increase survival of free embryos. Channel reconfiguration refers to reconstruction of some combination of main channel geometry, channel margin geometry, river-training structures, and construction of off-channel water bodies like backwaters and flow-through side channels (chutes). The underlying assumption is that engineering latitude exists in the present channel and channel reconfigurations can be designed to be compatible with other authorized purposes.

C.3.4.3 Relation to Effects Analysis

This Big Question encompasses two related hypotheses from the EA (14, 19). The first states that the flow regime at Gavins Point Dam may be optimized to decrease velocities, decrease effective drift distance, and potentially minimize direct mortality of free embryos. Our present emphasis is on minimizing direct mortality, because there is no evidence to support the idea that increased drift distance (e.g., into the Middle Mississippi River) by itself would lower survival. On the other hand, it has been

hypothesized that increased turbulent energy associated with high discharges from dam releases could directly damage fragile free embryos at very early stages. The second hypothesis holds that reconfiguring channel morphology in selected reaches will increase channel complexity that will serve to intercept and retain drifting free embryos in areas with supporting habitats. This so called interception habitat is a critical part of IRCs and will therefore be addressed in part in close coordination with Big Question 3.

C.3.4.4 Approaches

These components are a suite of studies intended to elucidate fundamental controls and biology of drift, dispersal, and retention of free embryos. Level 1 components include technology studies to develop necessary tracking and sampling tools, engineering studies to define designs of interception habitats, and field and laboratory based studies to provide scientific context. Level 2 components include experimental flow releases and channel reconfigurations intended to test the efficacy of those actions in increasing free embryo survival.

C.3.4.5 Level 1

C.3.4.5.1 Component 1

The primary objective of this study is to determine whether surrogate particles can be used for tracking and predicting movement in a large riverine system. The first issue to address is whether virtual, physical, or mechanical surrogates perform similarly to biological counterparts. Large flume studies, replicate streams, and field trials can be used to compare the performance of proposed surrogates to biological counterparts.

The study element will be addressed through technological development and research of virtual, physical, mechanical, and biology surrogates for early pallid sturgeon life stages. Virtual particles can be used within existing hydrological models (2-d, 3-d) to model the transport and fate of virtual particles in riverine systems like the Missouri River. Physical surrogates may be developed as positively, neutrally, or negatively buoyant particles. Mechanical particles may take the form of some sort of developed particle that may be tracked in real time or provide some sensor for retrieval. Biological surrogates may use marked propagated fish. Marking may be chemical, such as oxytetracycline, genetic, or physical, such as coded wire tags such that the origin of recaptured fish can be determined. These 4 approaches provide potential methods to ascertain the transport and fate of particles in a large riverine system.

Metrics

Metrics for this study component will include recovery rate of marked particles used in tracer studies and measures of strength of prediction for particle fate (1-d and 1-2 models compared to field tests), including particle residence time in the main channel and adjacent habitats.

Timelines and contingencies

This component is expected to take 4 years to complete; because part of this work is already underway it could be completed by 2017. Because the component addresses the interception part of the IRC concept, it is highly interdependent with emerging information on IRC habitat (food-producing and foraging), and this component could therefore be tightly coordinated with Lower Big Question 3, component 2, 3, 5, and 6. This component may occur with substantial overlap with components 1-6.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to use the technology in related studies. If methods cannot be developed that provide strong inference on transport pathways, the decision may be made to delay additional components until satisfactory detection technology has been developed.

C.3.4.5.2 Component 2

The objective of this screening component is to characterize how resilient pallid sturgeon free embryos are to hydraulic conditions, particularly turbulent energy. If embryos are fragile, flow modifications, such as increased flow during spawning periods may increase embryo mortality. If embryos are found to be susceptible to mortality due to physical disturbance imparted by velocity or turbulence, flow regimes may be modified to minimize embryo mortality.

The study element may be addressed experimentally in circular or racetrack flumes where a range of flow and substrate, and resulting turbulence and shear conditions can be evaluated. Using this approach, embryos will be introduced into pond or flume systems for a range of flow velocities and substrates (e.g., sand, gravel, organic). Fragility, which is related to survival, will be estimated as the number of embryos introduced to the experiment and the number of living free embryos produced. The effect of flow and substrate can then be compared to the survival or free embryo production from a negative control. This type of experiment can be analyzed using a generalized linear model assuming a binomial response. Effects observed in the

laboratory will be interpreted in the context of known velocities and turbulent intensities in the Missouri River.

Metrics

Metrics for this component will be survival of free embryos related to measures of fluid stress, including velocity distributions, turbulent intensity, and shear.

Timelines and contingencies

This component addresses the subhypothesis that free embryos are too fragile to survive the turbulent, fast flow in the Missouri River. It is not contingent on other components in this Big Question, but may have implications for understanding of limiting conditions being addressed by other components. The laboratory studies are expected to require 2 years, assuming availability of free embryos. This component is staged at the same time in parallel with other components. The mesocosms used in this study will be optimized for early stage free embryos (0-4 dph) and therefore will not be the same as mesocosms used for late-stage free embryos and exogenously feeding larvae (Lower Big Question 3 components).

Decision criteria for implementation of component

Information from this component will be used to inform decisions and science components whether actions to naturalize the flow regime from Gavins Point Dam and/or channel reconfigurations would contribute to increased survival. If survival is sensitive to the range of velocities, turbulence, or shear prevailing in the river during dispersal, then this would provide evidence to support pursuing level 2 science components to address how flow and channel form could be manipulated to increase survival. Because we do not believe it will be feasible to actually measure free-embryo survival under Missouri River field conditions, decisions about implementation may need to be made largely from inference from laboratory results in this component.

C.3.4.5.3 Component 3

The objective of this component is to document conditions under which free embryos would fail to exit the thalweg and therefore starve. Testing of this hypothesis with free embryos might be impossible, as it would require tracking free embryos through starvation in the thalweg. However, physical surrogates (beads, dye) or computational particle tracking may provide useful indicators. Assuming that a well-calibrated particle-tracking model can be developed (component 1) that accurately depicts free

embryo transport and retention, a computational model could be used to evaluate a wide range of flow and channel morphology conditions under which retention succeeds or fails.

Metrics

Metrics for this component will be proportion of surrogate particles (real or computational) that exit the thalweg and are retained in IRCs under various channel geometries.

Timelines and contingencies

This component addresses the specific hydraulics affecting free embryo exit from the thalweg and is therefore highly interdependent with methods developed in component 1 and with emerging information on IRC habitat (food-producing and foraging). It could occur in parallel with components 1, 2, 4, 5 and 6, and may also be concurrent with level 1 IRC studies under Lower Big Question 3. This component start as early as 2017), overlapping with component 1 for one year) and ending after 3 years of directed study.

Decision criteria for application of component

Information from this component will be used to inform decisions and science components about whether actions to naturalize the flow regime from Gavins Point Dam and/or channel reconfigurations would contribute to increased advection of free embryos into IRCs. If advection of surrogate or digital particles varies substantially with discharge or channel configuration, then results could inform a decision to move ahead with implementation of field experiments at level 2. Results are likely to have substantial statistical uncertainty and application will likely require a judgement based on multiple lines of evidence.

C.3.4.5.4 Component 4

This component is an exploratory, field-gradient based study that will sample age-0 occurrence (e.g., catch per unit effort) from systematic sampling along a gradient of channel complexity. Relative catch of age-0 sturgeon will be compared to indices or measurements of channel complexity that should be related to interception mechanics and flow variation. The results will help narrow the definition of interception habitats and will serve to focus hypotheses regarding channel configurations that are amenable to interception and retention of free embryos.

Metrics

This component is complementary to Lower Big Question 3 component 3 and could make use of the same field-gradient sampling design. The difference is that candidate explanatory variables would focus on measures of channel complexity relevant to interception hydraulics, and sampling would attempt to evaluate the flux of free embryos from the thalweg. The fundamental metric, therefore, will be a catch per unit effort, but established from ichthyoplankton net sampling arranged to evaluate transport into IRCs.

Timelines and contingencies

This component could occur in parallel with components 1, 2, 3, 5 and 6, and could also be concurrent with level 1 IRC studies under Lower Big Question 3. The component would require 4 years of study.

Decision criteria for implementation of component

A field gradient study on free embryo transport paths is likely to lead to results with relatively high statistical uncertainty. The information developed will likely be used in a judgement based on multiple lines-of-evidence about whether to proceed with manipulated field experiments at level 2. The decisions would be informed by the strength of association between advection metrics and channel configuration options.

C.3.4.5.5 Component 5

A fundamental question for pallid sturgeon recovery in the Missouri River is what proportion of free embryos hatched in the Missouri River may disperse and recruit in the Mississippi River. This study component will be addressed through monitoring of young fish in the Lower Missouri River and Middle Mississippi River. Specifically, marked hatchery-origin fish will be stocked into the system and then recaptured over time. Marking of early life stages will be a significant challenge, however oxytetracycline, genetic, coded wire tag, and genetics have all been used to mark small fish. Monitoring efforts to recapture these fish will occur repeatedly over the study period. A Cormack Jolly Seber (CJS) model will then be used to estimate apparent survival using the multiple recapture occasions; this effort would proceed efficiently as part of the population monitoring plan (see Appendix D). Because there are discrete life stages, the CJS model may include a multistate model where the transition of pallid sturgeon from one stage to another (e.g., free embryo to exogenously feeding larvae) can be estimated conditional on the fish surviving to transition. Data of this nature can be

fit using traditional mark recapture software such as Program MARK and hierarchical Bayesian approaches can provide increased flexibility.

Metrics

The main metrics for this component are estimates of the number and survival rates for pallid sturgeon produced in the hatchery and released into the Missouri River that end up in the Mississippi River, relative to the number that remain and survive in the Missouri River, during the age-0 to juvenile-age interval. Micro-chemistry analysis to assess study fish duration of presence in each river would support study goals for this component.

Timelines and contingencies

This component depends on having sufficient age-0 fish from hatcheries and concurrence from the USFWS that stocking of these fish would align with stocking goals and genetics objectives of the propagation plan. It would occur in parallel with components 1, 2, 3, 4 and 6, and also be concurrent with level 1 IRC studies under Lower Big Question 3. The results would provide important context for both Lower Big Question 3 and 4 as it would indicate the extent to which free embryos and later stages may bypass IRCs constructed on the Missouri River. Moreover, if recruitment is sufficient on the Mississippi River to sustain the population, this science component would provide information fundamental to management decisions on the Missouri River. The technical approach to this question – a mark/recapture – would be most efficient if coordinated with the population trends monitoring described in Appendix D. Understanding of the significance of recruitment in the Mississippi River will require comparison to similar population trends data for the Missouri.

We estimate that 6 years of sampling would be necessary to provide useful data, assuming that stocking of marked age-0 is sustained and genetic and micro-chemistry techniques would allow for discrimination of Missouri River, wild-produced fish.

Decision criteria for application of component

Information developed in this component could be fundamental to multiple decisions. If the population recruiting in the Mississippi River is high enough to sustain the population – by reference to applicable population models –there may be implications for the species recovery strategy, and potentially the understanding of what constitutes jeopardy on the Missouri River. If survival

and recruitment in the Mississippi River are zero or insufficient to sustain the population, this information may be used to justify increased effort to intercept free embryos in the Missouri River. Survival and recruitment estimates from the mark/recapture approach are likely to have wide confidence intervals, so that decisions will likely require multiple lines of evidence.

C.3.4.5.6 Component 6

The objective of this component is to validate, in the field, the outputs of 1- and 2-d drift models to determine dispersal and retention of drifting pallid sturgeon. The study will use experimental tracking of free embryos and/or other tracers introduced under existing hydrologic and morphologic conditions. Results and predicted patterns generated from 1- and 2-d drift models will be compared to experimental patterns observed in the Lower Missouri River. This can be done by predicting patterns of distribution and retention for a reach on the Lower Missouri River. Then pallid sturgeon free embryos or surrogates can be introduced there during a period with similar flow conditions as modeled. Once drifting particles are introduced, field crews can sample downstream locations to document a pattern of dispersion and interception. This sampling should occur in areas of high drifting particle abundance identified by simulations, but also areas of low or no particle abundance to verify model predictions. Tracer sampling will be coordinated with detailed hydraulic data collection (by boat-mounted acoustic Doppler current profilers) to provide independent estimates of advection/dispersion model parameters. These field experiments will be conducted for the range of flows that pallid sturgeon free embryos can be expected to experience to ensure the 1- and 2-d drift models adequately predict dispersion and interception for a range of conditions.

This component is very similar to manipulated field experiments envisioned in components 7, 8, and 9, but will rely on opportunistic flows and existing channel configurations rather than instituting specific, more-controlled experiments. These experiments also have elements in common with drift/dispersal experiments in the upper river. Tracer methods and modeling developed for the upper river, in particular, will contribute to efficiencies in the lower river.

Metrics

Key metrics for this component will be the distributions of free embryos or other tracers, over time and space, as the constituents disperse downstream as a function of discharge and interception efficiency. From the distributions, mean constituent velocity, range of velocities, and fate (range of river miles at a specific developmental stage) can be evaluated. In the opportunistic context of this

component, these metrics will be compared to prevailing discharges and current velocities, and related to the types of channel configurations that the particles encounter. Longitudinal dispersion coefficients will be calculated from the ADCP measurements and compared to tracer distributions to help in calibration and validation of 1-d advection/dispersion models.

Timelines and contingencies

Success of this component would be improved by methods developed in component 1, and on supporting information developed in components 3 and 4. In a parallel staging, these components could operate with considerable overlap. Experimental design for this study would also benefit from results of free-embryo drift experiments in the upper river (Upper Big Question 5, component 3. Use of free embryos as tracers will require sufficient production from hatcheries and sufficient confidence that these fish could be lost from the population-augmentation process, or would not unbalance genetics of the population.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move forward with level 2. Results from this component will contribute substantially to decisions to move forward with field experiments, both for the value of experiments and for specific design parameters. The results from this component are likely to have considerable statistical uncertainty but will be useful for decision making when combined with mutually supportive information from components 1-5 and results from Lower Big Question 3, level 1 components. The results will also serve to test validity of 1-dimensional advection/dispersion models for application to understanding dispersal and management options. In the case of the advection/dispersion models, results may well be amenable to statistical tests of how well models represent reality.

C.3.4.5.7 Criteria to move to level 2

The decision to move to field experiments under level 2 will be based on the lines-of-evidence judgement that there are (or are not) systematic relations between flows and channel reconfigurations and increases in retention of free embryos in supportive IRC habitats. The judgement should be based on the strength and replicability of relations between abiotic habitat variables describing drift behaviors/retention, and growth and measured retention of free embryos (or surrogate tracers) in IRCs. Results from component 5 – transport to the Mississippi River --may also have a bearing on moving to field experimentation. If linkages from stocking or wild production on the Missouri

River to recruitment on the Mississippi River are documented, it might be argued that retention in the Missouri River is not needed or useful to the population, and therefore the action hypothesis could be dropped and level 2 experimentation would not be necessary.

C.3.4.6 Level 2

C.3.4.6.1 Component 7

Field experimentation to elucidate drift/retention/survival dynamics will require a preliminary step of engineering studies for site-specific design and test of IRC concepts. Designs will explore range of options available in channel reconfigurations while maintaining other authorized purposes, principally navigation and flood control. The objective of these studies will be to use computational models to explore hydraulic geometries that will contribute to interception of free embryos (through increased secondary currents) while minimizing other effects. The study component will be based on information gathered from previous level 1 components. That is, once optimal flows and channel configuration criteria are established to intercept and retain free embryos, engineers can use that information to develop in-stream designs for habitat and in-channel structure or modification that meet interception and retention habitat objectives. To provide the best foundation for field experimentation, designs would ideally include a range of interception efficiencies.

Metrics

Results from this component will be a range of designs that meet practical hydraulic needs of the Missouri River channel and contribute to interception/retention of drifting free embryos. Metrics would be similar to those listed in Level 1 Components 5 and 6. Relative cost would also be a relevant metric.

Timelines and contingencies

Benefits may be recognized from starting this component early, especially if some aspects of the field experimentation are expected to have long time lags associated with them. The staging scenario (Appendix F) indicates 6 years for this component from recognition that designs for IRC complexes may be developed in the near term with existing shallow water habitat projects; geomorphic form of the complexes may take several years to reach equilibrium.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move to manipulative experiments in components 8 and 9. That decision will be based on lines of evidence that the designs will provide information needed to assess the contribution of the IRCs to growth and survival of age-0 pallid sturgeon, and will do so while minimizing effects to other authorized purposes.

C.3.4.6.2 Component 8

The first set of field experiments related to drift will incorporate tracer releases with manipulated flows from Gavins Point Dam to validate modeled relations between discharge and advection/dispersion. Pallid sturgeon free embryos or surrogates will be introduced into the Lower Missouri River at varying flows. Downstream interception habitats will then be monitored for these released pallid sturgeon or surrogates to evaluate whether interception is occurring. This will be done for varying flows out of Gavins Point such that the optimal flow can be identified; assuming flow is related to the likelihood of interception. This study can occur over the year if suitable pallid sturgeon surrogates can be used, or during the period of year that sufficient free embryo life stages are available from conservation hatchery operations. Analysis will focus on relating the proportion of free embryos intercepted as it relates to flow, which can be evaluated using a generalized linear model assuming a binomial distribution. However, imperfect sampling will underestimate the proportion of free embryos intercepted, and therefore hierarchical Bayesian approaches will likely be necessary to estimate capture probability and interception probability. These two probabilities, while confounded can be estimated if replicate sampling in time or space is used. Tracer sampling will be coordinated with detailed hydraulic data collection (by boat-mounted acoustic Doppler current profilers) to provide independent estimates of advection/dispersion model parameters. Because control over flows decreases downstream, most of the assessment will in the Gavins, Big Sioux, and Platte segments of the river. Channel configuration will be a necessary covariate for the experiments.

Metrics

The fundamental metric for this component will be the proportion of free embryos intercepted and retained. Additional metrics will include the distributions of free embryos or other tracers, over time and space, as the constituents disperse downstream. From the distributions, mean constituent velocity, range of velocities, and fate (range of river miles at a specific developmental stage) can be evaluated. In the experimental context of this component, these metrics will be compared to a series of flow releases and

resultant current velocities, and related to the types of channel configurations that the tracers encounter. Longitudinal dispersion coefficients will be calculated from the ADCP measurements and compared to tracer distributions to help in calibration and validation of 1-d advection/dispersion models.

Timelines and contingencies

Success of this component will be increased with the information provided in components 1, 3, 4, 6, and 7. It will occur after component 7, and be conducted concurrently with component 9. It is likely that flows explored in this component will interact with flows envisioned for experiments in Lower Big Questions 1 and 2; the experiments may be designed to complement one another in a naturalized flow regime, or may instead need to occur in separate years to avoid confusion. The experiment should clearly occur after the design phase (component 7). The series of experiments is estimated to take 7 years as a minimum, to allow for a range of 4 treatments, some replication, and the logistical challenges of experimentation within a highly dynamic hydrologic system.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move forward with level 3 implementation, considering results from both components 8 and 9. The results of this component are expected to document sensitivity of drift and retention to manipulated flows. The science will inform decisions about how much retention and survival are likely to be affected by flow releases, with channel configuration as a necessary covariate. For the physical results (tracer distributions) the results may attain statistical rigor, but there will be substantial residual uncertainty about how physical results can be linked to pallid sturgeon survival and growth. Therefore, criteria for implementation of results from these experiments may need to be based on multiple lines of evidence.

C.3.4.6.3 Component 9

This study component will evaluate proposed engineering designs for instream modifications of channel and habitat as a field experiment. Similar to component 8, free embryos or surrogates will be introduced upstream of restoration projects. The number of free embryos intercepted and retained in the new habitat will be quantified and the proportion of fish intercepted and retained will be evaluated using a generalized linear model assuming a binomial distribution. Accurate and precise estimates of the number of free embryos intercepted and retained will be challenging, especially given imperfect capture. Therefore unless numbers are adjusted for imperfect capture, the estimated

proportion will be underestimated. Ideally, a range of interception geometries will be used for multiple experiments so varying geometry can be tested. Tracer tests will be most useful if accompanied by computational particle-tracking models that will serve as explicit hypotheses of particle movement and will aid in sample design. This component is interactive with component 8. In order to understand separate and combined effects of flow regime and channel configuration, the experimental design will include a range of configurations in the Platte Segment and a range of configuration sin the Grand Segment. It is anticipated that over the 7 years of experiment, there will be opportunity for both replication and a wide range of hydrologic conditions using this upstream/downstream comparative approach.

Metrics

The fundamental metric for this component will be the proportion of free embryos intercepted and retained. Additional metrics will include the distributions of free embryos or other tracers, over time and space, as the constituents disperse downstream. From the distributions, mean constituent velocity, range of velocities, and fate (range of river miles at a specific developmental stage) can be evaluated. In the experimental context of this component, these metrics will be compared to a series of flow releases and resultant current velocities, and related to the types of channel configurations that the tracers encounter. Longitudinal dispersion coefficients will be calculated from the ADCP measurements and compared to tracer distributions to help in calibration and validation of 1-d advection/dispersion models.

Timelines and contingencies

Success of this component will be increased with the information provided in components 1, 3, 4, 6, and 7. It is likely that flows explored in this component will interact with flows envisioned for experiments in Lower Big Questions 1 and 2; the experiments may be designed to complement one another in a naturalized flow regime, or may instead need to occur in separate years to avoid confusion. These experiments would occur after the design phase (component 7) and concurrent with component 8. The series of experiments is estimated to take 7 years as a minimum, to allow for a range of 4 treatments, some replication, and the logistical challenges of experimentation within a highly dynamic hydrologic system.

Decision criteria for application of component

Decision criteria at this stage apply to the decision to move forward with level 3 implementation, considering results from both components 8 and 9. The results of this component are expected to document sensitivity of drift and retention to manipulated channel configuration. The science will inform decisions about how much retention and survival are likely to be affected by channel configuration, with flow regime as a necessary covariate. For the physical results (tracer distributions) the results may attain statistical rigor, but there will be substantial residual uncertainty about how physical results can be linked to pallid sturgeon survival and growth. Therefore, criteria for implementation of results from these experiments may need to be based on multiple lines of evidence.

C.3.4.7 Critical uncertainties and constraints

Critical uncertainties include the extent to which dispersal of free embryos deviates from the assumption of passive transport. To the extent that free embryos have the facility to move vertically and horizontally in the water column in the highly turbulent Lower Missouri River, fundamental assumptions of advection/dispersion and particle-tracking models may be violated. Additionally, locomotor capacity may not be static, but improving along an age gradient (scaled to days or hours) as embryos develop (whether in dispersion or retention status); calibrating models to account for continually improving locomotor capacity may significantly improve output. Studies proposed here are intended to test model assumptions with biological data when possible. Other authorized purposes and land availability may be constraints for implementation of field experiments.

C.3.4.8 Utility of study components

These study components are essential for developing understanding of controls on free embryo dispersal, how to increase retention in supportive habitats, and how to improve simple advection/dispersion models. Results may relate to mortality – direct through damaging turbulence and indirect through starvation – and will also be applicable to regional planning and design of IRCs.

C.3.4.9 Risks

Level 1 components involve little risk until free embryos are used in experiments. Experimental seeding of free embryos promises to provide the most realistic information on transport and fate, but puts those free embryos at risk because they will be stocked at a very early age (~ day 1). Parentage will need to be well documented so future collections can be used to assess survival and so that genetic diversity is not

compromised. Level 2 components include similar risks to free embryos stocks and general risks to other authorized purposes associated with flow manipulations as well as some minimal risks to navigation and floodplain development from construction.

C.3.4.10 Adaptive actions

Quantitative hydraulic information that can be associated with increased retention (and probably survival) of free embryos can be used to design interception components of additional IRCs and can be used to extrapolate retention through other parts of the river system. Understanding of relations between discharge, velocity, and advection of free embryos can be used to tailor flow management and channel geometry to promote retention of free embryos in particular parts of the Lower Missouri River system.

C.3.4.11 Estimated costs

Because field-based particle tracking studies are complex, the costs will be substantive. Costs of field experiments will be high, but costs will be shared with field experimentation for food-producing and foraging habitats.

C.3.5 Lower Big Question 5: Can channel reconfiguration and spawning substrate construction increase probability of survival through fertilization, incubation, and hatch?

C.3.5.1 Objective of study components

While numerous spawning areas have been documented in the Lower Missouri River, the functionality of the spawning locations have been questioned, leading to the action hypothesis that improved spawning habitat will result in increased probability of recruitment. It has been suggested that the distribution and characteristics of existing spawning sites may not provide the properties needed for the successful aggregation of reproductive pallid sturgeon, gamete release, fertilization, egg adhesion, incubation and/or hatch. At present, a comprehensive understanding of the habitat conditions which promote successful spawning on the Lower Missouri River has not been determined. This information is vital to validating or refuting the hypothesis that survival probability through hatch will increase with improved channel reconfiguration and spawning substrate.

Channel reconfiguration or re-engineering is used in the Big Question to mean construction of patches of habitat that meet hydraulic and substrate requirements for successful spawning. The patches are anticipated to be relatively small and we believe they would have minimal effect on channel geometry, although designs have not yet

been validated. The underlying assumption is that the designs will minimize conflict with authorized purposes.

The objective of these study components is to determine whether spawning habitat is limiting to pallid sturgeon population growth, and if so, determine ways to improve functioning of the habitat to increase probability of producing viable gametes to the extent that positive population growth results.

C.3.5.2 Description of study components

Three study components are presented at level 1 and two at level 2. Level 1 components seek to understand Lower Missouri River spawning needs through evaluation of successful spawning locations on the Yellowstone River and understanding the biological response and mechanics of spawning under current and potential future habitat conditions. Level 2 elements build upon the knowledge gained during level 1 by implementing pilot spawning habitat restoration and evaluating resulting spawning with detailed microhabitat analyses of river dynamics effects on developing eggs. By understanding habitat and biological factors, these study elements will inform design of the hydraulics, geometry, and substrate which are supportive of spawning on the Lower Missouri River. Such an optimized spawning habitat is expected to provide environments for successful adult aggregation, fertilization of gametes, egg adhesion, embryo incubation and hatch of viable free embryos thereby increasing probability of survival.

A corollary hypothesis that extends beyond specific properties of spawning habitat is that existing habitats selected by pallid sturgeon for spawning are suboptimal and not sufficiently attractive (or rare) to attract aggregations of reproductive fish. This hypothesis recognizes the social aspect of spawning and that functional spawning may require aggregations of multiple prospective mates. If this hypothesis holds, managed spawning habitat may need to satisfy biological functions to support incubation and hatch, but may also need to have characteristics that would attract fish to it in preference over abundant, poorly functioning habitats on outside revetted bends. If constructed spawning habitat is not sufficiently attractive, purposeful degradation of alternative habitats may be necessary.

C.3.5.3 Relation to Effects Analysis

These study components provide information to support EA hypothesis 16: Re-engineering of channel morphology in selected reaches will create optimal spawning conditions -- substrate, hydraulics, and geometry -- to increase probability of successful spawning, fertilization, embryo incubation, and hatch.

C.3.5.4 Approaches

Approaches to these study components at level 1 include engineering studies to evaluate what is possible in the Lower Missouri River navigation channel, field-based screening studies to confirm whether spawning habitat is limiting, field-gradient studies to learn what abiotic factors are most directly associated with successful spawning, and laboratory studies. Laboratory studies are needed to establish fundamental biomechanics of egg release, fertilization, adhesion, hatch, and initial drift behaviors; mesocosm studies may provide for controlled experiments of adult reproductive responses to spawning habitat characteristics. At level 2, components would include site-specific engineering studies of design and construction techniques for spawning habitat, and field-scale experiments that will quantify effectiveness of restored spawning habitats.

C.3.5.5 Level 1

C.3.5.5.1 Component 1

This component will map and evaluate the documented spawning habitat from the natural reference condition on the Lower Yellowstone River. Quantitative assessment of these spawning patches will be used to develop engineering design parameters for construction of optimized spawning patches on the Lower Missouri River.

This study element will build upon previous bathymetric, sidescan sonar mapping and substrate sampling and imaging of the Lower Yellowstone River spawning patches. Radio telemetry and 3-d tracking of acoustic telemetry tags will be utilized to track reproductive pallid sturgeon to persistently used spawning patches at Yellowstone river miles 4.5-7.5 (Fairview reach). Upon initiation of spawning behaviors, previous techniques – complemented with new technologies (dual-scale submersible benthic imaging system) -- be employed allowing for habitat mapping and fine-scale sediment evaluation throughout the spawning event, incubation period, and hatch.

Metrics

The metrics developed in this component will be design parameters for spawning habitat based on assessment of habitat selection in the Fairview reach. The specified metrics will be combinations of depth, velocity, or substrate, and possibly derivatives such as shear velocity or basal shear stress. Habitat stability – measured as bed mobility -- will be evaluated as an additional metric.

Timelines and contingencies

This component is already underway and is expected to require until 2017 to have well-documented design parameters. Completion of this component is contingent on availability of telemetry-tagged, reproductive males and females in the Upper Missouri/Lower Yellowstone segments. The component will be most useful in comparison to conditions documented in component 2, and will proceed concurrently with components 2 and 3.

Decision criteria for application of component

The relevant decision from this component is whether to use results from the reference condition in design of mesocosm experiments, and eventually field-scale experiments, based on the results of this work and comparative information from components 2 and 3. The habitat selection information from the Fairview reach is likely to be indicative, but not statistically rigorous, and may therefore need to be combined with other lines of evidence. The decision will be informed by the strength of spawning habitat selection documented at Fairview, the ability to replicate results within and among years, the degree of contrast with Lower Missouri River results (component 2), and the concordance of results with spawning habitats quantified for other sturgeon species.

C.3.5.5.2 Component 2

This study component is a field-gradient study to document reproductive response of adults and gametes to the range of habitat conditions existing on the Lower Missouri River. Evaluations will help determine which spawning habitat characteristics are lacking and limiting relative to the natural reference condition on the Yellowstone River. Similar imaging and hydroacoustic technologies to that used in component 1 (submersible benthic imaging system, side scan, ADCP, multibeam bathymetry) will be optimized to observe and characterize *in situ* pallid spawning behavior from gamete release to hatch. This scale of measurement presents a significant challenge that may require development of new technology to evaluate spawning mechanics at the scale needed to verify which spawning sites are not functional. The study component will use tracking of telemetry tagged, reproductive fish to increase understanding of where and when spawning occurs under current conditions on the Lower Missouri River.

Metrics

The metrics developed in this component will be similar to the design parameters for spawning habitat based on assessment of habitat selection in the Fairview reach, but will expand to include metrics for reproductive behaviors and

spawning success. The specified metrics will be combinations of depth, velocity, or substrate, and possibly derivatives such as shear velocity or basal shear stress. Habitat stability – measured as bed mobility -- will be evaluated as an additional metric.

Timelines and contingencies

Although this component is under way since 2013, we anticipate it will require until 2017 to have well-documented habitat selection on the Lower Missouri River. This due to the need to establish new methods to evaluate substrate at > 6 m depth and at velocities in excess of 2.5 m/s. Components 1, 2, and 3 could be pursued concurrently.

Decision criteria for application of component

The relevant decision from this component is whether to go ahead with mesocosm experiments, and eventually field-scale experiments, based on the results of this work and comparative information from component 1. The habitat selection information from the Lower Missouri River serves to document the degree of difference from that documented on the Yellowstone River at Fairview. The difference may not be statistically significant because of lack of true replication and a relatively small number of events, and may therefore need to be combined with other lines of evidence and submitted to expert judgement.

C.3.5.5.3 Component 3

This study element will build upon previous information obtained and will utilize various controlled laboratory and mesocosm settings to systematically determine the effect of abiotic conditions on spawning behaviors and mechanics. Laboratory studies will evaluate the mechanics of spawning, egg deposition, fertilization, incubation, and hatch under variable conditions including turbidity, temperature, current velocity, light regimes, and substrate types. Controlled experiments will be carried out in raceways /living streams, circulating tanks/ponds, and hatching chambers. An initial, fundamental question to answer is whether free embryos drift immediately after hatch or instead take up residence in substrate for some period of time; understanding of this phenomenon will have a substantive influence on how many days are needed for dispersal, and therefore how much total river distance would be used. Multivariate statistical models predicting probability of successful hatch will be constructed from measured variables and measured success rates.

At a broader scale, reproductive adult behaviors will be documented in mesocosms to develop models for factors that result in aggregations, interactions, and spawning behaviors. Behaviors will be quantified using 3-d telemetry and observations using acoustic cameras. These mesocosm facilities for adult reproductive behavior will presumably be the same as used for Big Question 1, component 3 and Upper River Big Question 1, component 3. The mesocosm facilities for egg biomechanics may be the same as used in other mesocosm studies in which water velocities and substrate can be controlled.

Metrics

The ultimate metric for this component is hatch rate as a function of different combinations of depth, velocity, substrate, and derivative hydraulic variables, with covariates relating to water quality and fish behaviors. Intermediate metrics will be fundamental measures of fish aggregation and spawning behaviors (e.g., optimum male: female ratios in spawning aggregations), degree of attraction/specificity of adults to different spawning substrates, and biomechanics of egg adhesion and dispersal.

Timelines and contingencies

The mesocosm experiments can be carried out concurrently with components 1 and 2 to maximize development of supportive information.; under parallel staging the component (which already has some pilot information) would extend to 2019. The component is highly contingent on having the ability to construct mesocosm, pond, or side channel facilities with sufficient range of depth, velocity, and substrate to support controlled experiments under a range of conditions applicable to the Missouri River. It is also contingent on availability of a captive research population of pallid sturgeon sufficient in size to have reproductive individuals available each year over the 4 years of the component. The success of the component will depend as well on implementation of technology that can be used to evaluate reproductive movements and success; work is currently underway on validating combinations of acoustic video platforms, 3-d telemetry, and data storage tags for these purposes.

Decision criteria for application of component

The relevant decision at this component is whether and how to move ahead to level 2. Component 3 results are intended to contribute to this decision by providing quantitative criteria for abiotic (and biotic) variables influencing spawning, from aggregation of adults to hatch of embryos. Although some

mesocosm results may be statistically robust, it is inevitable that mesocosm conditions will not perfectly replicate field conditions, and therefore residual uncertainty will remain about the quantitative dependencies of successful hatch on design variables.

C.3.5.5.4 Criteria to move to level 2

The decision to move to active field experimentation will necessarily be based on multiple lines of evidence because no single source of information is likely to provide statistically robust results. Information from components 1, 2, and 3 is intended to provide the best attainable information to underlie this decision.

C.3.5.6 Level 2

C.3.5.6.1 Component 4

In preparation for field-scale experimentation, we anticipate the need for site-specific engineering design studies for spawning habitats, especially to understand how to sustain habitats in the dynamic sediment-transport environment of the Missouri River. Designs will also need to minimize effects on navigation and other authorized purposes; spawning patches will likely directly underlie the navigation channel. Detailed velocity surveys, hydrodynamic modeling, and bathymetric mapping will be used to evaluate habitat characteristics and stability.

Metrics

The metrics for this component will be design performances, measured in terms of how well they create the hydraulic and substrate conditions developed in components 1-3. Additional relevant metrics will be how well designs support other authorized purposes (principally degree of interference with the navigation channel), and cost, including sustainability in a dynamic channel.

Timelines and contingencies

Component 4 is dependent on components 1-3. Evaluation of alternative designs is expected to take at least 2 years assuming useful design criteria are provided from level 1.

Decision criteria for application of component

The applicable decision at this component is whether and how to move forward to active field experimentation. This will be based on a combination of

information that defines functional spawning habitat and the feasibility of designs to achieve that habitat as documented in this component. The decision to move forward would be based on the judgement that designs will provide useful information while minimizing adverse effects to other authorized purposes.

C.3.5.6.2 Component 5

Study component 5 will be field-scale implementation and testing of prototype spawning habitat on the Lower Missouri River. Location of the test spawning patches will be determined through analysis of previous spawning locations. Evaluations will include:

- Evaluating interactions of migrating, telemetry-tagged, reproductive pallid sturgeon to determine whether these fish are attracted to habitat. Both male and female reproductive, tagged fish will be used because of previous information indicating that habitats may be selected by males who subsequently attract reproductive females. 3-dimensional telemetry receiver networks will provide high-frequency, high-precision tracking of spawning behaviors near spawning sites.

- Evaluating hydraulics (velocity and turbulence) of as-built spawning patches compared to biomechanical properties of eggs, in particular specific gravity, fall velocity, and rate of development of adhesion.

- Evaluating disposition of spawned, fertilized eggs during incubation, particularly where they are deposited relative to release location and whether they are subject to burial or abrasion by transporting sand.

- Quantifying hatch rate *in situ*. As indicated in component 2, new technologies may need to be developed to visualize and document hatch rates at depths, velocities, and turbidities common in the Missouri River. The objective of these studies will be to quantify hatch success as a function of habitat design variables.

Metrics

The ultimate metric for this component is hatch rate, which can be equated to the probability for that stage transition in the population model, but it will be challenging to determine this from field conditions. From ichthyoplankton sampling downstream from known spawning events, catch per unit effort may be compared among habitat treatments to evaluate relative hatch performance.

Sampling biases in these nets are unknown, however, and the inherent error is likely to be large. This process would also need to assume spawning of parents with known genotypes and the ability to identify their progeny genetically.

Short of hatch rates, several other metrics will provide information on relative performance of different designs. Repeat high-resolution multibeam maps of the spawning patches during incubation will indicate whether the substrate is subject to burial or erosion, either of which is likely to result in zero hatches. Measured hydraulic variables can be compared to fall velocities of unfertilized eggs to evaluate whether eggs are likely to be deposited in the manipulated habitats; innovative imaging techniques from remote cameras may be able to validate exactly where eggs are deposited. Single receiver and multi-receiver, 3D telemetry and acoustic video can be used to evaluate behaviors of reproductive adults on the spawning patches to identify spawning aggregations and egg-release events.

Timelines and contingencies

This component is logically contingent on completion of engineering studies in component 4, and construction of spawning habitat treatments. The experiments are expected to take at least 4 years to allow for natural variability in hydroclimatic events and to attempt to achieve some replication. Success will depend on having a sufficiently large population of telemetry tagged adults so there will be 6-12 available for intensive tracking each year of the experiment. It may be possible to seed the prevailing population of adults with captive adults that have been treated with hormones to assure they are reproductively ready. High-resolution imaging of spawning substrate in the fast, turbid Missouri River remains a challenge and will require additional technical development. This component interacts with experimental flow pulses in Lower Big Questions 1 and 2: flow and temperature pulses may or may not serve as additional stimuli to draw fish upstream to spawning habitats. Successful design of the experiment will also require additional identification of spawning sites so locations of experimental patches can be placed where fish are likely to encounter them.

Data collected on reproductive migrations of adults may also shed light on a complementary hypothesis, that existing bank revetment serves as an attractive nuisance with low probability of successful hatch. Under this hypothesis, restored spawning patches would have to be sufficiently attractive that adults would not select the more abundant, easy to find revetment habitat.

Decision criteria for application of component

The relevant decision would be whether to move forward into level 3 implementation, change the experimental patch design, or abandon the action hypothesis. Robust statistical results cannot be expected for the ultimate metric – hatch rate – because of the difficulties in enumerating this under field conditions. However, the results of other metrics described above should contribute to a lines-of-evidence decision of whether the spawning patches are functioning as intended.

C.3.5.7 Critical scientific uncertainties and constraints

Present (2017) fertilization and hatching success is unknown. Although it is hypothesized that spawning success is low, little effort has been directed at evaluating until recently. In 2014, 4 pallid sturgeon drifting free embryos and 3 age-0 pallid sturgeon were sampled despite the extreme difficulty in sampling. These collections may indicate that successful spawning, fertilization, incubation, and hatch occur, but there continues to be uncertainty whether the numbers of fish participating in spawning and numbers of fish that hatch successfully are sufficient to maintain the population.

Critical uncertainties relate as well to understanding and measuring processes at the scale of deposited, incubating eggs. Success of incubation and hatch may depend on hydraulic or water quality effects at a very fine scale that will be challenging to measure in real-world conditions. Laboratory and mesocosm studies can provide greater observability at these scales with the trade-off of diminished reality.

Optimal locations of spawning habitats for implementation of field experiments are unknown, although previously documented spawning locations provide some guidance and tracking associated with components 2 and 5 will provide additional information.

Implementation of field experiments under component 5 may be constrained by achieving designs that do not interfere with navigation.

C.3.5.8 Utility of study components

The study components under this Big Question address a hypothesis thought to be important in explaining recruitment failure of pallid sturgeon. Understanding gained through these studies will provide information to validate or invalidate the notion that spawning habitat is limiting, and if validated, the studies will provide design specifications that can lead to habitat restoration, successful spawning, and population growth.

Deployment of sensors to observe processes associated with spawning success will likely also shed light on a reserve hypothesis: that predation of pallid sturgeon eggs may be a significant source of mortality.

C.3.5.9 Risks

Risks to pallid sturgeon populations presented by these science components are low. Telemetry has been shown to have low risk and laboratory/mesocosm studies can be carried out with research broodstock propagation.

Risks to stakeholders appear to be low with the possible exception of navigation interests. Constructed spawning habitats will be located in areas of high velocity and unit discharge, either directly in the navigation channel or adjacent. Design and construction will minimize risk to navigation.

C.3.5.10 Adaptive actions

Information provided through field experimentation will indicate whether channel geometries and/or substrate should be altered to improve performance, and whether additional locations would contribute to spawning success and population growth.

C.3.5.11 Estimated costs

Costs of development of sensors to image fine-scale processes in spawning patches may be substantive, although the technology can probably be adapted from existing marine technology. Costs of implementing field experiments would include design and construction, but because the spatial scope of spawning patches is much less than IRCs, the relative cost will be low.

C.3.6 Lower Big Question 6: Can population augmentation (stocking) processes be enhanced to increase survival and genetic fitness of stocked fish?

C.3.6.1 Objective of study components

The science components for this Big Question are nearly identical to those for the upper river (Upper Big Question 6) with differences limited to geographic location. The objective of these study components is to provide the understanding needed to optimize population augmentation in recovery of the pallid sturgeon. While population augmentation is thought to be *necessary* for recovery of the pallid sturgeon, by itself it is not *sufficient* as the Endangered Species Act requires a self-sustaining population objective. Nevertheless, augmentation can help severely depleted populations recover numbers of individuals needed to evaluate what works and what doesn't in recovering

the population. Moreover, if a depensation effect applies, very low numbers of fish may have low rates of reproduction because mates cannot find one another.

The study components listed here will provide information to improve population augmentation methods and hopefully achieve higher survival at lower cost, while maintaining needed genetic diversity. Because population augmentation is already taking place at the level where it has a measurable effect on the population (level 3), the study components described here are not considered necessary steps before implementing level 3. Instead, the level 1 and level 2 components will develop information to backfill and improve on the level 3 implementation. In addition, it is assumed that population augmentation is presently following best management practices to maintain genetic diversity, as determined and implemented by the Pallid Sturgeon Recovery Team. We recognize that the USFWS is preparing an update of the Pallid Sturgeon Rangewide Stocking Plan that, in combination with the collaborative decision making process of the Pallid Sturgeon Recovery Team and basin workgroups, may determine specific population-augmentation policies and information needs. The study components outlined here may be considered indicative of the types of studies that may be needed.

C.3.6.2 Description of study components

Study components include an engineering study to investigate facility-design options for the pallid sturgeon hatchery system to determine size and type of facilities, and hatchery operations that might be possible to increase and maintain consistent production with appropriate, size, health, and genetics; some of this assessment may be accomplished by the drafting of a new propagation plan by the USFWS. Field monitoring components are proposed to evaluate how size, health, and genetics have affected survival of previously stocked fish. To develop quantitative relations between propagation decisions and survival probabilities, a modeling study is proposed to evaluate population sensitivity to typical ranges of differential survival that might be affected by size, health, and parentage, and varied stocking rates that might arise from year to year variability in available broodstock or hatchery survival. A similar modeling study is proposed to investigate sensitivity of population genetics to variability in available parents, variable survival of family lots. Finally, a series of field experiments can be envisioned to provide a systematic evaluation of costs and population benefits associated with stocking at a range of ages (sizes).

C.3.6.3 Relation to Effects Analysis

These study components provide information to support EA hypotheses 20 and 21. Since the EA integrative report was written, new information has become available

indicating that incidence of disease in hatchery origin fish has substantially constrained stocking levels in recent years. Although disease was not identified as a priority working hypothesis in the EA, the issue is intimately connected to the two issues that were identified, genetic parentage and size. In the case of parentage, population augmentation best-management practices generally do not support culling populations based on genetic makeup, as doing so would apply an unnatural selective pressure. Hence, management actions related to genetics (hypothesis 21) are actually quite limited aside from existing best management practices that seek to manage for diversity. Size at stocking, however, is a variable that can be managed, and doing so has implications for costs, numbers available to stock, and disease. While survival nominally increases with size at stocking, the longer a fish is maintained in the hatchery the greater the cost (including opportunity cost for other fish species that are not propagated) and the greater the opportunity for disease. Consideration of hypothesis 20, therefore, implicitly involves consideration of facilities capacity and disease risk.

Additional information that has emerged since the EA relates to reports of poor fish condition in the Lower Missouri River. Hypotheses to explain poor condition include several that assert that the carrying capacity of the river to support pallid sturgeon has diminished in recent years. If so, assumptions that more fish should be stocked may need to be re-evaluated.

C.3.6.4 Approaches

Approaches to these study components at level 1 include an engineering design study, field-based monitoring of differential survival rates, and sensitivity assessments using population and population genetics models. At level 2 a series of field-based experiments is proposed for systematic evaluation of size at stocking effects on differential survival.

C.3.6.5 Level 1

C.3.6.5.1 Component 1

This component would be an engineering feasibility design study to address costs and presumed population benefits for propagation facilities of different designs and capabilities. The selection of design and capability would be based on costs relative to results of component studies 2-4, which would indicate benefits of stocking size, and related disease risk. Much of the work may be accomplished by the USFWS revised propagation plan currently (2017) under development.

Metrics

Metrics for this study would be costs and measures of likely survival for a range of facilities designs. Measures of survival would be based on existing data for differential survival for stocked age-0, age-1, and juvenile fish, plus an estimate of the relations among designs, operations, size at stocking, and risk of disease.

Timelines and contingencies

The immediacy of the propagation issue, and likely time lag between a study and changes in facilities and operations, indicates that the feasibility study should start soon, perhaps as early as 2017. The study is estimated to take two years for completion and could be pursued concurrently with components 2 and 3.

Decision criteria for application of component

The results of the feasibility study would indicate a range of options in facilities and operations, with attendant costs and benefits to the propagation program in terms of probable increased survival and stocking rates. The decision of what improvements to implement (a level 3 or 4 action) would be based on costs and information developed in components 2-4 that would quantify benefits.

C.3.6.5.2 Component 2

This study will use monitoring data on growth and survival of hatchery-origin fish to assess how factors such as size at stocking, health history, and parentage may have affected survival. The study assumes that genetic and propagation records for hatchery-origin fish are complete and accurate. Appropriate monitoring could be a stand-alone operation or it could be incorporated within a population-trends monitoring program (see population monitoring Appendix D). Monitoring would need to extend to the Middle Mississippi River to include fish that may have migrated out of the Lower Missouri. A Cormack Jolly Seber (CJS) model will then be used to estimate apparent survival using the multiple recapture occasions. Data of this nature can be fit using traditional mark recapture software such as Program MARK and hierarchical Bayesian approaches can provide increased flexibility.

Metrics

The main metrics for this component are estimates of the number and survival rates for stocked pallid sturgeon by stocked size, hatchery of origin, and health history.

Timelines and contingencies

This component can be done concurrently with components 1 and 3. The technical approach to this question – a mark/recapture model– would be most efficient if coordinated with the population trends monitoring described in Appendix D and with Lower Big Question 4, component 5. We estimate that 3 years of sampling would be necessary to provide useful data on differential survival.

Decision criteria for application of component

Information developed in this component will illustrate the scope of differential survival and whether a need exists for fundamental changes to the propagation facilities and operations. The statistical rigor of the analysis is difficult to anticipate and decisions may need to be made based on judgments informed by multiple lines of evidence.

C.3.6.5.3 Component 3

These study components are model simulation studies intended to test sensitivity of population dynamics and population genetic structure to variability in augmentation. The first of these would assess how population dynamics would be affected by typical variation in survival related to size at stocking – results of which would indicate if there is value to the population to develop hatchery capabilities to optimize size. The model would also be used to assess effects of variable stocking rates (due to year-to-year variability in broodstock availability), health history and parentage. The second of these models would investigate sensitivity of population genetics to mating decisions made in the hatchery and other factors like year to year variation in availability of wild broodstock. Results will provide a quantitative basis for assessing risks of genetic swamping and insights into effort needed to collect and keep broodstock.

Metrics

Metrics from these modeling studies will include probability of quasi extinction, instantaneous growth rates, and sensitivity measures under various scenarios and parameterizations of the models.

Timelines and contingencies

Some of the parameters for the models will be informed with data from the mark/recapture survival data developed in component 2. This component will be

done concurrently with components 1 and 2, and the time for completion of the study is estimated to be 3 years.

Decision criteria for application of component

The information developed in this component will have a bearing on decisions about hatchery facilities, operations, and propagation plans, the decision to move to level 2 experimentation. The mix of empirically derived differential survival data and modeled extrapolations of those data will not necessarily provide a statistically defensible decision criterion. The decision will likely be based on judgment informed from multiple lines of evidence.

C.3.6.5.4 Criteria to move to level 2

Level 2 components are envisioned to be field based experiments that will vary size at stocking and assess differential survival. These level 2 activities may not be necessary to decide among facilities/operations options if the retrospective evidence is sufficiently robust. Moving to level 2 would be indicated if models indicate a high sensitivity of cost and survival to size at stocking, and more precise parameters for the relationships are needed.

C.3.6.6 Level 2

C.3.6.6.1 Component 4

If results of component 2 are equivocal about relations between size at stocking and differential survival, this component will provide a systematic, field-based experiment to assess the effect. The study would involve stocking fish at variable sizes (representing variable hatchery costs) keeping all other factors as constant as possible. Monitoring over several years would provide information on mortality and provide guidance on tradeoffs between survival and cost. The experiment would require that fish are identifiable from year to year based on tags or genetics, and that genetic and propagation records for the fish are complete and accurate. A CJS model will then be used to estimate apparent survival using the multiple recapture occasions. Data of this nature can be fit using traditional mark recapture software such as Program MARK and hierarchical Bayesian approaches can provide increased flexibility.

Metrics

Metrics from these experiments will be differential survival as a function of size or age at stocking as well as ancillary variables including health history, hatchery of origin, stocking location, and parentage.

Timelines and contingencies

This component would only be pursued if deemed necessary to make decision regarding facilities and operations. The monitoring approach would be a subset of the previously described population trends assessment (Appendix D); we estimate a minimum of five years to provide useful information on survival based on two years of stocking of 4 size ranges and 4 years of monitoring.

Decision criteria for application of component

The information developed in this component will have a bearing on decisions about hatchery facilities and operations and stocking. The mix of empirically derived differential survival data and modeled extrapolations of those data will not necessarily provide a statistically defensible decision criterion. The decision will likely be based on judgement informed from multiple lines of evidence.

C.3.6.7 Critical scientific uncertainties and constraints

One critical uncertainty for these components is the geographic scope that needs to be sampled to assess survival, in particular how fish disperse among tributaries and the Middle Mississippi River. Another uncertainty is how covariates – environmental conditions, genetics, and health history – will interact to determine actual survival. A critical constraint in implementing field-based experiments with stocking is the availability of fish, with appropriate genetics, from the hatchery system.

C.3.6.8 Utility of study components

The study components under this Big Question address information that may be useful in improving effectiveness of the population augmentation program, which is in turn, a critical part of the recovery program. The information developed will be useful in cost: benefit decisions about investments in hatchery facilities and capabilities.

Monitoring proposed as parts of components 2 and 4 will be consistent with monitoring efforts envisioned for drift/dispersal studies and may contribute to population-trends monitoring.

C.3.6.9 Risks

Risks to pallid sturgeon populations presented by these components are low as long as best-management practices for maintaining genetic diversity are followed. Risks to stakeholders appear also to be low.

C.3.6.10 Decision criteria

The information gained in these studies will inform investments in hatchery facilities and capabilities, and perhaps contribute to refinement of some propagation decisions.

C.3.6.11 Adaptive actions

Information provided through these components would be useful in incremental changes to hatchery facilities and procedures.

C.3.6.12 Estimated costs

Costs of development of new facilities could be high. The intent of this set of components is to provide a cost: benefit basis for understanding the value of that investment.

C.4 Technical Development Components

Two areas of technical development have been identified as priority science components because of their applicability to the science and monitoring at all levels. These science components are a) development, refinement, and maintenance of a collaborative pallid sturgeon population model and b) optimization of a population monitoring effort.

C.4.1 Collaborative population model

Although much of the structure and parameterization of the pallid sturgeon population dynamics model has been developed through the EA process, we recognize that this model will be the central, integrating process for assimilating data on management actions and population responses. As such, it will be continuously updated as new information becomes available from science components, monitoring of process effectiveness, and from monitoring of population status and trends. This will require a standing level 1 science effort over the lifetime of the adaptive management program to maintain and update the model.

A critical feature of the population model is the presence of explicit links from management actions to key model parameters, chiefly survival from life stage to life stage. The explicit linkages allow for exploration and forecasting of how management actions will affect population growth.

The model is described as a collaborative population model (Appendix D) to emphasize that agencies, universities, and other institutions involved in pallid sturgeon science will have access to the model and ability to alter parameters and algorithms. The

collaborative and flexible structure of the model will promote growth to keep pace with technical advances. The archival version of the model would be maintained within the AM program Technical Team. More information on the population model is available in Appendix D.

C.4.2 Optimization of population monitoring

We have identified the need to undertake a specific investigation of how population monitoring might be optimized to support management decision making as a level 1 science effort. Appendix D presents options for population monitoring and some limited results of simulations that address characteristics of a program that will provide useful estimates of numbers and survival of fish. Design of the optimal monitoring program will require an additional level 1 science effort. An optimal design will maximize information on the size and quality of the population, will support and be supported by the population model, and will perform with high cost effectiveness.

This technical component proposes two years of intensive sampling and simulation modeling to help in that design process. Intensive sampling will provide improved estimates of the capture/recapture probabilities that are fundamental to designing the scope and intensity of a mark/recapture monitoring effort. Simulations will be used to assess monitoring performance as assumptions are relaxed or violated, thereby indicating worst case scenarios for monitoring efficiency. The result of this effort will be a redesign of the pallid sturgeon population assessment program that will provide the data needed to link pallid sturgeon populations to management actions of the MRRP.

Simulation modeling will be conducted through an iterative process that will use targeted sampling to update model parameters. In addition, the modeling team will elicit feedback from fisheries biologists with experience in pallid sturgeon sampling to address practicalities and logistics of sampling design.

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Appendix D. Population Monitoring and Modeling for Pallid Sturgeon

DRAFT/Pre-Decisional/For Discussion Purposes

Prepared: September 30, 2016

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D.1 Introduction

The Missouri River Recovery Management Plan (MRRMP) consists of a series of management actions intended to avoid jeopardy to interior least terns, piping plovers, and pallid sturgeon, while achieving acceptable trade-offs with authorized purposes and socio-economic considerations. Management of all three species exists within the context of hydro-climatic uncertainty imposed by the Missouri River basin, and also must accommodate imperfect knowledge of linkages from independent drivers, to habitat conditions, to ecological consequence, and finally to population dynamics. Implementing an appropriate suite of timely management actions to avoid jeopardy of the species in the face of this uncertainty dictates an adaptive management (AM) approach.

D.1.1 Background on Effects Analysis and Adaptive Management

The MRRMP has been influenced by the Missouri River Effects Analysis (EA), an effort to compile what is known and unknown about the three species. The results of the pallid sturgeon have been documented in four reports (Jacobson et al. 2015b, Jacobson et al. 2016a, Jacobson et al. 2016b). While the EA documents the wealth of information that has been developed about pallid sturgeon reproductive ecology and the Missouri River over the last 2 decades, it also demonstrates the fundamental uncertainties linking habitats to population processes and rates (Jacobson et al. 2016a). As a result, the AM plan for the pallid sturgeon emphasizes a systematic and strategic science effort to address these uncertainties. The EA compiled and assessed working management hypotheses believed to be relevant to pallid sturgeon population dynamics, resulting in 21 key hypotheses, 10 in the Upper River and 11 in the Lower River. In turn, these hypotheses were organized and grouped according to common physical context and scientific approaches into 12 Big Questions (6 Upper River, 6 Lower River) to focus high priority management decision needs and facilitate effective communication.

The AM plan recognizes the need for long-term population trend assessment to complement the detailed science components that address specific management hypotheses. The AM plan is organized around 4 levels of implementation that progress from an emphasis on learning to full implementation:

1. Foundational, enabling science.
2. Field-scale experiments.
3. Initial implementation of actions at a level intended to elicit a population response.
4. Full implementation of actions.

Level 1 and 2 science components are presented in Appendix C. It should be noted that the population monitoring and the collaborative population modeling described in this appendix also are level 1 science components where additional technical development is needed and ongoing. Therefore, Section D.4 of this appendix will receive significant scrutiny as part of level 1 science to optimize monitoring design, evaluate the consequences of violated assumptions, and how to appropriately estimate population trend and abundance. As information is developed through the science components, we anticipate that hypotheses, management options, and information needs will change, and therefore plans for acquiring that information will change. Information needs for understanding population trends, however, are expected to be fairly stable.

D.1.2 Management Objectives

Adaptive management of the pallid sturgeon (*Scaphirhynchus albus*) in the Missouri River is intended to fulfill the fundamental species objective developed by the U.S. Fish and Wildlife Service (USFWS): "Avoid jeopardizing the continued existence of the pallid sturgeon from US Army Corps of Engineers (USACE) actions on the Missouri River." (USFWS, Draft Species Objectives, 9/12/2013). The USFWS notes that this objective is consistent with species recovery goals (U.S. Fish and Wildlife Service 2014) but is specific to Missouri River management actions. The fundamental species objectives are accompanied by sub-objectives that are measurable and relevant (Table D1).

Table D1. Fundamental and sub-objectives for pallid sturgeon provided by the U.S. Fish and Wildlife Service during development of the Missouri River Recovery Management Plan.

Fundamental Objective	Avoid jeopardizing the continued existence of the pallid sturgeon from the US Army Corps of Engineers actions on the Missouri River.			
Sub-objectives		**Metric**	**Target**	**Time Frame**
Sub-objective 1	Increase pallid sturgeon recruitment to age 1	Catch rates of age 2 and 3 year-old pallid sturgeon	Short-term: recruitment; long-term: projection from population models of an annual egg to age-1 survival rate > 0.03.	10 years
Sub-objective 2	Maintain or increase numbers of pallid sturgeon until sufficient and sustained natural recruitment occurs	Catch rate of all size classes	Viable population size necessary to successfully overcome recruitment bottleneck. Target: Minimum of 5000 adults in each management unit*	20 years

*From U.S. Fish and Wildlife Service (2014).

The emphasis on recruitment reflects the fact that in the Missouri River, no genetically determined, successful recruitment of pallid sturgeon to age-1 has been recorded over the last 20 years (that is, no wild-spawned, naturally produced fish have been collected) (U.S. Fish and Wildlife Service 2014).

The MRRMP is the umbrella planning effort of the USACE under which AM takes place. The geographic scope of the MRRMP is the Upper Missouri River mainstem from Fort Peck Dam to the headwaters of Lake Sakakawea, the Yellowstone River upstream of the confluence with the Upper Missouri River for an unspecified distance, the Lower Missouri River mainstem from Gavins Point Dam to confluence with the Mississippi River at St. Louis, tributaries used by pallid sturgeon, and an unspecified distance downstream in the Mississippi River (Figure D1). The geographic scope is constrained in part by decision-making authority of the USACE and in part by present understanding of the geographic distribution of pallid sturgeon. The reservoirs and

inter-reservoir reaches (from Lake Sakakawea to Lewis and Clark Lake) are excluded from the analysis based on the assumption that these habitats are unlikely to sustain reproductive populations of pallid sturgeon. The distance in the Mississippi River is unspecified because presently available information (2015) is ambiguous about the extent to which Missouri and Mississippi river populations mix through migrations and dispersal.

D.1.3 Monitoring and Assessment

Adaptive management of the pallid sturgeon in the Missouri River will require multiple sources of information. In addition to the level 1 and level 2 science components (Appendix C), we recognize three types of monitoring and assessment that will accompany implementation of management actions:

1. **Implementation monitoring/assessment** – was the management action implemented as intended. For example, did construction of an interception-rearing complex (IRC) follow and achieve specifications related to size, elevation distribution, and hydroperiod?
2. **Process monitoring/assessment** – did the management action achieve desired changes to ecological processes thought to lead to increased growth and survival? For example, did an IRC achieve an increase in functional food-producing and foraging habitats? Did food abundance actually increase? Were more free embryos advected into and retained in the IRC? Can increases in population growth-rate parameters be inferred confidently from performance of the IRC?
3. **Population monitoring/assessment** – did the effect of the management action propagate to recruitment and population growth? For example, can IRC development be associated or linked by cause and effect with increases in population size or growth rate?

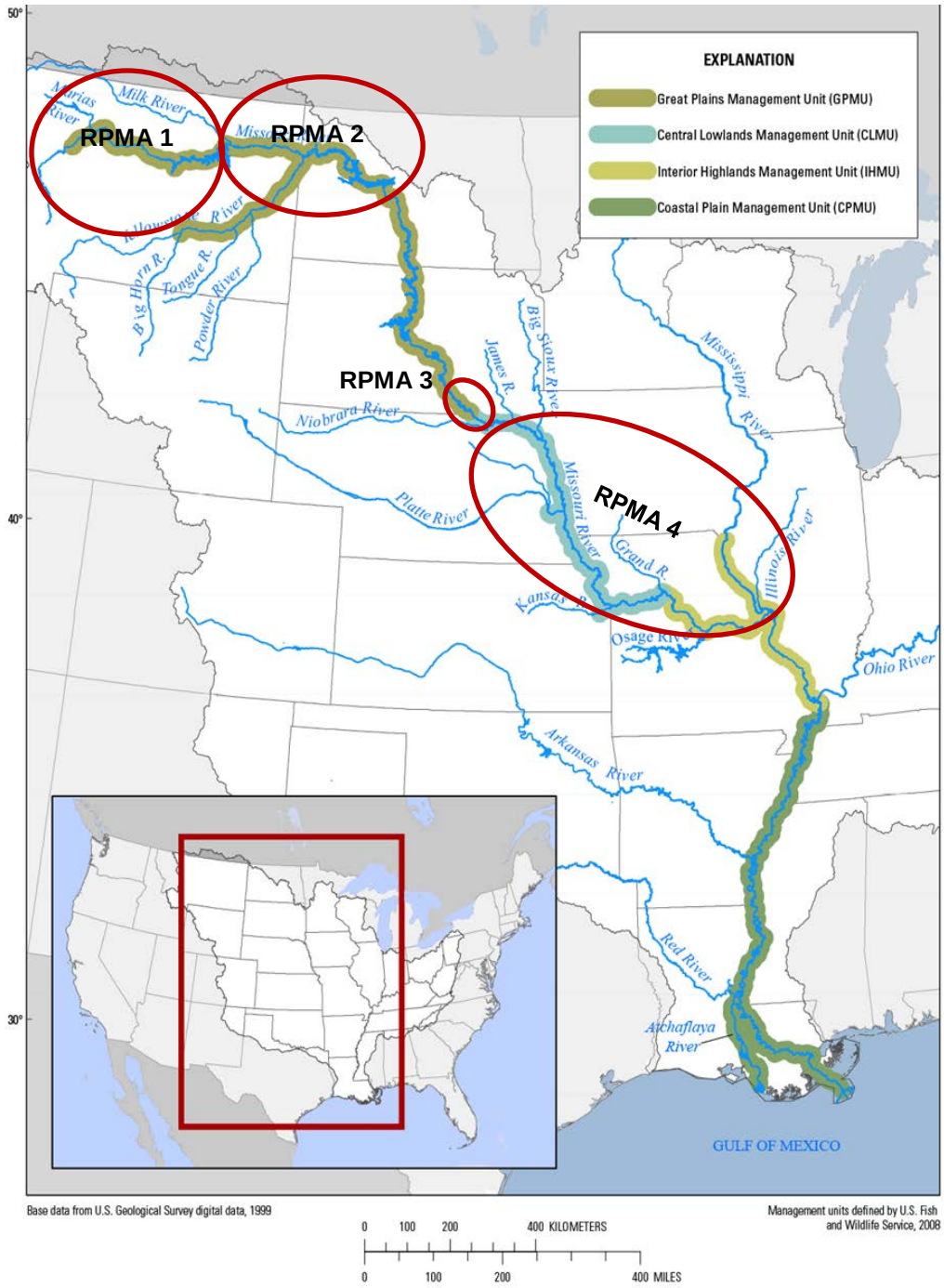

Figure D1, Pallid sturgeon recovery management units, showing previous recovery priority management areas (RPMA) and contemporary management units (U.S. Fish and Wildlife Service, 2014).

All three of these types of monitoring and assessment may provide important information for decision making and AM. There is debate, however, about the distribution of resources among the three types and the resulting utility of information to support decisions. Whereas the contributions of implementation and hypothesis-

driven process monitoring are fairly clear, the value of population monitoring is less clear. In particular, there are differences of opinion (for pallid sturgeon and many other rare species) about the relative value of enumerating numbers of organisms to document status and trends, compared to modeling population changes based on measured or inferred changes to population growth parameters.

Arguments against investment in population-level monitoring center around high costs (or low information:cost ratio) and the difficulty in testing management hypotheses with population-level data. For example, we would anticipate difficulty assigning cause and effect to changes in estimated pallid sturgeon population as a result of management actions like increased flow naturalization or IRC area. Arguments to include some level of effort in population-level monitoring include:

- Value of population estimates as a reality check on inferences from process monitoring/assessment and (or) population models. Without a population-level assessment, indicators of general population health – positive and negative – may be missed resulting in risk to the species or spending resources where they are not needed.
- Value of population estimates as a metric of success for achieving population targets.
- Value of population estimates to track and predict need for continued investment in population augmentation.
- Value of population estimates and associated survival estimates to continuously update critical parameters in population models, thereby increasing reliability.
- Value of population estimates as a metric for understanding trend compared to performance and cost effectiveness of other metrics such as catch per unit effort (CPUE).
- Value of population estimates in understanding density-dependent processes in population dynamics including potential carrying-capacity limitations or depensation effects.
- Some process-level hypotheses are effectively tested, or testing will be enhanced, by population-level monitoring. This is particularly true about hypotheses related to population augmentation.

The present pallid sturgeon Population Assessment Program (PSPAP) is based on a catch per unit effort that is applied consistently throughout the geographic scope of the Missouri River Recovery Program (MRRP). The PSPAP was developed to support information needs articulated in the USFWS 2003 Amended Biological Opinion (BiOp) (U.S. Fish and Wildlife Service 2000, 2003). It is reasonable to expect that information needs and priorities would shift in 15 years since implementation of the BiOp and that the new management plan would have new information needs.

D.1.4 Objective of This Report

The objective of this report is to explore options for refining a population trends monitoring approach so it is effective and efficient in meeting the needs of the adaptive-management program. Effectiveness will be judged based on ability to discern long-term trends and the degree to which the monitoring complements and enhances assessments of specific management actions. Because there are many unknowns about future performance of a population monitoring effort, we do not make specific recommendations about the details of the effort. Instead, we present an assessment of existing efforts and current information needs (Section D.2), design guidance from previous studies (Section D.3), and a general concept for redesign (Section D.4). We provide detail on existing efforts, including sampling protocols and gears, because that information is the foundation from which more effective and efficient methods can be designed. The greatest unknown is level of effort and cost, and the degree to which population-level monitoring can coordinate and leverage resources (staffing, equipment) with process-level monitoring. We therefore recommend investment in a detailed planning and simulation process to refine a population-monitoring effort as a level 1 science effort (included in science components, Appendix C and described in section D4.2.1).

D.2 Past and Current Monitoring Projects

Several long-term monitoring projects have been implemented on the Missouri River and its tributaries during the last 10 years. Most were specifically designed to meet reasonable and prudent alternatives (RPA) elements in the BiOp for the Missouri River, each with different objectives. The PSPAP was developed to provide an assessment of long-term trends in pallid sturgeon abundance, population structure, and habitat use. Catch-per-unit effort (CPUE) was selected as the metric to evaluate trends in abundance due to the low numbers of sturgeon in the river and the perceived amount of effort that would be required to provide reliable abundance estimates through a mark-recapture effort. A description of the PSPAP and other, past projects is below.

D.1.5 Pallid Sturgeon Population Assessment Project

The PSPAP is the primary fish monitoring element for the BiOp (U.S. Fish and Wildlife Service 2000, 2003) and the MRRP. Data collected through the PSPAP are used to evaluate the pallid sturgeon propagation and population-augmentation management action (RPA element IV) and provide long-term assessments of fish metrics (RPA element V; population trends, survival, movement, distribution, and habitat use by pallid sturgeon and other target fishes). The PSPAP also collects pallid sturgeon broodstock each spring for meeting BiOp stocking requirements (RPA element IV) and the stocking levels identified by management biologists for Recovery Priority

Management Areas 1-4 (RPMAs, Figure D1).

D.1.1.2 Objectives

The Project objectives, sample design, and protocols were developed by an inter-agency team of Missouri River basin experts and continue to be guided by the Project Delivery Team (PDT) that is comprised of 8 agency offices from the USFWS, Montana Fish, Wildlife, and Parks (MTFWP), South Dakota Game, Fish, and Parks (SDGFP), Nebraska Game and Parks Commission (NGPC), Missouri Department of Conservation (MDC), and USACE. In addition to pallid sturgeon, a representative group of native Missouri River fishes is also monitored to detect improvements in the system as reflected by changes in the warm water benthic fish community. Project monitoring targets the following species: pallid sturgeon (*Scaphirhynchus albus*), sand shiner (*Notropis stramineus*), sicklefin chub (*Macrhybopsis meeki*), sauger (*Sander canadensis*), shovelnose sturgeon (*Scaphirhynchus platorynchus*), plains minnow (*Hybognathus placitus*), western silvery minnow (*Hybognathus argyritis*), shoal chub (*Macrhybopsis hyostoma*; formerly speckled chub, *Macrhybopsis aestivalis*), sturgeon chub (*Macrhybopsis gelida)* and blue sucker (*Cycleptus elongatus*).

Objectives for PSPAP were developed to meet the 2003 BiOp RPA elements IV and V and are as follows:

- Evaluate trends in pallid sturgeon population abundance, distribution and habitat use throughout the Missouri River system.
- Evaluate survival, growth and habitat use of stocked pallid sturgeon in the Missouri River system.
- Document and evaluate pallid sturgeon reproduction and recruitment in the Missouri River system.
- Evaluate current and long-term trends in native Missouri River fish species abundance, distribution and habitat usage, with emphasis on warm water benthic fish community.

D.1.1.3 Geographic Scope

The PSPAP area encompasses the Missouri River from Fort Peck Dam, Montana at rivermile (RM) 1771.5 downstream to the confluence of the Missouri and Mississippi rivers near St. Louis, Missouri (RM 0) and the lower reach of the Kansas River (Figure D1). The BiOp divides the PSPAP area into river and reservoir segments and assigns high, moderate, or low priority management action to these segments for the pallid sturgeon. The focus of the PSPAP is the high-priority management-action segments (Figure D1). The segments identified as moderate or low priority for pallid sturgeon are

categorized as reservoirs or transitional zones between rivers and reservoirs (USFWS 2000).

D.1.1.4 Sample Design

Fish and habitat data collections within 13 river segments (Figure D2) began in 2003 with full implementation of standardized sampling in all high-priority segments in 2006. The PSPAP uses a three-tiered hierarchical habitat classification system (macrohabitat, mesohabitat and microhabitat; see Welker and Drobish (2012) for a detailed description of habitat types) that allows for both general and specific categorization for sampling to serve the needs for biological and physical data collection efforts. PSPAP recognizes 14 river segments based on hydrologic criteria. Within each segment, macrohabitats are arranged by bends, which serve as the basic sampling unit (replicate) within each river segment. A bend comprises three continuous macrohabitats, an outside bend (main channel; OSB), an inside bend (main channel; ISB) and a channel crossover (main channel; CHXO). Within a segment, a minimum of 25.2% of all bends are sampled in a sample year. Within a bend, 12 potential discrete macrohabitats could occur beyond the three continuous macrohabitats [that is, large (TRML) and small (TRMS) tributary mouths, confluences (CONF), large (SCCL) and small (SCCS) secondary connected channels, non-connected secondary channels (SCN), deranged (DRNG), braided (BRAD), dendritic (DEND), and island tips (ITIP)]. All available macrohabitats are subsampled within a randomly-selected bend.

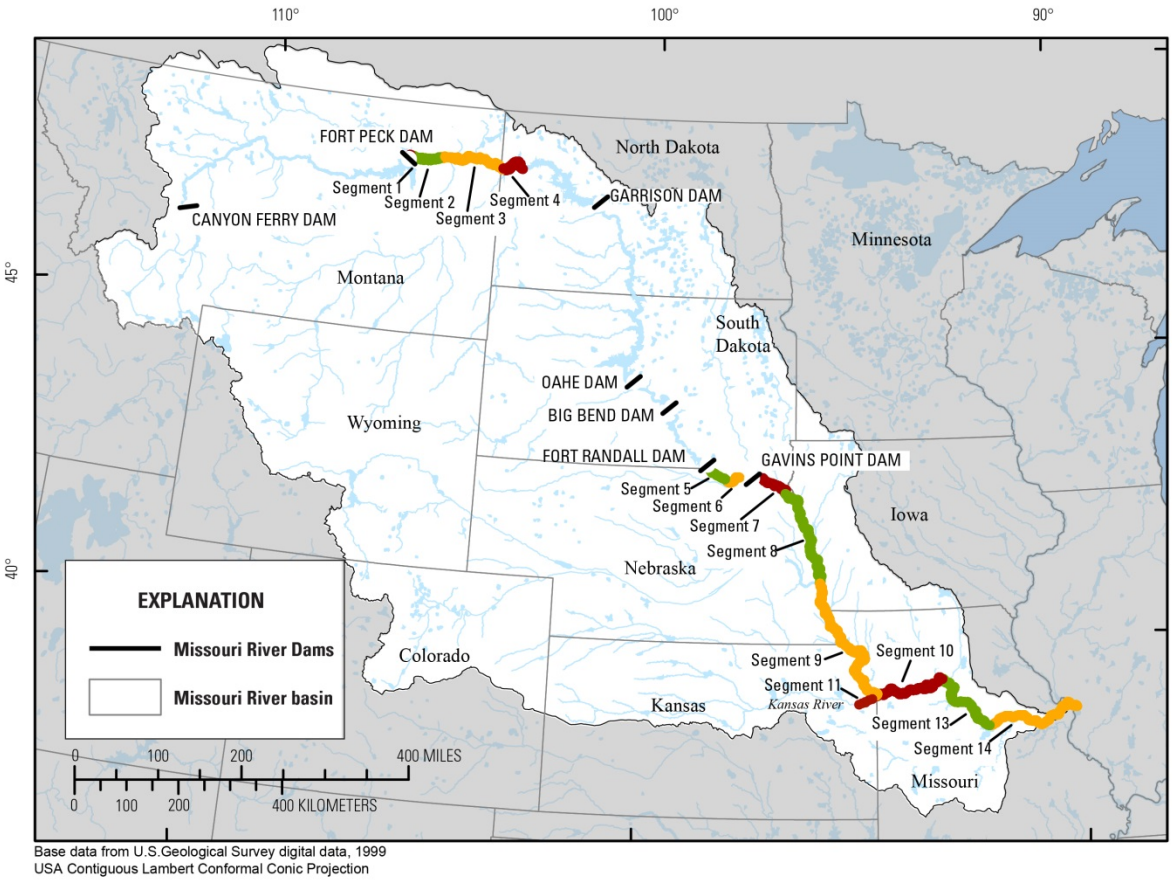

Figure D2. Segments used by the Pallid Sturgeon Population Assessment Program.

Sampling occurs from October 31 (or when water temps fall below 12.8 C (55 °F)) of the preceding calendar year to October 30 of the current calendar year. Each year includes two sampling seasons: sturgeon-focused (Sturgeon Season; ST) and native fish community-focused (Fish Community Season; FC) season. Sturgeon season runs from fall when water temperatures are first below the maximum (12.8 °C) set for gill nets to June 30 in attempts to minimize pallid sturgeon stress during collection. Fish community season runs from July 1 to October 31, overlapping ST for water temperatures below 12.8 °C (55 °F) prior to October 31.

A variety of fish and habitat metrics are measured through the PSPAP. For each pallid sturgeon capture, length and weight, morphological (meristics), genetic, marking (PIT tags, elastomer tags, or scute removal), habitat at capture location (depth, velocity, turbidity, and temperature), and location data are collected; some of these data are also collected for the other target fish species. Additional information on PSPAP data is available in Jacobson et al. (2015a).

D.1.1.5 PSPAP General Sampling Approach

Fish-sampling gears and methods were developed by the PSPAP team and are described in detail in Welker and Drobish (2012). A list of the standard-gear types analyzed in this report and the methods used by the PSPAP to deploy the gears are listed below.

D.1.1.5.1 Sampling Seasons

Two sampling seasons were established to accomplish sampling objectives for the PSPAP. These sampling seasons are determined by dates and water temperatures to provide flexibility in sampling across the geographic range of the Missouri River Basin. The sturgeon season begins in the fall when the water temperature is < 12.8°C (55°F) and continues through June 30th. The water temperature criteria addresses the issue of the water temperature variations between the upper and lower portions of the Missouri River and the amount of time in the field season to accomplish restrictive sampling (that is, gill netting) prior to ice up. On July 1st, sampling efforts remain the same with an additional emphasis on the associated fish community. The fish community season runs from July 1st through October 31st. The two seasons may overlap in portions of the river when temperatures fall below 12.8°C prior to the conclusion of the fish community season. A variety of fish-sampling gears were used during the sample seasons in both the Upper and Lower Missouri River.

D.1.1.5.2 Trammel Net

Trammel nets were used during both sampling seasons within the Upper and Lower Missouri River; however, trammel net sampling was dropped from the sturgeon season in the Lower Missouri River in 2010. The standard trammel net was 125 feet (38.1 m) long by 8 feet (2.4 m) high and had 1-inch (2.5-cm) inner panel bar mesh and 8-inch (20.3-cm) outer panel bar mesh. The top of each trammel net was supported by foam float line; a lead line ran along the bottom. Targeted drift distances for trammel nets were between 75 m and 300 m.

D.1.1.5.3 Otter Trawl

Otter trawls were used during both sampling seasons within the Upper and Lower Missouri River. The standard otter trawl was 16 feet (4.9 m) wide at the mouth, 3 feet (0.9 m) high, and 25 feet (7.6 m) long. Otter trawls had ¼-inch (6-mm) inner bar mesh, ¾-inch (19-mm) outer bar mesh, and a cod-end opening of 16 inches (40.6 cm). Trawl doors were 30 inches (76.2 cm) by 15 inches (38.1 cm) and were used to keep the trawl deployed while on the bottom of the river. Otter trawls were fished in a downstream direction with the distance of the tow depending on the size of the macrohabitat and

mesohabitat being sampled and presence of snags. Targeted tow distances for otter trawls were between 75 m and 300 m (minimum of 75 m required).

D.1.1.5.4 Gill Net

Gill nets were used only during the sturgeon season within the Lower Missouri River. The standard gill net was a 100-foot (30.5-m) long by 8-foot (2.4-m) high experimental gill net that consisted of four 25-foot (7.6-m) long panels. Each net had one panel each of 1.5-inch (3.8-cm), 2-inch (5.1-cm), 3-inch (7.6-cm), and 4-inch (10.2-cm) multifilament square/bar mesh. A 200-foot (61.0-m) experimental gill net was also used and consisted of two 100-foot nets attached together. The first panel deployed from the boat during each set was randomly selected. Gill nets were set over night with a targeted maximum set time of 24 hours.

D.1.1.5.5 Trotline

Trotlines were used during both sampling seasons within the Upper and Lower Missouri River. The standard trotline consisted of a 105-foot (32-m) main line with hooks spaced 5 feet (1.5-m) on 18-inch (0.5-m) leaders (20 hooks per 105-foot main line). The level of effort (hooks and lines) could be doubled per deployment (205 ft. main line length with 40 hooks). Hooks were baited with night crawlers. Trotlines were set over night with a targeted maximum deployment of 24 hours.

D.1.1.6 Evaluation

PSPAP data provide useful information for several reasons in addition to trend detection:

1) It allows an evaluation of gear effectiveness and comparison with other fish collecting gears.
2) It provides a way to evaluate the cost of monitoring with a particular gear and to compare that cost to other gears.
3) It can be used to optimize the sampling strategies needed to meet objectives.

Pallid sturgeon objectives for the MRRP include reproduction (<1 year-old pallid sturgeon), recruitment (1-3 year-old pallid sturgeon), and quantifying demographic parameters. It is somewhat difficult to determine ages of pallid sturgeon based on body length; however, it is generally accepted that those <109 mm (Ridenour et al., 2011) are < 1 year old (that is, age-0, young-of-year; hereafter referred to as YOY). For this assessment, we quantified CPUE separately for fish <=109 mm (YOY) and >109 mm (juvenile + adult). Few pallid sturgeon <=109 mm have been captured through MRRP

monitoring; therefore, we used shovelnose sturgeon as a surrogate for YOY pallid sturgeon.

The PSPAP uses a variety of standard gears to sample the different ages and sizes of pallid sturgeon. For fish <109 mm, the otter trawl was the gear used to quantify catch (Table D2). The trammel net, gill net, trotline, and otter trawl were used to quantify catch for fish > 109 mm (Table D2). Gear subsamples were averaged across years and segments within a basin to obtain a single CPUE value for each gear type. Catch was reported as number of fish/100 m^2 for the trammel net and the otter trawl. Gill net catch was quantified as number of fish/net night and trotline catch as number of fish/20 hooks. The number of sturgeon/gear deployment (subsample) was also reported for all gears (Table D3). For a description of standard gear dimensions, consult Welker and Drobish (2012).

Table D2. Sturgeon catch for gears used during standard, random sampling in the Pallid Sturgeon Population Assessment Project (PSPAP; 2006-2015)*, targeted broodstock collection (2006-2015)**, the Habitat Assessment and Monitoring Project (HAMP; 2013-2014), and the Platte River Assessment (Platte River; 2009-2012).
[Standard Error (when available) has been identified in parenthesis below catch data]

Monitoring Effort	Size/Age	Gears					
		Trawl* (#/100 m^2)	Trammel Net* (#/100 m^2)	Trotline*/** (#/20 hooks)	Gill Net* (#/net night)	Trammel Net 48** (#/100 m^2)	Trammel Net 610** (#/100 m^2)
Upper Basin							
PSPAP	<109 mm	0.030 (0.004)					
	>=109 mm	0.002 (0.0001)	0.001 (0.0001)	0.55 (0.030)			
Broodstock	>=109 mm					0.001 (0.0002)	0.001 (0.0001)
Lower Basin							
PSPAP	<109 mm	0.004 (0.003)					
	>=109 mm	0.004 (0.0002)	0.0005 (0.00003)	0.108 (0.005)	0.035 (0.001)		
HAMP	<109 mm	0.330 (0.027)					
Broodstock	>=109 mm			0.180 (0.006)			
Platte River	>=109 mm			0.058			

Table D3. Sturgeon catch (number of fish per deployment) for gears used during standard, random sampling in the Pallid Sturgeon Population Assessment Project (PSPAP; 2006-2015)*, targeted broodstock collection (2006-2015)**, the Habitat Assessment and Monitoring Project (HAMP; 2013-2014), and the Platte River Assessment (Platte River; 2009-2012).
[Standard Error (when available) has been identified in parenthesis below catch data]

		Gears					
Monitoring Effort	**Size/Age**	**Trawl***	**Trammel Net***	**Trotline*/****	**Gill Net***	**Trammel Net 48****	**Trammel Net 610****
Upper Basin							
PSPAP	<109 mm	0.080 (0.0095)					
	>=109 mm	0.087 (0.0041)	0.106 (0.0053)	0.55 (0.030)			
Broodstock	>=109 mm					0.062 (0.025)	0.065 (0.013)
Lower Basin							
PSPAP	<109 mm	0.129 (0.0073)					
	>=109 mm	0.011 (0.0010)	0.019 (0.0014)	0.180 (0.0071)	0.0035 (0.001)		
HAMP Broodstock	<109 mm	0.472					
	>=109 mm			0.336 (0.010)			

For pallid sturgeon >109 mm, trotlines had the highest CPUE in both the Upper (0.55/20 hooks, 0.55/deployment) and Lower (0.180/20 hooks, 0.180/deployment) basins (Table D2). The gill net had the lowest CPUE for all gears (0.035/net night, 0.0035/deployment). Catch for the trawl and trammel net were similar within their respective basins across the two size classes (Table D2). Catch as quantified by number of fish/deployment followed similar trends across the gears (Table D3).

In addition to the data presented here, several analyses of the PSPAP add understanding of what the project has provided (Sustainable Ecosystems Institute 2004, Wildhaber et al. 2011b, Wildhaber et al. 2015).

D.1.6 Habitat Assessment and Monitoring Project

The Habitat Assessment and Monitoring Project (HAMP) was developed in 2004 by an interagency collaboration of representatives from the Iowa Department of Natural Resources, Missouri Department of Conservation (MDC), Nebraska Game and Parks Commission (NGPC), South Dakota Game, Fish and Parks (SDGFP), University of Missouri, USACE, USFWS, and U.S. Geological Survey (USGS). The HAMP was initiated to evaluate habitat modifications designed to increase shallow, slow water habitat within the main channel of the Missouri River. The concept of shallow water habitat (SWH) has been defined operationally as 0-5 ft (0-1.5 m) depth and 0-2 ft/s (0-

0.6 m/s) current velocity (U.S. Fish and Wildlife Service 2000a); a recent clarification emphasized dynamics and variability of SWH elaborated on its hypothesized functions: "Shallow water habitat provides locations for increased primary productivity, invertebrate production, and larval/young-of-year nursery habitat" (Olson 2009).

From 2004-2009, pallid sturgeon and other target species were monitored to evaluate changes in relative abundance between habitat-modified and unmodified river bends. A before-after-control-impact (BACI) study design was used to evaluate the potential effects of habitat alteration (dominantly dike notching) on fish communities. The assessment (Schapaugh et al. 2010) cited the HAMP as an excellent design to achieve active AM, yet noted that the assumptions of the underlying BACI designs were not being met under real-world conditions and therefore ability to detect effects of SWH was limited. In particular the authors reported that the actions of dike notching did not result in detectable changes in the fish community. The authors suggested that specific hypotheses addressing mechanisms of change associated with changes in habitat and fish production need to be addressed. . However, Ridenour et al. (2009) used HAMP collected Macryhbopsis spp. chubs to demonstrate ontogenetic shifts in habitat use from age-0 to adulthood, and discussed the role of SWH and the potential for strategic dike notching, in support of pallid sturgeon recovery.

Recently, HAMP efforts have been modified to de-emphasize the previous BACI design and to focus on specific hypotheses relating SWH and life-stage processes of larval and young-of-year pallid sturgeon (Todd Gemeinhardt, USACE, pers. comm.). The purpose of the current HAMP study is to evaluate the efficacy of existing SWH to support early life stages of age-0 *Scaphirhynchus spp.* (undifferentiated age-0 pallid sturgeon and shovelnose sturgeon) to facilitate adaptive decision making for future habitat construction actions.

D.1.1.7 Objectives

The recent, primary objectives of HAMP are to: 1) compare density (numbers per unit area) of age-0 sturgeon between reaches with high acreages of SWH (existing or restored) against reaches with no or minimal SWH; and 2) identify and prioritize the types, or suite of types, of habitats that best promote use by age-0 sturgeon to guide management decisions on future SWH restoration.

D.1.1.8 Geographic Scope

The current HAMP study includes 5 river reaches that are approximately 20 miles in length. The study area begins at RM 327 (approximately 30 miles downriver from Kansas City, MO) and extends to RM 33 near St. Louis, MO.

D.1.1.9 Sample Design

To maximize efficiency and value of the HAMP's limited sampling resources, a stratified random approach was used in 2014-2015 to guide sampling efforts through the habitat classification hierarchy to avoid oversampling in habitats where age-0 sturgeon (≤109 mm) are not likely to occur (based on PSPAP capture data collected from 2003 to 2013 in segments 10, 13, and 14 and existing HAMP data). Sampling units are limited to short (approximately 20 mile) reaches of Missouri River from Kansas City to St. Louis and is implemented to meet the two objectives listed above. Subsampling was distributed with a goal of achieving representativeness (prevent clustering of sampling in any part of reach) and rapid progression through each reach to minimize effects of changing environmental conditions on data interpretation within and among reaches. Additional information related to the sample design can be found in Gosch et al. (2015). Habitats in the 5 reaches are sampled from May through October. Habitats >1.5 m in depth are sampled with an otter trawl similar to that used by the PSPAP (see Welker and Drobish 2012 for description); however, the HAMP trawl has a smaller mesh size (4 mm vs. 6.35 mm for PSPAP). In habitats <1.5 m deep, the HAMP samples with a 4-mm mesh push trawl (Gosch et al. 2015).

D.1.1.10 Evaluation

The catch information reported here is for the 2014 sample season. Catch for age-0 (<109 mm) *Scaphirhynchus* sturgeon through the HAMP project was approximately 5 times greater than the catch rate obtained for PSPAP (Tables D2 and D3). This is likely due to differences in sample design and gear types, in particular the emphasis on targeted, habitat-based sampling rather than completely non-stratified randomizaton.

D.1.7 Broodstock Sampling

The pallid sturgeon Propagation and Population Augmentation element (RPA IV) is a direct effort to supplement year-class structure to the pallid sturgeon population due to the lack of spawning and/or recruitment in the Missouri River. It also attempts to provide for survival of the species, retention of the remaining population genetics and structure, provides adults to test management actions and recruitment hypotheses, and provides a reliable source of progeny for addressing uncertainty related to age-0 pallid sturgeon survival.

D.1.1.11 Objective

The objective of broodstock sampling is to provide reproductive adults for the augmentation program. Wild pallid sturgeon are collected each spring and brought into hatcheries for spawning and the eventual stocking of their progeny into the Missouri River; this occurs in the Upper (Fort Peck Reservoir to Lake Sakakawea and

the Lower Yellowstone River) and Lower (Lewis and Clark Lake to the Missouri River mouth) Missouri River basins (Figure D1). Currently, pallid sturgeon broodstock collection activities in the upper river are conducted by Montana Fish, Wildlife, and Parks (MTFWP), U.S. Geological Survey (USGS), and the U.S. Fish and Wildlife Service (USFWS), and generally occur in May and June. In the Lower River, broodstock collection occurs primarily in April and is conducted by the USFWS and the states of South Dakota, Missouri, and Nebraska.

The largest broodstock collection effort occurs in the Lower River. For example, in 2015 over a two-week sample period, Nebraska Game and Parks Commission (NGPC) utilized 175 personnel, mostly volunteers, in an intensive effort. A similar, but smaller effort was conducted in the Lower Missouri River by the Missouri Department of Conservation (MDC) where they used a combination of 78 agency and volunteer personnel to collect pallid sturgeon broodstock. In the Upper and Lower rivers, most of the agency personnel that are involved with broodstock collection also conduct fish monitoring through USACE funded projects (e.g., PSPAP, HAMP, and Comprehensive Sturgeon Research Project [CSRP]).

D.1.1.12 Geographic Scope

Pallid sturgeon broodstock collection occurs in the four Recovery Priority Management Areas (RPMA; 1-4) for pallid sturgeon in the Missouri River. RPMA 1 is outside of the geographic scope of the MRRP (that is, upriver of Fort Peck Reservoir); however, the MRRP does include those portions of the Missouri River encompassed by RPMA's 2-4. The USACE has jeopardy responsibilities for pallid sturgeon under the Endangered Species Act in these three RPMA's.

D.1.1.13 Sample Design

Broodstock sampling throughout the Missouri River basin is a targeted effort rather than randomized, and is therefore subject to considerable bias in estimating fish density. Sampling is concentrated during spring in areas where adult-sized pallid sturgeon have been found in high concentration in the past (e.g., reaches, bends, habitats, river confluences). A variety of fish sampling gears are used throughout the basin; trammel nets (TN48, 38.1 m long x 2.4 m deep with 4 in and 8 in panel mesh; TN610, 38.1 m long x 2.4 m deep with 6 in and 10 in panel mesh) serve as the primary gear in the upper river with PSPAP standard trotlines the primary gear used in the Lower River (for a description of gear dimensions, consult Welker and Drobish (2012)). Sampling by the various resource agencies is concentrated into a two- to three-week period.

D.1.1.14 Evaluation

For this report, broodstock CPUE was quantified for two types of trammel nets in the Upper Basin and for the standard PSPAP trotline. Gear subsamples were averaged across years and segments within a basin to obtain a single CPUE value for each gear type. Catch was reported as number of fish/100 m^2 for the trammel nets and the number of fish/20 hooks for the trotline. The number of sturgeon per gear deployment (subsample) was also reported for all gears (Table D3).

In the Lower River, targeted broodstock sampling with the trotline provided the highest catch per deployment (0.336; Table D3) when compared to the gears used for PSPAP standard, random sampling (Table D2). Targeted broodstock sampling in the upper river provides lower catch rates (Table D3) compared to trotline and trammel net sampling through PSPAP (Table D2). However, the broodstock trammel nets (TN48 and TN610) were selected and are deployed to capture the large and rare upper river legacy broodfish. This likely results in a lower catch rate than if the entire population of pallid sturgeon were also targeted for capture.

D.1.8 Platte River Assessment

Sampling for pallid sturgeon began in 2009 as part of a research effort designed to determine the distribution and abundance of pallid sturgeon in the Lower Platte River. Pallid sturgeon were collected annually from 2009-2012 with the research effort renewed in 2014.

D.1.1.15 Geographic Scope

The research area extends up the Platte River from river kilometer (rkm) 0 at the confluence with the Missouri River to rkm 159 near the Loup River Power Canal confluence.

D.1.1.16 Sample Design

Data collection occurred in randomly selected 1-km reaches within two study segments. A stratified-random sampling approach was used to select 20 sample reaches within each segment. Fish were collected with drifting trammel nets (depth=1.8 m; length=38.1 m; outside mesh panel=15.0 cm; inside mesh panels=2.5 cm) and trotlines (30.5 m main line; 20 3/0 O'Shaughnessy hooks). Data provided as a personal communication from M. Hamel (2015).

D.1.1.17 Evaluation

Trammel net catch for pallid sturgeon >=109 mm was 0.058 fish/100 m drifted which is higher than the 0.017/100 m found for the PSPAP in the Lower Missouri River. Trotline CPUE in the Lower Platte River was 0.015/20 hooks which is lower than the 0.108/20 hooks obtained for pallid sturgeon in the Lower Missouri River through the PSPAP. Targeted broodstock sampling with the trotline for the PSPAP yielded 0.180/20 hooks. It should be noted that the Platte River is substantially shallower and has more complex habitats on average than the Missouri River, so gear efficiencies would be expected to vary.

D.1.9 Comprehensive Sturgeon Research Project

The CSRP is an interagency collaboration of the USGS, NGPC, MTFWP, USFWS, and the USACE Missouri River Recovery—Integrated Science Program. The goal of CSRP is to improve the fundamental understanding of the reproductive ecology of the pallid sturgeon (*Scaphirhynchus albus*) to better inform river and species management decisions. The CSRP is not intended to be a monitoring project, but it has had aspects of monitoring in its long-term datasets.

D.1.1.18 Objectives

Specific objectives pursued 2005-2014 include:

- Determine movement, habitat use, and reproductive behavior of pallid sturgeon;
- Understand reproductive physiology of pallid sturgeon and relations to environmental conditions;
- Determine origin, transport, and fate of drifting pallid sturgeon larvae and evaluate bottlenecks for recruitment of early life stages;
- Quantify availability and dynamics of aquatic habitats needed by pallid sturgeon for all life stages; and
- Manage databases, integrate understanding, and publish relevant information into the public domain.

CSRP has emphasized understanding of reproductive ecology of adult and early-life-stage sturgeon. For understanding reproductive behaviors of adults, the CSRP approach has been to capture adult shovelnose and pallid sturgeon, evaluate the reproductive status of each individual (Korschgen 2007), and instrument each with a uniquely coded acoustic or acoustic/radio combined telemetry transmitter and archival data storage tag (DST) to record temperature and depth (as pressure) at 15 to 30 minute interval. Telemetry has been used to locate individual sturgeon over long periods to collect

information on movement, habitat use, behavior, and response to environmental cues or habitat manipulations.

D.1.1.19 Geographic Scope

CSRP activities range from the Upper Missouri and Yellowstone rivers to the Middle Mississippi River. Some telemetry and supporting abiotic datasets have collected in tributaries like the Osage, Kansas, Platte, and Big Sioux rivers. The inter-reservoir reaches from Lake Sakakawea to Lewis and Clark Lake have not been included.

D.1.1.20 Sample Design

The CSRP telemetry dataset is focused on hypotheses relating to the reproductive ecology of pallid sturgeon adults. The sample design includes comparative studies of migration, aggregation, and spawning in the Upper Missouri-Yellowstone and the Lower Missouri River. In the Lower Missouri River, reproductive behaviors upstream of the Platte River are compared to reproductive behaviors downstream of Kansas City in an attempt to isolate effects of flow management.

Since the CSRP was initiated, 175 pallid sturgeon and 376 shovelnose have been implanted with telemetry tags and telemetry tags in combination with DST devices in the Lower Missouri River. Of these, 172 (98.3%) pallid sturgeon 352 (94.6%) Shovelnose Sturgeon were located at least once after release. More than 80 pallid sturgeon have been in the CSRP study for multiple years and had multiple telemetry and DST devices during that time. From pallid sturgeon implanted with DST devices, CSRP has archived more than 3.3 million depth and temperature records. All locations on the Lower Missouri River are determined through boat-mounted acoustic receivers. On the Upper Missouri and Yellowstone Rivers, most tags have been radio frequency.

CSRP has also carried out some free-embryo sampling to address specific questions about where and when sturgeon spawn. Systematic sampling for free embryo sturgeon and paddlefish was initiated through CSRP in 2012 and is conducted along transects perpendicular to the flow of the river at intervals throughout the spawning and dispersal periods. Systematic sampling was performed in 2012 in the Lower Missouri River near St. Charles, MO from mid-April into October to detect timing, and extent of spawning by sturgeon and paddlefish, and species composition and abundance of Acipensiform free embryos drifting in the Lower Missouri River. Systematic sampling efforts during 2012 and 2013 resulted in a total of 2043 gear deployments at two locations, collecting a total of 665 sturgeon and 412 paddlefish free embryos.

D.1.1.21 Evaluation

CSRP studies have established telemetry methods for implantation, tracking, and data analysis for pallid sturgeon. The experience indicates that boat-based acoustic telemetry tracking is viable on the Lower Missouri River and combined acoustic and radio tags are useful on the Upper Missouri River. The results show the long distances some fish will travel in their reproductive migrations (100's of km) and, in some case, some spatial fidelity to their reproductive home ranges. This experience with telemetry techniques and data processing is likely to be useful in design and implementation of future population trends monitoring, including the use of telemetry in evaluating emigration and immigration.

D.1.10 Summary of Past and Current Projects

Of the projects described above, only the PSPAP was developed and implemented to capture trends in pallid sturgeon population metrics. PSPAP catch information, evaluated within the context of the other projects, documents which gears, habitats, and sampling designs appear to be most efficient and therefore likely to be useful in future population monitoring. In addition to the data presented here, several analyses of the PSPAP add understanding of what the project provides and the reliability of the quantified trends. Early in the development of PSPAP, an independent science review was conducted by Sustainable Ecosystems Institute (2004). A number of recommendations was provided and later implemented to better integrate the project components and meet objectives. Statistical power analyses were performed periodically (Peery 2004, Bryan et al. 2010, Schapaugh and Tyre 2011) to identify investments and trade-offs in the project design and to evaluate the ability to detect changes in abundance. Population trends were quantified through a number of assessments (Oldenburg et al. 2010, Wildhaber et al. 2011, Wildhaber et al. 2015) following standardization of the project design in 2006. Recent work by Wildhaber et al. (2015) provided new models that incorporated covariates (e.g., water temperature, velocity, gear, habitat) that improved the detection of abundance and habitat-use changes over time. Their assessment determined that "....a large-scale, large-river, PSPAP-type monitoring program can be an effective tool for assessing population trends and habitat usage of large-river fish species. Using multiple gears, PSPAP was effective in monitoring shovelnose and pallid sturgeons, sicklefin, shoal and sturgeon chubs, sand shiner, blue sucker and sauger." However, the question to be answered through this report is: will implementing the current PSPAP monitoring design, or an alternative design, best meet the future needs and objectives identified in the MRRP AM Plan?

D.1.11 Design Guidance from Current Monitoring Information

Current and past monitoring projects on the Missouri River can provide valuable insight into important design criteria such as when, where, and at what level of effort to sample; choosing the appropriate level of each criterion will optimize the sample design for meeting MRRP objectives. Review of these projects will lead to development of the most efficient design that provides high quality data, the least-biased estimates, and high precision or certainty. Detailed analysis (e.g., simulations that examine trade-offs) as part of a level 1 science effort will be required to identify the most appropriate design based on the type of information needed, the level of detail, the metrics, and the cost of collecting the data; however, at this preliminary stage, numerous design considerations can be identified. The design considerations are provided below for sub-objectives 1 and 2. Considerations identified for sub-objective 2 would also apply to quantifying or updating population demographics (that is, catch rates for all size classes of pallid sturgeon).

D.1.1.22 Temporal Sampling Distribution

Temporal sampling considerations will depend on the objectives and the metrics selected to assess the Fundamental and Species objectives. The current temporal sampling units vary depending on the project (e.g., PSPAP or HAMP). The PSPAP sampling is separated into two temporal units per year, a sturgeon season (ST) and a fish community season (FC); these generally run from early winter through spring (ST) and summer to late fall (FC). Sampling in the PSPAP has occurred sporadically, representing every month of the year and usually summarized by season or year. Other projects have more specific time periods for sampling such as during the spring/early summer to track reproductive adults or during the late summer to sample for larval sturgeon in the drift, for example.

Temporal sampling units can widely vary (e.g., day, month, season, or year). Depending on the specific objectives of a study, timing of sampling is important especially when directed at certain life stages. Thus, identifying time frames to conduct sampling for specific life stages of interest throughout the year at specific locations will result in the collection of data that can address the objectives of a study. Pallid sturgeon use many locations in the Missouri River and can move extensively throughout the year, thus timing of sampling and location must match to address study objectives.

D.1.1.23 Upper River

Most effort for age 2-3 pallid sturgeon from 2006-2014 was in May (n=3,679 subsamples) and June (n=3,132 subsamples) followed by August and September

(n=2,894 and 2,904 subsamples, respectively) (Figure B3). Although the number of subsamples averaged 506 fewer in August/September than in May/June, catch rate (#/subsample) was highest in August/September (mean = 0.04) compared to May/June (mean = 0.025). However, the month of April also had a catch rate of 0.04 when the number of subsamples was only 1,105. The highest catch rate was 0.05 in October where the number of subsamples was 2,081.

The majority of pallid sturgeon < 109 mm were caught in August (Figure B3). Sub-adult pallid sturgeon catch rates were low in the spring/summer and higher from August through October. Few (n=40) large pallid sturgeon (> 1,000 mm) have been caught, however, 31 of those were caught from August through October (Table D5).

The largest amount of subsampling from 2006-2014 has been in May and June, although these two months have generally resulted in a fewer number of pallid sturgeon caught per subsample relative to the other months. The month of April has the largest catch rate relative to number of subsamples for age 2-3 fish and August generally appears to have the greatest catch rates for all sizes of pallid sturgeon.

Table D5. PSPAP catch for pallid sturgeon (>=109-1,000 mm; >1,000 mm; age 2-3) and *Scaphirhynchus* species (< 109 mm FL) for each month (March-October) in the upper Missouri River basin for the years 2006-2014. *

[FL: fork length; mm: millimeter.]

Size	Month	Area	Number sturgeon caught	Number per subsample
<109 mm	Apr	Segment 4	6	0.02
	May		15	0.03
	Jun		3	0.01
	Jul		12	0.05
	Aug		77	0.27
	Sep		28	0.07
	Oct		6	0.02
>=109 mm – 1,000 mm	Mar	Segments 2-4	0	0
	Apr		188	0.17
	May		515	0.14
	Jun		345	0.11
	Jul		248	0.12
	Aug		695	0.24
	Sep		842	0.29
	Oct		728	0.35

Only otter trawl subsamples are reported for *Scaphirhynchus* spp. sturgeon <109 mm; otter trawl, trammel net, and trotline subsamples are reported for the other length/age groups.

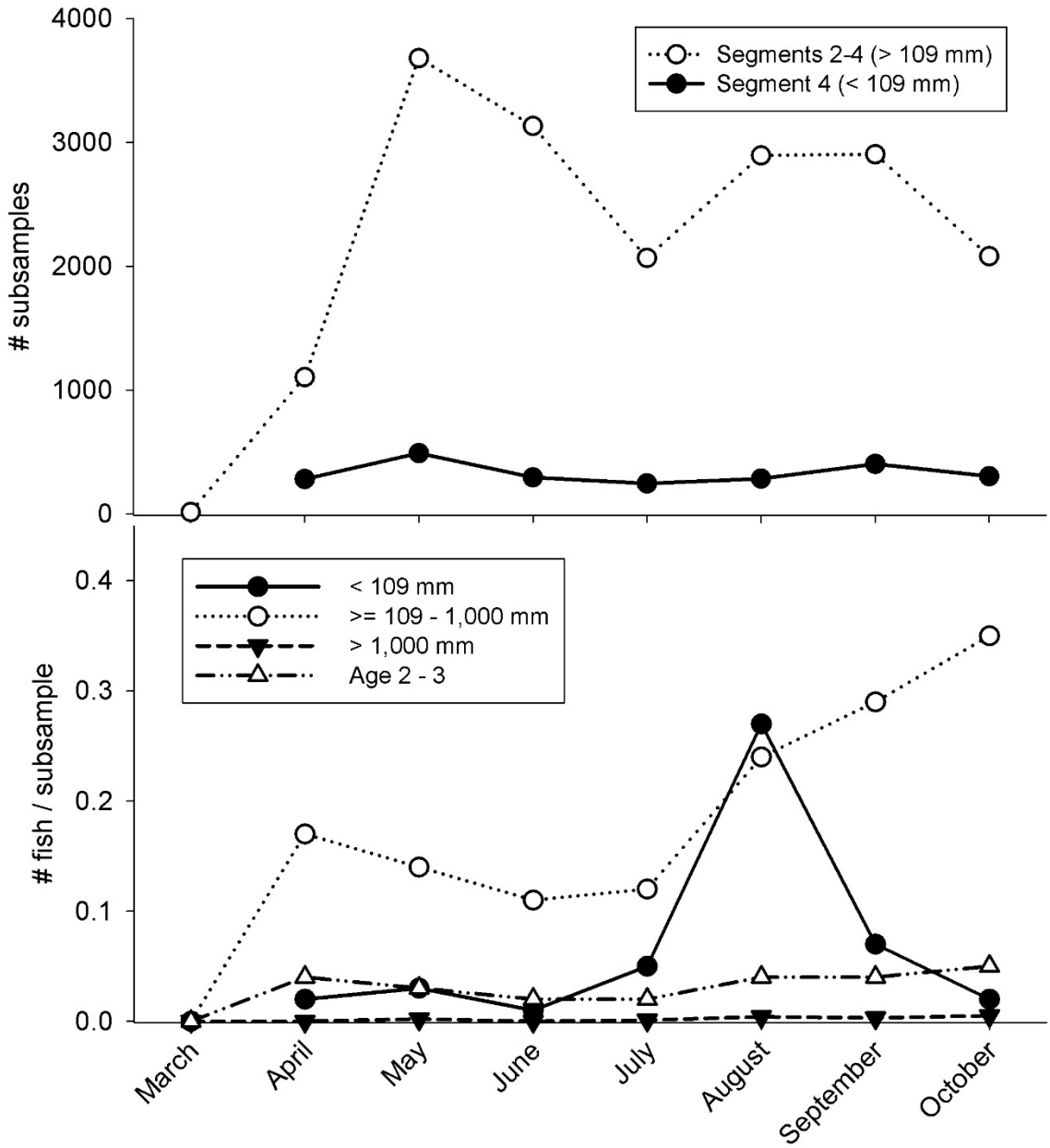

Figure D3. PSPAP effort (top panel) and catch (bottom panel) for pallid sturgeon (>=109-1,000 mm; >1,000 mm; age 2-3) and *Scaphirhynchus spp.* (< 109 mm FL) for each month (March-October) in the upper Missouri River basin for the years 2006-2014. Only otter trawl subsamples are reported for *Scaphirhynchus spp.* sturgeon <109 mm; otter trawl, trammel net, and trotline subsamples are reported for the other length/age groups.

D.1.1.24 Lower River

Most effort for age 2-3 pallid sturgeon from 2006-2014 was from May through August (range: 3,946-5,072 subsamples) (Figure B3). The lowest effort was from December through February. Catch rate (#/subsample) was either 0.0 or 0.01. Age 2-3 pallid sturgeon have only been caught from March-May and October-November (Table D6).

Pallid sturgeon < 109 mm were catch rate increased from May to August and peaked in September (Figure D3). Sub-adult pallid sturgeon catch rates were highest in the spring and late fall while low from June through September (Figure D3). The month for the highest catch rate of large pallid sturgeon (> 800 mm) was October.

D.1.1.25 Summary

The largest amount of subsampling from 2006-2014 has been from May through August, although these months have generally resulted in a fewer number of pallid sturgeon caught per subsample relative to the other months. Both spring and fall months have similar catch rates age 2-3 fish, but the months of September and October generally appear to have the greatest catch rates for all sizes of pallid sturgeon. Furthermore, catch rates in September and October are higher with less effort than that observed for the month of May through August.

Table D6. PSPAP catch for pallid sturgeon (>=109-1,000 mm; >1,000 mm; age 2-3) and *Scaphirhynchus* species (< 109 mm FL) for each month (March-October) in the lower Missouri River basin for the years 2006-2014. *

[FL: fork length; mm: millimeter.]

Size	Month	Area	# sturgeon caught	#/Subsample
<109 mm	May	Segments 10, 13, 14	19	0.02
	Jun		65	0.08
	Jul		74	0.13
	Aug		143	0.18
	Sep		201	0.31
	Oct		60	0.13
>=109 mm – 800 mm	Jan	Segments 7-14	15	0.03
	Feb		44	0.05
	Mar		198	0.06
	Apr		147	0.06
	May		190	0.04
	Jun		39	0.01
	Jul		101	0.02
	Aug		84	0.02
	Sep		71	0.02
	Oct		281	0.08
	Nov		251	0.09
	Dec		48	0.06
>800 mm	Jan	Segments 7-14	5	0.01
	Feb		26	0.03
	Mar		66	0.02
	Apr		25	0.01
	May		0	0
	Jun		0	0
	Jul		0	0

	Aug		0	0
	Sep		0	0
	Oct		140	0.04
	Nov		56	0.02
	Dec		16	0.02
Age 2-3	Jan	Segments 7-14	0	0
	Feb		0	0
	Mar		33	0.01
	Apr		25	0.01
	May		48	0.01
	Jun		0	0
	Jul		0	0
	Aug		0	0
	Sep		0	0
	Oct		35	0.01
	Nov		28	0.01
	Dec		0	0

Only otter trawl subsamples are reported for *Scaphirhynchus* spp. sturgeon <109 mm; otter trawl, trammel net, gill net, and trotline subsamples are reported for the other length/age groups.

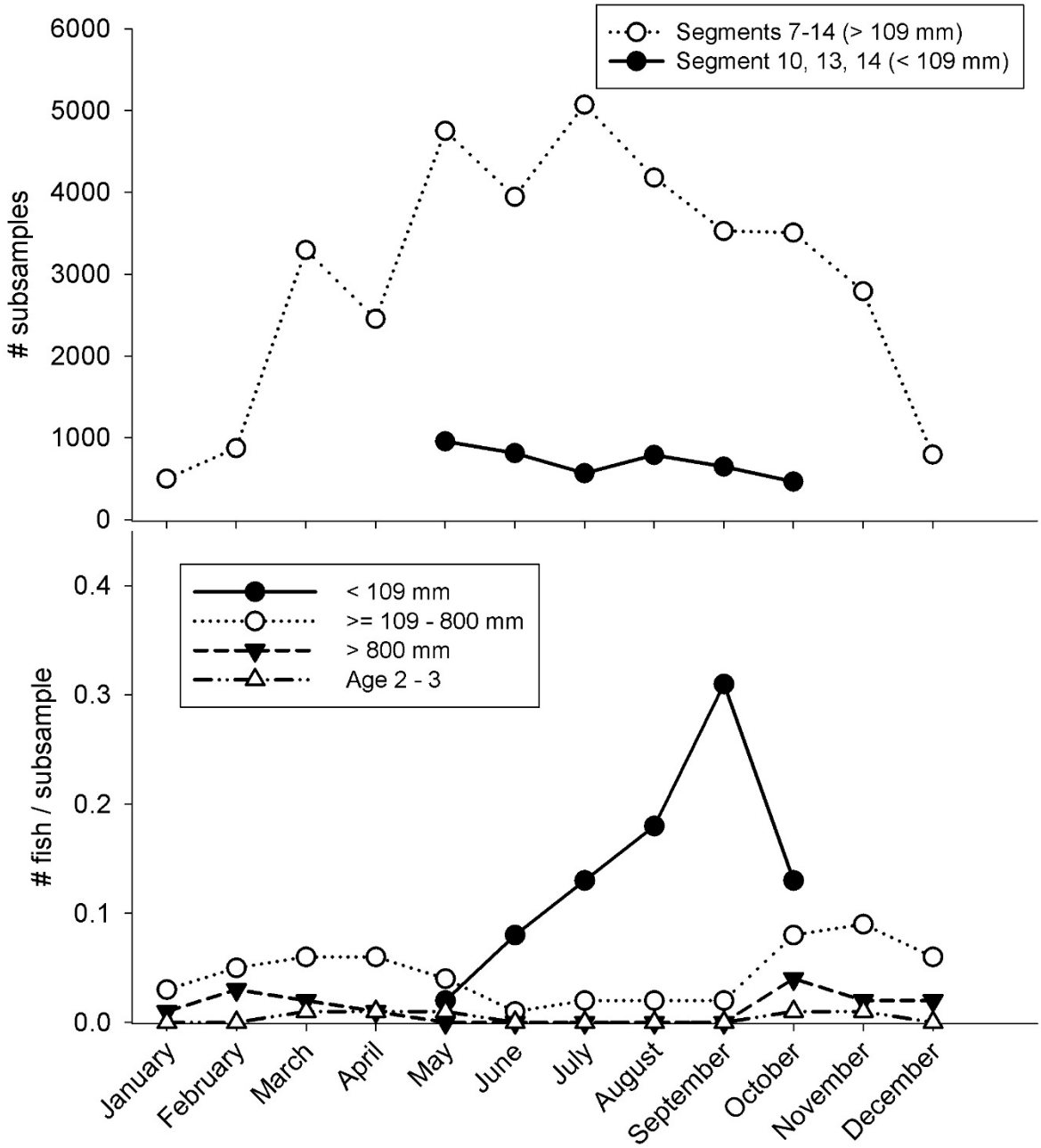

Figure D4. PSPAP effort (top panel) and catch (bottom panel) for pallid sturgeon (>=109-800 mm; >800 mm; age 2-3) and *Scaphirhynchus spp.* (< 109 mm FL) for each month in the lower Missouri River basin for the years 2006-2014. Only otter trawl subsamples are reported for *Scaphirhynchus spp.* sturgeon <109 mm; otter trawl, trammel net, gill net, and trotline subsamples are reported for the other length/age groups.

D.1.1.26 Spatial Sampling Distribution

Spatial sampling considerations depend upon the objectives under consideration and the metrics selected to assess how actions are meeting these objectives. The largest spatial units of interest for pallid sturgeon monitoring are identified in the EA and MRRMP and are as follows: 1) the Upper Missouri River mainstem from Fort Peck Dam to the headwaters of Lake Sakakawea and 2) the Lower Missouri River mainstem from Gavins Point Dam to confluence with the Mississippi River at St. Louis. These are the largest spatial units that may be considered when developing a monitoring plan for pallid sturgeon through the MRRP for a variety of reasons: 1) these two spatial units reflect biologically significant opportunities for achieving benefit to pallid sturgeon, 2) management actions may be implemented in these areas, 3) the results of management actions may be detected in these spatial units (e.g., successful recruitment), 4) these are the areas where the USACE impacts to pallid sturgeon have been previously identified (e.g., 2003 BiOp), and 5) they encompass the decision-making authority of the USACE. Other spatial units to consider (see reasons 1 and 2 above) are the Yellowstone River upstream of the confluence with the Upper Missouri River for an unspecified distance, an unspecified distance downstream in the Mississippi River, and tributaries used by pallid sturgeon.

The fundamental spatial sampling consideration for any design will be the gear (e.g., trammel net, or gill net) subsample location. Subsample locations can be organized and selected in a variety ways; the most objective approach would be to randomly select points within a larger spatial construct (e.g., river reach). However, such an approach would seem haphazard as much has been learned regarding habitat use by pallid sturgeon in the Missouri River for a variety of life stages. Identifying the habitat types most likely to contain the life stage(s) of interest and incorporating this information into the sample design will likely provide the most efficient path to decision-influencing results. Further, the habitat types that are utilized by pallid sturgeon may also vary longitudinally in the Missouri River. The PSPAP employs a hierarchical sample design that progresses from largest to smallest spatial units as follows: Basin (Upper, Middle, Lower MR), Segment, River Bend, Habitat (Macro, Meso, Micro), and gear subsample. The current HAMP project selected and then targeted those habitat types from PSPAP that provided the highest catch rates for very young (that is, age-0) *Scaphirhynchus* sturgeons. The HAMP project provides an example of what a targeted habitat-sampling effort can provide with regard to detecting a size/age of interest. Tables D5 and D6 provide the number of *Scaphirhynchus spp.* (surrogate for age-0 pallid sturgeon), juvenile/sub-adult pallid sturgeon, and adult pallid sturgeon captured in each habitat type from 2006-2014 within Upper and Lower Missouri River segments. HAMP capture information for the 2014 sample year is provided in Table D7. Body length was used to partition the captures into age-0 (<109 mm; Ridenour et al. 2011), juvenile/sub-

adult (>= 109 mm – 800 mm in the LB and 1,000 mm in the UB), and adult (>800 mm LB, >1,000 mm UB) for sub-objective 2. Tables D5 and D6 provide the same information for pallid sturgeon 2-3 years of age (hereafter referred to as 2-3 yr old). The length range for 2-3 yr-old pallid sturgeon was derived from the growth models of known-age hatchery-produced pallid sturgeon in Shuman et al. (2011); the length range between the predicted length for the 2 and the 3-year old age groups was used to select the catch information for this category (that is, 275-400, Upper River; 325-425, Lower River).

Table D7. Catch [number/subsample] for *Scaphirhynchus spp.* (less than 109 millimeters fork length) for each Macrohabitat-Mesohabitat combination in the Lower Missouri River below Kansas City, Mo. sampled through the HAMP from 2013-2014.
[See Welker and Drobish 2012 for a description of gears and habitat types.]

Macro/Meso	Gear	Gear Subsample Count	Individuals Captured/Subsample
River miles 327-307; 237-215			
CHXO-BARS	Micro-mesh Otter Trawl	12	0.25
CHXO-CHNB	Micro-mesh Otter Trawl	41	0.46
ISB-BARS	Micro-mesh Otter Trawl	142	0.27
ISB-CHNB	Micro-mesh Otter Trawl	451	0.73
OSB-CHNB	Micro-mesh Otter Trawl	1	1.00
OSB-BARS	Micro-mesh Otter Trawl	9	0.22
SCCL-BARS	Micro-mesh Otter Trawl	136	0.11
SCCL-CHNB	Micro-mesh Otter Trawl	530	0.44
SCCL-ITIP	Micro-mesh Otter Trawl	1	0.00
River miles 180-157; 110-94; 54-33			
CHXO-BARS	Micro-mesh Otter Trawl	59	0.05
CHXO-CHNB	Micro-mesh Otter Trawl	436	0.38
CHXO-POOL	Micro-mesh Otter Trawl	12	0.5
ISB-BARS	Micro-mesh Otter Trawl	257	0.20
ISB-CHNB	Micro-mesh Otter Trawl	2040	0.51
ISB-ITIP	Micro-mesh Otter Trawl	2	4.50
ISB-POOL	Micro-mesh Otter Trawl	7	3.14
SCCL-BARS	Micro-mesh Otter Trawl	21	0.05
SCCL-CHNB	Micro-mesh Otter Trawl	26	0.15
SCCL-ITIP	Micro-mesh Otter Trawl	16	0.19
SCCL-TLWG	Micro-mesh Otter Trawl	6	0.00
SCCS-CHNB	Micro-mesh Otter Trawl	2	0.50

While Tables D5-D7 provide an average of the annual catch rates for sampling through the PSPAP and HAMP, Tables D8-D11 of pallid sturgeon (or *Scaphirhynchus* spp.) throughout the sample year (by month). Tables D12-D15 (Upper River) and Tables D16-D19 (Lower River) provide the gear-habitat distributions of catch rates over the same monthly time frame for the combined segments in each basin (Upper River and Lower River).

Table D8. Heat map of sturgeon catch rates for Scaphirhynchus sturgeon less than 109 millimeters in fork length captured with the otter trawl within segments of the Upper River and Lower River.

[Catch rate is defined as the number of fish caught divided by the subsample size. The UpperRiver includes those areas of the Missouri River from Fort Peck Dam to Lake Sakakawea and the Lower River includes those areas from Gavins Point Dam to the mouth.]

	Segments													
	Upper Basin						Lower Basin							
Month	Fort Peck Dam	2	3	4	Lake Sakakawea		Gavins Point Dam	7	8	9	10	13	14	Mississippi River
Mar.												0.000	0.000	
Apr.		0.000	0.000	0.021				0.000	0.000	0.000	0.000	0.043	0.000	
May.		0.000	0.005	0.029				0.000	0.000	0.000	0.016	0.014	0.038	
Jun.		0.000	0.000	0.007				0.000	0.003	0.054	0.015	0.109	0.115	
Jul.		0.000	0.000	0.035				0.000	0.045	0.118	0.086	0.130	0.043	
Aug.		0.000	0.004	0.338				0.000	0.000	0.056	0.222	0.211	0.088	
Sep.		0.000	0.002	0.059				0.000	0.008	0.034	0.261	0.375	0.160	
Oct.		0.000	0.000	0.019				0.000	0.000	0.054	0.367	0.216	0.162	
Nov.									0.000		0.038			

Catch rate key (number/subsample)
Low Value
Mid-point (50th percentile)
High Value

Table D9. Heat map of sturgeon catch rates for pallid sturgeon greater than or equal to 109 millimeters but less than 800 millimeters (Lower River) or less than 1000 millimeters (Upper River) in fork length captured with the otter trawl, trotline, trammel net, and gill net (Lower River only) within segments of the Upper River and Lower River.

[Catch rate is defined as the number of fish caught divided by the subsample size. The Upper River includes those areas of the Missouri River from Fort Peck Dam to Lake Sakakawea and the Lower River includes those areas from Gavins Point Dam to the mouth.]

	Segments													
	Upper Basin						Lower Basin							
Month	Fort Peck Dam	2	3	4	Lake Sakakawea		Gavins Point Dam	7	8	9	10	13	14	Mississippi River
Jan.								0.079		0.023	0.059	0.007	0.025	
Feb.								0.010	0.150	0.060	0.016	0.057	0.052	
Mar.		0.000						0.047	0.074	0.066	0.051	0.082	0.035	
Apr.		0.116	0.298	0.153				0.034	0.090	0.074	0.073	0.061	0.022	
May		0.132	0.165	0.103				0.037	0.051	0.033	0.014	0.023	0.012	
June		0.095	0.129	0.062				0.021	0.031	0.007	0.000	0.010	0.004	
July		0.048	0.096	0.249				0.027	0.031	0.013	0.004	0.016	0.004	
Aug.		0.096	0.115	0.413				0.034	0.031	0.010	0.004	0.014	0.004	
Sept.		0.169	0.195	0.388				0.039	0.013	0.005	0.018	0.005	0.009	
Oct.		0.211	0.238	0.527				0.027	0.144	0.143	0.068	0.008	0.011	
Nov.								0.089	0.142	0.103	0.055	0.077	0.051	
Dec.								0.118		0.045	0.000	0.036	0.025	

Catch rate key (number/subsample)	
	Low Value
	Mid-point (50th percentile)
	High Value

Table D10. Heat map of sturgeon catch rates for pallid sturgeon 2-3 years of age captured with the otter trawl, trotline, trammel net, and gill net (Lower River only) within segments of the Upper River and Lower River.

[Catch rate is defined as the number of fish caught divided by the subsample size. The Upper River includes those areas of the Missouri River from Fort Peck Dam to Lake Sakakawea and the Lower River includes those areas from Gavins Point Dam to the mouth.]

	Segments													
	Upper Basin						Lower Basin							
Month	Fort Peck Dam	2	3	4	Lake Sakakawea		Gavins Point Dam	7	8	9	10	13	14	Mississippi River
Jan.								0.000		0.008	0.000	0.007	0.000	
Feb.								0.000	0.050	0.000	0.000	0.008	0.000	
Mar.		0.000						0.015	0.013	0.012	0.000	0.010	0.002	
Apr.		0.101	0.188	0.094				0.007	0.006	0.009	0.008	0.016	0.000	
May		0.085	0.089	0.057				0.014	0.012	0.006	0.000	0.002	0.000	
June		0.055	0.068	0.044				0.010	0.014	0.002	0.000	0.004	0.000	
July		0.029	0.061	0.121				0.011	0.011	0.003	0.002	0.000	0.000	
Aug.		0.059	0.074	0.192				0.018	0.010	0.002	0.000	0.002	0.000	
Sept.		0.114	0.117	0.144				0.016	0.006	0.000	0.004	0.000	0.002	
Oct.		0.114	0.143	0.199				0.005	0.012	0.006	0.023	0.000	0.000	
Nov.									0.039	0.024	0.011	0.012	0.004	
Dec.										0.000	0.000	0.006	0.000	
Catch rate key (number/subsample)														
		Low Value												
		Mid-point (50th percentile)												
		High Value												

Table D11. Heat map of sturgeon catch rates for pallid sturgeon greater than 800 millimeters (Lower River) or greater than 1000 millimeters (Upper River) in fork length captured with the otter trawl, trotline, trammel net, and gill net (Lower River only) within segments of the Upper River and Lower River.

[Catch rate is defined as the number of fish caught divided by the subsample size. The Upper River includes those areas of the Missouri River from Fort Peck Dam to Lake Sakakawea and the Lower River includes those areas from Gavins Point Dam to the mouth.]

	Segments													
	Upper Basin						Lower Basin							
Month	Fort Peck Dam	2	3	4	Lake Sakakawea		Gavins Point Dam	7	8	9	10	13	14	Mississippi River
Jan.								0.032		0.008	0.000	0.007	0.012	
Feb.								0.000	0.000	0.006	0.032	0.041	0.026	
Mar.		0.000						0.006	0.026	0.021	0.019	0.014	0.005	
Apr.		0.000	0.000	0.000				0.004	0.045	0.021	0.000	0.002	0.012	
May		0.001	0.000	0.004				0.001	0.003	0.003	0.000	0.000	0.004	
June		0.000	0.000	0.000				0.000	0.001	0.000	0.000	0.000	0.000	
July		0.001	0.000	0.004				0.000	0.000	0.001	0.002	0.000	0.000	
Aug.		0.000	0.002	0.007				0.001	0.002	0.002	0.000	0.000	0.000	
Sept.		0.000	0.000	0.006				0.000	0.006	0.001	0.004	0.003	0.002	
Oct.		0.003	0.001	0.010				0.014	0.052	0.068	0.028	0.021	0.002	
Nov.								0.010	0.017	0.027	0.028	0.014	0.024	
Dec.								0.008		0.000	0.068	0.006	0.022	

Catch rate key (number/subsample)	
	Low Value
	Mid-point (50th percentile)
	High Value

Table D12. Heat maps of catch rates for *Scaphirhynchus* sturgeon less than 109 millimeters in fork length captured with the otter trawl in Segments 2-4 (minimum of 200 subsamples) within select macro-mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations code, OT indicates fish were caught with otter trawls.]

	Gear_Macrohabitat-Mesohabitat Combination			
Month	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Mar.				
Apr.	0.000	0.029	0.008	0.000
May	0.002	0.030	0.000	0.000
June	0.000	0.004	0.000	0.000
July	0.009	0.006	0.015	0.000
Aug.	0.101	0.078	0.169	0.000
Sept.	0.022	0.022	0.039	0.000
Oct.	0.012	0.000	0.014	0.000

Catch rate key (number/subsample)	
	Low Value
	Mid-point (50th percentile)
	High Value

Table D13. Heat maps of catch rates for pallid sturgeon greater than or equal to 109 millimeters to 1,000 millimeters in fork length captured with the trammel net, trotline, and otter trawl captured in Segments 2-4 (minimum of 200 subsamples) within select macro-mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations, TN indicates fish were caught with trammel nets, TL indicates fish were caught with trotlines, and OT indicates fish were caught with otter trawl.]

	Gear_Macrohabitat-Mesohabitat Combination										
Month	TN_CHXO-CHNB	TN_ISB-CHNB	TN_OSB-CHNB	TN_SCCL-CHNB	TL_CHXO-CHNB	TL_ISB-CHNB	TL_OSB-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Mar.	0.000	0.000	0.000								
Apr.	0.234	0.134	0.266	0.010	0.400	0.759	0.105	0.136	0.080	0.090	0.227
May	0.085	0.124	0.102	0.145	0.567	0.496	0.269	0.105	0.109	0.075	0.071
June	0.097	0.037	0.060	0.090	0.734	0.560	0.447	0.076	0.118	0.048	0.088
July	0.173	0.142	0.167	0.068	0.211	0.292	0.105	0.090	0.107	0.073	0.104
Aug.	0.195	0.229	0.527	0.349	0.360	0.351	0.125	0.147	0.097	0.110	0.059
Sept.	0.284	0.275	0.471	0.440	0.382	0.345	0.257	0.171	0.205	0.179	0.068
Oct.	0.127	0.103	0.280	0.488	0.734	0.715	0.832	0.180	0.103	0.146	0.133

Catch rate key (number/subsample)
Low Value
Mid-point (50th percentile)
High Value

Table D14. Heat maps of catch rates for pallid sturgeon 2-3 years old captured with the trammel net, trotline, and otter trawl in Segments 2-4 (minimum of 200 subsamples) within select macro-mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations, TN indicates fish were caught with trammel nets, TL indicates fish were caught with trotlines, and OT indicates fish were caught with otter trawl.]

	Gear_Macrohabitat-Mesohabitat Combination										
Month	TN_CHXO-CHNB	TN_ISB-CHNB	TN_OSB-CHNB	TN_SCCL-CHNB	TL_CHXO-CHNB	TL_ISB-CHNB	TL_OSB-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Mar.	0.000	0.000	0.000	0.033							
Apr.	0.122	0.070	0.050	0.084	0.275	0.571	0.100	0.120	0.043	0.053	0.091
May	0.043	0.067	0.065	0.087	0.383	0.289	0.063	0.051	0.061	0.043	0.060
June	0.041	0.023	0.037	0.045	0.461	0.284	0.184	0.055	0.061	0.030	0.031
July	0.092	0.059	0.095	0.291	0.053	0.083	0.105	0.059	0.060	0.037	0.074
Aug.	0.105	0.120	0.221	0.213	0.220	0.228	0.000	0.076	0.062	0.050	0.036
Sept.	0.149	0.099	0.161	0.220	0.236	0.155	0.143	0.111	0.138	0.091	0.067
Oct.	0.085	0.071	0.099	0.488	0.337	0.312	0.248	0.117	0.078	0.085	0.100

Catch rate key (number/subsample)
Low Value
Mid-point (50th percentile)
High Value

Table D15. Heat maps of catch rates for pallid sturgeon greater than 1000 millimeters captured with the trammel net, trotline, and otter trawl in Segments 2-4 and 22 (Lower Yellowstone River); minimum of 200 subsamples within select macro-mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations, TN indicates fish were caught with trammel nets, TL indicates fish were caught with trotlines, and OT indicates fish were caught with otter trawl.]

	Gear_Macrohabitat-Mesohabitat Combination										
Month	TN_CHXO-CHNB	TN_ISB-CHNB	TN_OSB-CHNB	TN_SCCL-CHNB	TL_CHXO-CHNB	TL_ISB-CHNB	TL_OSB-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Mar.	0.000	0.000	0.000								
Apr.	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
May	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010
June	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
July	0.003	0.003	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Aug.	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sept.	0.002	0.005	0.005	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.000
Oct.	0.005	0.005	0.005	0.000	0.000	0.007	0.020	0.000	0.000	0.005	0.000

Catch rate key (number/subsample)
Low Value
Mid-point (50th percentile)
High Value

Table D16. Heat maps of catch rates for Scaphirhynchus sturgeon less than 109 millimeters in fork length captured with the otter trawl in Segments 7-14 (minimum of 300 subsamples) within select macro- and mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations code, OT indicates fish were caught with otter trawls.]

	Gear_Macrohabitat-Mesohabitat Combination				
Month	OT_BRAD-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Mar.		0.000	0.000	0.000	
Apr.	0.000	0.000	0.024	0.000	0.000
May	0.000	0.007	0.012	0.010	0.000
June	0.000	0.059	0.059	0.000	0.034
July	0.000	0.017	0.122	0.000	0.037
Aug.	0.000	0.050	0.121	0.026	0.078
Sept.	0.000	0.048	0.179	0.010	0.000
Oct.	0.034	0.105	0.108	0.000	0.000
Nov.		0.000	0.000		

Catch rate key (number/subsample)	
	Low Value
	Mid-point (50th percentile)
	High Value

Table D17. Heat maps of catch rates for pallid sturgeon greater than or equal to 109 millimeters to 800 millimeters in fork length captured with the trammel net, trotline, gill net, and otter trawl in Segments 7-14 (minimum of 300 subsamples) within select macro- and mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations, TN indicates fish were caught with trammel nets, GN indicates fish were caught with gill nets, TL indicates fish were caught with trotlines, and OT indicates fish were caught with otter trawl.]

	Gear_Macrohabitat-Mesohabitat Combination											
Month	TN_BRAD-CHNB	TN_CHXO-CHNB	TN_ISB-CHNB	TN_OSB-CHNB	GN_BRAD-CHNB	GN_CHXO-CHNB	GN_CHXO-POOL	GN_ISB-CHNB	GN_ISB-POOL	GN_OSB-CHNB	GN_OSB-POOL	TL_BRAD-CHNB
Jan.						0.021	0.018	0.006	0.036	0.038	0.028	0.000
Feb.					0.000	0.048	0.060	0.024	0.091	0.059	0.019	
Mar.	0.000	0.000	0.023	0.000	0.018	0.039	0.079	0.029	0.071	0.008	0.028	0.147
Apr.	0.043	0.000	0.010	0.100	0.000	0.031	0.100	0.011	0.076	0.000	0.000	0.100
May	0.059	0.020	0.020	0.000			0.000					0.039
June	0.047	0.017	0.002	0.022								0.000
July	0.055	0.013	0.021	0.027								
Aug.	0.028	0.006	0.026	0.019								0.000
Sept.	0.032	0.000	0.018	0.142								0.000
Oct.	0.017	0.000	0.005	0.022	0.000	0.040	0.092	0.073	0.139	0.041	0.038	0.053
Nov.					0.020	0.042	0.069	0.052	0.091	0.017	0.013	0.127
Dec.						0.015	0.012	0.025	0.014	0.000	0.000	0.096

Table D17. Heat maps of catch rates for pallid sturgeon greater than or equal to 109 millimeters to 800 millimeters in Segments 7-14 - Continued

Month	TL_CHXO-CHNB	TL_ISB-CHNB	TL_ISB-POOL	OT_BRAD-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Jan.	0.000	0.059	0.000					
Feb.	0.053	0.087	0.036					
Mar.	0.164	0.171	0.099		0.000	0.019	0.000	
Apr.	0.123	0.165	0.097	0.000	0.000	0.008	0.000	0.000
May	0.214	0.202	0.018	0.019	0.012	0.010	0.030	0.016
June		0.000		0.012	0.009	0.017	0.014	0.034
July				0.019	0.004	0.011	0.023	0.019
Aug.	0.000	0.000		0.000	0.009	0.006	0.013	0.000
Sept.	0.000	0.059	0.000	0.000	0.005	0.008	0.000	0.053
Oct.	0.282	0.251	0.108		0.026	0.020	0.000	0.000
Nov.	0.224	0.229	0.109		0.000	0.000		
Dec.	0.229	0.153	0.095					

Catch rate key (number/subsample)

Low Value

Mid-point (50th percentile)

High Value

Table D18. Heat maps of catch rates for pallid sturgeon 2-3 years old captured with the trammel net, trotline, gill net, and otter trawl in Segments 7-14 (minimum of 300 subsamples) within select macro- and mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations, TN indicates fish were caught with trammel nets, GN indicates fish were caught with gill nets, TL indicates fish were caught with trotlines, and OT indicates fish were caught with otter trawl.]

	Gear_Macrohabitat-Mesohabitat Combination											
Month	TN_BRAD-CHNB	TN_CHXO-CHNB	TN_ISB-CHNB	TN_OSB-CHNB	GN_BRAD-CHNB	GN_CHXO-CHNB	GN_CHXO-POOL	GN_ISB-CHNB	GN_ISB-POOL	GN_OSB-CHNB	GN_OSB-POOL	TL_BRAD-CHNB
Jan.						0.021	0.018	0.000	0.000	0.000	0.000	0.000
Feb.					0.000	0.000	0.000	0.004	0.006	0.020	0.000	
Mar.	0.000	0.000	0.000	0.000	0.000	0.013	0.018	0.002	0.012	0.000	0.009	0.059
Apr.	0.043	0.000	0.000	0.067	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.000
May	0.029	0.005	0.005	0.000			0.000					0.000
June	0.009	0.006	0.002	0.000								0.000
July	0.021	0.002	0.005	0.009								
Aug.	0.009	0.004	0.008	0.010								0.000
Sept.	0.006	0.000	0.006	0.071								0.000
Oct.	0.017	0.000	0.003	0.000	0.000	0.000	0.031	0.006	0.014	0.000	0.000	0.026
Nov.					0.000	0.008	0.017	0.010	0.027	0.000	0.000	0.016
Dec.						0.000	0.000	0.000	0.000	0.000	0.000	0.027

Table D18. Heat maps of catch rates for pallid sturgeon 2-3 years old captured in Segments 7-14 - Continued

Month	TL_CHXO-CHNB	TL_ISB-CHNB	TL_ISB-POOL	OT_BRAD-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Jan.	0.000	0.000	0.000					
Feb.	0.000	0.000	0.000					
Mar.	0.014	0.005	0.000		0.000	0.000	0.000	0.000
Apr.	0.014	0.018	0.010	0.000	0.000	0.005	0.000	0.016
May	0.031	0.028	0.000	0.013	0.005	0.002	0.020	0.022
June		0.000		0.008	0.003	0.007	0.007	0.000
July				0.009	0.000	0.004	0.023	0.000
Aug.	0.000	0.000		0.000	0.000	0.002	0.000	0.026
Sept.	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000
Oct.	0.007	0.010	0.015		0.010	0.004	0.000	
Nov.	0.047	0.034	0.016		0.000	0.000		
Dec.	0.029	0.000	0.000					

Catch rate key (number/subsample)
Low Value
Mid-point (50th percentile)
High Value

Table D19. Heat maps of catch rates for pallid sturgeon greater than 800 millimeters in fork length captured with the trammel net, trotline, gill net, and otter trawl captured in Segments 7-14 (minimum of 300 subsamples) within select macro- and mesohabitat combinations.

[Catch rate is defined as the number of fish caught divided by the subsample size. In the Gear_Macrohabitat-Mesohabitat Combinations, TN indicates fish were caught with trammel nets, GN indicates fish were caught with gill nets, TL indicates fish were caught with trotlines, and OT indicates fish were caught with otter trawl.]

	Gear_Macrohabitat-Mesohabitat Combination											
Month	TN_BRAD-CHNB	TN_CHXO-CHNB	TN_ISB-CHNB	TN_OSB-CHNB	GN_BRAD-CHNB	GN_CHXO-CHNB	GN_CHXO-POOL	GN_ISB-CHNB	GN_ISB-POOL	GN_OSB-CHNB	GN_OSB-POOL	TL_BRAD-CHNB
Jan.						0.000	0.000	0.000	0.036	0.000	0.000	0.000
Feb.					0.000	0.012	0.012	0.020	0.057	0.039	0.019	
Mar.	0.000	0.000	0.000	0.000	0.000	0.007	0.025	0.008	0.025	0.023	0.009	0.000
Apr.	0.000	0.000	0.000	0.000	0.000	0.000	0.020	0.011	0.023	0.000	0.000	0.017
May	0.000	0.000	0.002	0.000			0.000					0.000
June	0.000	0.000	0.000	0.000								0.000
July	0.000	0.000	0.001	0.000								
Aug.	0.005	0.000	0.002	0.000								0.000
Sept.	0.000	0.000	0.003	0.000								0.000
Oct.	0.000	0.000	0.000	0.022	0.000	0.035	0.041	0.030	0.060	0.041	0.000	0.026
Nov.					0.000	0.013	0.026	0.006	0.030	0.000	0.000	0.000
Dec.						0.029	0.037	0.015	0.007	0.000	0.000	0.014

Table D19. Heat maps of catch rates for pallid sturgeon greater than 800 millimeters in fork length captured in Segments 7-14 - Continued

Month	TL_CHXO-CHNB	TL_ISB-CHNB	TL_ISB-POOL	OT_BRAD-CHNB	OT_CHXO-CHNB	OT_ISB-CHNB	OT_OSB-CHNB	OT_SCCL-CHNB
Jan.	0.000	0.000	0.000					
Feb.	0.053	0.000	0.036					
Mar.	0.000	0.059	0.022		0.000	0.000	0.000	
Apr.	0.043	0.047	0.019	0.000	0.000	0.000	0.000	0.000
May	0.010	0.008	0.000	0.000	0.000	0.002	0.000	0.000
June		0.000		0.000	0.000	0.001	0.000	0.000
July				0.000	0.000	0.001	0.000	0.000
Aug.	0.000	0.000		0.000	0.000	0.001	0.000	0.000
Sept.	0.000	0.029	0.000	0.000	0.000	0.004	0.000	0.000
Oct.	0.074	0.116	0.046		0.000	0.002	0.000	0.000
Nov.	0.037	0.031	0.047		0.000	0.000		
Dec.	0.029	0.014	0.000					

Catch rate key (number/subsample)
Low Value
Mid-point (50th percentile)
High Value

D.1.1.27 Upper River

Scaphirhynchus sturgeon <109 mm (that is, age-0) and sub-adult (>=109 mm-1,000 mm) pallid sturgeon were most often captured in three habitat types: ISB-CHNB, OSB-CHNB, and CHXO-CHNB (Tables D12 and D13).

In addition, data indicate that segment 4 (downstream from the Yellowstone River-Missouri River confluence) provides the best opportunity to capture pallid sturgeon < 109 mm (few *Scaphirhynchus spp.* <109 mm are captured upstream from the confluence).

D.1.1.28 Lower River

The highest catch rates for *Scaphirhynchus* sturgeon <109 mm occurred in CHXO-BARS and ISB-BARS habitats (Tables D16 and D17); however, only 39 subsamples were taken from these habitat types. Of the remaining habitat types, the ISB-CHNB provided the highest catch rate (Tables D16 and D17). Sub-adult (>=109 mm-800 mm) and adult (>800 mm) pallid sturgeon were captured in a variety of habitat types, but most frequently in the CHNB mesohabitat (CHXO-CHNB, ISB-CHNB, OSB-CHNB, SCCL-CHNB) and macrohabitats associated with tributaries (CONF-CHNB, CONF-POOL) (Tables D16 and D17).

Additional insights can be gained from HAMP samples. The current HAMP implements a design that focuses sampling in habitats where age-0 *Scaphirhynchus* sturgeon were most commonly found through the PSPAP. This approach allows the HAMP to avoid over sampling in habitats that are unlikely to contain young sturgeon. From RM 327-215, ISB-CHNB and SCCL-CHNB provided the highest catch rates for sturgeon <109 mm for habitat types with >100 subsamples (Table D7). CHXO-CHNB and ISB-CHNB exhibited the highest catch rates between RM 180 and RM 33 (Table D7). Catch rates of sturgeon <109 mm for the HAMP were at least 6 times greater than those found for the PSPAP (Tables D16 and D17).

D.1.1.29 Summary

Reviewing capture information for macrohabitat types provides insight into fine-scale spatial elements of a sample design, however, it does not provide insight into larger-scale elements. Murray et al. (2014) conducted a basin-wide analysis of PSPAP capture data to elucidate geographical patterns in pallid sturgeon abundance and found that several small- and large-scale factors were associated with higher probability of pallid sturgeon capture in both the Upper and Lower Missouri River:

1) in the Lower Missouri River, gears used in the pool mesohabitat had significantly higher probability of capturing a pallid sturgeon than any other habitat type;
2) macrohabitats associated with a large tributary mouth or a tributary confluence had a greater probability of catching a pallid sturgeon, as well as having greater abundance in the Upper Missouri River;
3) wider valley floor widths were associated with greater probabilities of pallid sturgeon capture or high pallid sturgeon relative abundances in the Upper and Lower Missouri River;
4) in the Upper Missouri River, the probability of pallid sturgeon capture and the relative abundance increased with increasing distance downstream from Fort Peck Dam;
5) in the Lower Missouri River, the abundance of pallid sturgeon decreased from upstream to downstream.

Murray et al. (2014) did not evaluate spatial distribution patterns according to size or age structure. The possibility of examining differences between juvenile/sub-adult and adult habitat preferences was evaluated early in their study; however, only a small proportion (~6.4%) exceeded the adult-length cutoff used to identify adult pallid sturgeon (>800 mm in the Lower MR and >1,000 mm in the Upper MR). Therefore, both size classes of pallid sturgeon were combined for the analysis (which was comprised mainly of juvenile/subadult-sized pallid sturgeon). The longitudinal distribution of catch summarized in this report indicates that age-0 (<109 mm) *Scaphirhynchus* sturgeon are most likely to be found in the lower segments of the Upper and Lower rivers (Table D8); however, older and larger pallid sturgeon tend to be distributed throughout the segments (Tables D9-D11; it should be noted that stocking location likely influences the distribution of age 2-3 year-old pallid sturgeon catch in Table D10).

D.1.1.30 Effective Gears

To evaluate specific fisheries objectives requires the selection of gears that most effectively sample the species or life history of interest. Researchers must consider the selectivity of the sampling gear during field-study design. Capture efficiency is a complex dynamic that includes the sampling gear, technique, and the availability/vulnerability of the target species. Capture efficiency and size selectivity bias is problematic for researchers because it can lead to under or over estimating a population and it can also affect estimates of various population factors, such as recruitment, size structure, and mortality (Levesque 2013). Thus, selecting the most appropriate fish collecting gears should be at the core of any sample design.

In the Upper Missouri River basin, four gears are used by PSPAP crews to sample the fish community: trotline, trammel net, otter trawl, and mini fyke. PSPAP crews in the

Lower Missouri River sample pallid sturgeon with the mini fyke, gill net, trotline, trammel net, and otter trawl. The mini fyke net does not effectively sample pallid sturgeon, so it was not considered during this assessment. The HAMP uses an otter trawl similar to that employed by the PSPAP (see Welker and Drobish 2012 for description) in habitats >1.5 m in depth; however, the HAMP trawl has a smaller mesh size (4 mm vs. 6.35 mm for PSPAP). In habitats <1.5 m deep, the HAMP samples with a 4-mm mesh push trawl (see Gosch et al. (2015) for a description of HAMP gears).

D.1.1.31 Upper River

Pallid sturgeon similar in length to 2-3 year old known-age fish were most effectively captured with the trotline in a variety of habitat types (Table D14). The trammel net was also an effective gear, while capture rates for the otter trawl were similar to, but lower than, the trammel net (Table D14).

For PSPAP, only the otter trawl was effective at sampling pallid sturgeon <109 mm (that is, age-0) (Table D12). Sub-adult (>=109 mm – 1,000 mm) pallid sturgeon were most effectively sampled with the trotline (Table D13); nearly 30% of the subsamples in CHXO-CHNB, ISB-CHNB, OSB-CHNB, and SCCL-CHNB contained sub-adult pallid sturgeon. Capture rates for pallid sturgeon greater than 1,000 mm were low for the trotline and trammel net (Table D15). This is likely due to the low numbers of these larger, older fish and the potential poor capture efficiency for these gears. Larger mesh trammel nets are used to capture these larger, adult fish during broodstock collection, although catch rates are still low (Table D15).

D.1.1.32 Lower River

Catch rates were similar and low for pallid sturgeon in the 2-3 year-old length category for all gear types (Table D18). Better catchability information can likely be obtained by reviewing the catch information for sub-adult pallid sturgeon (Table D17) as the sample size is much higher.

Similar to the Upper River, the otter trawl was the only gear effective at sampling age-0 sturgeon (Table D16). As described previously, the combined catch of <109 mm *Scaphirhynchus* sturgeon for the HAMP trawls exceeded those found for PSPAP, likely due to the smaller mesh size, the use of the push trawl in shallow habitat replicates, and the focus on habitats most likely to contain young sturgeon.

The highest catch rates for sub-adult (>=109 mm – 800 mm) pallid sturgeon were obtained using the trotline (Table D17); 11.8% of the trotline subsamples contained at

least 1 pallid sturgeon from this category. Pallid sturgeon >800 mm in length were also most effectively captured with the trotline (Table D19).

D.1.1.33 Summary

Analysis of PSPAP catch data by Murray et al. (2014) identified gear-related patterns for pallid sturgeon that can be considered in developing a monitoring approach that meets the two sub-objectives and provides the demographic data needed to update population models. Their gear-related findings are as follows: 1) the trotline was found to be the most efficient gear for catching pallid sturgeon when sampling in both the Upper and Lower Missouri River; it had a significantly lower proportion of deployments with zero catch than the other trawl, trammel net, and gill net, 2) expanding the trotline sampling effort at the cost of reduced sampling effort among other standard gear types may be beneficial, and 3) the otter trawl and trammel net deployments did not provide much useful information about the abundance and distribution of pallid sturgeon. It should be noted that pallid sturgeon less than 109 mm were not evaluated by Murray et al. (2014) as none were collected through PSPAP; however, shovelnose sturgeon <109 mm are frequently captured with the otter trawl (Tables D12, D16).

D.1.12 Summary Guidance

The purpose of this section is to summarize the foregoing analysis of temporal, spatial, and gear influences on catch rates to provide guidance for future sampling. This sampling could be a continuation of a CPUE-centered sampling strategy for documenting trends, or as discussed in Section D.4, the sampling could be integrated into a mark/recapture-centered strategy that promises to provide estimates of population size and survival, as well as trends. The guidance is organized by subobjectives.

D.1.1.34 Sub-objective 1 – Increase Pallid Sturgeon Recruitment to Age 1

D.1.1.34.1 Upper River

Longitudinal Sampling Distribution

Past sampling through PSPAP indicates that the majority of age-0 *Scaphirhynchus* sturgeon has been captured downstream from the confluence of the Yellowstone and Missouri rivers in Segment 4 (FigureD2, Table D8). Further, predictive flow models developed through the Effects Analysis indicate that the majority of the drifting free-embryo pallid sturgeon would settle into this segment, if they do not drift through it into Lake Sakakawea. Therefore, the most effective and efficient trawling to capture age-0 and age-1 pallid sturgeon and to detect recruitment to age-1 would be in Segment 4.

Macrohabitats

Age-0 pallid sturgeon have been captured in a variety of macro-mesohabitats through the PSPAP; however, the highest catch rates were obtained in the CHXO-CHNB, ISB-CHNB, and the OSB-CHNB macro-mesohabitat combinations (Table D12). The highest CPUE in these habitats has been found in the months of July through September (Table D12). In the Upper River, pallid sturgeon (and shovelnose sturgeon) typically spawn in late-April through May. Therefore, age-0 *Scaphirhynchus* should be available for capture in June, July, and August. The lack of catch in the month of June and a low CPUE in July for age-0 *Scaphirhynchus* sturgeon (Figure D4) may be an artifact of the sampling gear used by the PSPAP. The HAMP has recently used a smaller mesh size to collect very young and small sturgeon (that is, < 50 mm total length) in the Lower River. For maximum efficiency, sampling for age-0 pallid sturgeon would begin in June and focus on the three habitat types identified above.

Gears

The only gear utilized by PSPAP and HAMP for sampling age-0 sturgeon is the trawl. PSPAP uses an otter trawl (OT16) with an opening 16 ft. (4.9 m) wide by 3 ft. (0.9 m) high and 6-mm inner bar mesh. HAMP uses a trawl (OT04) of similar dimensions; however, the inner bar mesh is 4-mm. The HAMP has implemented a targeted sampling protocol that primarily uses the OT04 trawl in the habitats with the highest CPUE values found during 10 years of sampling through the PSPAP. This resulted in the HAMP sampling over 1,300 *Scaphirhynchus* sturgeon < 50 mm in length in the Lower River during a single season (2014). Comparatively, the PSPAP has sampled less than 200 of these small sturgeon in 10 seasons (2005-2014). It is recommended that age-0 and age-1 sturgeon sampling be conducted with either the OT04 or the OT16 fitted with 4-mm inner bar mesh instead of the standard 6-mm mesh size.

Summary

For maximum efficiency in addressing the recruitment objective, sampling for age-0 would begin in June, following the pallid sturgeon spawning period. Sampling with the trawl (OT04 or OT16) for these small sturgeon could continue through the summer and into the fall; however, it is anticipated that much of the effort in the fall will need to be focused on mark-recapture sampling. Therefore, it is recommended that trawling to sample age-0 and age-1 pallid sturgeon occur in the months of June and July. The spatial focus of the sampling should be restricted to Segment 4 in the CHXO-CHNB, ISB-CHNB, and OSB-CHNB habitat types. A complete summary of the information can be found in Table D20.

D.1.1.34.2 Lower River

Longitudinal Sampling Distribution

Past sampling through PSPAP (Table D6) and HAMP (Table D7) indicates that the majority of age-0 *Scaphirhynchus* sturgeon occur downstream from Kansas City, MO in Segments 10, 13, and 14; the only larval (non-drifting) pallid sturgeon found in the Lower River were captured downstream from Kansas City, although drifting free embryos have been captured upstream of the Platte River (DeLonay et al., 2016). Similar to the Upper River, predictive flow models developed through the Effects Analysis show that the majority of the drifting free-embryo pallid sturgeon would settle into this portion of the Missouri River or downriver in the Mississippi River. These models still need to be calibrated and validated, but to maximize efficiency age-0 and age-1 pallid sturgeon trawling would be restricted to Segments 10, 13, and 14 (Figure D2); this restriction could be removed as more is learned about dispersal of age-0 pallid sturgeon.

Macrohabitats

Age-0 pallid sturgeon have been captured in a variety of macro-mesohabitats through the PSPAP; however, the highest catch rates were obtained in the CHXO-CHNB and ISB-CHNB macro-mesohabitat combinations (Table D16). The highest CPUE in these two habitats has been found in the months of June through October (Table D16). Similarly, 95% of the age-0 *Scaphirhynchus* sturgeon sampled through HAMP were collected in these two habitat types in the same time frame. In order to maximize efficiency for the recruitment objective, sampling for age-0 pallid sturgeon would begin in June and focus on the two habitat types identified above.

Gears

The only gear utilized by PSPAP and HAMP for sampling age-0 sturgeon is the trawl. As described above, PSPAP uses the OT16 otter trawl with 6-mm inner bar mesh and the HAMP uses the OT04 that possesses a much smaller (4 mm) mesh. The smaller mesh size used through HAMP results in a much higher catch rate for sturgeon < 50 mm (total length). Therefore, it is recommended that age-0 and age-1 sturgeon sampling be conducted with either the OT04 or the OT16 fitted with 4-mm inner bar mesh instead of the standard 6-mm mesh size.

Summary

For maximum efficiency of sampling applied to the recruitment objective, sampling for age-0 pallid sturgeon would begin in June, following the spawning period. Sampling with the trawl (OT04 or OT16) for these small sturgeon could continue through the summer and into the fall; however, it is anticipated that much of the effort in the late fall will need to be focused on mark-recapture sampling. Therefore, it is recommended that trawling to sample age-0 and age-1 pallid sturgeon occur in the months of June, July, and August. The spatial focus of the sampling should be restricted to Segments 10, 13, and 14 in the CHXO-CHNB and ISB-CHNB habitat types. A complete summary of the information can be found in Table D20.

D.1.1.35 Sub-objective 2 – Population Growth, Abundance, and Stability

D.1.1.35.1 Upper River

Longitudinal Sampling Distribution

Past sampling through PSPAP and other monitoring projects indicates that pallid sturgeon juvenile and adult (>109 mm in length) have been captured in all Segments (2, 3, 4) on the Missouri River (Tables D9-D11, D13-D15). Therefore, it is recommended that mark-recapture monitoring occur in all Segments (2, 3, 4) of the Missouri River.

Macrohabitats

Juvenile and adult pallid sturgeon have been captured in a variety of macro-mesohabitats through the PSPAP; however, catch rates are closely linked to gear-habitat combinations and time of year. Overall, the highest catch rates have been found for the same three habitat types (that is, CHXO-CHNB, OSB-CHNB, ISB-CHNB) as YOY Scaphirhynchus sturgeon (Tables D13-D15) with high catch rates also found for the SCCL-CHNB. Tributary mouths have also provided high catch rates for juvenile and adult pallid sturgeon in the Upper River and could also be included in the sample design. Catch rates are highest in April-May and August-October.

Gears

The trammel net and the trotline have been used to effectively sample juvenile and adult pallid sturgeon in the Upper River (Tables D13-D16). Trotline CPUE is generally higher than that of the trammel net. Sampling with the trotline is generally ineffective in the spring due to high debris loads in the river that bury the gear and in the summer/early fall due to loss of bait to non-target fish species. The trammel net is most effective in August-October when river stage and discharge begins to decline.

Summary

For maximum efficiency in addressing the population growth, abundance, and stability objective, sampling for juvenile and adult pallid sturgeon would begin in August with the trammel net and continue through October. Trotline sampling can occur in October when this gear is effective at sampling pallid sturgeon (Ryan Wilson, USFWS, pers. comm.). The spatial focus of the sampling should be Segments 2, 3, 4 (Table D14) in the CHXO-CHNB, ISB-CHNB, OSB-CHNB, and SCCL-CHNB habitat types. Tributary mouths (TRML), such as the mouth of the Yellowstone River, may also be incorporated into the sample design. A complete summary of the information can be found in Table D20.

D.1.1.35.2 Lower River

Longitudinal Sampling Distribution

Past sampling through PSPAP indicates that pallid sturgeon juvenile and adult (>109 mm in length) have been captured in all Segments (7, 8, 9, 10, 13, 14) of the Lower River (Tables D9-D11). Therefore, it is recommended that monitoring for pallid sturgeon >/= 109 mm occur in all segments of the Lower River.

Macrohabitats

Past PSPAP sampling indicates catch rates for juvenile and adult pallid sturgeon are closely linked to gear-habitat combinations and time of year. Overall, the highest catch rates have been found for the four habitat types: BRAD-CHNB, CHXO-CHNB, ISB-CHNB, and ISB-POOL (Tables D17-D19). Tributary mouths have also provided high catch rates for juvenile and adult pallid sturgeon in the Lower River and could also be included in the sample design. Catch rates are highest in March-May and October-December (Tables D17-D19).

Gears

In the Lower River, the trotline has been the most effective gear for sampling juvenile and adult pallid sturgeon (Tables D17-D19). Sampling with the trotline is generally effective in the spring and late fall. The gear is much less effective during May-September when small, non-target fishes remove much of the bait from hooks (Kirk Steffensen, NGPC, pers. comm.). The other gears exhibit very low catch rates for pallid sturgeon and would require large amounts of effort in a mark-recapture approach (Tables D7, D17-D19); however, fall sampling with the gill net may be considered as catch rates are comparable to the trotline.

Summary

For maximum efficiency in addressing the population growth, abundance, and stability objective, sampling for juvenile and adult pallid sturgeon would occur with the trotline during two time periods: 1) in spring beginning in March and continuing through mid-May and 2) in fall beginning in mid-September and continuing through December. The beginning and end of each sample period in a particular segment is closely tied to water temperature. Water temperature greatly influences the capture efficiency of the trotline as the activity of bait-stealing fish increases as water temperature increases. Ice-up can also prevent crews from accessing sample sites in the late fall. The spatial focus of the sampling should be all Lower River segments in the BRAD-CHNB, CHXO-CHNB, ISB-CHNB, and ISB-POOL habitat types. Tributary mouths (TRML), such as the Platte River, have provided high catch rates for the trotline and therefore may also be incorporated into the sample design. A complete summary of the information can be found in Table D20.

Table D20. Summary of sampling information from previous pallid sturgeon monitoring projects that identifies the most effective gears, habitats, segments, and sample periods for capturing pallid sturgeon.

Targeted Size	Gear	Habitats	Segments	Effective Periods
Upper Missouri River				
<109 mm (age-0)	OT04/OT16	CHXO-CHNB, ISB-CHNB, OSB-CHNB	4	June-October
>=109 mm	Trammel Net	CHXO-CHNB, ISB-CHNB, OSB-CHNB	2, 3, 4, lower 48 km of the Yellowstone River	August-October
	Trotline	CHXO-CHNB, ISB-CHNB, OSB-CHNB, SCCL-CHNB	2, 3, 4, lower 48 km of the Yellowstone River	October
Lower Missouri River				
<109 mm (age-0)	OT04/OT16	CHXO-CHNB, ISB-CHNB	10, 13, 14	June-October
>=109 mm	Trotline	BRAD-CHNB, CHXO-CHNB, ISB-CHNB, ISB-POOL	7, 8, 9, 10, 13, 14	March-May; October-December

D.3 An Integrated Approach to Population-level Monitoring, Assessment, and Modeling

In this section we discuss a potential approach to optimize population-level monitoring, assessment, and modeling to support AM of the pallid sturgeon in the Missouri River. Additional future analysis will be required to develop details of this approach as a level 1 science effort. Our objective in this section is to provide a broad outline of this potential approach.

Our approach has been highly influenced by concerns that many species monitoring programs have been poorly structured to address specific management hypotheses and fit into the category of unfocused and inefficient surveillance monitoring (Nichols and Williams 2006). This same concern was articulated by the Missouri River Independent Science Advisory Panel (ISAP) in its recommendation that "monitoring programs along the Lower Missouri River should be re-designed so as to determine if expected outcomes are attributable to specific management actions" (Doyle et al. 2011). While the approach implemented by the PSPAP has met BiOp RPA requirements, the ISAP described it as surveillance monitoring that has "unfocused monitoring targets, unrelated to specific hypotheses or management actions" that "produce results that are problematic to interpret" (Doyle et al. 2011).

The three types of monitoring and assessment described in the introduction are designed to address these concerns, although optimal distribution of effort among the three hasn't been determined. According to the draft AM plan, the population trends monitoring and assessment process will track metrics for the fundamental objectives, whereas science components and process-level monitoring/assessment will develop the understanding of how management actions affect population processes. Each of the science components is aimed at understanding relationships between management actions and changes to growth or survival. Inferences for how management actions propagate to the population level will be strengthened through integration in the population model (discussed in Section D4.2).

Based on the assumption that some level of population-level monitoring/assessment will be beneficial to management of the river and the species, we present a broadly defined framework for what a new, more effective population-level assessment would look like. A new approach to assessing population trends in pallid sturgeon in the Missouri River will optimally address multiple objectives, including:

- Provide accurate assessments of population status and trends to evaluate fundamental species management objectives;
- Make maximum use of historical population assessment data;

- Benefit from information developed through science components that focus on specific management hypotheses as well as providing information to those science components;
- Support population modeling and decision making;
- Include relevant ancillary variables that would be useful to explain occupancy, such as physical and chemical habitat;
- Achieve results that are efficient and cost effective.

While the previous population assessment effort provided a means for tracking indicators of population status through CPUE, it was not amenable to providing population or survival estimates needed for population-dynamics models and decision making. The approach described here is a hybrid of methods intended to track population metrics relevant to the fundamental species objectives while also providing mechanisms to estimate population size and survival rates for updating population models. The approach is intended to increase efficiency, cost effectiveness, and utility of monitoring to support AM.

Because the approach is focused narrowly on information needed to understand pallid sturgeon population dynamics related to management actions, the approach sacrifices collection of a broad suite of surveillance data. Using the analysis presented in Section D.3 of this appendix, the gears, habitats, and timing of fish sampling can be optimized for the specific sub-objectives. By neglecting other native fish species (in contrast to the PSPAP), however, the approach would exclude opportunities to use CPUE of multiple species to infer inter-species interactions or multi-species responses to stressors. While efficiencies will be gained in the new approach some additional risk will result from loss of ancillary information that could provide context and explanation. An alternative to a broad monitoring program to establish comparable time series of pallid sturgeon and native or non-native species, would be to address specific hypotheses about interactions with specific, short-term science projects. While the data and analyses presented here are not meant to be a comprehensive evaluation of PSPAP and HAMP data, they are intended to provide context and understanding that has a bearing on potential, future designs for population monitoring.

D.1.13 Mark-Recapture Based Alternatives

There are several possible approaches to undertaking a monitoring program for pallid sturgeon in the Missouri River. The current program, PSPAP, uses a CPUE based approach, which is designed to yield trend information, but not demographic parameters. A CPUE sampling design may be thought of as a place-based approach, rather than an individual-based approach. CPUE sampling programs yield valuable life

history information in showing spatial and temporal use of varying habitats by life stages of an organism. However, they tend to be extensive in scope, and therefore relatively expensive. Once there is an understanding of an organism's use of available habitats through its life stages, if the focus of the study is to be the organism itself, it is usually more efficient to switch to an individual based mark-recapture methodology. Mark-recapture analysis tends not to yield extensive habitat information, but instead yields demographic information about the population, in particular, population size, survival, and capture probability.

CPUE programs have some inherent flaws. There are inevitable problems with observer bias, for example. From the analysis standpoint, all equipment sets are treated equally, yet those sets are made by people, who differ greatly in both their experience and fishing ability. The problem of individual variation in fishing "power" (that is, the "skipper effect") has been acknowledged as a real, if understudied and little acknowledged, effect (Hilborn 1985, Abrahams and Healey 1990). A CPUE approach also tends to treat fish as inert particles, disregarding the ability of fish to learn (that is, trap-happy or trap-shy). CPUE approaches, because of rigid sampling schemes, normally are zero heavy; that is, the sampling design, unless an AM scheme is built in, will continue to sample areas and utilize gears found to have lower probabilities of capture, and thus have high numbers of zero catches.

There are few other approaches toward population estimation of fishes, such as transect sampling or multiple removal methods. Most of these have their intellectual roots in a CPUE framework, and all would be inapplicable to pallid sturgeon, a rare fish in a large, turbid, low-visibility system.

In comparison, mark-recapture programs work by repeatedly sampling a population over a series of defined time periods. The metric of interest is not the gear set, but rather the capture or recapture of individuals. Individuals are marked with unique and lasting identifying marks, and released back into the population. By assessing the proportion of recaptures of these marked individuals to the capture of unmarked individuals over multiple recapture periods, population demographics including survival, recapture probability, and population size are estimated.

D.1.1.36 Assumptions of Mark-Recapture

There are several assumptions that have to be met for a mark-recapture program to generate valid data. They include:

- Marked and unmarked animals have equal probabilities of capture;

- marked animals mix evenly in the population of interest between capture sessions;
- marks are unique, distinguishable over the time of the study, do not adversely affect the survival or behavior of the animals, and are not lost;
- effort is proportional to the size of the study area and the size of the study population (the rate of recapture has to be reasonably high); and
- emigration and immigration can be measured or estimated reliably.

Many violations of these assumptions can be compensated for through model selection, if the effects aren't severe. If, for example, the act of marking an animal causes it to be trap-shy, or avoid recapture for a time period, the effect can be accommodated for in the population model if the study length exceeds the period of trap-shyness. If, however, the act of capture and marking causes the animal to permanently avoid recapture, then assumptions 1 & 3 are violated, and a mark recapture program may not generate reliable estimates.

The sampling universe has to be well defined, such that marked animals have the ability to mix through the population of interest. If the interval between the marking period and the resampling period is too short for marked animals to have physically spread throughout the defined sampling universe, then assumption 2 may be violated, and the population of interest may have to be redefined in terms of where marked animals may have been able to spread to.

Marks must be unique, and last. If the animal loses its mark, then when it is recaptured it will be mistakenly treated as a new, never-before-seen animal. This has the effect of inflating the population estimate, by creating an invalid capture history. If an animal is recognized as a recapture but has no identifying information (that is, has tag scars, but no readable tag), it creates a limbo state for that animal in terms of the population estimation.

The effort and catch must be proportional to the study area and the estimated size of the population. There are no hard rules for the proportion of the population under study that must be observed in each sampling period. However, there must be recaptures in order for the method to work. Rule of thumb and simulation studies suggest that a study should attempt to observe approximately 10% of the expected population per period if the study is to be short-term (between 2-10 sampling periods), or 5% per period if the study is to be long term (>10 sampling periods, where a sampling period is biologically relevant to the population of interest). The initial population estimate can be an order-of-magnitude estimate, if no prior information is available, and should be revised as information is gathered during sampling. If, for example, the original estimate was that

there were 1,000 animals in the population, but the first sampling event captures 200, then the estimate should be revised upwards; if the second sampling event captures another 200, with no recaptures, then the estimate, and the expected sampling intensity, should be revised upwards again. If, on the other hand, 100 of the animals in the second sample are recaptures, then the estimate would be revised downwards, and the estimate of capture efficiency would be revised upwards. Sampling should be distributed across the study universe in order to ensure that all animals have an equal opportunity to be sampled, but should be highly weighted towards the gears, habitats, and seasons with the highest efficiency.

Mark-recapture studies report apparent survival, as emigration and immigration from or into the study population create confounding effects. Over short time frames, the study population can be treated as a closed population, but over long time frames, births, deaths, immigration, and emigration must be accounted for in the modelling. Within a mark-recapture framework, there are multiple model designs available, ranging from the simple to the complex. The choice of models depends on the complexity of the sampling situation and biology of the population under study. Pallid sturgeon populations in the Missouri River are a situation of high complexity. Factors adding complexity include: a long lifespan, stocking of juveniles of different ages, and the inherent complexity of environmental changes along the long latitudinal range of the species.

Telemetry can be merged with mark recapture in several ways. First, telemetry returns can be used as a proxy for actual captures of the telemetered fish; if they were alive and moving during the sampling period, then they can be included as a virtual recapture. Secondly, telemetered fish can serve as an indicator for where sampling should occur (that is, “Judas animals”). Last, if enough animals are telemetered, and the tag life is long enough, then demographic estimates of survival, emigration, and immigration can be derived directly from telemetered animals, and applied to the rest of the population of interest.

D.1.1.37 Comparisons: CPUE, Mark-Recapture, Telemetry

Telemetry, mark-recapture, and CPUE trend analysis each have unique strengths, but also certain weaknesses. Telemetry is limited in that only a small portion of fish can be instrumented, tags have limited life, and it is difficult to maintain continual observation of marked animals. However, telemetry reveals details of fish movements and distributions in a way that no other observation system can. The entry costs for telemetry continue to decline as technology improves, and adoption of the latest technology (e.g., autonomous receivers) can decrease observation costs to entirely reasonable levels. A specific science component in Appendix C addresses a feasibility

study of autonomous receivers on the Missouri River. Mark-recapture programs can generate capture histories for individuals that reveal information about population demographic values such as survival, recruitment, population size and composition. However, mark-recapture programs yield very limited information of movements, or the characteristics of other fish stocks. CPUE trend analysis gives an imprecise view of population demographic values, and almost no knowledge of fish movements, but does yield local-level use information, and a larger picture of local fish stock assemblages.

D.1.1.38 Benefits and Limits of Mark-Recapture

The current population of pallid sturgeon in the Missouri River can be best thought of as being several disjunct populations. In the upper river, RPMA 1, (RM 2052-1867) above the headwaters of the Fort Peck reservoir, has a very small (~40) population of old wild fish, which recruited over 60 years ago, and approximately 8,000 surviving hatchery reared fish (2013 estimate; Rotella et al.., 2015), released since 1998. RPMA 2, from the Fort Peck dam to Lake Sakakawea (RM 1764.1 to 1537; PSPAP Segments 1-3), including 147 RM of the Lower Yellowstone River, has a small (~100-200) population of old wild fish, and a hatchery released population of approximately 43,000 fish (2013 estimate; Rotella et al., 2015), released since 1998.

In the Lower River, RPMA 3, between Fort Randall Dam and Lewis and Clark Lake (RM 863-843; PSPAP Segments 5-6), is not thought to have any wild fish, and only approximately 1900 hatchery released fish (2013 estimate; Rotella et al., 2015). RPMA 4, from Gavins Point Dam to the Mississippi River confluence (RM 811-RM 0; PSPAP Segments 7-10, 13-14), has an unknown (but probably in the high hundreds to low thousands) number of wild fish, and approximately 29,000 surviving hatchery released fish (2015 estimate, of 155,316 hatchery fish released through 2014, based on Steffensen et al., 2010). Steffensen et al. (2013) estimated a wild population between 715 and 437, and a hatchery population between 2,304 and 2,600 for a 80.5 km stretch of this RPMA between 2008 and 2010. Extrapolating this to the entire reach yields estimates of a wild population between 7,000 and 11,500 wild fish, and 37,000 and 41,800 hatchery fish. However, this would assume an even distribution along the entire reach, a tenuous assumption; the 80.5 km section sampled by Steffensen is one of the higher quality areas, and probably has a higher population density than other reaches. Limited natural recruitment may occur in this RPMA; however, there is also probably emigration of larvae from this RPMA into the Mississippi River, with only limited return of adults. RPMAs 1 and 3 are outside the scope of the MRRMP; however, downstream emigration (through Gavins Point Dam) has been documented for RPMA 3 and likely occurs for RPMA 1 (through Fort Peck Dam) as well. The Mississippi and Atchafalaya Rivers (RPMA 5 &6) are also outside the scope of the MRRMP, but are known to have adult populations which may migrate into the Missouri, but with an unknown extent.

If the criteria for selection of a sampling approach is that the sampling tests the effectiveness of the system changes proposed to avoid extirpation of pallid sturgeon, then a combination of a long term mark-recapture program and a modest telemetry effort may be an effective prescription. The number of animals in the system (approximately 82,000 hatchery released fish, and a few thousand wild fish), as well as the quantity of information derived from the years of sampling conducted by the PSPAP, HAMP, and CSRP, provides sufficient information for designing a sampling program.

There are several objectives that a mark-recapture/ telemetry program will not address that the current sampling does address. A sampling regime aimed at providing robust mark-recapture data would not sample newly recruiting fish. Thus, there would be a lag of two to three years after a recruitment event before the juveniles would be vulnerable to the sampling gear and be detected. Therefore, fundamental sub-objective 1 – increase recruitment of age-1 fish – may need to be addressed through a separate sampling design. Also, a targeted sampling design would not furnish ecological information on the other fish species present in the system. However, there is an argument to be made that a sampling regime to which fish are vulnerable two to three years after recruitment is valid, as long as there is a commitment for the sampling to extend a sufficient length of time.

D.1.1.39 Mark-Recapture Level of Effort

The level of effort needed to derive high quality estimates of population and demographic rates can be estimated broadly based on the estimated population in each RPMA and the expected catch rates from the current sampling. From the PSPAP, HAMP, and broodstock sampling, catch rates on trotlines in the upper river are expected to be 0.55 fish/ 20 hooks, while the Lower River catch rate is expected to be 0.25 fish/ 40 hooks. If the objective is to capture 5% of the expected population in each segment, and if a field crew can run 10 40-hook lines in a day, then a rough estimate of the required effort would be 218 crew-days in RPMA 2and 344 crew-days in RPMA 4 (Table D21).

Table D21. Recovery priority management area, population estimate, sample size and estimated effort required for robust population estimation assuming trotline deployment (*RPMA 2 = PSPAP Segments 1-3; RPMA 4 = Segments 7-10, 13-14).

Recovery priority management area*	Length, kilometers	Number of wild pallid sturgeon	Number of hatchery pallid sturgeon	Number of wild fish per kilometer	Number of hatchery fish per kilometers	Number to sample each year at 5% target	Number of trotline sets at 40 hooks/set at 5% capture	Crew days at 10 sets per day
2	598.4	150	43000	0.25	71.86	2158	1961	218

4	1297.6	2000	29000	1.54	22.35	1550	6200	344

D.1.1.40 Robust Design Overview

A variant on the mark-recapture design is what is referred to as a robust design (Pollock 1982, Kendall 1997). As originally described by Pollock (1982), a robust design consists of primary sampling occasions with secondary sampling occasions nested within the primary sampling occasion. Primary occasions are spaced temporally to capture processes such as survival and growth. Secondary occasions occur over a short timeframe, short enough that closure of the population from demographic processes (that is, recruitment, mortality, immigration, emigration) can be assumed. The secondary sampling occasions also provide multiple opportunities for individuals to be captured, allowing for the estimation of capture probability providing an estimate of the population rather than an index of relative abundance. True abundance estimates are important to ongoing AM and recovery because species recovery objectives and sub objectives are specified as abundance and population growth rate (λ) is estimated as $\lambda = N_{t+1} / N_t$ where N is population abundance.

The robust sampling design has been applied across a wide range of taxa to estimate demographic rates and population abundance. The robust design was originally conceived to provide a robust population estimates derived from open capture-recapture models, the Jolly Seber model in particular. Its use has been extended to studies of species occurrence (i.e., occupancy models; MacKenzie et al. 2002 Tyre et al. 2003) and abundance (N-mixture models; Royle 2004b, Royle 2004a) of unmarked individuals. Therefore it provides a rigorous framework that allows for the estimation of relevant demographic rates and abundance, using marked or unmarked individuals. It should be recognized that monitoring pallid sturgeon in a system as large as the Missouri River is inherently challenging and it is likely that any approached used will violate one or more assumptions required to estimate demographic rates or population abundance. Additional modeling calculations will be needed to evaluate whether violations of assumptions would lead to unreliable results as part of a level 1 science effort. The following sections provide a preliminary overview of the robust design as a potential monitoring design for pallid sturgeon populations of the Upper and Lower Missouri River.

D.4 A Hybrid Population Assessment Approach

The hybrid approach presented here is intended to achieve pallid sturgeon population-level monitoring and assessment objectives. It involves a core of mark-recapture effort based on a robust design, sampling to identify recent recruitment (age-0 and age-1), an integrative population model to serve as the population inventory framework, collection

of ancillary data needed to estimate parameters for the population model and to provide explanation, and a CPUE effort to provide a check on population-estimate trends. The population-level monitoring is intended to complement level 1 and 2 science components, and effectiveness and process monitoring of level 3 and 4 implementations of management actions.

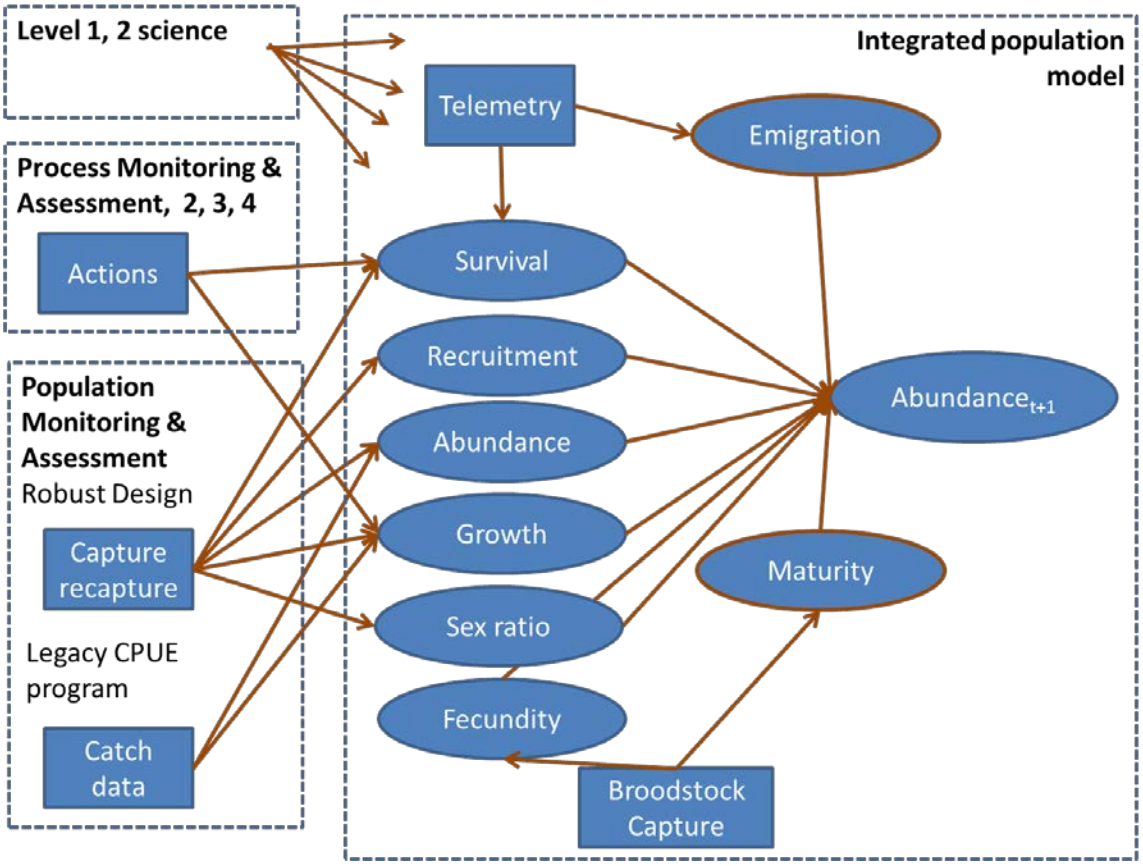

Figure D5. Concept of interrelations among level 1, 2 science, process monitoring and assessment, population-level monitoring and assessment, and the integrative population model.

D.1.14 Population Monitoring

Population monitoring for the MRRP will be designed to provide the data to meet the USFWS's species objectives (that is, Fundamental Objective; Sub-objectives 1 and 2) and the demographic data needed to develop the pallid sturgeon population model (e.g., survival, population size). The approach detailed below is a recommended starting point and should be evaluated as part of a level 1 science effort and adjusted periodically to improve the design so that it more effectively meets the monitoring and species objectives. The recommended population monitoring will consist of two components: 1)

age-0/age-1 trawling to detect reproduction and recruitment to age 1 (Objective 1) and 2) mark-recapture sampling to evaluate Objective 2 and provide the demographic data needed for predictive population modeling. Both components will be implemented in the Upper and Lower Missouri rivers; however, the sample designs may differ depending on factors like relative gear efficiencies and seasonality. The general design elements (e.g., river bend, macrohabitat, segment) will follow that of USACE's PSPAP (Welker and Drobish 2012) which includes the river bend functioning as the sample unit. Much has been learned regarding pallid sturgeon distribution, sample gears, and sampling effort through the monitoring programs implemented by the USACE since 2005 (Section D.3). This information along with input from PSPAP and HAMP biologists was used to form the monitoring and sampling recommendations below, including the target levels of effort provided in Tables D22-D24.

D.1.14.1 Sampling to Identify Recent Recruitment (age-0 and age-1)

Monitoring recent reproduction and recruitment can be used to track the effects of management actions. Increases in the occurrence of young pallid sturgeon through time can be used to identify the positive incremental effects on this portion of the population, the portion that is hypothesized as the recruitment bottleneck. Additionally, annual fluxes in the occurrence of these fishes may be used to directly evaluate the effects of individual management actions (e.g., IRC). Trawl sampling will be used to monitor the occurrence of age-0 and age-1 pallid sturgeon in the Upper and Lower Missouri rivers to detect reproduction and recent recruitment of pallid sturgeon. Yearly changes in abundance of young sturgeon will be measured using CPUE or changes in occupancy rates.

D.1.1.40.1 Upper River

Under this proposed design, sampling for age-0 and age-1 pallid sturgeon would be restricted to Segment 4 (below the confluence of the Missouri and Yellowstone rivers). Past sampling and Effects Analysis drift models (Fischenich, in review) indicate that the majority of young pallid sturgeon will reside in this portion of the Upper River. At the local scale, sampling will be confined to the CHXO-CHNB, ISB-CHNB, and OSB-CHNB habitat types during the months of June and July. These habitats have provided the highest CPUE values for young *Scaphirhynchus* sturgeon during the previous 10 years of PSPAP sampling. Although these small sturgeon will recruit to the sampling gear from June through September, sampling will be restricted from June (near the time of spawning) through July to accommodate the start of mark-recapture sampling.

Gears

To maximize efficiency, only two types of trawls should be considered for sampling age-0 and age-1 pallid sturgeon as they have been used extensively and effectively by USACE monitoring projects: OT16 otter trawl (PSPAP; consult Welker and Drobish 2012 for a detailed description) and the OT04 trawl used by the HAMP (Gosch et al. 2015). Using the OT16 would provide continuity between the monitoring through the AM plan and the historic PSPAP monitoring. However, pallid sturgeon < 50 mm would not be effectively sampled with the OT16. Therefore, we recommend that sampling be conducted with the OT04 or the OT16 fitted with an inner bag made of 4 mm bar mesh.

Effort

The level of effort needed to monitor age-0 and age-1 pallid sturgeon is difficult to determine as few have been captured in either the Upper or Lower Missouri rivers through USACE monitoring. The HAMP has been very successful at sampling YOY *Scaphirhynchus* sturgeon and the targeted monitoring approach described here follows that of the HAMP. The HAMP samples at an effort of 4 trawls per mile (approximately 3/km) with repeated sampling at sites where young sturgeon are captured. The average river-bend size in the Upper Missouri River is 2.3 km which would result in an average of 7 trawls per bend (based on the 3 trawls/km sample through the HAMP; Table D22). Twenty-five percent of bends in Segment 4 will be sampled each month (June and July), resulting in 50% of the bends (that is, 24) sampled per year; this was a realistic level of effort (25%) for this type of sampling in the PSPAP (Table D22). Additional trawl subsamples will be taken at sites where young sturgeon are captured and may result in more than 7 trawls per bend and 84 trawls per month (Table D22). Additional bends may be added per sample period as time allows. Sampling designs and levels of effort may be evaluated via simulation to identify tradeoffs in efficiency and precision.

Table D22. Target sampling effort for Objective 1 (Identify recruitment to age 1) in Recovery Priority Management Area 2 and 4 with trawls (OT04 and/or OT16).

Recovery Priority Management Area	Pallid Sturgeon Population Assessment Program Segment	Length, in kilometers	Average Bend Length (km)	Number of Trawls per Kilometer	Average Number of Trawls per Bend[1]	Number of Bends	Number of Bends to Sample per Month	Estimated Total Trawls per Segment per Month[2]
2			2.3	3	7			
	4	84				47	12	84
4			4	3	12			
	10	191				39	10	120
	13	193				45	9	108
	14	210				56	14	168

[1] Based on HAMP sampling experience

[2] Additional trawls will be sampled at sites where age-0 Scaphirhynchus sturgeon are captured

D.1.1.40.2 Lower River

Sampling for age-0 and age-1 pallid sturgeon will be restricted to Segments 10, 13, and 14 (below Kansas City, MO to the Missouri River mouth). The HAMP has recently sampled larval pallid sturgeon in habitats below Kansas City which represent the only larval (settled) pallid sturgeon captured in the Lower River. Effects Analysis drift models also indicate that the majority of young pallid sturgeon will reside in this portion of the Lower River (and the Middle Mississippi River). At the local scale, sampling will be confined to the CHXO-CHNB and ISB-CHNB habitat types in the months of June, July, and August. These habitats have provided the highest CPUE values for young *Scaphirhynchus* sturgeon during the previous 10 years of PSPAP sampling and recently through the HAMP. Although these small sturgeon will recruit to the sampling gear from June through October, sampling will be restricted from June through August to accommodate the start of mark-recapture sampling.

Gears

As with the Upper River, the most effective sampling gears for age-0 and age-1 *Scaphirhynchus* sturgeon are the OT16 and the OT04 trawls. Therefore, the recommendation for sample gears follows that made for the Upper River with either the OT04 or the OT16 (fitted with an inner bag made of 4-mm bar mesh) used to sample age-0 and age-1 pallid sturgeon.

Effort

Monitoring in the Lower River will follow that of the HAMP. The average river-bend size in the Lower River is 4 km which would result in an average of 12 trawls per bend (based on the 3 trawls/km sample through the HAMP; Table D22). A target of 25% of the bends in Segments 10, 13, and 14 will be sampled each month (June, July, August), resulting in 75% of the bends (that is, 24) sampled per year (Table D24). Additional trawl subsamples will be taken at sites where young sturgeon are captured and may result in more than 12 trawls per bend and the estimated trawls per month (Table D22). Additional bends may be added per sample period as time allows. Tradeoffs (that is, cost, precision, bias) amongst candidate sample designs may be evaluated through simulation.

D.1.14.2 Sampling for Population Characteristics: Mark-Recapture Robust Design

D.1.1.40.3 Description

Changes in population size through time are a function of births, deaths, immigration, emigration, and recruitment. Open capture-mark-recapture (CMR) models assume that the population is influenced by natality, mortality, emigration, and immigration and is therefore considered open between sample periods. Closed population models assume that the size of the population remains unchanged between sampling events and require that multiple samples are taken over a short period of time to assume closure. The advantages and disadvantages of each type of model are well documented (Pollock et al. 1990, Nichols 1992) with CMR models used to estimate survival, emigration, and immigration and the closed CMR models used to estimate population size and capture probability. The Robust Design integrates the advantages of both types of models which allows considerable flexibility in estimating a very large number of important demographic parameters, including abundance, survival, and recruitment. The concept behind the Robust Design is to break the mark-recapture sessions into shorter sampling occasions so that capture probabilities can be estimated among encounter occasions within these sessions. The capture sessions are brief enough that we can assume the population is closed (that is, no births, deaths, immigration, or emigration). Therefore, closed models can be used for the estimation of population size and then integrated with open models to estimate true survival, emigration, and immigration over the longer, open primary sampling periods. The basic design is to sample over two temporal scales.

The pallid sturgeon populations in the Upper and Lower Missouri Rivers are unique in many respects (e.g., size and age at maturity, growth rates, life span). The habitats in which they live are also very different. The Lower River is characterized by a narrow, self-scouring channel with higher water velocities, especially in the main channel. In contrast, the Yellowstone and Upper Missouri Rivers are characterized by lower velocities, shallower depths, and a more natural channel form. The nature of the differences between these two portions of the Missouri River has shown that the most effective sampling methodologies and potential strategies also differ significantly and therefore necessitate that the mark-recapture sample designs be tailored to each population.

The accurate estimation of population parameters represents a critical component of assessing the system state for pallid sturgeon in the Missouri River and providing key demographic values for evaluating management actions through predictive population modeling. The estimation of these metrics depends on the quality and quantity of data collected from a well-developed sampling design. The optimal design must be cost-efficient, and provide reliable, accurate data. Implementing an untested design on a

large system like the Missouri River could prove costly from the expenditure of time and effort if the selected design performs poorly. For the initial stage of development, we recommend that candidate sampling designs be evaluated by simulation modeling to identify the optimal design (that is, tradeoffs between precision, bias, and cost) and provide proof of concept prior to testing or implementing in the field. This effort is included as a level 1 science component in Appendix C under Technical Development. Once the sample design has been optimized through implementation and adjustment over a number of sample years, only periodic monitoring may be required (e.g., every few years) to estimate and update demographic values.

D.1.1.40.4 Design Understanding from Simulations

A preliminary simulation was performed as a proof of concept to evaluate whether a capture-recapture study of individual fish using a robust design would be feasible on a river the size of the Missouri River. First a geographic template was used based on the current PSPAP river bend sampling units, where a river bends are defined as a three continuous habitats (channel cross-over, inside bend, outside bend) and vary in number and size from for the lower and upper basin (Lower: N=317, mean=4 rkm, min=0.2, max=19; Upper: N=157, mean=2.3, min=0.6, max=8). Simulations were performed using the lower basin sampling units as templates. Population dynamics were simulated given known recruitment, survival, and abundance. Given the population dynamics, capture histories were simulated for two levels of capture probability 0.1 and 0.4. These values were selected based on capture probability estimates (Rotella and Hadley 2010, Steffensen et al. 2015b). These simulated capture histories were then used to estimate population abundance, survival, and recruitment. The robust design estimator used was the simplest case, assuming homogenous capture probabilities among secondary sampling units and that capture probability was homogenous among bends. The simulation used 5 primary sampling periods and varying secondary sampling occasions (2 through 10) to evaluate estimator performance, reliability, and effort levels.

Within a primary sampling occasion at least 2 secondary capture occasions are required to estimate the population using capture-recapture of marked individuals and more are likely needed if heterogeneous capture probabilities are present. Over a spatial extent, sampling at least 20% of the river bends was necessary in preliminary simulations. While this preliminary simulation does not address specific gears, selecting gears and sampling occasions that maximize catch will likely result in reduced effort (Section D.3). Based on preliminary analyses, the population abundance could be estimated (Figure D6). With the exception of a capture probability of 0.1 reasonable abundance estimates were achieve by sampling 20% of the bends if capture probability was 0.4 (Figure D6). If capture probability was 0.1 either more bends needed to be sampled or 6 or greater sampling occasions. There was no appreciable effect of increased secondary occasions

to estimate population abundance if capture probability was 0.4. It should be recognized these simulations were conducted under the best case scenario (that is, homogenous survival and capture probability) and therefore may not reflect the challenges to sampling a large turbid river like the Missouri River and additional study is required to evaluate 'worst case' scenarios.

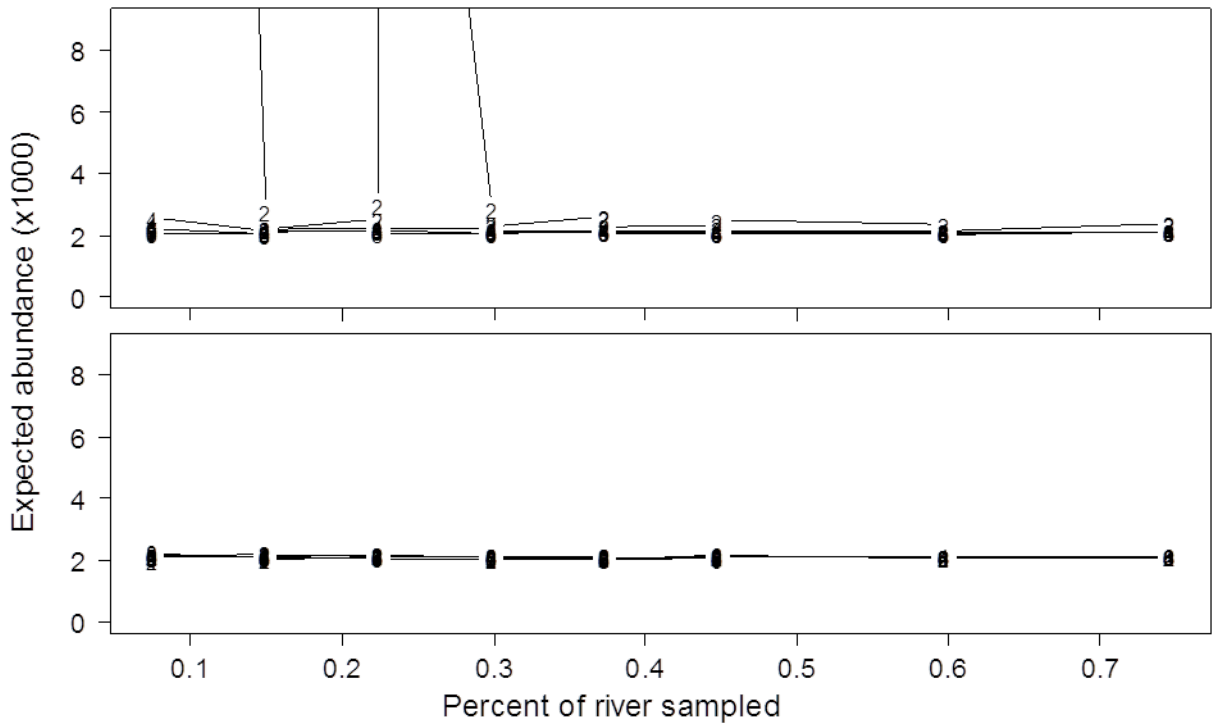

Figure D6. Effect of number of secondary samples and amount of river bends sampled on population abundance estimates. The upper graph assumes a capture probability of 0.1; the lower graph assumes a capture probability of 0.4. The number in the graphs represent the number of secondary sampling occasions.

D.1.1.40.5 Additional Information to Complete Design

This simulation study is preliminary and suggests that a robust design mark-recapture approach may be a useful monitoring approach. To fully complete the robust design, a level 1 study should be implemented to evaluate spatial and temporal configurations required to achieve acceptable population and demographic rate estimates (Appendix C). Additionally, if the monitoring program will be used to detect the effect of management actions, a power analysis must be completed. The amount of effort required to provide reasonable estimates should be considered. Lastly, including auxiliary information such as data from telemetry tracking in an integrated population model is intended to provide a unifying framework incorporating system level

monitoring and providing estimates and feedback necessary to parameterize and calibrate the population model.

D.1.1.40.6 Caveats and considerations

There are many assumptions required to estimate population abundance and demographic rates. For example, in this preliminary analysis, survival and detection probability were constant among primary and secondary occasions, which is likely a poor assumption. Additionally, factors affecting pallid sturgeon survival, such as age, growth, condition were not evaluated and should be accounted for to improve estimates and also capture the effect of these variables on survival such that they can then be potentially linked to management actions. Additional research will be required to evaluate the tradeoffs of efforts with estimate bias and precision as part of a level 1 science effort. Also, evaluation of how sensitive estimates are to violation of assumption will be necessary prior to implementation of monitoring programs. Lastly, the monitoring design will have to be optimized within the constraints of the finite resources available to monitor pallid sturgeon on an annual basis, which is not a trivial task in a large turbid system like the Missouri River.

D.1.1.40.7 Upper River

If mark-recapture is to be implemented as part of the population-level monitoring, we would recommend that sampling occur in Segments 2, 3, 4, and the lower 48 km of the Yellowstone River. Past sampling (2000 to present) indicates that the majority of the pallid sturgeon reside in these areas during fall. Gear subsample deployments should occur primarily in the four habitat types that have provided the highest catch rates for pallid sturgeon >/= 109 mm in length: CHXO-CHNB, OSB-CHNB, ISB-CHNB, and SCCL-CHNB. As identified previously, tributary mouths have also provided high catch rates of pallid sturgeon and may be included as a focus habitat. Sampling should occur in August through October dependent upon flows and water temperature.

Gears

The trotline and the trammel net have been effective gears for sampling pallid sturgeon in the Upper River (Tables D13, D14, and D15). However, the trotline is only (generally) effective at sampling pallid sturgeon during October when the water temperatures are low enough to reduce the level of bait stealing by small-bodied fishes (Ryan Wilson, USFWS, pers. comm.). In contrast, the trammel net can be fished effectively from August through October and provides the flexibility to repeatedly sample areas (that is, bends, habitats) within the same day that contain high concentrations of pallid sturgeon. Therefore, we recommend using the trammel net for mark-recapture

sampling in the Upper River. The trotline could serve as a replacement gear when low river flows reduce the capture efficiency of the trammel net.

Effort

The proposed sample season for the Upper River would occur in the months of August, September, and October. Approximately 2,150 pallid sturgeon juveniles and adults need to be sampled per year (August, September, October) to achieve a 5% capture rate for the population (Table D21). A capture rate of 0.6 pallids/subsample would require 3,596 trammel net subsamples (1,200 drifts/month) to reach the target of 2,158 pallid sturgeon (Table D23). Closed population estimates of abundance will be obtained at the bend level through repeated sampling of an individual bend over a 3-day period. Simulation will be used to identify the sample design that optimizes the level of effort and precision and that minimizes bias. The estimated number of drifts, bends, and effort needed per segment is included in Table D23.

Table D23. Target sampling effort for targeted Mark-Recapture of pallid sturgeon in Recovery Priority Management Area 2 with the trammel net.

Recovery Priority Management Area	Pallid Sturgeon Population Assessment Program Segment	Length, kilometers	Number of Bends	Number of Bends to Sample Each Year (at 5%)	Number of Net Drifts, 5% of Pallid Sturgeon Population	Number of Drifts per Sample Month	Total Bends per Segment per Year, [number to sample per sample period]	Crew Days
2			145	2158**	3596**			40
	2	59	40		1007	336	12 [4]	12
	3	178	61		1510	503	18 [6]	18
	4	84	24		611	204	9 [3]	9
	Yellowstone River	48	20*		503	168	6 [2]	6

*represents lower 48 km (30 miles) of the Yellowstone River

** targeted sampling capture rate of 0.60/drift (2015 field season, Ryan Wilson, USFWS, pers. comm.)

D.1.1.40.8 Lower River

If mark-recapture is to be implemented as part of the population-level monitoring, we would recommend that mark-recapture monitoring occur throughout the Lower River (Gavins Point Dam to the Missouri River mouth) as past PSPAP monitoring has collected numerous pallid sturgeon in all Segments (7, 8, 9, 10, 13, and 14). Gear subsample deployments should occur primarily in the four habitat types that have provided the highest catch rates for pallid sturgeon >= 109 mm in length: BRAD-CHNB, CHXO-CHNB, ISB-CHNB, and ISB-POOL. Tributary mouths have also provided high catch rates of pallid sturgeon and may be included as a focus habitat. Sampling should occur in March-May and October-December with the timing of sampling dependent upon water temperature.

Gears

The trotline has been the most effective sampling gear for pallid sturgeon >/= 109 mm; therefore, it is recommended that the trotline be used for mark-recapture sampling in the Lower River. The effectiveness of this gear is restricted to spring and late fall due to the activity of bait-stealing fishes.

Effort

The proposed split-sample season for the Lower River contains approximately two sample months in the spring and two months in the fall. Approximately 1,550 pallid sturgeon juveniles and adults need to be sampled per year to achieve a 5% capture rate for the population (Table D21). A capture rate of 0.25 pallids/subsample would require 6,200 trotline (40 hooks/set) subsamples (1,550 sets/month or 3,100 per season) to reach the target of 1,550 pallid sturgeon (Table D24). Selected bends will be sampled for 3 consecutive days to obtain the closed population estimate. Table D24 provides the estimated number of sets, bends, and effort needed per segment. As with the Upper River, simulation will be used to compare designs and optimize the level of sampling effort.

Table D24. Target sampling effort for Mark-Recapture of pallid sturgeon in Recovery Priority Management Area 4 with the trotline.

Recovery Priority Management Area	Pallid Sturgeon Population Assessment Program Segment	Length, kilometers	Number of Bends	Number of Bends to Sample Each Year	Number of Troline Sets, 40 Hooks/Set, 5% of Pallid Sturgeon Population	Number of Sets per Segment, per Sample Period	Total Bends per Segment per Year, [number to sample per sample period]	Crew Days
4		1297.6	316	1550	6200*			
	7		34		682	171	14 [4]	14
	8		61		1178	295	25 [6]	25
	9		81		1612	403	34 [9]	34
	10		39		744	186	16 [4]	16
	13		45		868	217	18 [5]	18
	14		56		1116	279	23 [6]	23

*capture rate of 0.25 pallid sturgeon/set

D.1.14.3 Integrative Pallid Sturgeon Population Model

D.1.1.40.9 Model overview and spatial organization

The collaborative population model structure was developed to meet three objectives:

1) provide a quantitative framework to forecast pallid sturgeon population dynamics given inputs from the CEMs;
2) provide a flexible model structure template that can be used to model upper and lower basin populations, and;
3) account for whether a pallid sturgeon was produced in the Missouri River System or the hatchery system.

A secondary consideration in the development of the integrative model structure was the availability of biological data commonly collected during population assessments

(e.g., size, weight, age, sex, origin), which will be necessary to parameterize the model and allow the model to provide decision support and inform monitoring efforts. We provide a brief overview of the model structure as it has documented in detail in the EA integrative report (Jacobson et al. 2016a). Current versions have expanded the temporal and spatial resolution of the model which does not change to stage and age structure in previous versions.

Stages were used to organize pallid sturgeon life history and as a framework to model population dynamics. Seven stages were used in the model to capture biologically important pallid sturgeon stage transitions similar to those identified in Wildhaber et al. (2011a) and correspond to life stage-specific CEMs. Pallid sturgeon life history in the Missouri River System was organized into the following stages:

1) **Embryo** (5-8 days): period from fertilization to hatching.
2) **Free embryo** (8-12 days post hatch (dph)): period from hatching until the larval fish initiates feeding.
3) **Exogenously feeding larvae** and age-0 (8-12 dph - June 1): period from full development of fin rays over the winter period until June 1 of the following year.
4) **Juvenile** (age-1 to age-9): period of pallid sturgeon sexual immaturity, a fish can remain in this stage until age-9.
5) **Spawning adult** (age-7 to age-41): this stage includes juvenile fish that have become sexually mature and are read to spawn and adult fish that have already spawned and are ready to spawn again.
6) **Post-spawn adult**: a pallid sturgeon that has released its gametes, model assumes fish remain in this state until June the following year.
7) **Recrudescent adult**: a post-spawn pallid sturgeon, replenishing gametes, may remain in this state for up to 4 years post-spawn.

Each stage represents an important portion of pallid sturgeon life history in the Missouri River System that varies in duration from days to years. The effect of hatchery operations on the population was accounted for with the addition of stages specific to the hatchery system, including:

1) **Broodstock**: sexually mature fish ready to spawn that are removed from the Missouri River System and used as a source of gametes to fertilize and produce offspring in a controlled hatchery environment.
2) **Fingerlings**: pallid sturgeon hatched in a hatchery setting and reared for 3–4 months and released back into the Missouri River System.
3) **Yearlings**: pallid sturgeon hatched in a hatchery setting and reared for 10–12 months and released back into the Missouri River System.

The current implementation of the model has a geographic extent limited to the Lower and Upper Missouri River segments, denoted as RPMA 2 and 4 (Figure D1). These two river segments are subdivided into bends representing the spatial grain of the population model. River bends are defined as a three continuous habitats (channel cross-over, inside bend, outside bend) and vary in number and size from for the lower and upper basins (lower: N=317, mean=4 rkm, min=0.2, max=19; upper: N=157, mean=2.3, min=0.6, max=8). As currently implemented, fish move among bends. We use bends as a spatial organization because they are the sampling units for the PSPAP and are likely to be retained as the spatial organization for future monitoring. Current temporal extent is user defined and can be up to 50 years with a monthly time step.

D.1.1.40.10 Integrating the population model with monitoring and research

The integrated population model (IPM) can be used to evaluate scenarios of interest, but to be a useful as a decision support or scenario planning tool it needs be able to accept information from ongoing monitoring and research. These monitoring and research efforts can be thought of as 'plugins' into the model. A preliminary view of this is illustrated in figure B5. Specifically, various monitoring programs and research efforts will provide data for demographic rates and abundances. This approach assimilates monitoring and science programs to inform population simulations. Within this framework we have identified 3 major programs (Level 1 and 2 Science, Process monitoring and assessment, and Population monitoring and assessment) that can inform demographic rates and 2 ancillary programs (Telemetry, Broodstock capture) that can further inform demographic rates.

How specific science and monitoring programs will plug in to the IPM will vary among the programs. Level 1 and 2 science should provide at least baseline or best-case estimates of what parameters might be that cannot be estimated in the system (e.g., embryo survival). Process monitoring and assessment should be able to inform the effect of management actions on demographic rates. For example, IRC habitat is hypothesized to increase survival, so monitoring data from in-river experiments may be assimilated into the model. Lastly the population-level monitoring and assessment can potentially inform survival, recruitment, abundance, growth, and sex ratio of the population. The robust design capture-recapture program proposed can also potentially be used to calibrate CPUE data using a Bayesian framework.

Ancillary programs like telemetry and broodstock capture can further be used to refine relationships and demographic rates. For example, within the broodstock program, information on fish size and fecundity can be used to refine fecundity maturity relationships, which will likely be important to link growth. Telemetry can inform survival and emigration. Periodic detections, if designed correctly, provide information

regarding whether a fish is in the system and alive. The use of strategically located autonomous telemetry receiver arrays may be useful inform migration rates (Appendix C).

D.1.1.40.11 Caveats and considerations

The IPM described here is a work in progress and specific methodological and analytical details will be presented as they are developed. Some additional effort is needed to be made to develop the framework and evaluate whether or not it will work given system constraints. The additional effort is planned as a level 1 science effort. However these efforts primarily require computer simulation and therefore could be evaluated early in the process. Another caveat to consider is that with the addition of information streams, computation time may become a limiting factor, however once parameters are estimated population simulation should go relatively quickly. Lastly, in order for science and monitoring programs to plug in to the integrated population model, studies and data need to be conducted in a manner that allows for integration. For example, if all studies estimating survival use a logit-linear model these results can be integrated, however if a study is set up differently, the study may need to be reanalyzed to be integrated. The refinement and maintenance of the IPM is considered to be an ongoing Technical Development in Appendix C.

D.1.14.4 Ancillary Data for Population Assessment

D.1.1.40.12 Data for Parameter Estimation

A population monitoring and modeling intended to provide useful estimates of population size and growth will require several types of information in addition to population size and survival estimates from the mark-recapture robust design. These include:

- Tag loss estimates
- Sex ratios
- Reproductive ratios
- Fish condition, health
- Fecundity estimates
- Age at first reproduction
- Age at senescence
- Growth rates
- Emigration and immigration

Estimates of these parameters values will require additional effort in the monitoring program but required data can be gathered with minimal extra effort.

D.1.1.40.13 Links from Action Hypotheses to Population Assessment

The level 1 and 2 science components outlined in Appendix C are structured to determine whether each hypothesized action will be effective in increasing the population of pallid sturgeon, and if so, how survival at specific life stages will be affected by the action. Changes in survival estimated from laboratory, mesocosm, or field experiments will provide new estimates to update the population model and thereby indicate whether the population is likely to increase. The likelihoods projected from implemented actions will be compared to population sizes estimated from the robust design, documented survival, and CPUE.

In this framework, the level 1 and 2 science components and population assessment are mutually supportive. The population assessment and IPM will serve as the over-arching accounting process to document population trends whereas the science components provide the causal linkages from management actions to changes in survival. Importantly, survival from age-0 to age-1 or age-2 will probably not be measurable in the field or in mark-recapture because of gear limitations in capturing/recapturing small fish. Therefore, science component estimates may be the only information available to address survival at these important life stages.

In addition, we recommend that some ancillary abiotic data be collected during the robust design. These data are not intended to provide habitat selection or resource-use data; instead, they are intended to provide indicators that may be related to survival, or to catchability. We recommend that water temperature, conductivity, and turbidity should be collected with each gear deployment.

D.1.14.5 Catch per Unit Effort Continuity and Check

A limited CPUE effort would serve to provide continuity with previous population trend data developed through the PSPAP and to serve as a check on population estimates obtained from the robust design. The original goal from the PSPAP was to provide information to detect changes in pallid sturgeon populations and the first objective of the PSPAP was to evaluate annual and long-term trends in pallid sturgeon population abundance and geographic distribution throughout the Missouri River System (Welker and Drobish 2012). Although CPUE does not estimate true abundance of the population, it does theoretically detect changes (increases or decreases) in relative population abundance (Hubert and Chamberlain 1996). Because the PSPAP has collected CPUE data for 10+ years and because the pallid sturgeon is a long-lived species, continuing to collect such data would be useful to track relative changes in population abundance in the future.

As previously mentioned, CPUE is not capable of estimating population abundance, but it is assumed to be proportional to estimates of abundance, which will be derived from the robust design. The two measures of abundance (CPUE and population estimates) should serve as abundance measure checks to one another. For example, if population estimates show an increase, it follows that CPUE values should increase as well. In this situation, the combination of both abundance measures would suggest that the population increased. This level of confirmation may provide confidence in a system characterized by great variability.

Measures of CPUE are sometimes prone to large measures of error due to variation in fish behavior and other factors. One way to reduce variability in CPUE is to standardize sampling methods, which the PSPAP has done with their sampling regime and use of gears (Drobish 2008) to a certain degree. The PSPAP currently has large sampling time periods for each of its sampling seasons (sturgeon season = ~8 months, less when constrained by ice in northern segments; fish community season = ~4 months). A further reduction in variability might be obtained by decreasing the length of sampling time periods to narrower time frames, such as spring or fall (2-3 month time periods). Optimizing gear use for each river location (Upper and Lower) might also reduce variability of CPUE estimates. Gears in the Lower River are not necessarily as effective when used in the Upper River. Based on evaluations of the effectiveness of gears (see Section D.3), it seems using trammel nets and otter trawls in the Upper River and trotlines and the otter trawl in the Lower River would most effectively estimate CPUE of pallid sturgeon. The use of trotlines, otter trawls, and trammel nets to estimate CPUE would provide continuity to the 10+ previous years of sampling during the PSPAP.

D.5 Assimilation and Interpretation of Data: Application to Decision Making

D.1.15 Assimilation of Data in Population Model

Adaptive management of the pallid sturgeon in the Missouri River will require multiple sources of information, at varying spatial and implementation scales. Hypothesis driven monitoring and research also will be required to assess specific management actions. Population-level monitoring data provide three inputs to the decision making process and AM. First, monitoring data provides information which in turn reduces uncertainty of the current state of the system (that is, abundance of pallid sturgeon). This is important as management decisions likely depend on the current state of the system. For example, the annual to multiple-year level of population augmentation (that is, stocking) required to meet sub-objectives will likely depend on knowing population abundance and trend with some confidence. Second, population-level monitoring data provide feedback necessary to evaluate implemented system-level management

decisions (level 3) as part of the AM process, albeit it may take many years to realize a system level effect in monitoring data. In this case, the effect a management action on the population is predicted and monitoring data provide the necessary feedback to evaluate whether the predicted population response was realized. Population-level monitoring needs to be coordinated with process monitoring in order to evaluate management actions that may not be detectable at the system level (e.g., effect of IRC on free embryo and exogenously feeding larval pallid sturgeon survival). Lastly population-level monitoring is necessary to determine whether population objectives and sub-objectives have been met.

Challenges exist to using monitoring data that provide a relative index of the population for AM and decision making. Specifically, previous PSPAP monitoring indexed population abundance by CPUE, which assumes that CPUE is proportional to abundance and catchability is constant over time and space (Harley et al. 2001). Catch effort data can exhibit patterns of hyper-stability where catch suggests population abundance is higher than it actually is or hyper-depletion where catch suggests population abundance is lower than it actually is. The use of CPUE data is also in apparent conflict with population objectives stated in the present pallid sturgeon recovery plan of 5,000 individual pallid sturgeon in each management unit (U.S. Fish and Wildlife Service 2014). Calibration of CPUE to pallid sturgeon abundance would be necessary to determine whether this population objective has been met. The value of uncalibrated CPUE data can be of limited value in a decision making context if fundamental objectives focus on population abundance rather than relative abundance, especially if relative indexes are biases. The use of varying sources of information (Level 1 and 2 science, process and implementation monitoring, and system level monitoring) in a decision making context presents a final challenge to the AM process.

The model developed to simulate population dynamics and evaluate management actions provides a flexible framework to evaluate the consequences of management actions on population dynamics and growth (λ; defined as N_{t+1} / N_t). The effects of management actions are propagated to the population through effects to demographic rates, survival in this case. In many cases baseline survival is unknown with a high degree of uncertainty and the effect of a management action on survival is an additional unknown. These unknowns may be parameterized by expert elicitation, existing values, new science, or by model calibration. As the adaptive-management process moves forward additional information will become available that will refine and ideally improve the survival rates and associated uncertainties. These values may become available as a result of controlled experiments or field studies and this information should be assimilated and incorporated in a manner that results in a useable input such that the population model can be used as a decision support tool.

D.1.16 Assimilation and Integrating Monitoring, Research, and Management

Integrating monitoring with the AM plan will pose challenges in a decision making context. In particular, the AM plan utilizes multiple sources of information at varying scales of implementation (Level 1 and 2, Process and implementation). Level 1 study consists of small scale experiments and information learned from these studies may not adequately scale to the population level. For example, scientific studies conducted in ponds, flumes, or under controlled laboratory conditions may not generalize to the population level. However this information is important to synthesize and incorporate into decision making and AM as these values may be the only source of that can inform demographic rates used in the population model. A formal framework to integrate information acquired from studies at the varying levels has not been developed and represents a challenge to integrate information across study levels.

The exact nature of a framework to integrate what is learned from levels of studies in the AM plan is uncertain. One approach that has been used to combine sources of information is Bayes Theorem, which can assimilate prior and current information into a posterior distribution of values. This approach is potentially useful because it can be used in either a scenario planning approach (that is, evaluating scenarios through a model) or in a decision model such as a Bayesian Decision Network (BDN) (Nyberg et al. 2006). This section provides an example of how Bayes Theorem may be used to update a distribution of survivals for embryos and some potentially useful applications of BDNs to assimilate and incorporate information learned from studies at varying levels in a decision making context. It should be recognized that this is one approach that shows promise and is commonly used in a decision making context, but there may be other approaches that are more suitable, albeit not yet unidentified.

D.1.17 Example: assimilating and incorporating information on embryo survival

Suppose that prior to any level of study, survival of embryos to free embryos (ϕ_{embryo}) was believed to be some value with some measure of uncertainty. This value and associated uncertainty can be derived by literature review or expert elicitation. In this hypothetical example, suppose the initial value and associated uncertainty for embryo survival (ϕ_{embryo}) was determined by expert elicitation. An approach to perform the elicitation would be to have experts adjust the parameters of the equation $\text{logit}(\phi_{embryo}) = \beta_0 + \varepsilon$, where β_0 is the expected survival on logit scale and ε is a normally distributed error term controlling the uncertainty around ϕ_{embryo}. If the results of this hypothetical elicitation were $\beta_0 = -12.1$ and $\varepsilon = 0.2$, the resulting distribution of ϕ_{embryo} is illustrated in figure B7. This distribution of ϕ_{embryo} values can then be used in stochastic population simulations to evaluate population dynamics and viability over the long term.

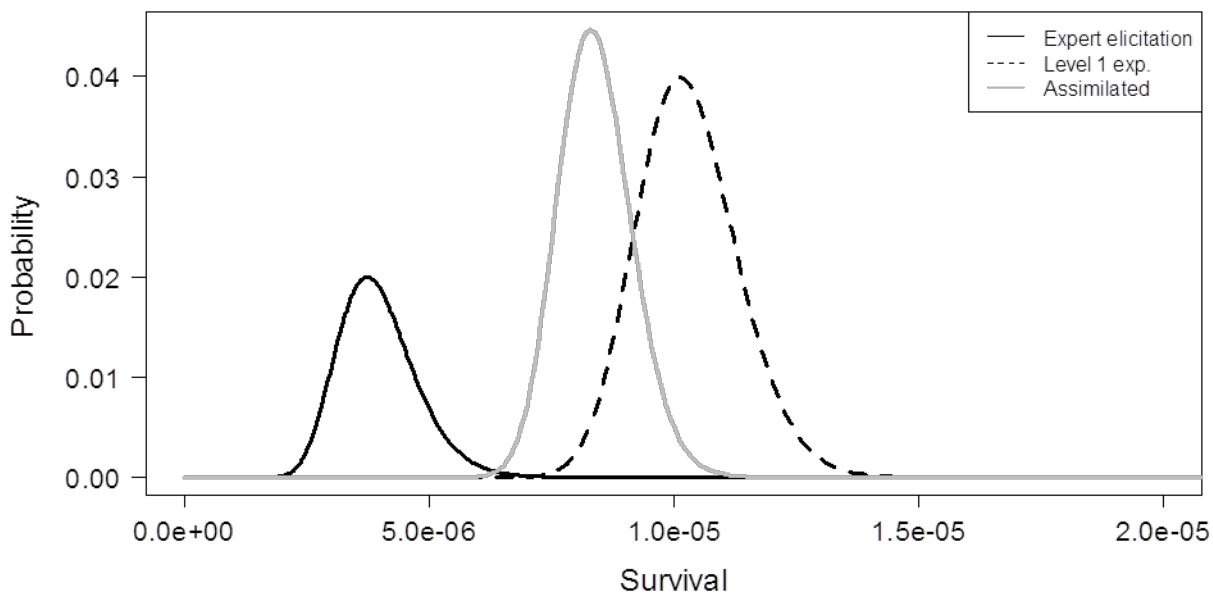

Figure D7. Hypothetical Pallid Sturgeon embryo survival based on expert elicitation (black line), level 1 study (dotted line), and the assimilation of the two using Bayesian updating (grey line).

Model parameterization by expert elicitation provides a rapid framework to evaluate the effect of management actions on an objective that otherwise may take months to years or may be impossible to estimate. Sensitivity analysis provides a method to evaluate how dependent model outcomes are on these inputs and potentially guide research and monitoring. As the AM plan moves forward, studies at varying levels will further inform demographic parameters like ϕ_{embryo}. For example, suppose a study is implemented that provides estimates of embryo survival based on a flume study and survival was estimated from the same logit linear model where $\beta_0 = -11.5$ and $\varepsilon = 0.1$ (Figure B7). This study, while not at the scale of the entire system, provides additional information on embryo survival and can be incorporated and assimilated using Bayes theorem to update the distribution of survival values resulting from expert elicitation (Hilborn and Mangel 1997, Clemen and Reilly 2001, Conroy and Peterson 2013). Incorporating and assimilation the information results in a posterior distribution representing the assimilation of the two information sources (gray line in Figure B7). Population model simulations can then be conducted using the new distribution of survivals assimilating expert elicitation and monitoring results.

D.1.18 Power of Population-Level Monitoring Data to Detect Management Effect

If population-level changes are to be related to management actions, the population-level monitoring program should be designed to provide sufficient power to detect the effect of the action. In most research studies, power is typically set such that the sampling program detects an *a priori* effect size 80% of the time. In the case of pallid sturgeon, management actions are believed to effect population demographic rates, which are illustrated in the CEMs. Many of these responses are on survival which is bound by 0 and 1. Given the bounds on survivals, effects are likely asymmetrical which can complicate simple power analyses. For example, a 10% increase or decrease in an adult survival (ϕ_{adult}) of 0.92 is 1.012 and 0.828 respectively. The 10% increase results in survival exceeding 100%, highlighting the challenge of power analysis to reliably detect biologically meaningful effects due to constrained parameter space. Lastly, suitable effect size should be determined *a priori*, however the practical realities of finite sampling resources will likely limit the reliable detection of an effect, unless the effect is large (that is, it is easier to detect large effects with less effort). Simulation studies as part of ongoing application of the IPM promise to provide information to evaluate whether detecting effects of varying magnitudes is feasible.

D.1.19 Value of Monitoring Data

A challenge facing monitoring programs is how much data is sufficient to make a decision and in the context of finite sampling resources. The value of information can be meaningful in decision contexts where multiple sources of information are assembled to reduce uncertainty around current system state or functional relationships (Conroy and Peterson 2013, Canessa et al. 2015). If a BDN is developed, the network contains a utility that corresponds to an objective, the value of various sources of information, perfect or imperfect (that is, population-level monitoring data), can be calculated (Moore and Runge 2012, Conroy and Peterson 2013, Canessa et al. 2015). Additionally, in cases where there are multiple metrics that require monitoring but resources preclude monitoring all desired metrics, a value-of-information analysis can facilitate prioritization of monitoring efforts in the context of making a decision. For example, the number of pallid sturgeon 50 years in the future depends on the current number of pallid sturgeon. However, there is uncertainty in current pallid sturgeon abundance estimates that could be reduced by monitoring. Similarly, there also is uncertainty in survival rates that could be reduced by monitoring or additional research. How finite monitoring and research resources are allocated (e.g., does an agency target abundance or survival) to reduce uncertainty can be informed by a value of information analysis. This type of analysis when performed in conjunction with a sensitivity analysis can provide a framework to determine how valuable information acquired from monitoring

and research is, but it requires BDN which in turn requires a set of decision alternatives and a utility.

D.1.20 Caveats and Considerations

The approach illustrated in the two hypothetical examples is one approach that may be used to assimilate and incorporate information from varying monitoring designs and levels of study in the AM process. This approach is easily used in a BDN framework as well as in scenario modeling, providing support to using the population model for scenario planning or decision support. As demonstrated in the example, attention needs to be applied to studies such that analyses can be assimilated. Specifically one needs to be able to combine information based off a distribution or predictive model. Additional consideration should be given to how much belief or weight is given each information source, if this approach is applied. For example, should data from mesocosm experiments receive similar or twice the weight of expert elicitations? What about in relation to field level studies and implementations? Assimilating and incorporating varying information sources that will arise from the AM plan will be a challenge requiring careful consideration as to how results will fit together with the population model to support for decision analysis and scenario planning.

D.6 Summary and Conclusions

This report explored options for refining a population trends monitoring approach so it is effective and efficient in meeting the needs of the adaptive-management program. Analysis of previously collected data indicates how age-0 through adult age pallid sturgeon can be sampled with increased efficiency and initial exploration of robust design mark-recapture indicates that reliable monitoring of the pallid sturgeon population may be cost effective. Population-level monitoring promises to provide an important complement to level 1 and 2 science, and monitoring for implementation and process, to contribute to information for decision making. We develop an approach that would combine CPUE trawling for age-0 and age-1 (to address the objective of assessing recruitment) with a robust design mark-recapture effort (to address the objective of assessing increases to population size).

The results of level 1 and 2 science components, level 3 monitoring and assessment, and population-level monitoring can be effectively integrated in a population-dynamics modeling framework, the integrated population model (IPM). Under the approach developed in this report, the IPM becomes the central mechanism to assimilate data from diverse sources and provide information for decision making. Importantly, confidence in the IPM will be highly dependent on data from population-level monitoring which will provide key parameter estimates and validation.

In the context of limited resources, simulation modeling of robust design sampling can provide increased detail in how to optimize the contribution of population-level monitoring at least cost. We also discuss how a Bayesian Decision Network may be used to assimilate new information into the integrative population model and to evaluate the value of investments in various forms of monitoring.

Appendix E. Listing and Description of Protocols for Sturgeon-Based Process Monitoring and Assessment

Monitoring and assessment will be components of many level 1 and level 2 science components as well as level 3 and level 4 implementations. Multiple agencies and projects have contributed to more than a decade of experience on the Missouri sampling for pallid sturgeon and characterizing their habitats. This collective experience will be the foundation for design of monitoring and assessment protocols that are optimized for projects. Notwithstanding this broad experience, we also anticipate that some field projects may require development of new measurement and sampling protocols, and sample designs. The purpose of this appendix is to describe an approach to developing specific protocols and to document existing protocols.

For many, if not most, level 1-4 actions, monitoring and assessment protocols will need to be refined from existing protocols, or in rare cases, developed anew. Therefore, we anticipate that at the beginning of each component or implementation, there would be a step in which the experimental design, and sampling, measurement, and assessment protocols are developed and documented. This step would include a power analysis to determine whether the experimental design will be able to discriminate among alternative hypotheses. It may also require pilot studies in the laboratory or field to refine existing techniques or to develop new ones. Some adaptation of designs and protocols may occur also during the course of the project, but care will need to be applied to assure that adaptation does not impart bias. An example of the piloting approach is documented in Appendix A in the Technical Development section wherein a specific level 1 science effort is proposed to optimize population-level monitoring.

A large number of existing protocols exists. The following is not intended to be an exhaustive list; rather it is intended to illustrate the depth and breadth of existing sampling and measurement protocols. Some protocols have been documented in published reports specifically about the protocol, some have been documented in other reports or published articles, and some are documented in unpublished agency documents. The quality and detail of information varies considerably among these formats. The protocols are listed by major project.

- All handling of the endangered pallid sturgeon must conform to U.S. Fish and Wildlife handling protocols (U.S. Fish and Wildlife Service, 2012).

- Pallid Sturgeon Population Assessment Project (PSPAP) protocols are documented in multiple reports, notably (Welker and Drobish, 2012a, b, 2016).
- Habitat Assessment and Monitoring Project (HAMP). Early HAMP projects used PSPAP protocols whereas protocols for later HAMP projects are documented in (Dzialowski and others, 2013; Morris and others, 2013; Gosch and others, 2014; Gemeinhardt and others, 2015; Gosch and others, 2015).
- Comprehensive Sturgeon Research Project (CSRP). This US Geological Survey research project includes integrated abiotic and biotic studies of the reproductive ecology of pallid sturgeon, including extensive research using telemetry, laboratory studies, and physical habitat assessments. The USGS maintains unpublished, very detailed standard operating practices (SOPs) for all aspects of the research. In addition, methods are documented in a variety of documents including (Jacobson and others, 2004; Wildhaber and others, 2005; Bryan and others, 2007; Papoulias and others, 2007; Wildhaber and others, 2007; Reuter and others, 2008; DeLonay and others, 2009; Elliott and others, 2009; Papoulias and others, 2009; Reuter and others, 2009; Papoulias and others, 2011; McElroy and others, 2012; Albers and others, 2013; DeLonay and others, 2016).
- In addition, CSRP scientists have contributed assessments of existing monitoring data and power analyses (Bryan and others, 2010; Wildhaber and others, 2011b)

The following section is an example of a draft monitoring plan for a major MRRP action, creation of interception-rearing complexes (IRCs) for age-0 pallid sturgeon. Attachment 2 presents a monitoring plan for adjustments to existing shallow water habitat projects with an emphasis on chutes. Similar monitoring plans and protocols will be developed for other management actions as the adaptive management process proceeds.

Attachment E.1 IRC Construction and Monitoring

DRAFT/Pre-Decisional/For Discussion Purposes Prepared: April 15, 2016
By: Todd Gemeinhardt, Nathan J. Gosch, Brian O. Ma, Carl Schwarz

E.1.1 Introduction

An Effects Analysis proposed functional definitions of Age-0 sturgeon habitat as interception, food producing, and foraging habitat types (Jacobson and others, 2016a). Collectively these habitat types are referred to as Interception and Rearing Complexes (IRCs) when they are co-located within geographic proximity to benefit age-0 pallid sturgeon. The physical components of these habitat types are defined as follows: 1) food-producing habitat occurs where velocity is less than 0.08 m/s, 2) foraging habitat are areas with 0.5 – 0.7 m/s velocity and 1-3 m depth, and 3) interception habitat is qualitatively described as zones of the river where hydraulic conditions allow free embryos to exit the channel thalweg.

For interception habitat, the hypothesis posed by Jacobson and others (2016a) is that recruitment failure occurs because newly hatched free embryos are not able to exit the thalweg (navigation channel) before they starve because the river lacks hydraulic conditions that would transport them into supportive channel-margin habitats with food and protection. Therefore, construction of IRC restoration sites is planned to enhance interception of age-0 sturgeon as they transition from the drift stage to benthic feeding and provide increased amounts of foraging and food producing habitats.

E.1.2 Management Hypotheses

The IRC Monitoring Plan was developed to monitor the success of the construction of IRC restoration sites on increasing age-0 pallid sturgeon recruitment. To measure the success of restoration activities, monitoring will focus on exogenously feeding age-0 sturgeon with the primary response metric being catch per unit effort (CPUE) of age-0 *Scaphirhynchus sp*. sturgeon given the low numbers of age-0 pallid sturgeon present in the lower Missouri River. This monitoring plan focuses on interception, while the rearing portion of the EA hypothesis (food and protection) is currently being addressed in an ongoing HAMP study. Specifically, this study will test the following hypothesis for the biological response of sturgeon to IRC restoration sites:

$H_{0,1}$: 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.

Coupled with the measurement of the biological response (CPUE of age-0 sturgeon), physical monitoring will characterize the hydrodynamics of interception habitat treatment and control bends. The measure of hydrodynamics will include depth and velocity magnitude and direction. Specifically, this study will test the following hypothesis on the physical response to the construction of IRC restoration sites:

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

$H_{A,2}$: The hydrodynamics of the river bends that include IRC habitat restoration sites are different than control sites before and after habitat restoration actions and allow free embryos to exit the channel thalweg.

E.1.3 Approach

E.1.3.1 Sampling Design

Key uncertainties in the IRC Monitoring Plan were (1) the selection of IRC habitat restoration sites (bends) and corresponding control sites, and (2) the timing of construction of IRC habitat restoration sites. To assist the development of a sampling design, analyses were conducted on existing baseline data from the Habitat Assessment and Monitoring Program (HAMP) on age-0 sturgeon catch data (Sub-Attachment 1A). Only the HAMP data (2005-2009, 2014-2015) were used to estimate the various components of variance in CPUE and conduct the analysis. Data from the MDC program (2014-2015) were also considered but were not used because the CPUE from this program was significantly higher than what is regarded as normal CPUE (~10× the typical CPUE for the Missouri River).

A hierarchical staircase study design was proposed to evaluate the response of age-0 sturgeon catch to IRC habitat restoration activities. A staircase design is a series of staggered before-after-control-impact (BACI) designs (Walters et al. 1988), and therefore requires paired control and treatment bends for the duration of the study. Each IRC habitat restoration site (i.e., treatment site) should also have a corresponding control site. Each IRC and control site should be sampled annually and at least one year prior to initiation of construction.

The decision to use this design was because of (1) logistical constraints, and (2) statistical considerations. Logistical constraints included the speed at which IRC habitat restoration sites could be constructed. It was estimated that up to two sites could be constructed per year. Statistical considerations consisted of power analyses conducted on several candidate configurations to determine a sampling design that would have the

most power to detect a significant difference when such a difference actually exists (Brown and Guy 2007) given the existing logistical constraints (see Sub-Attachment 1A).

Generally, power increases with the number of IRC sites implemented, the magnitude of change in CPUE and the total number of years of monitoring. After some exploration of alternative sampling designs, the AM team, Management Team, and Oversight Team converged on a sampling design with 12 IRC-control site pairs implemented over 7 years (i.e., baseline monitoring for the first IRC-control site pair, followed by six years of building and monitoring 2 IRC-control site pairs per year; Figure E4; Table E 1). This sampling led to approximately 80% power to detect an 80% increase in CPUE within 7 years, at an alpha=0.05 and beta=0.2 at the river bend scale based on estimates of variance.

The benefit of a faster rate of construction of IRCs is in providing accelerated learning about action effectiveness. If 10 or more years of monitoring were intended, there was little increase in power for constructing IRC habitats at a rate faster than one per year; however, the rate of two IRC-control sites per year yielded a relatively large increase in power when planning for less than 10 years of monitoring (Figure E 5). To obtain adequate statistical power within the first half of the 15-year time frame of the MRRP, the 12 IRC sites built over 7 years need to create an average increase in CPUE of at least 75% (Figure E 5). The construction of habitat can be delayed (e.g., every second year) without affecting the analysis, but delaying the implementation of an IRC will result in some reduction in power. The power analysis does not consider cost of construction or monitoring, which may add further constraints to the sampling design.

Table E 1:: Biological data collections at IRC and control bends. 'X' represents site-years where monitoring occurs. Shaded boxes indicate the year in which construction will be initiated; CT refers to the control site.

Site/Year	1	2	3	4	5	6	7	8
01	X	X	X	X	X	X	X	X
01 CT	X	X	X	X	X	X	X	X
02	X	X	X	X	X	X	X	X
02 CT	X	X	X	X	X	X	X	X
03		X	X	X	X	X	X	X
03 CT		X	X	X	X	X	X	X
04		X	X	X	X	X	X	X
04 CT		X	X	X	X	X	X	X
05			X	X	X	X	X	X
05 CT			X	X	X	X	X	X
06			X	X	X	X	X	X
06 CT			X	X	X	X	X	X
07				X	X	X	X	X
07 CT				X	X	X	X	X
08				X	X	X	X	X
08 CT				X	X	X	X	X
09					X	X	X	X
09 CT					X	X	X	X
10					X	X	X	X
10 CT					X	X	X	X
11						X	X	X
11 CT						X	X	X
12						X	X	X
12 CT						X	X	X

E.1.3.2 Site Selection

E.1.3.2.1 Treatment Bends

The selection of sites for treatment of IRC habitat designs is based on understanding of typical drift rates of pallid sturgeon free embryos, likely maximum upstream spawning locations, the limitations associated with habitat restoration actions on the river, judgment about the engineering feasibility of constructing an IRC habitat at a specific site, and relevancy of the location of the specific purpose of the IRC characteristic being designed and tested. Sites for IRC habitat implementation are limited to areas adjacent

to or owned by public entities. Although not a requirement, chosen sites are generally not in the vicinity of major or federal levee projects or near known navigation channel trouble areas. Once sites are screened out due to common restrictions or limitations, engineering judgment and experience are used to determine which sites are the most amenable to geomorphic or physical habitat change within areas that are most relevant for the specific habitat characteristic being tested. Site history is taken into consideration to determine what kind, if any, habitat restoration work was previously completed and if the site has undergone any previous biological monitoring. The culmination in the above factors will result in the reduction in the pool of potential sites to draw from based on preferential characteristics such as location, size, and accessibility.

E.1.3.2.2 Control Bends

Multiple factors may contribute to the selection of treatment bends (see above); however, increased flexibility in selection of control bends is available because modifications will not be made to those locations for the purposes of creating IRC habitat. In the analysis (Sub-Attachment 1A), we assume that control bends are randomly selected; however, power could be increased if control bends were selected to be as similar as possible to treatment bends, a form of blockingThe Lower Missouri River has been classified into six distinct geomorphic categories (robert Jacobson, unpublished data). For this study, control bends should be selected from the same geomorphic classification as paired treatment bends to minimize geomorphic variability between paired control and treatment bends. Ideally, control bends should be selected upstream of the paired treatment bends to avoid treatment actions from influencing control bends. If this cannot be achieved, the control bends should be selected from a sufficient distance downstream of the treatment bends to reduce treatment effects.

E.1.3.3 Data Collection Tasks

E.1.3.3.1 Biological Monitoring

The sampling protocol at each site (trawl location, site selection, frequency, etc.) of this study follows the sampling standard operating procedures (SOP) for 2014-2015 HAMP efforts, except when noted here. The SOP relied heavily on the SOP developed for monitoring and sampling Missouri River fishes between 2003 and 2013 by Welker and Drobish (2016), and includes protocol with collecting information on length, frequency, distribution, and catch per unit effort (CPUE) for all sturgeon species (Appendix I, Attachment 1). To address the unique sampling objectives of this study, highlights and modifications to the Welker and Drobish (2016) SOP are detailed below. Therefore, if not specified below, refer to Welker and Drobish (2016).

Field Measurements and Data Collection Procedures

To maximize efficiency of limited sampling resources, a stratified random approach will be used to guide sampling efforts through the habitat classification hierarchy (Welker and Drobish 2012) to avoid oversampling in habitats where age-0 sturgeon (<110 mm) are not likely to occur (based on Pallid Sturgeon Population Assessment Program [PSPAP] capture data collected from 2003 to 2013 in segments 10, 13, and 14 and existing HAMP data). Sampling will occur at the following Macro, Meso, and Micro habitats (during situations of extreme low or high water stages additional habitats may be sampled but only after agreement with all sampling crews and project manager to ensure sampling consistency):

Macro Habitats: ISB and CHXO
Meso Habitats: CHNB, ITIP, and BARS
Micro Habitats: Based on known age-0 sturgeon captures and available habitat types within each bend, sampling will focus on the first digit of the of the six-digit micro code. Proportional sampling of each microhabitat if available (first digit), will follow the percent of habitat type counts within each bend. The second and third digit will be recorded based on site specifics, and the last three digits of the micro code will be randomly selected in the field based on the available habitat.

First Digit: (micro habitats selected based on previous age-0 sturgeon capture data)

1 L-Dike
2 Wing Dike
4 Rootless Dike
6 Channel Sand Bar (1 Sampling Unit = 0.25 miles of bar length)

Example:

Bend 1: 4 miles * Sampling effort, 4 trawls/gear/mile. = 32 minimum total trawls each sampling period.

Habitat (Sampling Unit)	Counts	% of total	# trawls
L-Dike	3	17.6%	6
Wing Dike	12	70.6%	23
Rootless Dike	1	5.8%	2
Sand Bar	1	5.8%	2

Fishing gears will follow the original HAMP schedule with two variations on a small-mesh trawl; one to sample in deeper water habitats (OT04) and one in shallow water habitats (PT02/OT02). Based on results from Ridenour and Hill (2010), a target sampling intensity of 4 sites per mile should be completed for each bend per sampling period. A minimum of 4 trawls per mile for each bend will be deployed in depths ranging from 1.5 to 4 meters. Trawl depths should not exceed 6m, if depths exceed this,

an alternate site should be selected by the crew leader. An additional 4 trawls per mile for each bend will be deployed at 0.5 to 1.5 m of average depth. If depths do not meet these requirements, it will be considered unavailable and a sample will not be taken at the site. When bow trawling depths less than 1.5m, a bridal rope length of 12.2 to 15.2m may be used to maximize trawl effectiveness. Each control and treatment bend will be sampled during a period with similar environmental conditions (e.g., non-flood) (each bend will be sampled in its entirety within two weeks). Re-sampling of bends will occur monthly from May through September. Crew leader judgment will be important to determine if more sampling is required to adequately represent the fishes in any single bend during any sampling period.

Data collection and handling procedures will follow in accordance with the Missouri River Standard Operating Procedures for Fish Sampling and Data Collection (Welker and Drobish 2012) unless otherwise stated.

Age-0 sturgeon > 50mm will be measured and recorded by fork length to the nearest millimeter when a defined fork is present. Total length to the nearest millimeter, minus the filament, will be measured and recorded for all age-0 sturgeon < 50mm.

Each age-0 sturgeon genetics sample will include a completed genetics card which must contain the following information: Genetics vial #, Datasheet #, Fish ID #, Study Bend, River Mile, Date of Capture, and Length (denoting total length or fork length). Each age-0 sturgeon genetics sample should be in its own individual packaging (zip top bag), which includes the completed genetics card and 2ml genetics vial.

Physical monitoring will also occur, and some physical measures are noted here because they pertain to the modified trawl protocol (for more details, see Section E.3.3.2.1). Water depth, in meters will be measured at the beginning, middle, and end of each trawl run with a depth finder. Water current velocity will be measured near bed (also commonly called bottom velocity) at the middle of trawl run during the following situations:

- on at least 25% of trawl runs, distributed among trawl runs to be representative of and reflect habitat types (1st digit of micro code) sampled.
- on all deployments when age-0 sturgeon are collected

Water turbidity (NTU) measurements and substrate composition estimates are not required.

E.1.3.3.2 Physical Monitoring

Characterizing the geomorphic and hydraulic changes resulting from design features and understanding how changes relate to the capture of young-of-year sturgeon is crucial to the assessment of IRC habitats. Use of hydroacoustic tools to develop high-precision models of depth and velocity magnitude and direction will allow quantification of habitat conditions within both treatment and control bends with the intent of relating those conditions to the biological sampling.

The objective of the physical habitat data collections is to adequately characterize the hydrodynamics of interception habitat treatment and control bends through field surveys of depth and velocity to allow incorporation into 2D hydrodynamic models. This physical habitat data will then be compared with biological sampling data to increase our understanding of where and why age-0 sturgeon are captured and thought to successfully transition from the free-drifting embryo stage to the benthic exogenously feeding stage.

Data Collection Procedures

Hydroacoustic instruments will be used to measure and characterize the hydraulic conditions at IRC treatment bends, both pre- and post-construction, and Missouri River mainstem control bends. Instruments to be used will consist of survey-grade single beam echosounders (single-beam) and acoustic Doppler current profilers (ADCP) georeferenced using real-time kinematic global positioning systems (RTK GPS) or differential global positioning systems (DGPS). The most recently approved USACE digital survey maps will be used to plan transects at survey locations. Sampling transects will be generated between a 20-40-m spacing and oriented perpendicular to the recommended navigation sailing line of the Missouri River. Transect spacing will depend upon the particular site and should provide sufficient spatial coverage for creating continuous surface maps of depth, elevation, and velocity given the expected amount of spatial variation due to site specific features as well as variation expected under variable discharges. Repeat surveys will be conducted at each site utilizing the same transect design for subsequent surveys. Figure E 1 illustrates an example reach with transects spaced at 20-m intervals perpendicular along the recommended sailing line. Additional longitudinal survey lines along the banks and in the thalweg may be used to improve accuracy of continuous surface maps.

The frequency and timing of surveys will largely depend upon flow and water levels. At a minimum, one survey per site per year will take place between May-August, as close to assumed or known times of larval drift as possible. However, since it is likely that at “ideal” flow conditions, or flow conditions at which larval drift is believed to be

occurring, areas of shallow depth will occur and hinder the ability of a survey vessel to measure depth and velocity, it would be advantageous to conduct multiple surveys per year per site. At least one survey should take place at flow high enough to adequately capture the elevations of areas too shallow to measure during typical larval drift flows. Additional surveys during assumed or known times of larval drift should focus on ADCP collection to characterize the hydrodynamics that occur during these critical time periods.

The data collected at multiple flows will be beneficial during the construction and development of hydrodynamic models of the surveyed reaches. Surveys during high flow will promote the development of accurate terrain models which serve as the basis for the hydrodynamic model, while measured water surface profiles and velocities at more relevant flows will allow for meaningful calibration and validation of the models. A shift in the timing and frequency of surveys may occur as lessons are learned about the time it takes for sites to develop. Data collection will proceed at least one year in advance of design implementation for IRC sites to allow for development and analysis of the pre-construction site model. This timing is consistent with the biological monitoring effort associated with the staircase design (Table E 1).

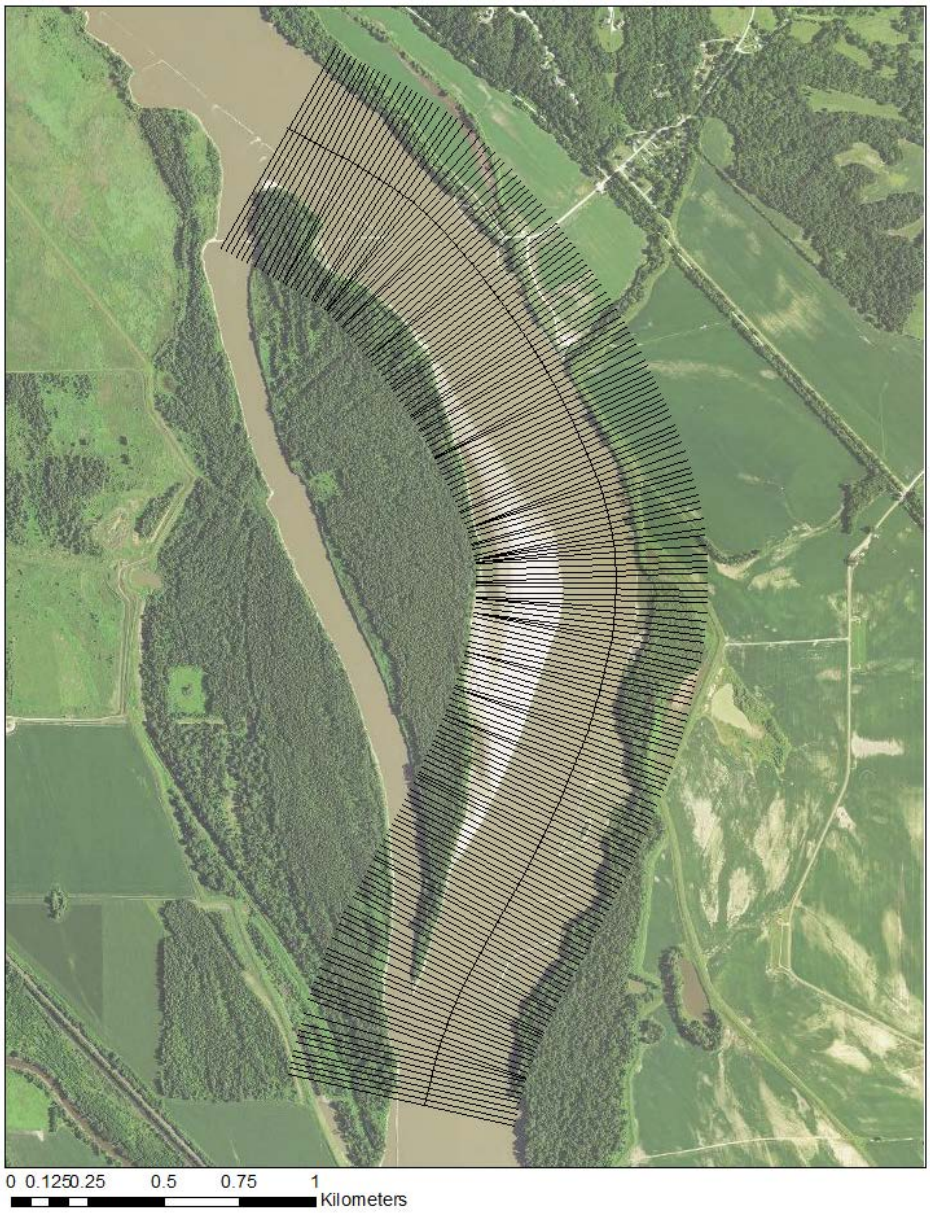

Figure E 1: Example survey reach showing 20-m spaced transects perpendicular to the recommended sailing line.

E.1.3.4 Data Analysis Tasks

E.1.3.4.1 Biological Data Analysis

The analysis of the IRC experiments starts with a data summary to obtain the CPUE at the site level each year because the site is the unit of analysis. The CPUE at the site level was computed as

$$CPUE_{ij} = \frac{\sum_{trawls} Fish_{ij}}{\sum_{trawls} Area_{ij}}$$

where (i, j) refer to site i in year j.

The statistical model for the staircase design (also known as the stepped-wedge design in clinical trials) is discussed in Walter (2008) and Hussey et al (2007). A general linear model can be fit:

$$CPUE_{ij} = \mu + s_i + t_j + (st)_{ij} + I(ij)T + \varepsilon_{ij} \quad (1)$$

where $CPUE_{ij}$ is the catch per unit area in site i in year j; μ is the overall grand mean; s_i is the effect of site i; t_j is the common year effect; $(st)_{ij}$ is the interaction term; $I(ij)T$ represents the treatment effect – the $I()$ term is 1/0 if the treatment is active/not active in site i in year j, the estimate of T represents the treatment effect; and ε_{ij} represents measurement error and other sources of random noise. This model can be fit with most statistical packages (such as R) and sample code is available in Sub-Attachment 1A.

This analysis can be performed each year after the first IRC restoration habitat is constructed and monitored.

E.1.3.4.2 Physical Data Analysis

Physical Model Development

Data collection will support the development of 2-dimensional hydrodynamic models which will serve as the primary mode for processing, quantifying, and analyzing the physical habitat data at treatment and control sites. The benefits of analyzing physical habitat data through the development of computational hydrodynamic models versus observation of the collected data with a static terrain model using a geographical information system (GIS) is the flexibility afforded by the computational model in predicting and observing the fluctuations of depth and velocity at environmental conditions beyond those during the time of the survey. Analyses are not limited to the flows at which the surveys took place. However, a considerable more amount of time is spent in model development.

Models will be developed using the Surface-Water Modeling System (SMS; Aquaveo, LLC) or comparable graphical interface. A numerical model such as Adaptive Hydraulics (AdH), or comparably advanced model (e.g. SRH-2D, TUFLOW, etc.), will

be used to run simulations of 2-dimensional flow through the bends to quantify depth and velocity at flows most relevant to larval drift.

Analysis - Pre-Construction Assessment and Design

Pre-construction surveys will be used to develop models of the sites at "existing conditions". The existing conditions model will serve as the baseline for each site against which the change in habitat is measured and serve as the foundation for the interception habitat design to be built from. A calibrated model can then use specific metrics, under certain assumptions, to approximate how effective interception currently is at a site and evaluate the amount of beneficial habitat that exists. Various engineering design alternatives should be incorporated into the existing conditions model by adjusting the model geometry and/or model input controls to represent the geomorphic or hydraulic transformations expected to occur as a result of the design features. These design alternatives can then be evaluated using the previously defined interception and habitat metrics and compared to the existing conditions model in an attempt to identify designs that improve those metrics.

The particle tracking model (PTM), a module within SMS, is a tool that should be used to provide a metric for conceptualizing and estimating larval interception within a model. PTM can be used to simulate the transport of drifting larval fish by using particles with simplified characteristics in conjunction with the hydrodynamic outputs from AdH or other hydrodynamic model code. Interception can be estimated by quantifying the number of particles entering into the area of interest and comparing to the total number of particles in the simulation to obtain a proportion of particles intercepted. This metric is useful for comparing various design alternatives under the same environmental conditions to evaluate which designs will potentially increase the portion of particles intercepted into the desired area. Additionally, design alternatives can be compared through the amount of beneficial habitat that is created based on specific depth and velocity criteria.

Analysis - Post-Construction Assessment and Design

Monitoring will be conducted following habitat construction and continue through the end of the study. The time required for full development of an IRC habitat will vary between habitats and designs and will be estimated during the design phase of the project. The timing of the post-construction evaluation will depend upon the time it takes the IRC habitat to develop to the desired state. Terrain models developed from survey data of depth and velocity using GIS are useful tools for tracking the progress of site development and should be used as an initial measure when assessing the state of the IRC habitat.

Once it is identified that the IRC habitat has substantially developed to either the design state, or a state of geomorphic quasi-equilibrium, the monitoring data should be re-incorporated back into the existing conditions models to develop post-construction models of depth and velocity. The post-construction model will be useful for direct comparisons to the existing conditions model and will provide a detailed representation of changes in depth and velocity direction and magnitude that occur at critical flows. Metrics used during the design phase can be re-evaluated using the post-construction models to assess the effectiveness of the design to function as intended and evaluate whether assumptions used in the design should be adjusted for ensuing habitats.

E.1.3.4.3 Predictive models of CPUE using physical data

Physical metrics of interception habitat should be compared with biological sampling data (e.g. CPUE) to evaluate any physical metrics are factors that can be used to predict larval interception on the Missouri River. General linear models comparing CPUE of age-0 sturgeon to physical metrics could be compared using an information theoretic approach to model selection like Akaike Information Criterion (AIC) to determine which physical metrics, if any, are useful predictors of larval interception on the Missouri River.

E.1.4 Schedule

The schedule is expected to follow the coarse schedule shown in Table E 2. Noteworthy is the ramping level of effort associated with the staircase design. When considering construction and monitoring activities, the highest levels of effort are in years 6 and 7 of the monitoring plan.

Table E 2: Schedule for IRC Restoration Habitat Construction and Monitoring

	Year							
	1	2	3	4	5	6	7	8
Construction of IRC Habitat		2	2	2	2	2	2	
Biological Monitoring (Bend)	4	8	12	16	20	24	24	24
Physical Monitoring (Bend)	4	8	12	16	20	24	24	24

E.1.5 Literature Cited

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E.1.6 Sub-Attachment 1A – IRC Power Analysis Technical Memorandum

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E.1.6.1 Introduction

The Before-After-Control-Impact (BACI) design is the standard design for investigating the effect of a treatment but controlling for temporal effects and site effects. In BACI designs, treatment sites are measured before and after the actual treatment occurs and control sites are also measured in each year. The control sites provide information on temporal trends, so that changes in the treatment site between pre- and post-treatment can be distinguished from the temporal trends.

BACI designs are quite flexible because the number of years measured pre- and post-treatment do not have to be the same, and it is also possible to have multiple sites in both the treatment and control groups. However, BACI designs usually assume that the treatment is applied to all the sites in the treatment group at the same time.

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. Walter et al. (1998) and Hussey et al. (2007) discuss a variant called the staircase (or stepped treatment) design. The staircase design relies on a series of staggered BACI designs where each new treatment (typically) starts one year later. The staircase design implicitly assumes that treatment effects are permanent and persist once the treatment has been applied to a site. Control sites serve as control for all of the treatment sites.

For example, Figure E 2 presents a schematic of one such design involving 6 IRC and their associated control sites. For the construction of IRC habitats, logistical constraints make it difficult to construct more than 1 or 2 habitats in a single year. While there is only one year of pre-treatment monitoring for the first treatment site, successive treatment sites have more than one-year of control monitoring.

The staircase design shown in Figure E 2 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; treatments can be implemented on a more irregular schedule rather than in successive years.

The statistical model for the analysis of data from a staircase design is discussed in Walter (2008) and Hussey et al (2007) and is shown in model 1:

$$Y_{ij} = \mu + s_i + t_j + (st)_{ij} + I(ij)T + \varepsilon_{ij} \qquad \text{(model 1)}$$

where Y_{ij} is the response in site *i* in year *j;* μ is the overall grand mean; s_i is the effect of site *i*; t_j is the common year effect; $(st)_{ij}$ is the interaction term; $I(ij)T$ represents the treatment effect; the *I*() term is 1/0 if the treatment is active/not active in site *i* in year *j*; and ε_{ij} represents measurement error and other source of random noise. This model is easily fit using most linear model routines in common statistical packages (Annex 1). No modification is needed to deal with the different variants of the staircase design discussed earlier except if control sites are explicitly paired with treatment sites. In this case, an additional term corresponding to the pairing (a blocking term) needs to be introduced as is commonly done for blocked designs.

The staircase design can be considered as a combination of small BACI designs, with each BACI components starting in a new year. Consider the mini BACI design consisting of sites 1 and 2 in years 1 and 2 in Figure E 2. The BACI contrast (which is used to see if there is evidence of a treatment effect) would be computed as $(Y_{11}-Y_{12}) - (Y_{21}-Y_{22})$, i.e., the differential response from year 1 to year 2 between the treatment and control sites. If we expand each of the *Y*'s in that expression by the model in (1), you see that the s_i terms cancel (the same site is measured in multiple years so a within-site contrast is free of site effects); the t_j terms disappear (the difference between the impact and control site in each year is free of time effects), but the $(st)_{ij}$ and ε_{ij} terms do not cancel. If you are willing to assume that the $(st)_{ij}$ and ε_{ij} terms have mean = 0 then the expected value of the BACI contrast is simply the effect of treatment. The actual computations using all of the cells in the design are more complex but the same analogies hold. Notice that the $(st)_{ij}$ and ε_{ij} are completely confounded with each other and represent the noise that reduces the ability to detect the treatment effect.

The power of the staircase design to detect the treatment effect depends on a number of factors:

- the size of the effect – Larger effects are easier to detect than smaller effects
- the noise in the response – Higher amounts of noise make it harder (reduce the power) to detect effects,
- the alpha level – usually set to 0.05; and beta level – usually set to 0.2
- the sample size – larger sample sizes lead to higher power to detect effects.

More specifically in the case of the IRC experiments, the power is a function of the number of IRCs proposed; how quickly the IRCs come on line; the number of control sites; and the length of time these sites are monitored.

The noise in a staircase design consists of three sub-components, some of which have no impact on the power.

First is the year-to-year variation in the response that acts in common on all sites. For example, a particular year may experience river conditions for successful spawning and so the number of young fish seen in the sampling trawls tends to be higher in all bends. Because both treatment and control sites are measured on all years, the year-to-year variation has no impact on the power because in the analysis this term “cancels” as shown earlier.

Second is the site-to-site variation. A particular bend may have some local characteristics that cause it to have higher catches than other bends in a consistent fashion over time. Because both treatment and control sites are repeatedly measured over time, pre- vs. post-treatment-year comparisons will again be “free” of site-effects, and again the site-to-site variation has no impact on the power.

Third is the site-year interaction variation, which represents the non-parallelism of response over time among the sites. For example, we assume that temporal effects have the same effect on all sites (parallel responses), but there may be some site-specific factors that inhibit or amplify temporal trends and so a non-parallel response is observed. The site-year interaction (the residual error in model 1) is the determining factor for the power of a staircase design.

A power analysis will require information on these noise components – in particular the site-year interaction variation.

E.1.6.2 Estimation of Variance Components

In order to estimate the power of a proposed IRC design we need estimates of the site-year interaction term. A site in the IRC experiments is the bend, which then becomes the unit of analysis; i.e., trawl data must be summarized to the bend-level. In order to estimate this term, we need a sample of bends that have been measured in multiple years. It is not necessary for all bends to be measured in all years.

We received data on trawls conducted as part of the HAMP and MDC programs from 2005 to 2009 and 2014 to 2015. Each trawl has information on the bend in which it was measured, the area of the trawl and the number of fish captured in the trawl (Table E 3),

and macro/meso habitat of the trawl. Because the bend will be the unit of analysis, the data was summarized to the bend level and the CPUE at the bend level was computed as

$$CPUE_{ij} = \frac{\sum_{trawls} Fish_{ij}}{\sum_{trawls} Area_{ij}}$$

This gives one number per bend in each year that it was measured.

We begin by pooling all trawls over all habitat types.

Some bends were measured in both the HAMP and MDC program and a summary of their results are shown in Table E 4. The CPUE from the MDC program is much higher than that from the HAMP. Based on discussions with the working group, it was decided that the MDC data does not represent realistic values for CPUE going forward. Consequently, it was decided to only use the HAMP data to estimate the variance components.

Many environmental effects operate multiplicatively rather than additively. For example, a year effect may double the CPUE in all sites raising a CPUE from .001 to .002 fish/m^2 and from .004 to .008 fish/m^2. Consequently, a log-transformation will convert the multiplicative year effect to additive effects on the log-scale (e.g., a doubling will simply add log(2)[1]=.7 to all values). A timeplot of the log(CPUE) from the HAMP data is shown in Figure E 3. Following the standard convention, all CPUE values were adjusted by ½ of the smallest non-zero CPUE value to prevent taking log(0). Both site and time effects are evident but there is a large amount of non-parallelism in the response.

A linear mixed model was used to estimate the associated variance components. In a short hand (*R* type) syntax, the model was

$$\log(CPUE) = Site + Time + (SiteTime)$$

Estimated variance components are shown in Table E5. . We see that the Site-Year interaction variance component is quite large relative to the effects of site or that of year. This can be seen in Figure E 3 in the generally weak parallel effects of site or year.

[1] log(x) implies natural logarithms unless otherwise indicated.

E.1.6.3 Power Analysis

These variance components were used to estimate power based on the results of Hussey et al (2007) but using the methods of Stroup (1999)[1]. The basic idea of Stroup (1999) is that the expected values (i.e., incorporating the treatment effects but no random noise) are analyzed as data using the variance components estimated from a pilot study. The resulting F-statistic in the ANOVA table provides information to estimate the power.

We computed the power for the IRC experiments under a number of scenarios involving:

- between 5 and 15 years of monitoring;
- between 6 and 12 IRC sites (plus the same number of control sites)
- between 1 or 2 IRC sites constructed per year
- effect sizes from a 10% to a 100% increase in mean CPUE in IRC sites.

Because the analysis took place on the log-scale, treatment effects can be easily specified using the relationship that a 10% increase in response corresponds very closely to a 0.1 increase on the log-scale.

The specific results for one such power analysis are shown in Table E 6. We see that this proposed design has an approximate 80% power to detect an 80% increase in CPUE at alpha=0.05. Figure E 4 illustrates the relationship between the number of IRC sites, the number of years monitoring, and the power for various effect sizes. Generally, effect sizes less than a 50% increase cannot be detected even with 15 years of monitoring and 12 IRC sites. However, acceptable power (around 80% power) is generally achievable for an effect size of 75% and at least 10 years of monitoring at a construction rate of one IRC site per year.

Over longer periods of monitoring, there is a negligible benefit of implementing 2 IRC-control pairs/year rather than 1 IRC-control pair/year (while keeping the total length of monitoring and total number of sites the same), as shown in Figure E 5. However, the benefit of doubling the rate of IRC construction increases in sampling designs where the number of monitoring years is small. If only one IRC-control pair is implemented per year, it may not be possible to implement all of the proposed IRC sites. For example, it is not possible to fully implement 6 IRC-control pairs with only 5 years of monitoring unless 2 IRC/year are implemented. However, once there are 10 or more years of

[1] The method of Stroup (1999) gave identical results to that of Hussey et al (2007) after correcting an error in Hussey et al (2007) power formula.

monitoring planned, there is no particular advantage to implementing the IRC at a faster rate.

The limiting factor to the power of the design is often the Site-Year interaction variance component. One potential reason why the responses are not-parallel over time is perhaps that the different habitat types respond differently over time and so the overall response at the bend level has extra noise. We investigated this by fitting the linear mixed model to only the trawls at BARS or CHNB meso habitat types (these two meso habitat types account for the majority of the habitat). The variance components from these separate habitat types are shown in Table E 7, but there is no evidence that partitioning by habitat type will lead to improvements as the Site-Year variance components are larger than when pooled together! A power analysis (not shown) indeed shows a reduced power.

Because we summarized CPUE to the bend level, we could not separate the (Site-Year) interaction variance component from measurement error. We can fit a more complex linear mixed effects model to separate out the two components (Table E 8). The two sets of variance components are not directly comparable because the logarithm of the CPUE computed by summing the number of fish and area does not separate into the individual CPUEs in the same fashion as would a regular mean, but this does seem to suggest that trawl-to-trawl variation is large. However, because the average number of trawls per bend is around 42, computing the average CPUE at the bend level reduces the impact of the trawl-to-trawl standard deviation by a factor of around $\sqrt{42}$ [1]. Consequently, the total variation at the bend-year level is mainly due to the Site-Year interaction. Additional sampling (i.e., more trawls) would only lead to minor reductions in the Site-Year variance component and negligible impact on power.

This power analysis assumes that control bends are selected at random from all possible bends. However, power could be increased if control bends were selected to be more similar to treatment bends. This should result in more parallel responses. Unfortunately, we currently lack any information to investigate this alternative.

E.1.6.4 Summary

This report estimated the variance components from the HAMP trawl data and used it to estimate the power of a potential IRC design. This is only an estimate of the power

[1] This is analogous to the fact that the variance of the sample mean is found as $sd(\bar{Y}) = \frac{sd(Y)}{\sqrt{n}}$

and the uncertainty in the variance components has not been incorporated. Consequently, the actual power may be different than forecasted.

Discussions of the analysis with biologists and managers suggested two options, both of which generate 80% statistical power with an effect size of 80% increase in CPUE:

A. 12 IRC-control site pairs implemented over 7 years at the rate of 2 sites / year, with 7 years of total monitoring;
B. 6 IRC-control site pairs implemented over 7 years at the rate of 1 site / year, with 12 years of total monitoring

Generally, power increases with the number of IRC sites and the number of years of monitoring. The benefit of option A is that it provides both a more rapid rate of learning (7 years vs 12 years), and potentially greater cumulative biological benefits (if the IRC sites are indeed effective). The tradeoff between the number of IRC sites and the number of years of monitoring will depend on the relative costs of both activities and was not pursued here. Adding more trawls to the bends is unlikely to lead to useful improvements in power because there is already substantial effort in each bend (mean of ~42 trawls per bend) so that the trawl-to-trawl variation has been “reduced” averaging over all trawls.

E.1.6.5 Literature Cited

Hussey, M.A. and Hughes. J. P. (2007). Design and analysis of stepped wedge cluster randomized trials. Contemporary Clinical Trials, 28, 182-191.

Stroup, W. W. (1999). Mixed model procedures to assess power, precision, and sample size in the design of experiments. Pages 15-24 in Proc. Biopharmaceutical Section. Am. Stat. Assoc., Baltimore, MD.

Walters, C.J., J.S. Collie and T. Webb. 1988. Experimental Designs for Estimating Transient Responses to Management Disturbances. Can. J. Fish. Aquat. Sci. 45: 530-538.

Table E 3: Summary of trawls by bend and year. HAMP and MDC data pooled.

Bend_ID	2005	2006	2007	2008	2009	2014	2015
375	0	0	40	30	40	0	0
379	0	0	0	0	0	801	514
381	0	1	37	33	38	0	0
390	0	0	44	35	39	0	0
391	0	0	0	0	0	8	3
392	0	0	0	0	0	57	37
393	0	0	0	0	0	43	38
394	0	0	0	0	0	170	101
395	0	0	0	0	0	35	19
396	0	4	57	34	28	45	34
397	0	0	0	0	0	70	36
398	0	2	95	74	82	88	48
399	0	0	0	0	0	14	0
403	0	0	0	0	0	1	0
423	0	0	0	0	0	60	62
424	4	9	43	26	45	94	98
425	0	0	0	0	6	107	610
426	0	0	0	0	8	131	128
427	0	0	0	0	0	66	76
428	0	0	0	0	0	32	35
429	0	0	0	2	1	92	88
430	5	20	43	28	46	76	59
432	0	17	48	28	31	0	0
433	0	0	0	0	1	0	0
434	0	0	0	0	2	0	0
442	0	14	42	22	31	0	0
443	0	0	0	0	3	0	0
444	0	11	40	21	40	0	0
445	0	0	0	0	3	0	0
446	0	0	0	2	10	0	0
447	0	0	0	9	24	71	42
448	0	0	0	0	7	77	60
449	0	0	0	0	0	65	37
450	0	0	0	0	0	138	83
451	0	0	0	0	0	97	74
452	0	12	52	24	33	46	42
453	0	0	0	0	0	76	63
454	0	0	0	0	0	4	0
461	0	0	0	0	1	0	0
465	0	0	0	0	0	180	340
466	0	0	41	20	28	0	0
467	0	0	0	0	0	379	525
468	0	0	0	0	0	110	62
469	0	0	0	0	0	39	27
470	0	0	0	0	0	63	32
471	0	0	0	0	0	116	73
472	0	0	0	0	0	60	40
473	0	0	38	14	20	57	50
474	0	0	0	0	0	45	24
475	0	0	0	0	0	61	26

476	0	0	0	0	0	120	73
482	0	0	39	20	25	0	0
489	0	0	43	18	33	0	0
494	0	0	0	0	0	4	0
495	0	0	0	0	0	38	24
496	0	0	0	0	0	40	25
497	0	0	0	0	0	43	28
498	0	0	0	0	0	44	28
499	0	0	0	0	0	70	38
500	0	0	0	0	0	55	47
501	0	0	0	0	0	23	15
502	0	0	0	0	0	29	16
503	0	0	0	0	0	48	34
506	0	0	48	15	25	0	0
510	0	0	44	17	43	0	0

Table E 4: Comparison of CPUE from bends simultaneously measured from HAMP and from the MDC programs.

	Bend_ID	Year	Source	total.Effort	total.numfish	CPUE
48	425	2009	2005-2009 HAMP	8277.0	0	0.0000000000
49	425	2014	2014 HAMP	41792.2	32	0.0007656931
50	425	2015	2015 HAMP	40336.1	40	0.0009916675
51	425	2015	2015 MDC	34507.8	139	0.0040280748
116	467	2014	2014 HAMP	14348.6	5	0.0003484661
117	467	2014	2014 MDC	21232.8	175	0.0082419653
118	467	2015	2015 HAMP	7070.2	0	0.0000000000
119	467	2015	2015 MDC	35330.4	191	0.0054061092

Table E 5: Estimated variance components from fitting a linear mixed model to log(CPUE)

Component	Std.Dev.
Site	0.373
Year	0.508
Site-Year	1.311

Table E 6: Estimated power from two sampling designs: A) 12 IRC-control pairs implemented over 7 years (i.e., two new IRC-control site pairs per year) and 7 years of total monitoring and B) 6 IRC-control site pairs implemented over 7 years (i.e., one new IRC site per year) and 12 years of total monitoring. See Figure E 1. Variance components from Table 3 were used to estimate the power using the method of Stroup (1999). An increase of .1 on the log-scale corresponds to a 10% increase in CPUE as the result of treatment. The power was found for one-sided tests (i.e., to look for an increase in CPUE) at alpha=0.05. If there is no treatment effect (i.e., effect 0.0) the experiment will still detect an effect 5% of the time – these are false positives.

Effect Size (Δ CPUE)	Power with Sampling Design A	Power with Sampling Design B
0.0	0.050	0.050
0.1	0.094	0.091
0.2	0.162	0.154
0.3	0.256	0.239
0.4	0.372	0.346
0.5	0.502	0.467
0.6	0.631	0.590
0.7	0.747	0.705
0.8	0.840	0.803
0.9	0.907	0.878
1.0	0.950	0.930

Table E 7: Estimated variance components when a separate analysis is done on each habitat type.

BARS habitats

Component	Std.Dev.
Site	0.58
Year	0.65
Site-Year	1.54

CHNB habitat

Component	Std.Dev.
Bend_ID	0.64
Year	0.72

Site-Year	1.42

Table E 8: Estimated variance components when trawl measurements are used directly in the linear mixed model (eq. 1). The average number of trawls/bend-year combination is around 42. This implies that the total variation when summarized at the bend-year level would be computed as: $\sqrt{.24^2 + \frac{1.06^2}{42}} = .2904$ which is not much larger than the Site-Year interaction term. Sampling more trawls/site will result in negligible improvements in the power.

Component	**Std.Dev.**
Site-Year	0.242
Site	0.115
Year	0.129
Trawl	1.061

Sampling Design A

	Year						
Site	01	02	03	04	05	06	07
01	C	T	T	T	T	T	T
02	C	C	C	C	C	C	C
03	C	T	T	T	T	T	T
04	C	C	C	C	C	C	C
05	C	C	T	T	T	T	T
06	C	C	C	C	C	C	C
07	C	C	T	T	T	T	T
08	C	C	C	C	C	C	C
09	C	C	C	T	T	T	T
10	C	C	C	C	C	C	C
11	C	C	C	T	T	T	T
12	C	C	C	C	C	C	C
13	C	C	C	C	T	T	T
14	C	C	C	C	C	C	C
15	C	C	C	C	T	T	T
16	C	C	C	C	C	C	C
17	C	C	C	C	C	T	T
18	C	C	C	C	C	C	C
19	C	C	C	C	C	T	T
20	C	C	C	C	C	C	C
21	C	C	C	C	C	C	T
22	C	C	C	C	C	C	C
23	C	C	C	C	C	C	T
24	C	C	C	C	C	C	C

Sampling Design B

	Year											
Site	01	02	03	04	05	06	07	08	09	10	11	12
01	C	T	T	T	T	T	T	T	T	T	T	T
02	C	C	C	C	C	C	C	C	C	C	C	C
03	C	C	T	T	T	T	T	T	T	T	T	T
04	C	C	C	C	C	C	C	C	C	C	C	C
05	C	C	C	T	T	T	T	T	T	T	T	T
06	C	C	C	C	C	C	C	C	C	C	C	C
07	C	C	C	C	T	T	T	T	T	T	T	T
08	C	C	C	C	C	C	C	C	C	C	C	C
09	C	C	C	C	C	T	T	T	T	T	T	T
10	C	C	C	C	C	C	C	C	C	C	C	C
11	C	C	C	C	C	C	T	T	T	T	T	T
12	C	C	C	C	C	C	C	C	C	C	C	C

Figure E 2: Staircase designs A and B. Staircase design A has 12 treatment sites and 12 control sites all measured for 7 years. The treatment (T) is applied to sites 1&3, 5&7, 9&11, 13&15, 17&19, 21&23 starting in years 2, 3, 4, 5, 6, and 7 respectively. Measurement continues in all sites until year 7. Control sites (even numbered sites) are left untreated (C) and measured in all years. Staircase design B has 6 treatment sites, 6 control sites all measured for 12 years. The treatment (T) is applied to sites 1, 3, 5, 7, 9 and 11 starting in years 2, 3, 4, 5, 6, and 7 respectively. Measurement continues in all sites until year 12. Control sites (even numbered sites) are left untreated (C) and measured in all years.

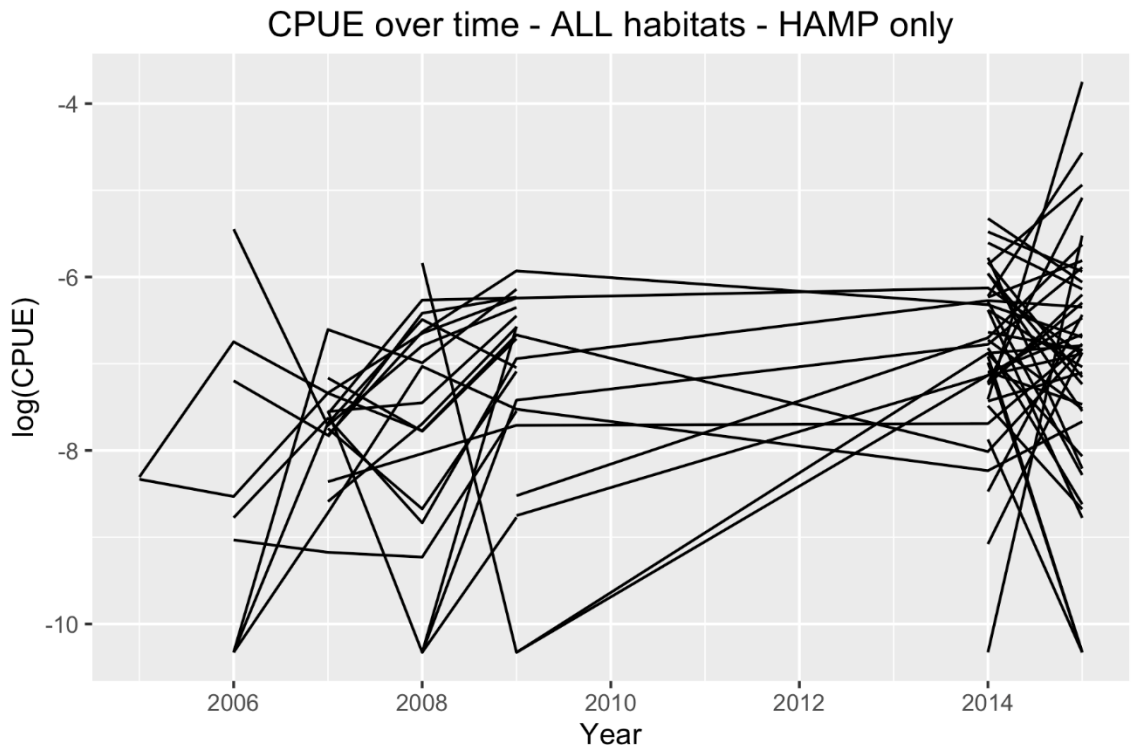
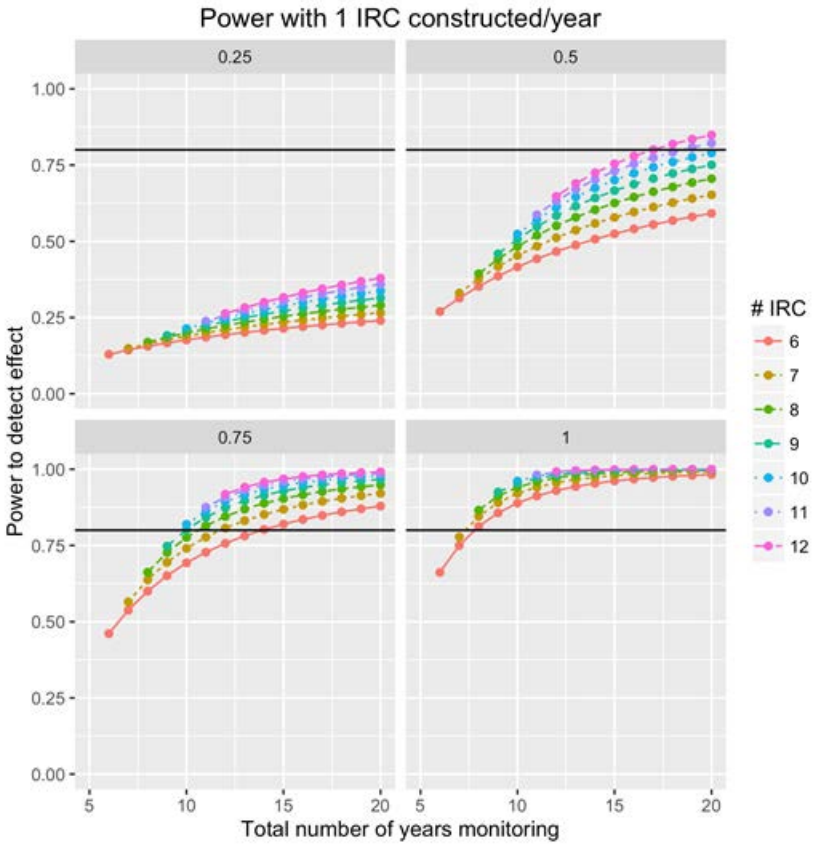


Figure E 3: Time plot of log(CPUE) for each bend from the HAMP data only. ½ of the smallest non-zero CPUE was added to all points to prevent taking log(0).


Power with 1 IRC constructed/year
0.25
0.5
0.75
1
Power to detect effect
1.00
0.75
0.50
0.25
0.00
5
10
15
20
Total number of years monitoring
IRC
6
7
8
9
10
11
12

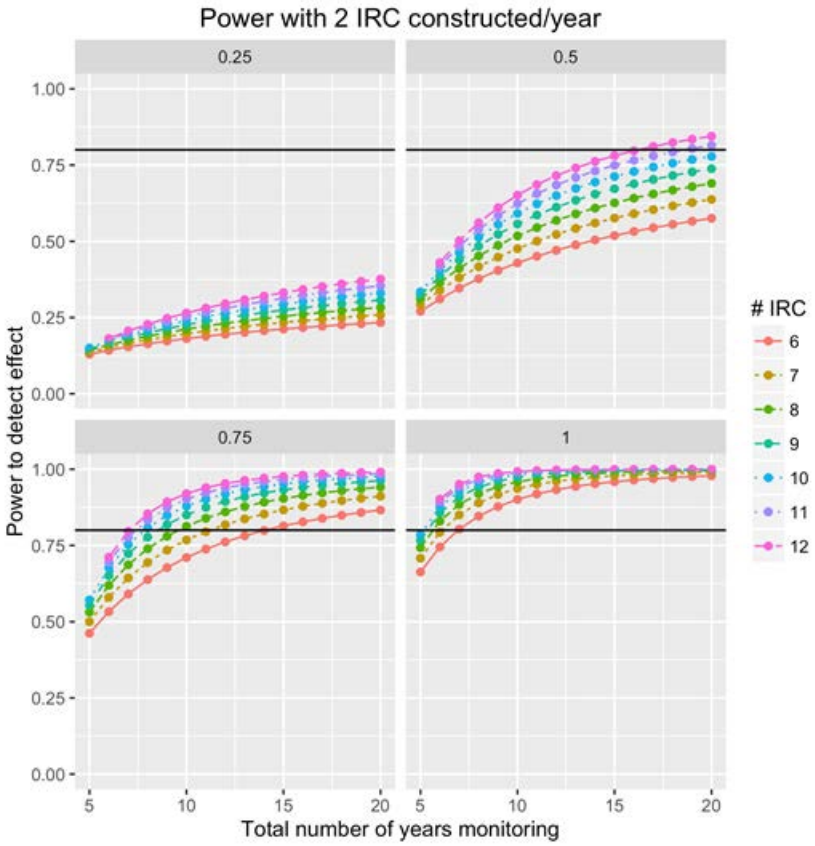


Figure E 4: Comparisons of power for different sampling designs. Top panel of four graphs shows statistical power when the number of IRC sites is varied from 6 to 12 with 5 to 20 years of monitoring and one IRC added per year. The four panels correspond to a 25%, 50%, 75%, or 100% increase in mean CPUE in the IRC sites. Lower panel of four graphs shows the same information with two IRC sites constructed per year.

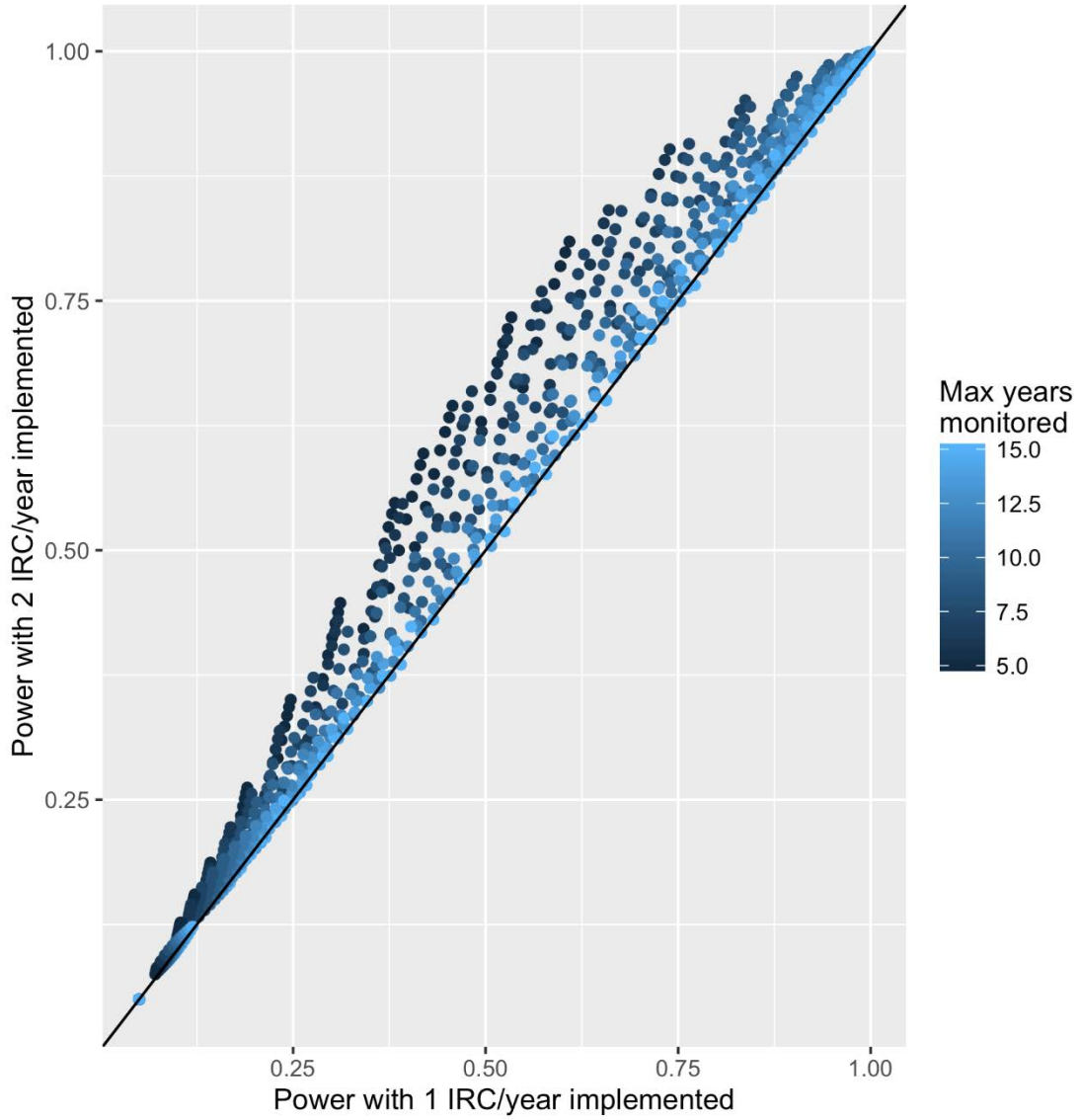


Figure E 5: Impact on power of increasing the number of IRC implemented per year from 1 to 2. Generally speaking the power impact is negligible except in cases where the number of monitoring years is small, and if only one IRC is implemented per year, it is not possible to implement all of the proposed IRC sites. For example, it is not possible to fully implement 6 IRC sites with only 5 years of monitoring unless 2 IRC/year are implemented.

Sample Data:

```
Site Year Treatment      Response
1    A    1          C          0.2543600359
2    A    2          C          0.5254238276
3    A    3          C          -3.4408767115
4    A    4          C          -5.0149562110
5    A    5          C          -8.6226452115
6    A    6          C          -1.3488555218
7    A    7          C          -0.0004504614
8    A    8          C          0.5050409681
9    B    1          C          0.5761786426
10   B    2          T          21.5507582294
11   B    3          T          18.6493742449
12   B    4          T          12.3983730044
13   B    5          T          18.0991001401
14   B    6          T          4.6648869696
etc
```

E.1.6.6 Annex 1 – R code for stair case design

Sample data and sample R code to analyze a staircase design. The data need 4 columns corresponding to the site (declared as a factor), the year (declared as a factor), a treatment indicator (declared as a factor), and the numeric response variable. In the portion of the raw data shown, the design is monitored for 8 years. Site A is a control site for all 8 years. Site B is control for year 1, and then has the treatment applied starting in year 2. Additional sites are added as needed.

The *R* code loads the required packages; declares the appropriate factors; and then fits a general linear model with *Site* declared as a random factor. The *lm()* function could also be used with site declared as a fixed factor with identical results in the case of a complete design, but will give different results if the design has missing data. The *lsmeans* package is then used to estimate the treatment effect.

```
library(lmerTest)
ibrary(lsmeans)

sample$Site <- factor(sample$Site)
sample$Year <- factor(sample$Year)
sample$Treatment <- factor(sample$Treatment)
sample.fit <- lmer(Response ~ Treatment+Year +(1|Site), data=sample)
anova(sample.fit)
sample.fit.lsmo <- lsmeans::lsmeans(sample.fit, ~Treatment)
sample.fit.pairs <- pairs(sample.fit.lsmo, infer=TRUE)
cld(sample.fit.lsmo)
vc <- as.data.frame(VarCorr(sample.fit))
vc
```

Attachment E.2 – Monitoring Plan for Existing SWH Projects

DRAFT/Pre-Decisional/For Discussion Purposes Prepared: May 25, 2016
By: Todd Gemeinhardt, , Dave Marmorek and Craig Fischenich

E.2.1 Introduction

E.2.2 Hypotheses

E.2.3 Approach

E.2.3.1 Sampling Design

E.2.3.2 Site Selection

E.2.3.3 Data Collection Tasks

E.2.3.4 Data Analysis Tasks

E.2.4 Schedule

E.2.5 References

Appendix F. Cost Estimates and Prioritization of Level 1 and Level 2 Science Components

This appendix compiles cost estimates for level 1 and level 2 science components for adaptive management of pallid sturgeon in the Missouri River. The objective is to provide general guidance of the order of magnitude of investment in science likely to accompany the Missouri River Science and Adaptive Management Plan (MRSAM) plan and to indicate how the investment would likely be distributed over time. It should be noted that as adaptive management and learning progress, some of these science components will no longer be necessary because the associated hypotheses are shown to be invalid. Similarly, new hypotheses may be introduced to explain documented changes in pallid sturgeon demographic rates or population, thereby requiring new science components with specific costs and timeframes. Hence, the cost estimates provided here should be viewed as general guidelines that will inevitably change over time.

F.1 Approach

Sequence, timing, and duration of each level 1 and level 2 science component were originally estimated assuming that all Level 1 activities occurred essentially in parallel. Subsequently the start dates of some Level 1 activities were shifted into the future, through a prioritization approach that is described below in section F.4 of this Appendix. The start and stop dates for each component were exported from the charting software to a spreadsheet and were used to calculate annual cost for the duration of each component. Annual cost for each component was estimated based on 2016 net costs to agencies. The cost estimates are based on experience with actual research and monitoring costs, and assumptions about whether each component might be pursued by the USACE, or contracted to Federal or State agencies, or universities.

Several important assumptions and caveats apply to these estimates:

- Science components are aggregated by “big questions”; big questions may include several hypotheses that have related science questions, and are therefore effectively pursued as a group. Some science components within a group have been prioritized to occur within the first five years, while others are assumed to occur later.
- Cost estimates begin in 2014 to reflect the fact that some science components are already under way.
- The science component costs do not include construction. Some laboratory/mesocosm studies may be more efficiently pursued if carried out in new facilities, however these estimates assume existing agency and university facilities

will be used. Similarly, estimates for level 2 field-experiment implementations are limited to the science components and do not include construction (of spawning habitat or interception-rearing complexes, for example) that will be accounted elsewhere in the Missouri River Recovery Management Plan (MRRMP).

- Science component costs do include estimates of engineering design and feasibility studies for many big questions because those studies are foundational to design and logistics level 2 science components.
- The annual costs are estimated as of 2016 and have not been adjusted for inflation over the time period of the science components.
- The annual costs are estimated as net to the agency that performs the task. Therefore, these estimates underestimate actual costs that will need to take into account complex agency overhead assessment rates. Accounting for increased costs based on overhead rates will be provided elsewhere in the MRRMP.
- The level 1 and level 2 science components outlined here incorporate existing science efforts under the USACE Integrated Science Program (ISP), including the Pallid Sturgeon Population Assessment Program (PSPAP), Habitat Assessment and Monitoring Program (HAMP), Comprehensive Sturgeon Research Project (CSRP), and various other associated USACE-funded research projects.
- Summary estimates include costs for the next generation of pallid sturgeon population monitoring. As indicated in Appendix D, the details of an efficient monitoring program need to be worked out through focused efforts in simulation modeling which will take one or two years to complete, depending on resources available. For the purposes of this appendix we have used the cost of the present PSPAP as an estimate.
- Some level 2 science components have been described in Appendix C but due to high costs and uncertainties are not planned for implementation during the first 15 years and costs are therefore not included in the estimates. These components are indicated as “Not currently planned” in the estimate tables.
- Some level 1 science components involve laboratory or mesocosm experimentation that applies to both the upper river and the lower river big questions. These costs are enumerated in the upper river table but apply to both upper and lower science components.
- Two technical development level 1 components are included at the end of the lower river table. As described in Appendix C, these are 1) development of an optimal population monitoring program and 2) the ongoing synthesis and assimilation of pallid sturgeon data through maintenance of the population dynamics model and database.
- Planning for science needs over a 15 year time frame is inherently uncertain, as new information will inevitably indicate new directions and science needs. The estimates provided here are all linked to specific hypotheses that emerged from the Effects

Analysis process and do not include components that might address fundamental conditions of the river system (for example, discharge and water quality) or research that could anticipate other stressors to pallid sturgeon populations (for example, hybridization, contaminants, or competition).

- The cost estimates provided here do not include level 3 monitoring and assessment. Some management actions are already at level 3 (population augmentation, for example), and others may proceed to level 3 during the 15-year planning interval. Level 3 monitoring and assessment activities are described in Chapter 4; details and associated costs of level 3 monitoring and assessment activities will depend to a large extent on information developed during level 1 and level 2 activities. Cost estimates for level 3 monitoring and assessment activities will be provided elsewhere.

F.2 Results

Table F 1 and Table F 2 show detailed cost estimates by big question, level, and component by year. The estimates extend to 2025 on the upper river (Table F1), reflecting management actions and science components that are anticipated to be completed by that date. Estimates on the lower river (Table F2) extend to 2032 because of the longer time frame associated with level 2 science on interception-rearing complexes and experimental flow releases). Table F 3 summarizes upper and lower river costs by year and adds in estimates of PSPAP costs. Figure F 1 shows a graph of costs by year. Table F 4 and

Table F 5 show the expected timing of each activity during the first 15 years, based on the prioritization efforts described below in section F.4.

Two additional components to the Gantt charts and cost synthesis (tables F2 and F5). These components are intended to address a) the need for scientific contingency funding to address new information and b) the continuing need for concerted efforts in outreach, reporting, and data management.

Table F 1: Cost estimates for level 1 and level 2 pallid sturgeon science components by year, upper river, reflecting prioritization described in section F.4. Shaded rows indicate components that are not currently planned.

Task Name	Begin	End	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Big Question 1: Spawning Cues	2015	2031																		
Level 1	2015	2031																		
Component 1 Design complementary telemetry network	2017	2019	$ -	$ -	$ 340,000	$ 340,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Opportunistic tracking of reproductive behaviors	2015	2025	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ 301,500	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Mesocosm experiments, reproductive behaviors	2022	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -
Level 2 – Not currently planned	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Engineering study effects on other authorized purposes	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Experimental flow releases, Fort Peck	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 2: Flow Naturalization and Productivity	2022	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2021	2030	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Engineering models, interactions authorized purposes	2022	2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 80,000	$ 80,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Screening: limitations of food or forage habitats	2021	2024	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Field studies along gradients, food and forage habitats	2023	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Mesocosm studies: habitat – survival relations	2023	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -
Level 2 – Not currently planned	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Design flow experiments	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 6 Experimental naturalization of flows, Fort Peck	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 3: Temperature manipulations at Fort Peck	2015	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2015	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Screening: Feasibility, modeling of effects	2022	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 150,000	$ 150,000	$ 150,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2a Screening: is food limiting to age-0 survival?	2021	2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2b Lake Sakakawea conditions limiting, age-0 survival?	2015	2019	$ 80,000	$ 80,000	$ 80,000	$ 80,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3a Field gradient, temperature and food production	2021	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component3b Field experiment drift model validation	2016	2021	$ -	$ 185,420	$ 185,420	$ 185,420	$ 185,420	$ 185,420	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4a Mesocosm studies: temperature, food, survival	2015	2019	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4b Development rates of embryos, free embryos, larvae	2015	2019	$ 173,000	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2 – Not currently planned	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Construct, test water temperature mechanisms	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 6 Manipulative field experiments with water temperature	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 4: Sediment bypass	2021	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2021	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Feasibility study sediment bypass and turbidity	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Mesocosm study of turbidity-limited survival	2021	2023	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Mesocosm study of turbidity-limited survival rates	2023	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2 – Not currently planned	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Pilot test of sediment bypass	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Field experiment sediment bypass and turbidity	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 5: Passage, drift, and recruitment	2016	2032	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2016	2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1a Model integration, drift and development	2017	2019	$ -	$ -	$ 100,000	$ 100,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1b Modeling location and rate of change of headwaters	2018	2019	$ -	$ -	$ -	$ 100,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2a Patchiness of anoxic zone	2018	2020	$ -	$ -	$ -	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2b Spawning habitat distribution on Yellowstone	2017	2019	$ -	$ -	$ 92,600	$ 92,600	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Experiment drift model validation	2016	2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Mesocosm studies to quantify transport	2018	2021	$ -	$ -	$ -	$ 173,000	$ 173,000	$ 173,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2	2018	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Engineering studies for effects of low flows	2022	2023	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 100,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 6a Drift experiments, Fort Peck flows and drawdowns	2022	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 185,420	$ 185,420	$ 185,420	$ 185,420	$ 185,420	$ -	$ -	$ -	$ -	$ -	$ -
Component 6b Adult translocation experiment, Yellowstone	2018	2022	$ -	$ -	$ -	$ 144,592	$ 144,592	$ 144,592	$ 144,592	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 6: Population Augmentation	2016	2044	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2016	2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Feasibility hatchery facilities, operations*	2016	2018	$ -	$ 50,000	$ 50,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Retrospective: survival and hatchery operations	2017	2019	$ -	$ -	$ 96,750	$ 96,750	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Model population sensitivity - size, health, genetics*	2017	2020	$ -	$ -	$ 65,000	$ 65,000	$ 65,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2 - Not currently planned	2036	2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Experiment with varying size, location of stocking	2036	2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
			$ 727,500	$ 962,920	$ 1,657,270	$ 2,197,862	$ 1,042,512	$ 804,512	$ 965,092	$ 1,508,920	$ 1,754,920	$ 1,501,920	$ 704,420	$ 704,420	$ -	$ -	$ -	$ -	$ -	$ -

Table F 2: Cost estimates for level 1 and level 2 pallid sturgeon science components by year, lower river. Shaded rows indicate components that are not currently planned, , reflecting prioritization described in section F.4..

Task Name	Begin	End	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Big Question 1: Spawning Cues	2015	2033																		
Level 1	2015	2038																		
Component 1 Design complementary passive telemetry network	2017	2019	$ -	$ -	$ 345,000	$ 345,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Opportunistic tracking of reproductive behaviors	2015	2026	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Mesocosm experiments, reproductive behaviors	2025	2030	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2	2017	2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Engineerng effects, other authorized purposes - Done	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Experimental flow releases, Gavins Point	2024	2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000	$ 675,000
Big Question 2: Temperature Control	2017	2029	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2018	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Model water temperature management options, Ft. Randall	2018	2020	$ -	$ -	$ -	$ 80,000	$ 80,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Field studies temperature and reproductive behaviors,	2022	2025	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 92,500	$ 92,500	$ 92,500	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Mesocosm studies temperature and reproductive behaviors	2023	2027	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 164,600	$ 164,600	$ 164,600	$ 164,600	$ -	$ -	$ -	$ -	$ -	$ -
Level 2 – Not currently planned	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Field tests of water temperature management, Gavins Point	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Experimental warm water releases, Gavins Point	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 3: Food and Forage	2015	2028	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2015	2026	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Screening: limitations of food or forage habitats	2015	2019	$ 125,000	$ 125,000	$ 125,000	$ 125,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Technology development for IRC sampling, modeling, measurer	2015	2021	$ 124,800	$ 124,800	$ 124,800	$ 124,800	$ 124,800	$ 124,800	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Field studies along gradients, food and forage habitats	2015	2025	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ 182,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Mesocosm studies: quantitative habitat – survival relations	2022	2026	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2	2016	2028	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Design studies for IRC experiments*	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 6 Manipulative field experiments with IRCs @ level 3*	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 4: Drift Dynamics	2015	2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2015	2026	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Technology development surrogate particles, particle tracking	2015	2019	$ 124,800	$ 124,800	$ 124,800	$ 124,800	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Resilience, stamina in turbulent flows (lab or mesocosm study)	2017	2019	$ -	$ -	$ 172,400	$ 172,400	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Field studies on free embryo exit paths	2018	2021	$ -	$ -	$ -	$ 297,400	$ 297,400	$ 297,400	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Field gradient study, age-0 survival and complexity	2015	2020	$ 223,250	$ 223,250	$ 223,250	$ 223,250	$ 223,250	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Free embryo transport to Mississippi River	2015	2021	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ 180,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 6 Field experiments with particle tracking, embryos, models	2018	2023	$ -	$ -	$ -	$ 243,330	$ 243,330	$ 243,330	$ 243,330	$ 243,330	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2	2016	2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 7 Engineering designs for interception experiments*	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 8 Field experiment: discharge and dispersion – Not currently plan	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 9 Field experiment: IRC complexes*	-	-	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 5: Spawning Habitat	2015	2028	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2015	2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Study of functional spawning habitat, Yellowstone River	2015	2019	$ 85,000	$ 85,000	$ 85,000	$ 85,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Field gradient study, habitat conditions LMOR	2015	2019	$ 85,000	$ 85,000	$ 85,000	$ 85,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Mesocosm studies on spawn conditions, behaviors	2017	2020	$ -	$ -	$ 172,400	$ 172,400	$ 172,400	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2	2018	2024	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Engineering studies for sustainable design	2018	2022	$ -	$ -	$ -	$ 125,000	$ 125,000	$ 125,000	$ 125,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 5 Manipulative field experiment for spawning habitat**	2020	2024	$ -	$ -	$ -	$ -	$ -	$ 271,000	$ 271,000	$ 271,000	$ 271,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Big Question 6: Population Augmentation	2017	2044	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 1	2017	2020	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 1 Engineering feasibility hatchery needs, facilities, operations	2017	2019	$ -	$ -	$ 80,000	$ 80,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 2 Retrospective study survival linked to hatchery operations	2018	2020	$ -	$ -	$ -	$ 96,750	$ 96,750	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 3 Simulation models, population sensitivity to size, health, geneti	2017	2020	$ -	$ -	$ 56,000	$ 56,000	$ 56,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Level 2	2036	2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Component 4 Field experimentation with varying size, location of stocking	2036	2036	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Technical Development: Modeling and Monitoring Needs	2015	2033	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Adaptive design and optimization of population monitoring	2017	2019	$ -	$ -	$ 80,000	$ 80,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Continued integration, refinement, and maintenance, collaborative populatio	2015	2033	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000
Research: contingency, outreach, reporting																				
Research contingency for basic science, surprises	2017	2033	$ -	$ -	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000	$ 250,000
Reporting and outreach	2015	2033	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500	$ 80,500
			$ 2,135,350	$ 2,135,350	$ 3,291,150	$ 4,133,630	$ 3,036,430	$ 2,679,030	$ 2,076,830	$ 2,044,330	$ 1,965,600	$ 2,369,600	$ 2,095,100	$ 1,420,100	$ 1,255,500	$ 1,255,500	$ 1,255,500	$ 1,255,500	$ 1,255,500	$ 1,255,500

Table F 3. Estimate net (to agency) combined level 1 and level 2 costs, Pallid Sturgeon Population Assessment Program costs, and combined costs, 2014 – 2032. The "-R" suffix in the column headings stands for "Revised following prioritization" (see section F.4).

Year	Upper River	Lower River	PSPAP	Combined
2015	$ 727,500	$ 2,135,350	$ 3,450,000	$ 6,312,850
2016	$ 962,920	$ 2,135,350	$ 3,450,000	$ 6,548,270
2017	$ 1,657,270	$ 3,291,150	$ 3,450,000	$ 8,398,420
2018	$ 2,197,862	$ 4,133,630	$ 3,450,000	$ 9,781,492
2019	$ 1,042,512	$ 3,036,430	$ 3,450,000	$ 7,528,942
2020	$ 804,512	$ 2,679,030	$ 3,450,000	$ 6,933,542
2021	$ 965,092	$ 2,076,830	$ 3,450,000	$ 6,491,922
2022	$ 1,508,920	$ 2,044,330	$ 3,450,000	$ 7,003,250
2023	$ 1,754,920	$ 1,965,600	$ 3,450,000	$ 7,170,520
2024	$ 1,501,920	$ 2,369,600	$ 3,450,000	$ 7,321,520
2025	$ 704,420	$ 2,095,100	$ 3,450,000	$ 6,249,520
2026	$ 704,420	$ 1,420,100	$ 3,450,000	$ 5,574,520
2027	$ -	$ 1,255,500	$ 3,450,000	$ 4,705,500
2028	$ -	$ 1,255,500	$ 3,450,000	$ 4,705,500
2029	$ -	$ 1,255,500	$ 3,450,000	$ 4,705,500
2030	$ -	$ 1,255,500	$ 3,450,000	$ 4,705,500
2031	$ -	$ 1,255,500	$ 3,450,000	$ 4,705,500
2032	$ -	$ 1,255,500	$ 3,450,000	$ 4,705,500

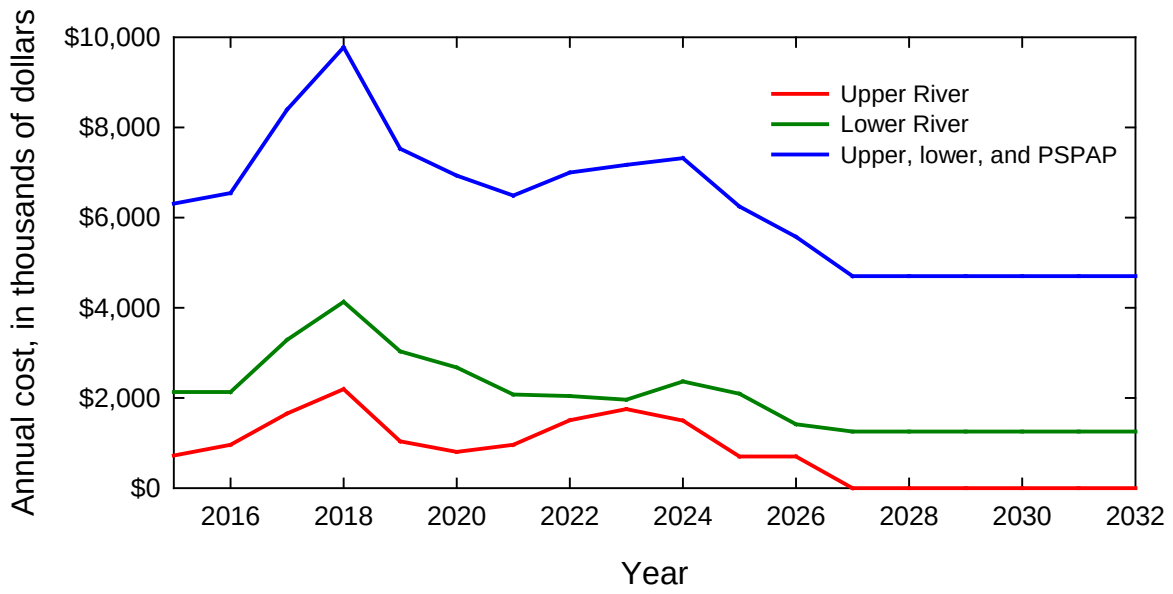


Figure F 1 Graph of level 1 and level 2 science components costs by year. The costs provided are estimates of net to projects; that is, they do not include agency overhead assessments. The blue line combines the upper river and lower river and adds $3.45 million/year for the Pallid Sturgeon Population Assessment Program.

ID	Task Name	Start	Finish
1	**Big Question 1: Spawning Cues**	**10/1/2014**	**10/3/2025**
2	**Level 1**	**10/1/2014**	**10/3/2025**
3	Component 1 Design complementary passive/active telemetry network	10/3/2016	10/3/2018
4	Component 2 Opportunistic tracking of reproductive behaviors	10/1/2014	10/2/2024
5	Component 3 Mesocosm experiments, reproductive behaviors	10/5/2020	10/3/2025
6	**Level 2 – Not currently planned**	**10/4/2035**	**10/4/2035**
7	Component 4 Engineering study effects on other authorized purposes	10/4/2035	10/4/2035
8	Component 5 Experimental flow releases, Gavins Point	10/4/2035	10/4/2035
9	**Big Question 2: Flow Naturalization and Productivity**	**10/5/2020**	**10/2/2026**
10	**Level 1**	**10/5/2020**	**10/2/2026**
11	Component 1 Engineering models, interactions with authorized purposes	10/5/2020	10/6/2023
12	Component 2 Screening: limitations of food or forage habitats	10/5/2020	10/5/2023
13	Component 3 Field studies along gradients, food and forage habitats	10/3/2022	10/2/2026
14	Component 4 Mesocosm studies: quantitative habitat – survival relations	10/3/2022	10/2/2026
15	**Level 2 – Not currently planned**	**10/3/2035**	**10/4/2035**
16	Component 5 Design flow experiments	10/3/2035	10/3/2035
17	Component 6 Experimental naturalization of flows, Fort Peck	10/4/2035	10/4/2035
18	**Big Question 3: Temperature manipulations at Fort Peck**	**10/1/2014**	**10/4/2035**
19	**Level 1**	**10/1/2014**	**10/4/2024**
20	Component 1 Screening: Feasibility, modeling of effects	10/6/2014	10/8/2014
21	Component 2a Screening: Is food limiting to age-0 survival?	10/5/2020	10/5/2023
22	Component 2b Are Lake Sakakawea conditions limiting to age-0 survival?	10/7/2014	10/5/2018
23	Component 3a Field gradient, temperature and food production	10/5/2020	10/4/2024
24	Component3b Field experiment drift/dispersal advection/dispersion validation	10/5/2015	10/2/2020
25	Component 4a Mesocosm studies: temperature, food, survival relations	10/1/2014	10/5/2018
26	Component 4b Development rates of embryos, free embryos, larvae	10/1/2014	10/5/2018
27	**Level 2 – Not currently planned**	**10/4/2035**	**10/4/2035**
28	Component 5 Construct, test water temperature mechanisms	10/4/2035	10/4/2035
29	Component 6 Manipulative field experiments with water temperature	10/4/2035	10/4/2035
30	**Big Question 4: Sediment bypass**	**10/1/2014**	**10/5/2035**
31	**Level 1**	**10/1/2014**	**10/2/2024**
32	Component 1 Feasibility study sediment bypass and turbidity	10/1/2014	10/1/2014
33	Component 2 Mesocosm study of turbidity-limited survival	10/5/2020	10/6/2022
34	Component 3 Mesocosm study of turbidity-limited survival rates	10/3/2022	10/2/2024
35	**Level 2 – Not currently planned**	**10/3/2035**	**10/5/2035**
36	Component 4 Pilot test of sediment bypass	10/3/2035	10/3/2035
37	Component 5 Field experiment sediment bypass and turbidity	10/4/2035	10/5/2035
38	**Big Question 5: Passage, drift, and recruitment**	**10/5/2015**	**9/29/2026**
39	**Level 1**	**10/5/2015**	**10/2/2020**
40	Component 1a Model integration, drift and development	10/3/2016	10/1/2018
41	Component 1b Modeling location and rate of change of headwaters	10/3/2017	10/5/2018
42	Component 2a Patchiness of anoxic zone	10/3/2017	10/2/2019
43	Component 2b Spawning habitat distribution on the Yellowstone River	10/3/2016	10/3/2018
44	Component 3 Field experiment drift/dispersal, advection/dispersion validation	10/5/2015	10/2/2019
45	Component 4 Mesocosm studies to quantify transport	10/3/2017	10/2/2020
46	**Level 2**	**10/3/2016**	**9/29/2026**
47	Component 5 Engineering studies for effects of low flows	10/5/2021	10/5/2022
48	Component 6a Drift experiments, Fort Peck flows and drawdowns	10/1/2021	9/29/2026
49	Component 6b Adult translocation experiment, Yellowstone	10/3/2016	10/1/2020
50	**Big Question 6: Population Augmentation**	**10/5/2015**	**10/4/2035**
51	**Level 1**	**10/5/2015**	**10/3/2019**
52	Component 1 Engineering feasibility hatchery needs, facilities, operations	10/5/2015	10/4/2017
53	Component 2 Retrospective study survival linked to hatchery operations	10/3/2016	10/3/2018
54	Component 3 Simulation models, population sensitivity to size, health, genetics	10/3/2016	10/3/2019
55	**Level 2 – Not currently planned**	**10/4/2035**	**10/4/2035**
56	Component 4 Field experimentation with varying size, location of stocking	10/4/2035	10/4/2035

Table F 4:. Planned timing of Level 1 and Level 2 activities for the Upper Missouri River during the first 15 years, based on the prioritization process described in section F.4.

ID	Task Name	Start	Finish
1	**Big Question 1: Spawning Cues**	**10/3/2014**	**10/4/2032**
2	**Level 1**	**10/3/2014**	**9/25/2030**
3	Component 1 Design complementary passive telemetry network	10/3/2016	10/3/2018
4	Component 2 Opportunistic tracking of reproductive behaviors	10/3/2014	10/4/2025
5	Component 3 Mesocosm experiments, reproductive behaviors	10/3/2024	9/25/2030
6	**Level 2**	**10/3/2016**	**10/4/2032**
7	Component 4 Engineering study effects on other authorized purposes	10/3/2036	10/3/2036
8	Component 5 Experimental flow releases, Gavins Point	10/3/2023	10/4/2032
9	**Big Question 2: Temperature Control**	**10/3/2017**	**10/1/2026**
10	**Level 1**	**10/3/2017**	**10/1/2026**
11	Component 1 Model water temperature management options, Gavins Point	10/3/2017	10/2/2019
12	Component 2 Field studies temperature and reproductive behaviors, surrogates	10/4/2021	10/3/2024
13	Component 3 Mesocosm studies temperature and reproductive behaviors	10/3/2022	10/1/2026
14	**Level 2 – Not currently planned**	**10/4/2032**	**10/2/2040**
15	Component 4 Field tests of water temperature management, Gavins Point	10/4/2032	10/3/2036
16	Component 5 Experimental warm water releases, Gavins Point	10/4/2032	10/2/2040
17	**Big Question 3: Food and Forage**	**10/1/2014**	**10/4/2027**
18	**Level 1**	**10/1/2014**	**10/3/2025**
19	Component 1 Screening: limitations of food or forage habitats	10/1/2014	10/3/2018
20	Component 2 Technology development for IRC sampling, modeling, measurement	10/1/2014	10/1/2020
21	Component 3 Field studies along gradients, food and forage habitats	10/1/2014	9/30/2024
22	Component 4 Mesocosm studies: quantitative habitat – survival relations	10/4/2021	10/3/2025
23	**Level 2**	**10/5/2015**	**10/4/2027**
24	Component 5 Design studies for IRC experiments	10/5/2015	10/1/2021
25	Component 6 Manipulative field experiments with IRCs	10/5/2015	10/4/2027
26	**Big Question 4: Drift Dynamics**	**10/1/2014**	**10/4/2032**
27	**Level 1**	**10/1/2014**	**10/3/2022**
28	Component 1 Technology development surrogate particles, particle tracking	10/1/2014	10/1/2018
29	Component 2 Resilience, stamina in turbulent flows	10/5/2016	10/5/2018
30	Component 3 Field studies on free embryo exit paths	10/3/2017	10/2/2020
31	Component 4 Field gradient study, age-0 survival and complexity	10/3/2014	10/3/2019
32	Component 5 Free embryo transport to Mississippi River	10/3/2014	10/2/2020
33	Component 6 Field experiments with particle tracking, embryos, models	10/3/2017	10/3/2022
34	**Level 2**	**10/5/2015**	**10/4/2032**
35	Component 7 Engineering designs for interception experiments	10/5/2015	10/1/2021
36	Component 8 Field experiment: discharge and dispersion – Not currently planned	10/3/2022	10/3/2028
37	Component 9 Field experiment: IRC complexes	10/5/2017	10/4/2032
38	**Big Question 5: Spawning Habitat**	**10/1/2014**	**10/3/2023**
39	**Level 1**	**10/1/2014**	**10/5/2020**
40	Component 1 Study of functional spawning habitat, Yellowstone River	10/1/2014	10/1/2018
41	Component 2 Field gradient study, habitat conditions LMOR	10/1/2014	10/3/2018
42	Component 3 Mesocosm studies on spawn conditions, behaviors	10/3/2017	10/5/2020
43	**Level 2**	**10/9/2017**	**10/3/2023**
44	Component 4 Engineering studies for sustainable design	10/9/2017	10/7/2021
45	Component 5 Manipulative field experiment for spawning habitat	10/3/2019	10/3/2023
46	**Big Question 6: Population Augmentation**	**10/3/2016**	**10/4/2035**
47	**Level 1**	**10/5/2016**	**10/5/2018**
48	Component 1 Engineering feasibility hatchery needs, facilities, operations	10/5/2016	10/5/2018
49	Component 2 Retrospective study survival linked to hatchery operations	10/3/2017	10/3/2019
50	Component 3 Simulation models, population sensitivity to size, health, genetics	10/3/2016	10/3/2019
51	**Level 2 – Not currently planned**	**10/4/2035**	**10/4/2035**
52	Component 4 Field experimentation with varying size, location of stocking	10/4/2035	10/4/2035
53	**Technical Development: Modeling and Monitoring Needs**	**10/1/2014**	**10/1/2032**
54	Adaptive design and optimization of population monitoring	10/3/2016	10/3/2018
55	Continued integration, refinement, and maintenance, collaborative population model	10/1/2014	10/1/2032
56	**Research: contingency, outreach, reporting**	**10/1/2014**	**10/3/2033**
57	Research contingency for basic science, surprises	10/3/2017	10/3/2033
58	Reporting and outreach	10/1/2014	10/1/2032

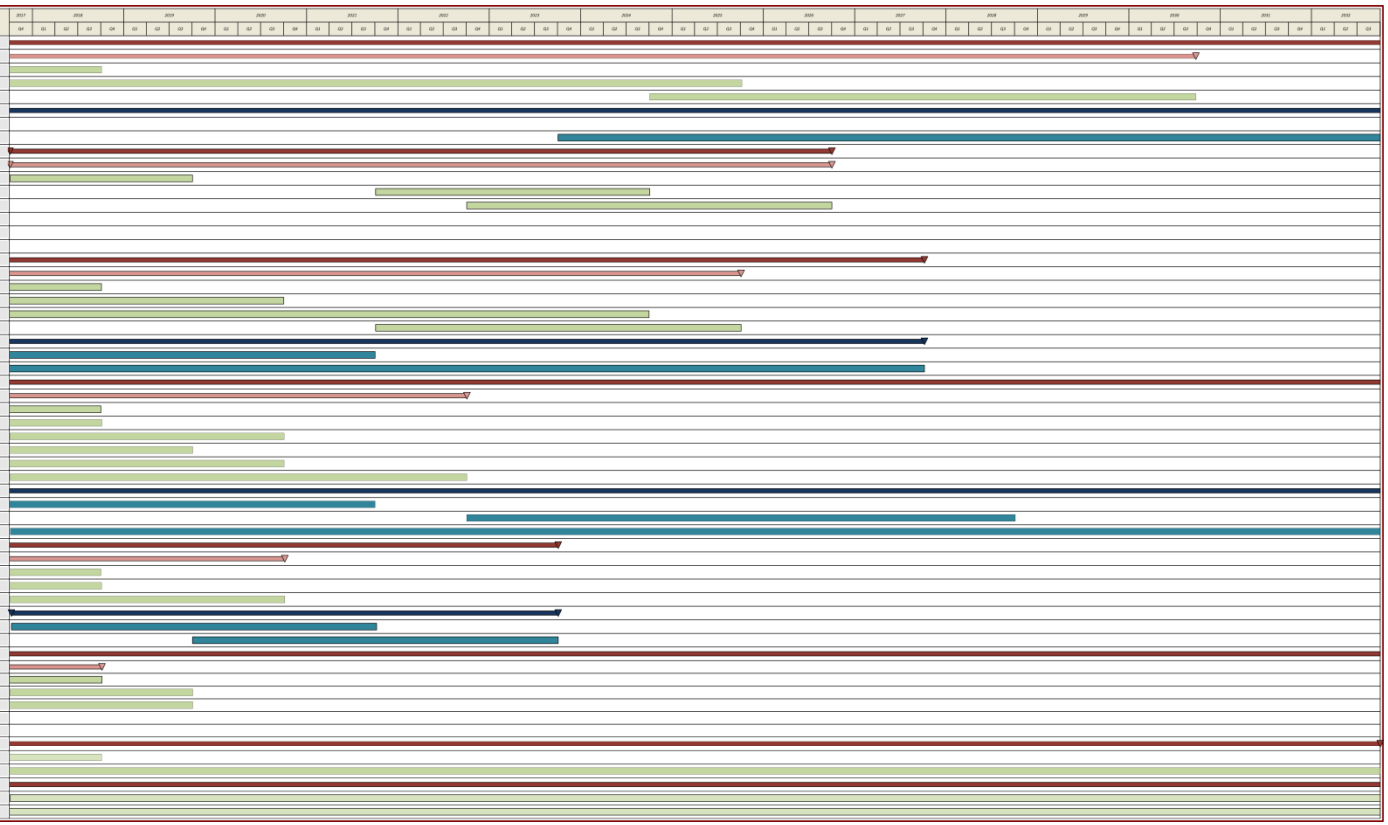


Table F 5:. Planned timing of Level 1 and Level 2 activities for the Lower Missouri River during the first 15 years, based on the prioritization process described in section F.4.

F.3 Discussion

The estimates provided here are intended to provide general understanding of the scope and timing of investment in pallid sturgeon science under the adaptive management plan, with the prioritization efforts described below. As noted in the Approach section, numerous caveats apply to these estimates. In particular, it should be emphasized that as learning progresses under adaptive management some anticipated information needs will diminish whereas some unanticipated needs may arise. In addition, a modest level of contingency funding is included to address surprises from new information. It is important to note that the net costs presented to not account for agency overhead costs, which may add substantially (50% or more) to the final costs.

The sequence of science investment indicates a rapid rise from 2015 to a peak in 2018 (Figure F 1). This sequence reflects the assumption that the MRRMP would be complete with a record of decision in 2017. If the record of decision and implementation of the new plan are delayed, the sequence of science investment would also be delayed. Nevertheless, the sequence of investment supports the notion of the “science surge” to quickly address fundamental level 1 science questions in the first 4-6 years of implementation. The surge in science investment is intended to provide the foundation for relevant and cost-effective management actions to avoid jeopardy to the pallid sturgeon.

F.4 Prioritization of Level 1 and Level 2 Components for the First 5 Years

As described above and in Appendix C, 74 science components have been identified that could potentially be implemented to reduce key uncertainties related to decisions on which actions are most likely to improve the survival and recovery of pallid sturgeon, to test the effectiveness of actions, and to assess progress towards defined objectives and sub-objectives for the population. These components include Level 1 (foundational research) and Level 2 (field experimentation) activities to test efficacy of priority management actions. These components are organized by the way in which they address critical information categories (i.e., big questions) and the 21 management hypotheses that emerged from the stepwise hypothesis filtering process (see Section 4.1.2.4,). The following considerations were used in developing these science components:

- need to address information for critical decisions (i.e., focus on need to know, not nice to know);
- must be cost effective;
- should include technical/engineering questions about implementation, including understanding some effects on Human Considerations;

- need to establish cause/effect, as much as possible, to support management decisions;
- implementation needs to be adaptive and flexible;
- should complement Level 3/4 activities and population level monitoring;
- multiple components and lines of evidence will be needed to address inherent challenges, given the rarity of pallid sturgeon and the very large size of the Missouri River; and
- need to support the population model by providing data to inform model structure and parameterization.

Sequential implementation of science components was explored in V3 of the AM Plan and was considered by the ISAP, the USFWS and other entities to take too long. To speed up the learning process, V4 of the AM Plan proposed implementing most Level 1 science components concurrently; this was considered by the ISAP to be overwhelming. Hence, the AM team undertook a prioritization exercise to clarify the immediate information needs and activities for the science and adaptive management program (i.e., within the first 5 years).

F.4.1 Prioritization Criteria

Given the need to prioritize the longer list of research components in Appendix C, a set of evaluation criteria were identified to assess the relative priority of components, the appropriate sequencing in time, the value of information provided, and the feasibility of implementation. The mix of criteria that were considered recognized that there are trade-offs involved when choosing one set of research activities versus another set. There needs to be a balance between research to reduce critical uncertainties and enhance learning about which *possible* future actions might address limiting factors, versus research to evaluate the effectiveness of actions that will *definitely* be implemented in the near term to benefit pallid sturgeon. The following criteria were used for prioritizing research components:

- **Relevance to current decisions/actions:** This criterion forces consideration of whether a research component contributes to thorough effectiveness evaluations of L2 or L3 actions that are included in the EIS, and therefore will be implemented. If an L3 action is already underway, then there may not need for all of the L1 / L2 work to justify it. In these instances, the primary value of the research may be to understand cause-effect links, evaluate effectiveness, and make adjustments to a Level 3 action. The relative priorities of actions being considered in the AM Plan are summarized in Table 41 (see Chapter 4). Level 3 actions have been identified in the EIS, informed by technical feasibility studies, and/or supported by policy and planning priorities provided by the USFWS through Planning Aid Letters.

- **Biological value of information:** An important consideration is whether a research component provides strong evidence to inform decisions on actions in terms of either their biological benefit or feasibility (i.e., high information value relative to cost). It is more important to focus on key branches in the decision trees for the Upper and Lower Missouri which simplify the decision problem (see Section F.4.2 and figures F2 and F3). Answering key questions in the decision trees provides relatively valuable information by reducing critical uncertainties on which actions to pursue, simplifying decision trees, and identifying necessary modifications to existing actions. The rationale for these decision trees is provided below.
- **Minimize risk to species:** Some federal actions may potentially impose a high risk to pallid sturgeon. There's a benefit to gaining information which helps to avoid taking actions that pose a high risk to pallid sturgeon.
- **Progress towards compliance:** This criterion relates to how a research component contributes to an evaluation of the status and trend of pallid sturgeon populations and progress towards USFWS objectives. Science to improve the valuation of status and trend may or may not also contribute to improved evaluation of action effectiveness (and vice versa).
- **Timeliness of learning:** If all other things are equal, components that provide fast answers are favored over components that take longer to provide answers. More specifically, if time lags for learning are longer than the USFWS deadlines for implementing a management action, is it still worth doing the work?
- **Cost feasibility:** This factor evaluates the varied benefits against the costs of research when setting research priorities.
-

F.4.2 Decision Trees

A key consideration in the prioritization process was the need to assess the relative value of information provided by each research component in terms of its ability to reduce one or more critical uncertainties. The critical uncertainties to be addressed are illustrated in the expanded decision trees in Figure F2 and Figure F 3.

Simplified decision trees were introduced in the Effects Analysis (AM) (Jacobson and others, 2016a) and reproduced in Chapter 4 of the Missouri River Science and Adaptive Management Plan (MRSAM). The decision trees provide a graphical and logical approach to thinking about prioritization and sequence of science components to inform decision making. The trees presented in the EA and Chapter 4 were constructed to illustrate how specific science information may constrain subsequent need for science information and may limit consideration of future management actions. The EA and Chapter 4 trees addressed a subset of the hypotheses in the upper and lower rivers. The following presents expanded decision trees that encompass all of the 21 EA hypotheses.

The decision trees are meant to illustrate the hypotheses and actions that prevail at this point in time (spring 2017). We expect hypotheses and decisions trees to change as additional learning takes place.

Hypotheses in the decision trees are presented in question form in yellow diamonds with yes/no or Boolean (and/or) results. The notation "&&" means that two or more questions need to all be in the affirmative. The notation OR means that any one of two or more of the linked questions needs to be in the affirmative. The blue boxes indicate the associated management actions related to yes/no decisions; some boxes have multiple management possibilities. Orange boxes are labeled "Likely recruitment failure", indicating that if the information progresses to these terminal boxes, there are likely no additional means to accomplish recruitment and avoid jeopardy. Some terminal blue boxes indicate that new hypotheses will need to be developed to explain observed data.

In practice, the decision trees will probably need to be employed iteratively. For example, one pass through the tree may address limitations of one factor (for example, food production), resulting in population growth. When that one factor is no longer limiting to the population yet a sustainable, genetically diverse population has not been achieved, it may be necessary to address a factor that has become the next limiting factor (for example, foraging habitat). Alternatively, it may be necessary to develop a new hypothesis for limiting factors that have not yet been identified.

F.4.3 Emerging Research Priorities

- The above criteria were applied by the AM team to identify priority research activities for the first 5 years of the AM program. The relevance of a research component to current decisions/actions and the biological value of the information (as articulated by the decision trees) were the most heavily weighted criteria in setting priorities. The complete list of components and their relative priority is summarized below in Table F6 and Table F7. The subset of components that are expected to begin in the first 5 years are identified in Tables 44 and 45 (see Chapter 4). Going forward there is an expectation that these priorities may be adjusted as knowledge is gained from these science components and, where appropriate, new information emerges around other hypotheses and related science components. There is an expectation, however, that the criteria to guide the evaluation of priority research components will generally remain the same as those listed above.

Table F6 :. Overview of priorities for Level 1 and Level 2 science components for the Upper Missouri River in the first 5 years of the Adaptive Management program. Priorities in the first 5 years are also listed in Table 44.

Research Component	***Priority in first 5 yrs?***	***Comments/rationale***
Big Question 1: Spawning Cues		
Level 1		
Component 1 Design complementary passive/active telemetry network	Y	Critical to the evaluation of Intake and also spawner responses to flow variation.
Component 2 Opportunistic tracking of reproductive behaviors	Y	Critical to evaluation of Intake, and may provide information around potential benefits of flow manipulation at Fort Peck. Continue this ongoing work unless information value is low due to little variation in flow.
Component 3 Mesocosm experiments, reproductive behaviors	N	Not necessary in first 5 years after ROD. Need to first determine if drift-dispersal distance is sufficient to make spawning below Fort Peck something to be encouraged.
Level 2		
Component 4 Engineering study effects on other authorized purposes	N	Not necessary in first 5 years after ROD (see above discussion of Upper Missouri decision tree).
Component 5 Experimental flow releases, Ft. Peck	N	First need to determine if Intake is working, so not necessary in first 5 years after ROD (see above discussion of Upper Missouri decision tree).
Big Question 2: Flow Naturalization and Productivity		
Level 1		
Component 1 Engineering models, interactions with authorized purposes	N	Not necessary in first 5 years after ROD. Postpone until drift dispersal studies complete.
Component 2 Screening: limitations of food or forage habitats	N	Not necessary in first 5 years after ROD. Dispersal distance more likely to be limiting. Postpone until drift dispersal studies complete.
Component 3 Field studies along gradients, food and forage habitats	N	
Component 4 Mesocosm studies: quantitative habitat – survival relations	N	
Level 2		
Component 5 Design flow experiments	N	Not necessary in first 5 years after ROD. Dispersal distance more likely to be limiting. Postpone until drift dispersal studies complete.
Component 6 Experimental naturalization of flows, Fort Peck	N	
Big Question 3: Temperature manipulations at Fort Peck		
Level 1		

Research Component	*Priority in first 5 yrs?*	*Comments/rationale*
Component 1 Screening: Feasibility, modeling of effects	N	Not required in short term based on Upper Missouri decision tree; drift dispersal distance more likely to be limiting, assess first. Temperature management not included in EIS. Not required in first 5 years after ROD.
Component 2a Screening: is food limiting to age-0 survival?	N	Dispersal distance is more likely to be limiting, assess first. Not required in first 5 years after ROD.
Component 2b Are Lake Sakakawea conditions limiting to age-0 survival?	Y	Important part of addressing drift-dispersal distance, so include in first 5 years of studies.
Component 3a Field gradient, temperature and food production	N	Temperature management not included in EIS. Dispersal distance is more likely to be limiting, assess first. Not required in first 5 years after ROD.
Component3b Field experiment drift/dispersal advection/dispersion validation	Y	Advection and dispersion are critical to free embryo survival. Already planned to occur in 2016.
Component 4a Mesocosm studies: temperature, food, survival relations	N	Dispersal distance is more likely to be limiting. Postpone until evaluation of Intake is complete or if new information suggests food is limiting.
Component 4b Development rates of embryos, free embryos, larvae	Y	Important part of drift-dispersal issue, so include in first 5 years of studies.
Level 2		
Component 5 Construct, test water temperature mechanisms	N	Temperature management not included in EIS. Postpone until evaluation of Intake is complete.
Component 6 Manipulative field experiments with water temperature	N	
Big Question 4: Sediment bypass		
Level 1		
Component 1 Feasibility study sediment bypass and turbidity	Already complete	Study completed for EIS. Sediment bypass infeasible. No need to do further work on this.
Component 2 Mesocosm study of turbidity-limited survival	N	Postpone until evaluation of Intake is complete. Predation appears to be less critical as limiting factor than dispersal distance and time for embryos in U. Missouri.
Component 3 Mesocosm study of turbidity-limited survival rates	N	
Level 2		
Component 4 Pilot test of sediment bypass	N	Postpone until evaluation of Intake is complete. Predation appears to be less critical as limiting factor than dispersal distance and time for embryos in U. Missouri.
Component 5 Field experiment sediment bypass and turbidity	N	
Big Question 5: Passage, drift, and recruitment		
Level 1		

Research Component	*Priority in first 5 yrs?*	*Comments/rationale*
Component 1a Model integration, drift and development	Y	Highest priority, planned for 2017. Critical to evaluation of Intake (and existing L3 action) as well as other possible Fort Peck actions.
Component 1b Modeling location and rate of change of headwaters	Y	
Component 2a Patchiness of anoxic zone	Y	Highest priority, planned for 2017. Critical to evaluation of Intake (existing L3 action); also important input to design of spawning habitat.
Component 2b Spawning habitat distribution on the Yellowstone River	Y	
Component 3 Field experiment drift/dispersal, advection/dispersion validation	Y	Highest priority, planned for 2016. Critical to evaluation of Intake (existing L3 action) as well as other possible Fort Peck actions.
Component 4 Mesocosm studies to quantify transport	Y	Highest priority after field drift/dispersal experiment. Complements and conditional upon field study to improve advection / dispersion models and improve insights on mgmt actions.
Level 2		
Component 5 Engineering studies for effects of low flows	N	Contingent upon outcomes of related L1 components and Intake performance. Low flow not included in EIS. Beyond 5-year planning horizon.
Component 6a Drift experiments, Fort Peck flows and drawdowns	N	
Component 6b Adult translocation experiment, Yellowstone	N	
Big Question 6: Population Augmentation		
Level 1		
Component 1 Engineering feasibility hatchery needs, facilities, operations	Y	Highest priority. Subject to Recovery Team and Propagation Strategy. Critical for ensuring population of sufficient size and genetic diversity.
Component 2 Retrospective study survival linked to hatchery operations	Y	
Component 3 Simulation models, population sensitivity to size, health, genetics	Y	
Level 2		
Component 4 Field experimentation with varying size, location of stocking	Y	Highest priority. Subject to Recovery Team and Propagation Strategy. Critical for ensuring population of sufficient size and genetic diversity.

Table F7:. Overview of priorities for Level 1 and Level 2 science components for the Lower Missouri River in the first 5 years of the Adaptive Management program. Priorities in the first 5 years are also listed in Table 45.

Research Component		
Big Question 1: Spawning Cues	***Priority in first 5 yrs***	***Comments/rationale***
Level 1		

Component 1 Design complementary passive telemetry network	Y	Spawning cues are part of LMR framework L3 actions. Critical for evaluating spawner responses to flow variation. Within 5-year planning horizon.
Component 2 Opportunistic tracking of reproductive behaviors	Y	May provide information around potential benefits of flow manipulation, which is important given high year to year variations and challenges observing rare fish in a big river.
Component 3 Mesocosm experiments, reproductive behaviors	N	Postpone beyond 5-yr planning horizon. Cost could be high due to size of mesocosms needed. Depends on outcomes from components 1 and 2.
Level 2		
Component 4 Engineering study effects on other authorized purposes	Already complete	Already done as part of EIS.
Component 5 Experimental flow releases, Gavins Point	N	Beyond 5-yr planning horizon; need to first mitigate possible flood impacts in Fort Randall reach. Implementation of this action depends on outcome of Level 1, Component 2, and the decision criteria described in the evidentiary framework, Table 49 in section 4.2.6.6 of AM Plan).
Big Question 2: Temperature Control		
Level 1		
Component 1 Model water temperature management options, Ft. Randall	Y	Worth exploring to determine if temperature manipulations benefit spawning cues.
Component 2 Field studies temperature and reproductive behaviors, surrogates	N	Contingent upon component 1 outcomes or may not be possible if temperature management is infeasible.
Component 3 Mesocosm studies temperature and reproductive behaviors	N	
Level 2		
Component 4 Field tests of water temperature management, Gavins Point	N	Contingent upon component 1 outcomes or may not be possible if temperature management is infeasible.
Component 5 Experimental warm water releases, Gavins Point	N	
Big Question 3: Food and Forage		
Level 1		
Component 1 Screening: limitations of food or forage habitats	Y	IRCs are in EIS and underway. Important for evaluation of IRC effectiveness, as well as existing chutes and SWH. Continue existing studies.
Component 2 Technology development for IRC sampling, modeling, measurement	Y	
Component 3 Field studies along gradients, food and forage habitats	Y	

Component 4 Mesocosm studies: quantitative habitat – survival relations	?	Contingent upon alternative methods of estimating survival in the field under component 2. Moves to "Y" if field methods of estimating survival rates of age 0 fish not feasible.
Level 2		
Component 5 Design studies for IRC experiments	Y	IRCs are in EIS and underway. Important for evaluation of IRC effectiveness. Within 5-year planning horizon - moving forward quickly.
Component 6 Manipulative field experiments with IRCs	Currently underway	
Big Question 4: Drift Dynamics		
Level 1		
Component 1 Technology development surrogate particles, particle tracking	Y	IRCs are in EIS and underway. Important for improving IRC effectiveness. Within 5-year planning horizon.
Component 2 Resilience, stamina in turbulent flows (lab or mesocosm study)	Y	
Component 3 Field studies on free embryo exit paths	Y	
Component 4 Field gradient study, age-0 survival and complexity	Y	
Component 5 Free embryo transport to Mississippi River	?	Possibly within 5-yr planning horizon. Need to first assess feasibility since sampling is challenging and expensive. Contingent upon progress with other methods (e.g., microchemistry); information valuable for population model and providing an unbiased estimate of hybridization.
Component 6 Field experiments with particle tracking, embryos, models	Y	IRCs are in EIS and underway. Important for improving IRC effectiveness. Within 5-year planning horizon.
Level 2		
Component 7 Engineering designs for interception experiments	Y	IRCs are in EIS and underway. Important for improving IRC effectiveness. Within 5-year planning horizon.
Component 8 Field experiment: discharge and dispersion	N	Not currently planned - beyond 5-yr planning horizon.
Component 9 Field experiment: IRC complexes	Y	IRCs are in EIS and underway. Important for improving IRC effectiveness. Within 5-year planning horizon.
Big Question 5: Spawning Habitat		
Level 1		
Component 1 Study of functional spawning habitat, Yellowstone River	Y	Spawning habitat is in EIS. Important for design of effective spawning habitat. Within 5-yr planning horizon.
Component 2 Field gradient study, habitat conditions LMOR	Y	
Component 3 Mesocosm studies on spawn conditions, behaviors	Y	

Level 2		
Component 4 Engineering studies for sustainable design	Y	Spawning habitat is in EIS. Important for design of effective spawning habitat. Within 5-yr planning horizon.
Component 5 Manipulative field experiment for spawning habitat	Y	
Big Question 6: Population Augmentation		
Level 1		
Component 1 Engineering feasibility hatchery needs, facilities, operations	Y	Highest priority. Subject to Recovery Team and Propagation Strategy. Critical for ensuring population of sufficient size and genetic diversity.
Component 2 Retrospective study survival linked to hatchery operations	Y	
Component 3 Simulation models, population sensitivity to size, health, genetics	Y	
Level 2		
Component 4 Field experimentation with varying size, location of stocking	Y	Highest priority. Subject to Recovery Team and Propagation Strategy. Critical for ensuring population of sufficient size and genetic diversity.
Technical Development: Modeling and Monitoring Needs		
Adaptive design and optimization of population monitoring	Y	Critical for the evaluation of action effectiveness and determining progress towards species objectives and sub-objectives.
Continued integration, refinement, and maintenance, collaborative population model	Y	

F.4.3.1 Upper River Decision Tree

The population augmentation section was added to both decision trees to illustrate hypotheses and information related to stocking of pallid sturgeon. It is important to note that population augmentation is considered a temporary measure to help avoid jeopardy to the species by providing better opportunity for population recovery. Stocking is intended to increase population to a size that is resilient to perturbations and to address potential depensation effects (that is, effects of low fish density leading to a small probability of mates finding one another), while maintaining the natural genetic diversity of the population. Whereas more specific hypotheses are likely to evolve through the Pallid Sturgeon Recovery Team and USFWS, the three general hypotheses shown are considered fundamental to population augmentation decisions.

Note that the third diamond “Is there sufficient food availability for growth, reproduction?” articulates a hypothesis that did not evolve through the EA, namely that adult population size and reproductive capacity may be limited by available food or

carrying capacity of the river. This hypothesis has been in the reserve in both the upper and lower river and is likely to get additional attention.

The structure of the decision tree begins with the population augmentation hypotheses. This reflects the idea that if the population is not prevented from going extinct, the remainder of the tree does not matter. The green box articulates that goal: attainment of a sufficient population of genetically diverse reproductive adults within the carrying capacity of the river. Having achieved this, the next series of questions relates to recruitment of young fish into the population.

The first diamond articulates to the presently (summer 2016) dominant hypothesis for mortality and recruitment failure in the upper river: that drift distance is inadequate and dispersal into Lake Sakakawea is lethal because of anoxic bottom sediments in the headwaters. If this is not the case, additional hypotheses will be needed to explain recruitment failure in the upper river. If the hypothesis is confirmed, attention turns to conditions that will allow for adequate drift and dispersal distance. In general, adequate dispersal distance is a function of spawning site (which needs to be sufficiently far upstream), drift rate, (controllable to some extent by velocity and channel condition), development rate (controlled in part by water temperature), and Lake Sakakawea level.

If the lethality of Lake Sakakawea is established, the next most influential question is whether reproductive adults elect to migrate a sufficient distance up the Yellowstone River. This hypothesis relates directly to the management action of providing passage at Intake Diversion Dam, as that dam limits most upstream migration to the lower 71.5 miles of the Yellowstone River. This is a major decision point, as it determines whether actions are likely to be beneficial or necessary on the Upper Missouri River.

If fish do not migrate at least past Intake Diversion Dam, then questions on the Upper Missouri River become more relevant (Upper Missouri Options). These are shown as two questions, both of which need to be affirmative. The first of these is sufficient upstream migration, which may be influenced by implementing attractive flows from Fort Peck. In addition, present EA models for downstream dispersal (Fischenich and others, 2014) indicate that net drift rates will likely need to be substantially less than would be indicated by water velocities. That is, there would need to be a combination of abiotic and biotic processes that would retard drift to allow more time in the free-flowing river. If both of those questions are answered affirmatively, then two additional questions become relevant to recruitment: is there sufficient food for age-0 pallid sturgeon and are they (embryo and free-embryo stage) subject to turbidity-mediated predation? Affirmative answers to either of these questions present additional potential management actions. Negative answers, indicating that these are not limiting factors,

combined with previous affirmative responses, indicate additional potential, relevant management actions on the Upper Missouri River.

The Yellowstone Options part of the decision tree relates to conditions where fish do pass upstream of Intake Diversion Dam. The next most relevant question is then whether the reproductive fish migrate far enough upstream to provide sufficient dispersal distance. The diamond indicates that 500 km is indicated as a minimum threshold for upstream migration, although more distance may be required depending on velocities and temperatures. To the extent that pallid sturgeon migrate shorter distances upstream or fail to find suitable spawning habitat, drift rates will need to be retarded below mean water velocity. Distance may still be limiting, however, indicating the potential to manage drawdown of Lake Sakakawea to increase distance. The EA (Fischenich and others, 2014) indicates probabilities of adequate drift distance calculated with present models.

F.4.3.2 Lower River Decision Tree

The left hand side of the Lower River tree is identical to the Upper River, although the details and importance of the hypotheses are likely to vary among the two river areas. The question about sufficient food for growth and reproduction was not among the EA hypotheses, but emerging information on fish condition has prompted the EA to consider the carrying capacity hypothesis in more detail.

In contrast to the Upper River, the Lower River does not have a dominant hypothesis for mortality and recruitment failure, hence the sequence of diamonds is more arbitrary. They are presented in life-stage sequence based on the rationale that recruitment to a given life stage ultimately requires survival from preceding life stages.

The first question, then, relates to spawning and asks whether fertilization, incubation, and hatch are successful. If the answer is negative, then there are action options related to aggregation flow pulses (spawning cues), increased number of adults, and reconfiguring the channel to provide more effective spawning habitats. The next question addresses whether once hatched, the free embryos can survive turbulence. This hypothesis was a specific corollary to the general drift dynamics (hypothesis 14) that flows affect drift distance and condition of free embryos.

If free embryos survive turbulence, the next question is whether they can transition to first feeding and find food in the thalweg (or instead, whether they require retention in more suitable, channel-margin habitats). If the answer is yes, they can feed efficiently in the thalweg, then they may still require sufficient food, but they won't necessarily need to be intercepted and retained. If the answer is no, a series of three questions about

limiting conditions in Interception-Rearing Complexes (IRCs) is relevant. These are related with Boolean OR statements as any one, or a combination, of the conditions could be limiting to free-embryo survival. Each condition also has specific management actions related to it, consisting of potential to manage flow regime, channel configuration, water temperature, or a combination. If information is available to move completely through this tree and determine that none of these conditions is limiting, it will be necessary to develop new hypotheses to explain recruitment failure.

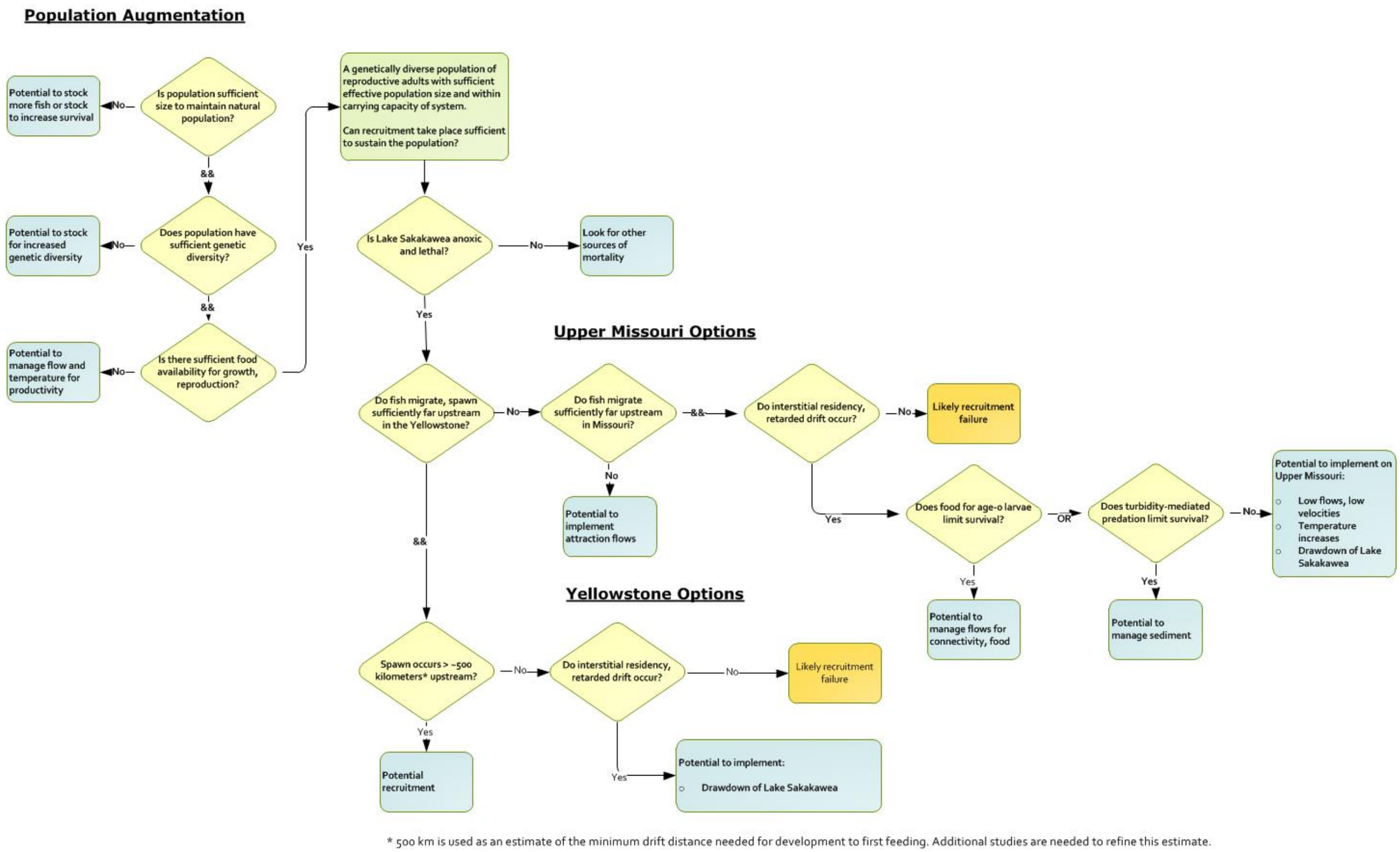


Figure F 2: Diagram of an expanded decision tree addressing the sequencing and contingency of information in the Upper Missouri River. A simpler decision tree can be found in Figure 62 (see Chapter 4).

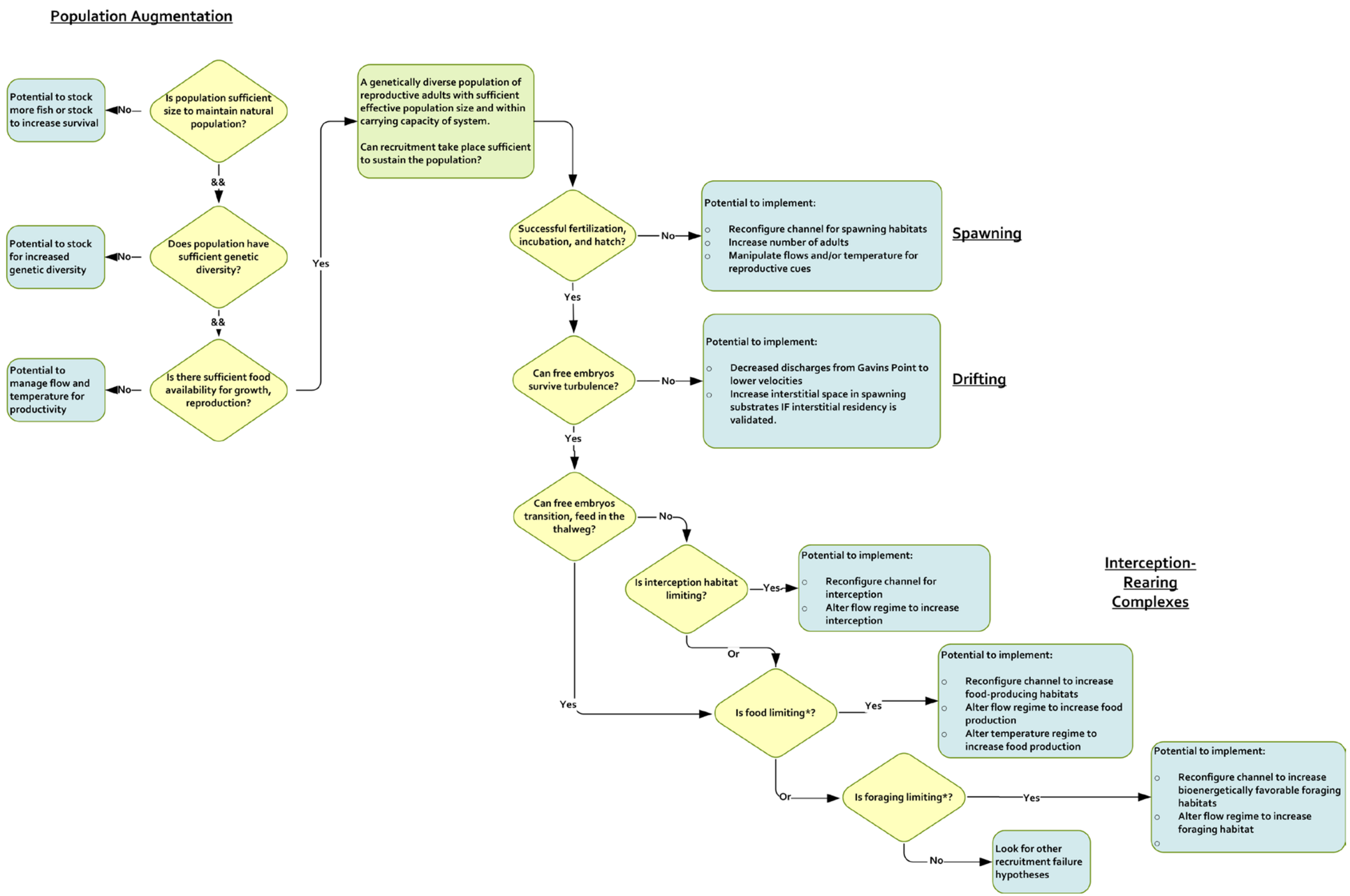


Figure F 3: Diagram of an expanded decision tree addressing the sequencing and contingency of information in the Lower Missouri River. A simpler decision tree can be found in Figure 63 (see Chapter 4).

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Appendix G. Monitoring and Assessment Protocols for the Birds

Note: This appendix will present common monitoring protocols employed by the program for the Plover and Tern. Additional content is TBD, but may include discussion guiding development of protocols for specific projects, which may require preparation after the project objectives, location, design, etc., are known.

Populating this appendix with the appropriate information will be an ongoing objective for activities following AMP V6 and continuing to the Final Draft AMP.

Attachment G.1 - Safety for Field Crews

Safety is critical to all USACE activities. Safety is everyone's responsibility. It is important that crew members be conscious of all possible safety hazards while they are working. Any time a potential safety hazard is discovered that cannot addressed by the crew it must be reported to the immediate supervisor so that proper action may be taken to correct the hazard. There are three areas of safety that are of particular importance in monitoring work. They are boat & all-terrain vehicle (ATV) safety, water safety and survey safety. Each will be discussed in detail below.

G.1.1. Boat & ATV Safety

All operators of USACE motorboats must obtain a boat operator's license. A license is acquired by passing the Corps' boat operators training course. When in a boat or on a personal watercraft that is under way, a personal flotation device (PFD), will be worn at all times.

- Before leaving, the boat, the boat trailer and the tow vehicle will be inspected so that all required equipment is in place and all equipment is working properly.

- Before taking out a watercraft, a float plan will be filed to ensure that if the crew does not come back from the survey, someone will come looking for the crew. The float plan needs to include the boat number, the boat operator, the names of the personnel on board, the launch location, itinerary, estimated time of return, time to activate a search, a contact person and the radio call number and/or cell phone number. The boat operator is responsible for closing out the float plan by notifying the appropriate personnel that the boat is off the water.

- Weather Conditions**:** Be cognizant of weather conditions when operating watercraft, especially on a reservoir. White caps will appear with wind speeds of around 13 – 15 mph. When wind speeds approach 25 mph it is time to abandon the survey and head for home. Likewise if a storm appears to be building it is time to terminate the survey and get off the water.

- For reservoir operation ensure that the proper type of boat is used for the survey. Generally a V-shaped hull boat or a personal watercraft is preferable to a flat bottom boat. Both of these boat types can handle waves better than a flat bottom boat.

- Operating watercraft on the river can be quite different from reservoir operation. A major difference is the river's current. The Missouri River generally flows around two to four miles per hour and the current must be taken into consideration as one navigates up and down the river. When trying to land on a sandbar or island it is

better to go down river a short distance and then come back up the river against the current. Going against the current gives the operator better control of the boat as it approaches the shore. The same technique should be used when loading the boat onto the trailer at the boat ramp.

- When boating on the Missouri River, the operator should try to stay in the ten to twenty foot deep thalweg or main channel of the river. Crew members need to stay alert while in areas with silver carp and should avoid snags, and floating objects. Snags are trees that have toppled into the river and have become anchored to the river bottom. They come in a variety of sizes and positions in the river. Snags are more commonly found in shallow areas, but can also be located in the thalweg. They may be submerged and just barely visible underwater or they may be just barely below the water surface with a V-shaped ripple of water being the only clue to their presence. The river must be scanned continuously for the presence of snags.

- Crews operating boats on the river below Gavins Point Dam face an additional hazard – silver carp (*Hypophthalmichthys molitrix*). The danger to boaters from silver carp comes from the tendency of the fish to jump out of the water when startled by a passing boat. Silver carp can weigh up to 40 pounds and leap as high as ten feet in the air. They act as a projectile that could seriously injure an unwary boater. Crew members need to remain alert for the possibility of being struck by a leaping silver carp.

- All-Terrain Vehicle Safety: As with boats, operators of ATVs are required to take and pass the ATV operators' training before being allowed to conduct a survey using an ATV. ATV operation presents its own dangers from uneven surfaces, rock and log obstacles to quicksand. ATVs will be operated in a safe and prudent manner at all times with a helmet on when the vehicle is in motion.

G.1.2. Water Safety

It is highly recommended, but not required, that personnel doing monitoring work be capable swimmers. Walking in water can be especially dangerous as the river bed can be irregularly shaped with deep holes and shorelines can quickly drop off from shallow to deep areas. No matter what a person's swimming proficiency is, from non-swimmer to highly skilled, all personnel are required to wear a PFD when going into the water or where there is a possibility that the person might fall into the water. Likewise, to protect the feet, approved footwear will be worn while walking through water.

G.1.3. Survey Safety

First aid kits should be readily available to all survey crews, along with sunscreen and bug spray. Drinking water is also a pertinent resource for ensuring safety.

Footwear: Protective footwear will be worn at all times. Personnel are not allowed to go barefoot when conducting surveys. While unloading and loading the boat at the dock, standard steel-toed safety boots will be worn. When operating the boat and conducting surveys, with project approval, sandals or water shoes may be worn in lieu of safety boots.

Clothing: Crews should carry proper clothing to protect against sudden temperature and weather changes. Wearing proper clothing will provide protection against a sudden temperature drop, high winds and precipitation, all of which can lead to hypothermia. Rain gear should be stored in a duffel bag and taken into the field as insurance against inclement weather.

Personal Safety: If a crew is threatened or assaulted by a member of the public, disengage as quickly as possible and leave. Report the incident immediately to the supervisor and the appropriate law enforcement agency. If an area is deemed unsafe to survey, the crew will be so advised by the supervisor and the area will not be surveyed.

Attachment G.2 - ESA Section 10 Permit Survey Conditions

G.2.1. Endangered Species Permit:

Prior to 2003, the U.S. Fish & Wildlife Service (USFWS) granted the USACE a permit that included conditions and restrictions for the Corps' monitoring work. After 2003, the USFWS 2003 Amended Biological Opinion took the place as the permit for the Corps' endangered species work. The conditions and restrictions from previous endangered species permits remain in force and must be observed when surveys are conducted.

G.2.2. Temperature:

Surveys will not be conducted when the ambient (air) temperature is at or above 90° Fahrenheit (32° Celsius). The temperature can be monitored through the use of a thermometer. With an air temperature above 90°F, the ground temperature on a sand-gravel substrate could easily be forty to fifty degrees (F) hotter. Ground temperatures this hot can cause heat stress and death for recently hatched chicks that cannot thermoregulate themselves. Likewise a high ground temperature can kill the embryo in an overheated egg. The adult must be allowed to stay on the nest during times of high ambient temperatures and this will not happen if surveys are conducted during these periods.

G.2.3. Wind:

When the wind speed is at or above 25 mph (40 kph) or if sand is observed blowing across a sandbar or beach, monitoring work will be terminated and the site will be vacated. Blowing sand can quickly fill in an exposed nest bowl and bury the eggs. The adults need to be able to return to the nest to prevent sand from filling in the nest bowl.

G.2.4. Precipitation:

If there is a threat of imminent precipitation (rain, sleet, hail, snow) in the area, a survey will not be done. If precipitation begins while a survey is underway, work will cease immediately and the area will be vacated. The adult must be given the opportunity to get back on the nest to protect the eggs or newly hatched chicks. If the precipitation ends and the time restriction has not been met, (see below) then surveying can resume.

G.2.5. Time Restriction:

When conducting a survey, the maximum amount of time adults and/or chicks can be disturbed or an adult can be kept away from a nest is twenty (20) minutes. A large colony site cannot be surveyed within twenty minutes; however the key is to make sure that the birds are not disturbed for more than twenty minutes. As the crew goes through

the colony, the birds that were first disturbed will settle back down to the nests after crew moves on. However, after twenty minutes have passed, personnel cannot go back and re-enter the previously disturbed part of the colony.

In areas where multiple crews (researchers) are working, a minimum of two hours must pass after one crew has left a site before a new crew can enter that site. Every effort will be made to coordinate surveys with researchers so that site visits do not overlap.

G.2.6. Visitation frequency:

Monitoring crews are not to return to a nesting site any sooner than five (5) days after their last visit. The purpose of this restriction is to minimize disturbance to the birds so as not to attract attention of predators to the site by frequent human disturbance.

G.2.7. Handling of Chicks and Eggs:

Handling of eggs and chicks will be kept to a minimum and will be done only in the performance of monitoring duties and management actions. Prior to handling an egg or chick, crew members will either wash their hands with no-scent soap or wipe their hands with a no-scent towelette.

G.2.8. Training:

All personnel conducting least tern and piping plover monitoring work are required to receive training prior to conducting surveys. The training will include information on the Endangered Species Act, life histories of the two species, monitoring techniques, data collection, management activities and safety.

G.2.9. Trespass:

An endangered species permit does not grant monitoring crews the right to trespass onto private property. Crews will be informed by their supervisor, prior to the beginning of monitoring, what areas are not to be surveyed due to private landowner refusal.

Attachment G.3 - Survey Segments

The Missouri River is divided into fifteen segments for monitoring purposes. Least terns and piping are found in 9 segments.

G.3.1. Segment 1. Fort Peck Lake

Segment 1 consists of the eastern part of Fort Peck Lake extending from river mile (RM) 1785.0 to Fort Peck Dam at RM 1771.0. Fort Peck Lake represents the northwestern most range of the interior population of the least tern.

Piping Plover Critical Habitat: Piping plover critical habitat includes all shorelines and islands on Fort Peck Lake north of RM 1780.0 including the Dry Arm.

Monitoring Responsibility: Fort Peck Project

G.3.2. Segment 2. Missouri River below Fort Peck Dam

Segment 2 extends from Fort Peck Dam at RM 1771.0 to the headwaters of Lake Sakakawea at RM 1568.1. This segment of the river runs a little more than 200 miles, primarily in an easterly direction.

Piping Plover Critical Habitat: Piping Plover Critical Habitat for this segment has been designated for the Missouri River from RM 1712.0 in Montana to RM 1568.1 in North Dakota

Monitoring Responsibility: Fort Peck Dam (RM 1771.0) to the Montana/North Dakota border (RM 1586.6) is monitored by the Fort Peck Project.

The Montana/North Dakota border (RM 1586.6) to the headwaters of Lake Sakakawea (RM 1568.1) is monitored by the Williston Office, Garrison Project.

G.3.3. Segment 3. Lake Sakakawea & Lake Audubon

Segment 3 extends from the headwaters of Lake Sakakawea at RM 1568.1 to Garrison Dam at RM 1389.6. Lake Sakakawea is located in north central North Dakota and extends 178 miles in a northwesterly direction from Garrison Dam. The reservoir covers 364,000 acres at the full pool elevation of 1850.0 feet msl. Lake Audubon is located ten miles northeast of the dam and was created by the placement of a three mile long causeway for U.S. Highway 83 across the eastern end of Lake Sakakawea.

Piping Plover Critical Habitat: All of Lake Audubon and all of Lake Sakakawea except for the Little Missouri Arm west of Little Missouri River Mile 15.0 (Wolf Chief Bay) is designated Piping Plover Critical Habitat.

Monitoring Responsibility: Garrison Project

G.3.4. Segment 4. Missouri River below Garrison Dam

Segment 4 extends from Garrison Dam (RM 1389.6) to the northern boundary of the Oahe Project (RM 1304.0). The river flows in a southerly direction from Garrison Dam before turning eastward south of Stanton ND at RM 1367. The river then turns south again east of Washburn ND at RM 1350. The river travels primarily south through the rest of the segment. Between RM 1320 and 1310 the river passes through the Bismarck/Mandan metropolitan area.

Piping Plover Critical Habitat: The entire segment has been designated as Piping Plover Critical Habitat.

Monitoring Responsibility: Garrison Dam (RM 1389.6) to the Washburn Bridge (RM 1355.0) is monitored by the Garrison Project, Riverdale Office.

The Missouri River from the Washburn Bridge (RM 1355.0) to the northern boundary of the Oahe Project (RM 1304.0) is monitored by the Oahe Project, Bismarck Office.

G.3.5. Segment 5. Lake Oahe

Segment 5 extends from the northern boundary of the Oahe Project at RM 1304.0 to the Oahe Dam at RM 1072.3.Lake Oahe, impounded by Oahe Dam, extends 220 miles northward from central South Dakota to central North Dakota. The lake spreads over 359,000 acres at the full pool elevation of 1617.0 feet msl. The Grand, Moreau and Cheyenne Rivers all flow into the reservoir from the west.

Piping Plover Critical Habitat: The entire segment has been designated as Piping Plover Critical Habitat.

Monitoring Responsibilities: The Oahe Project is responsible for all monitoring of Lake Oahe. The Pierre Office, the Mobridge Office, and the Bismarck Office share the responsibility.

G.3.6. Segment 7. Lake Francis Case

Segment 7 extends from Big Bend Dam at RM 987.4 to Fort Randall Dam at RM 880.0. The segment encompasses Lake Francis Case, the reservoir formed behind Fort Randall Dam. Lake Francis Case is kept at a constant pool during the nesting season and has very little shoreline habitat.

Piping Plover Critical Habitat: None of the segment has been designated as Piping Plover Critical Habitat.

Monitoring Responsibility: Fort Randall Project

G.3.7. Segment 8. Missouri River below Fort Randall Dam

Segment 8 extends from Fort Randall Dam at RM 880.0 to the Niobrara River's confluence with the Missouri River at RM 844.0. The Missouri River flows in generally a southeasterly direction in this segment. The entire segment has been designated the Missouri National Recreation River, which is administered by the National Park Service. There are several residential developments along the river, primarily on the Nebraska side.

Piping Plover Critical Habitat: The entire segment has been designated as Piping Plover Critical Habitat.

Monitoring Responsibility: Fort Randall Project

G.3.8. Segment 9. Lewis and Clark Lake

Segment 9 extends from the Niobrara River/Missouri River confluence at RM 844.0 to Gavins Point Dam at RM 811.1. Lewis & Clark Lake, impounded by Gavins Point Dam extends 34 miles in a westerly direction along the South Dakota-Nebraska border. The lake contains 28,000 acres at the full pool elevation of 1806 feet msl. The segment from the confluence with the Niobrara River at RM 844.0 to the Running Water boat ramp at RM 840.0 is a part of the Missouri National Recreation River. The upper part of the lake is riverine in nature due to an extensive sedimentation zone formed from sediment being deposited by the Niobrara River. An island complex was constructed to the east of the sedimentation zone at RM 827 in 2007.

Piping Plover Critical Habitat: The entire segment has been designated as Piping Plover Critical Habitat.

Monitoring Responsibility: Fort Randall Project

G.3.9. Segment 10. Gavins Point River

Segment 10 extends from Gavins Point Dam at RM 811.1 to Ponca State Park, Nebraska at RM 753.0. The Missouri in this segment flows in an east to southeast direction along the South Dakota-Nebraska border. The entire segment has been designated the Missouri National Recreation River, which is administered by the National Park Service. Several residential developments have sprung up on both sides of the river.

Piping Plover Critical Habitat: The entire segment has been designated as Piping Plover Critical Habitat.

Monitoring Responsibility: Gavins Point Project

Attachment G.4 - Habitat monitoring protocols

The habitat monitoring program has several purposes. The first purpose of habitat monitoring is to assess the efficacy of our management actions for maintaining quality tern and plover nesting habitat. The second purpose is to examine the differences in sandbar habitat where nesting does and does not occur in order to better understand suitable habitat characteristics. And finally, these data are used for accuracy assessment of the remote sensing habitat classifications.

G.4.1. Objectives

1. Examine the effects of management actions on sandbar habitat characteristics by comparing characteristics before and after treatment and comparing treatment sandbars to controls.
2. Evaluate the differences in habitat quality by comparing habitat characteristics between these sandbars used for nesting and unused sandbars.
3. Evaluate the accuracy of landcover habitat classifications by comparing percent vegetation from the line intercept data to landcover classifications.

G.4.2. Study Area

Habitat management actions will be implemented on the river segments below Gavins Point Dam from river mile 811 to 753, Fort Randall dam from river mile 880-844, and Garrison Dam from river mile 1389 to 1277 and on Lewis and Clark Lake from river mile 845-825. USACE habitat monitoring crews collect line intercept data on representative sandbars within the above mentioned segments annually.

G.4.3. Methods

Sampling design – Sampling design will be dependent on the specific management action being evaluated. We are currently evaluating spraying actions on sandbars. We systematically selected sandbars on each river segment and of those randomly selected 20 on each segment for sampling. We selected 10 treatment and 10 control that also represent used and unused sandbars. Random points are generated for each sandbar and used as starting points for transects. We sampled 16 transects per sandbar. We attempt to sample the same transects annually however if transects are lost due to

erosion or missing markers new transects are added as needed. Number of transects per bar may be adjusted based on study needs.

Habitat characteristics - Habitat conditions are quantified by measuring percent vegetation coverage of dominant and secondary vegetation categories, average vegetation height, percent coverage of dominant and secondary substrate categories, and percent of coverage of small and large debris.

Analysis

General linear mixed effects models are used to detect a change in habitat characteristics and productivity between treatment and control sandbars before and after treatment.

Attachment G.5 – ESH Toolbox Application

The ESH toolbox is designed to automate much of the data preparation, extraction and calculation necessary to compute emergent sandbar habitat (ESH) using the geodatabases provided by Larry Strong (USGS). This document serves as a general tutorial on how to use the toolbox to compute ESH.

This example uses images of Gavin's Reach from the summer of 2006. Specifically, we will use images collected from May 12th May 30th, July 5th July 18th and to compute ESH for the entire reach (Figure G 1).

G.5.4. Warning: avoid "Batch" applications of this toolbox

In most cases, the user will need to run the tools described here on multiple feature sets. Unfortunately, there are known issues with running user models with the ArcGIS "batch" function[1]. To ensure the calculations are done properly, the user must run the tools individually on each feature class.

G.5.5. Warning: Long file paths

Some of the tools in the ESHtoolbox may return error 000670. If you encounter this error, try using a shorter filenames/paths for the input and output files. This error occurs because ArcGIS truncates long filenames, which can result in duplicate names for intermediate files created by the tools.

[1] See http://gis.stackexchange.com/questions/36891/does-calculate-value-model-only-tool-work-correctly-in-tools-run-in-batch, https://geonet.esri.com/thread/15090 and https://geonet.esri.com/thread/28898 for more information.

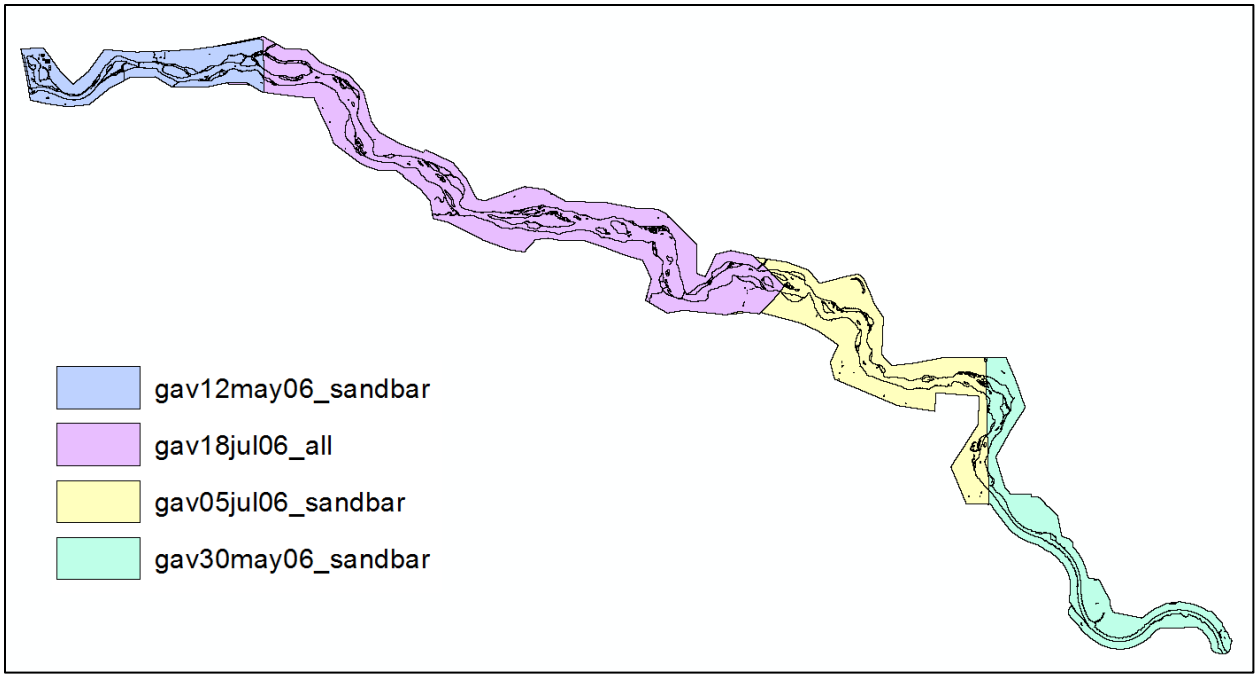


Figure G 1: Imagery of Gavin's Reach in Spring/Summer of 2006.

G.5.6. Step 1: Clip feature sets to river mile markers

In some cases, feature sets must be clipped to certain regions of interest, e.g. between two river mile markers. The **clipAndUpdateArea** tool can be called directly to achieve this. The user needs to provide a clip polygon specifying the area of interest as an input to the tool (Figure G 2). In general, this tool only needs to be applied to the end members of the image set (i.e. the furthest upstream and furthest downstream feature sets).

In order to update the ESH land cover class areas, certain assumptions must be made. Because land cover class areas are associated with geomorphic objects, rather than being explicitly represented in the geodatabases, **clipAndUpdateArea** simply scales down the areas of each land cover class in proportion to the reduction in area of a given geomorphic object due to clipping.

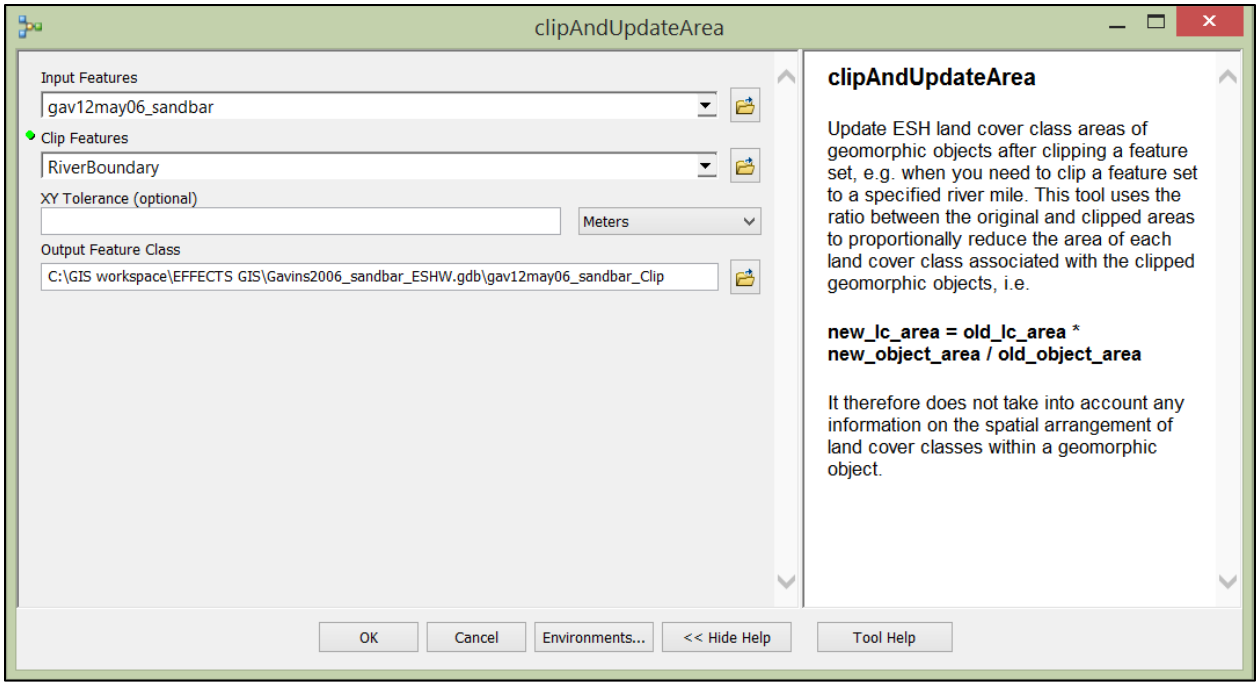


Figure G 2: Clip a feature set to a region of interest using clipAndUpdateArea. In this case, RiverBoundary is a single polygon defining a box around the region of interest.

G.5.7. Step 2: Extract Emergent Sandbar Habitat

Emergent Sandbar Habitat is a vague concept, and care must be taken to explicitly define it. The ESH toolbox provides two tools that calculate ESH based on different definitions. The tool **extractESH** extracts polygons identified as ESH objects and calculates ESH area using the definition in the ESH Adaptive Management Plan, http://moriverrecovery.usace.army.mil/mrrp/f?p=136:175:0::NO::: , whereas the tool **extractESHWEST** (Figure G 3) extracts and computes ESH following the definition of WEST (2014). The AM and WEST definitions of ESH are described below. Both **extractESH** and **extractESHWEST** output feature classes containing only those objects in the input feature classified as ESH, with the additional attribute table field *a_ESH*. The tools also provide an interface for adding discharge and date information to a feature set. The tool creates the fields *TOTAL_DISCHARGE_CFS* and *IMAGE_DATE*, accepting a numeric (decimal) value for discharge (cfs) and an integer (long) value for date, i.e. in the form YYYYMMDD. While this information can easily be added to an attribute table using the field calculator, using this tool ensures consistent and correct naming of the fields across the feature sets. Discharge information is usually included in the item description of each feature set.

Classifying ESH objects according to the Adaptive Management plan

The ESH Adaptive Management Plan defines ESH as areas of un-vegetated and sparsely vegetated dry and wet sand land cover classes on two island sandbar classes and two floodplain sandbar classes (i.e., dry sandbar, wet-dominated sandbar, dry floodplain sandbar, and wet-dominated floodplain sandbar), and on wet sandbars and herb shrub and woodland (i.e. more than 50% vegetated) islands and floodplains that have a fuzzy membership possibility values for a ESH sandbar class. The Adaptive Management program makes the assumption that wet sandbars with no membership for drier sandbar classes are not be used for nesting. The conditions for identifying ESH geomorphic objects in the USGS geodatabases are listed below:

1. Dry sandbar (drysb)
2. Wet-dominated sandbar (wdsb)
3. Floodplain dry sandbar (FPds)
4. Floodplain wet-dominated sandbar (FPwsd)
5. Wet sandbar (wsb)
    - If fuzzy membership for 1or 2
6. Herb shrub island (hsisl)
    - If fuzzy membership for 1or 2
7. Woodland island (woodisl)
    - If fuzzy membership for 1or 2
8. Floodplain wet sandbar (FPws)
    - If fuzzy membership for 3 or 4
9. Floodplain herb shrub
    - If fuzzy membership for 3 or 4
10. Floodplain woodland
    - If fuzzy membership for 3 or 4

ESH geomorphic objects are extracted and using the following Attribute Selection query:

```
(m_drysb + m_wdsb + m_FPds + m_FPwsd) > 0
```

Classifying ESH objects according to WEST (2014)

WEST (2014) described ESH slightly differently in their surveys. First of all, surveys were limited to unattached inter-channel sandbar features, i.e. floodplain sandbars were excluded from the analysis. Furthermore, sandbars smaller than one acre were excluded. It is important to realize that this is different than the procedure used to estimate ESH in the ESH Adaptive Management Program. The WEST method does not discriminate dry and wet sandbars; any exposed sandbar is assumed suitable for

nesting. Calculating ESH based on the WEST (2014) survey methods should correspond reasonably well to the conditions listed below:

1. Dry sandbar (drysb)
   - If Area_ha > 0.404686
2. Wet-dominated sandbar (wdsb)
   - If Area_ha > 0.404686
3. Wet sandbar (wsb)
   - If Area_ha > 0.404686
4. Herb shrub island (hsisl)
   - If non-zero fuzzy membership for any 1—3
   - If Area_ha > 0.404686
5. Woodland island (woodisl)
   - If Area_ha > 0.404686
   - If non-zero fuzzy membership for any 1—3

ESH objects are extracted and total ESH area is calculated by **extractESHWEST** using the following Attribute Selection query:

```
( (m_drysb + m_wdsb + m_wsb) > 0 ) AND ( Area_ha > 0.404686 )
```

Note that feature objects do not have non-zero memberships for both island and floodplain classes, i.e. they are classified as either “island” or “floodplain” exclusively.

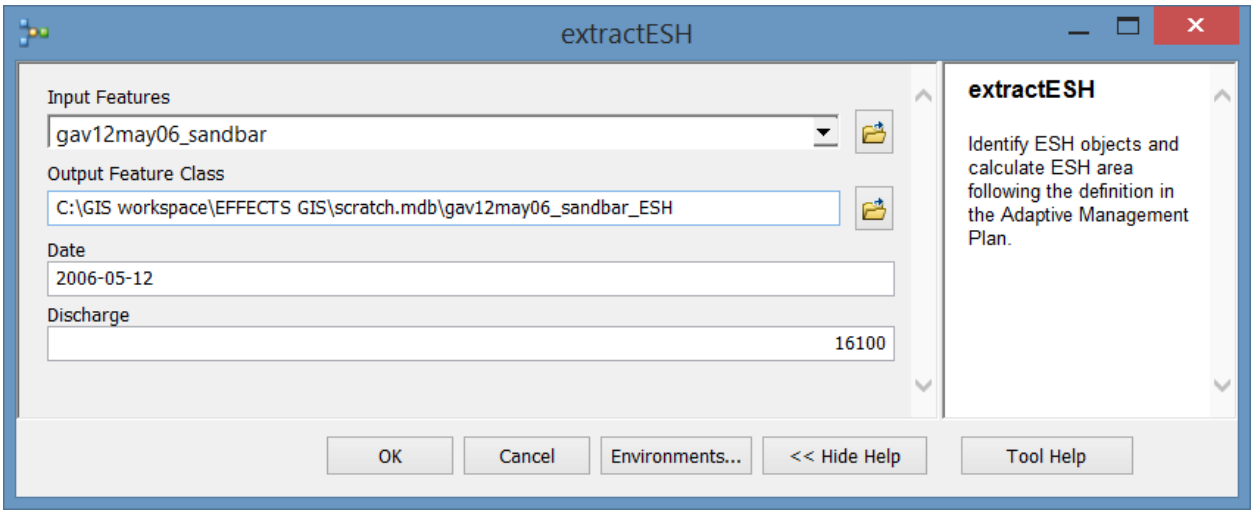


Figure G 3: using extractESH(WEST). Note the date is formatted as YYYY-MM-DD and discharge is in cubic feet per second. Discharge information is usually specified in the feature class metadata.

G.5.8. Step 3: Separate overlapping objects

The ESH features classes will often overlap to some extent, as shown in Figure G 4. These overlapping regions must be accounted for when calculating ESH for the entire reach. One strategy is for the user to manually edit the feature sets and combine them into a composite feature class. However, this strategy is time consuming and difficult to reproduce. Furthermore, complications arise when overlapping images are associated with different discharges. The **separateESH** tool helps automate this procedure by identifying ESH objects in adjacent feature sets that overlap and extracting them. Once the overlapping features are extracted, the user can choose which features to reject and which to maintain. For sets of three or more images, **separateESH** must be used sequentially to separate all overlapping regions.

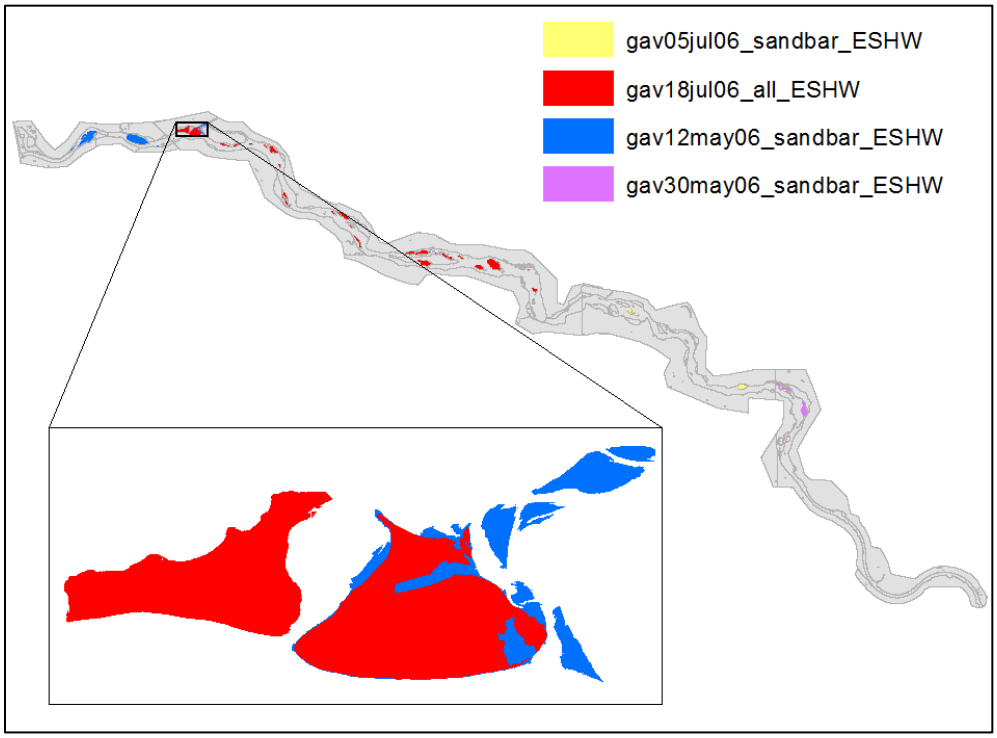


Figure G 4: ESH objects extracted from the original feature sets using extractESHWEST. The overlapping features shown in the inset can be separated from their parent feature sets using separateESH.

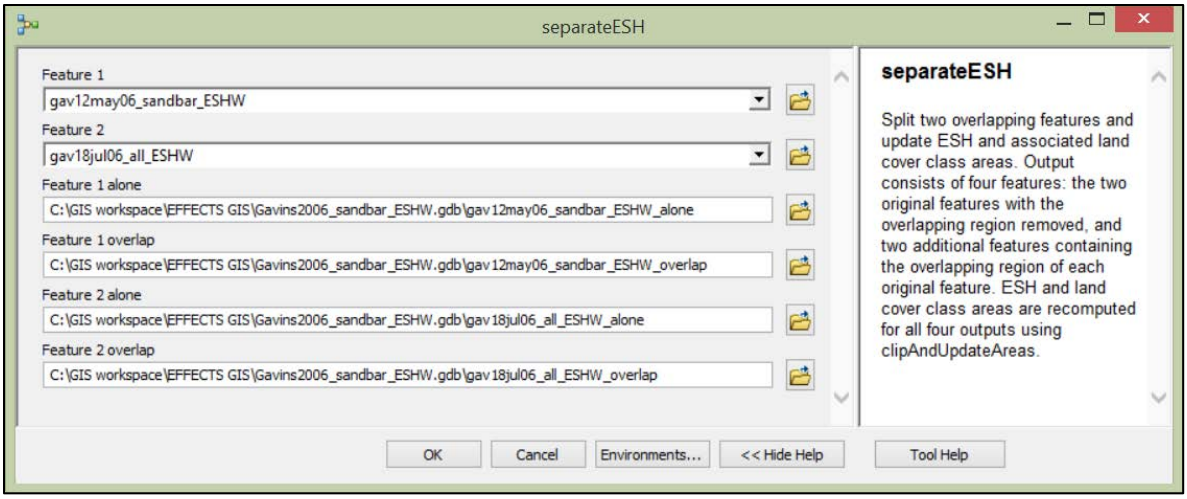


Figure G 5: Use separateESH to separate two overlapping feature sets.

G.5.9. Step 4: Select and discard overlapping features

Once the overlapping objects have been isolated, the user must select which version of each overlapping polygon to use and which to discard. While the choice of which features to use and which to discard is somewhat subjective, the following hierarchical approach is recommended for each pair of overlapping features to maximize reproducibility:

1. If one of the overlapping features occurs at the boundary of an image and is cut off or otherwise incomplete (e.g. due to cloud interference), this feature will be discarded in favor of the more complete feature (completeness).
2. If both overlapping features are complete, the feature associated with a flow closest to the baseline flow (~31,000 cfs) will be retained over the other feature (representativeness).
3. If the overlapping features have similar discharges, then the feature associated with the image that contains the larger number of features will be retained (concurrence).

G.5.10. Step 5: Account for edge features

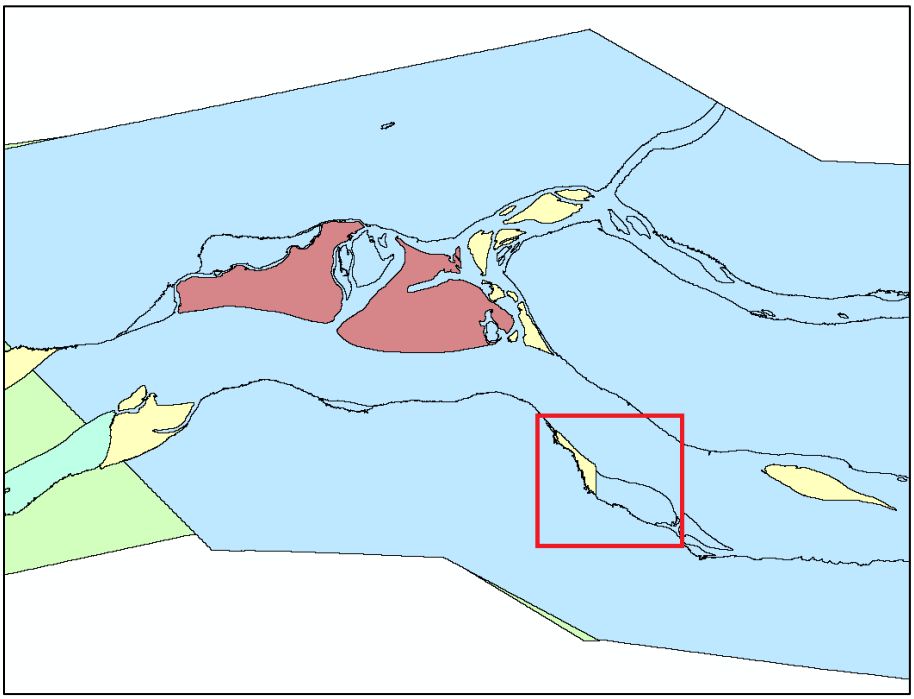


Figure G 6: ESH objects extracted from the original feature sets using extractESH. As shown in the red box, part of a floodplain object at the border of one feature set (green background) is classified as ESH (yellow) while the object captured in the adjacent feature set (blue background) is not.

Care must be taken to account for objects that are split between adjacent feature sets but do not overlap. Due to the way object memberships are calculated, there may be instances where a portion of an object in one feature set meets the ESH classification requirements, but the portion of the object in the adjacent image does not. The following hierarchical approach is recommended for each split feature to maximize reproducibility:

1. If the object is mostly contained in one feature set and is not classified as ESH in that set, then the portion in the adjacent feature set classified as ESH will be discarded.
2. If the object is split more or less equally between two adjacent feature sets and only one of the portions is classified as ESH, the portion classified as ESH will be discarded.
3. If the object is split between two adjacent feature sets and both are classified as ESH, then both objects will be retained. The user may choose to combine these features manually.

G.5.11. Step 6: Recombine feature sets

Once all overlapping polygons have been accounted for, the user can merge the ESH feature sets using the **merge** tool. In cases where there are three or more overlapping images, it may be easier to perform steps 3—6 iteratively; that is, take the first two overlapping images and extract the ESH objects, separate overlapping features and select which features to use in the overlapping region, and then merge them back together and repeat the process with the third overlapping image.

Figure G 7: ESH objects collected into one feature class using merge.

G.5.12. Step 7: Calculate ESH

Each ESH object is comprised of one or more land cover classes. For instance, a “dry sandbar” object may include “dry sand”, “dry sand sparse vegetation”, and “wet sand” land cover classes. The actual ESH habitat associated with an ESH object is the sum of multiple land cover classes. The following land cover classes are used to determine ESH area:

- un-vegetated dry sand (ds: a_FPds, a_ISLds)
- sparsely vegetated dry substrate (dssv: a_FPdssv, a_ISLdssv)
- un-vegetated wet sand (ws: a_FPws, a_ISLws)
- sparsely vegetated wet substrate (wssv: a_FPwssv, a_ISLwssv)

Total ESH area is calculated by **calcESH** using the following Field Calculator expression:

```
ESH = (a_FPds + a_ISLds) + (a_FPdssv + a_ISLdssv)
```

```
            + (a_FPws + a_ISLws) + (a_FPwssv + a_ISLwssv)
```

The **calcESH** tool also adds an additional field *ESHCLASS* which is identifies each feature as either a floodplain (FP) or island (ISL) object. This is achieved based on a comparison of the total floodplain land cover area to the total island land cover area, i.e.

```
      IF (a_FPds + a_FPdssv + a_FPws + a_FPwssv) > (a_ISLds + a_ISLdssv
            + a_ISLws + a_ISLwssv)
            ESHCLASS = "FP"
      ELSE
            ESHCLASS = "ISL"
```

In a small number of cases, a floodplain geomorphic object may contain both ISL and FP land cover classes. As a result of the calculations and logic described above, the ISL area component is reclassified as FP area in these cases as the ISL area component is much smaller than the FP area component. If the ESH objects were extracted using extractESHWEST, the value of *ESHCLASS* will always be "ISL".

G.5.13. Step 8: Adjust ESH area to baseline discharge

The Adaptive Management plan uses a scaling factor to adjust measurements of ESH area to a baseline discharge of 31,500 cfs. The formula is based on the survey data collected by WEST (2014) and is defined as

$$ESH_{base} = \frac{ESH_q}{a} e^{bQ}$$

where ESH_{base} is the adusted "baseline" ESH, Q is the discharge in kcfs, ESH_q is ESH area measured at that discharge, and the parameters a and b are empirical. The tool **calcBaseESH** computes the baseline ESH using the attribute fields a_ESH and *TOTAL_DISCHARGE_CFS*, and adds the field $a_baseESH$ to the attribute table. The tool automatically adjusts the discharge units from cfs to kcfs, and allows the parameters a and b to be overridden (Figure G 8).

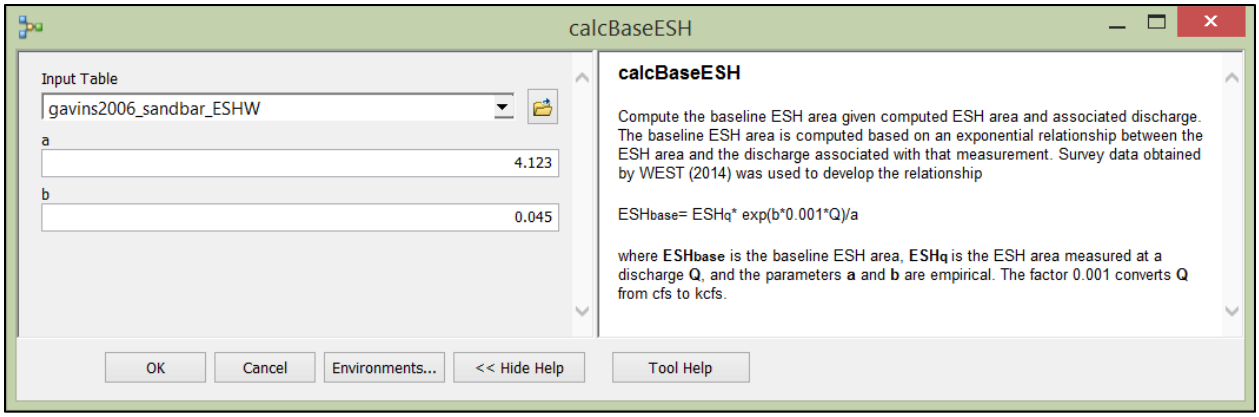


Figure G 8: Compute the baseline ESH area using calcBaseESH.

G.5.14. Step 9: Summarize ESH

In most cases we are interested in computing summary statistics of ESH, such as the total ESH area and the total number of ESH objects in the reach. The tool **summarizeESH** computes summary statistics for ESH including the total ESH area, the minimum and maximum ESH area associated with a single geomorphic object; and the average and standard deviation of ESH area across the geomorphic features (Figure G 9). By default the statistics are computed for the field *a_baseESH*, but statistics of other fields such as the raw ESH area or specific land cover classes can also be computed.

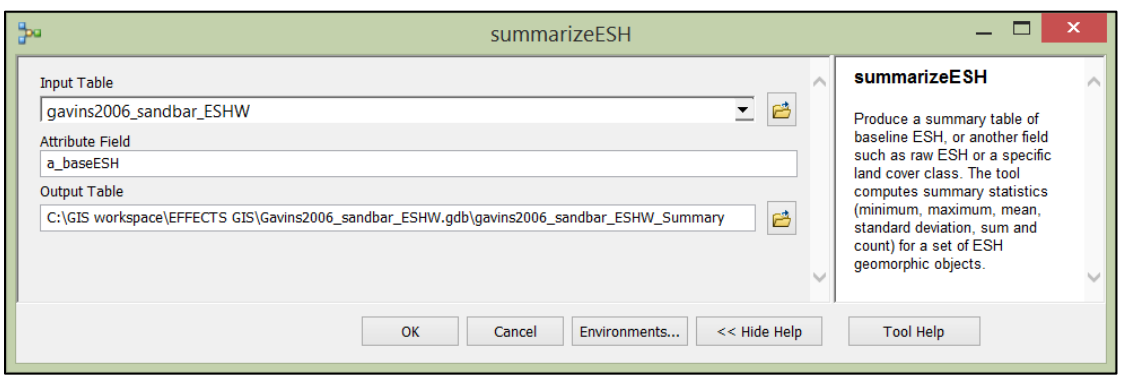


Figure G 9: Using summarizeESH to compute summary statistics for baseline ESH area.

Attachment G.6 Missouri River Emergent Sandbar Habitat Evaluation and Ranking system (ESHER)

The ESHER is a spatial decision support tool developed for evaluating and selecting new ESH restoration sites according to the 2003 BiOp. This attachment describes ESHER, contains detailed descriptions of all the default variables that can be used in an ESHER assessment, and provides instructions on applying and making modifications to the tool.

G.6.15. Description of ESHER

G.6.15.1. General Overview

ESHER is a spatial decision support system (SDSS) that was created using the ArcGIS ModelBuilder application and is run out of the ArcToolbox program (Figure 1). The tool consists of 7 distinct modules. Three of the modules (Calculate Variable Values, Scale Variables (Site Evaluation) and Scale Variables (Reach Evaluation)) are for pre-processing data; these modules need to be run before the 2 primary modules (ESHER Site Evaluation and ESHER Reach Evaluation) can be run. The last 2 modules (Create Site Scaled Variable Output, Part 1 and Part 2) are used to create an optional site evaluation output that depicts the un-weighted, scaled variable scores for each of the sites being evaluated. The Calculate Variable Values pre-processing module requires an ArcINFO level license in order to be run, all other modules can be run using the basic ArcView level license.

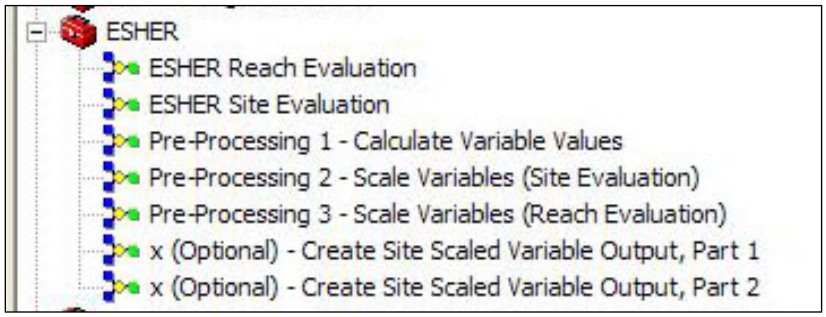


Figure G 10:. The ESHER ArcToolbox interface.

The ESHER Site Evaluation (ESE) module is used to score and rank potential ESH restoration sites that have already been pre-selected by the end-user. The ESHER Reach Evaluation (ERE) module calculates scores for every 10 meter x 10 meter cell contained in the Fort Randall, Fort Peck, Gavins Point, Garrison, and Lewis and Clark Lake segments. The output from the ESHER Reach Evaluation can then be used as a basis for identifying additional ESH restoration sites (which in turn can then be further evaluated with the ESE module).

The ESE and ERE modules allow the basic end-user to assign weights to pre-scaled, model variables. The ESE module includes 25 variables while the ERE module contains 18 variables. The ERE has less variables because it does not include any site-specific variables (size of restoration area, for instance). More advanced users can adjust the scaling of these variables by making edits to the "Scale Variables" (Pre-Processing 2 and Pre-Processing 3) modules (See Chapter 4).

2. ESHER Variables

The following section contains information on each of the variables that are included in the ESE and ERE modules. The variables chosen for inclusion in the model were based on input from a multi-agency project delivery team (PDT), which included personnel from the USACE, National Park Service, US Fish and Wildlife Service, Natural Resources Conservation Service, US Geological Survey, Nebraska Game and Parks Commission, South Dakota Department of Game, Fish, and Parks, North Dakota Game and Fish Department, and North Dakota State Water Commission. These variables are indicators of various management preferences for site selection, such as sandbar sustainability, nesting and habitat suitability, and limiting impact to other environmental and anthropogenic resources.

Information on each of the variables is included in the following format:

Relevant module: ESE, ERE, or both.

Data source and processing: Where the data layer was derived from, and a basic description of the process used to derive it.

Purpose: Justification for why the variable is included in the module(s).

Scaling: Default scaling that is used in the module(s), and an explanation as to how that scaling was determined.

Limitations: Any significant factors which could potentially affect the accuracy of the variable.

Three additional notes – 1) all raster geoprocessing functions (such as Euclidian Distance) were run using 10 meter x 10 meter cell sizes, 2) the distance of potential restoration sites to a given feature was calculated as the average distance of all cells within that site to the feature, and 3) reach habitat delineations and "sensitive resource" spatial data were provided by a USACE contractor, David Miller and Associates (DMA).

C.5.1.1.1 2.1. Channel Width

Relevant Module: ESE, ERE

Data source and processing: Channel widths were derived from the 2005 reach habitat delineations, using the following process: Channel "top" and "bottom" banks were created as polylines based on the outer edges of the habitat delineation, excluding riverine forest and shrub habitats. If there were large islands (categorization of island size was a subjective judgment) within the channel, additional top and bottom channels were created within the primary channel banks to account for these islands. The "Euclidian Distance" geoprocessing function was run using each bank as a source. The two resulting rasters were then added together. Finally, an extraction on the combined raster was performed using the original habitat delineation as a mask. Channel width for a potential site was measured as the average channel width across the length of the site. Widths derived from Elliott and Jacobson (2006) were used to cross-check this methodology to ensure that results of the ESHER processing method are similar to those used to establish the scaling for this variable.

Purpose: The channel width is an important variable for creation of sandbar habitats, as width of the channel will affect the erosion rates at the sandbar. Additionally, existing emergent sandbars and shallowly submerged sandbars occurring in depositional areas are often used as a base on which to construct ESH in order to limit the potential for changes to channel geomorphology as a result of the project and reduce the amount of fill needed for construction.

Scaling: The scaling of this variable is specific to each reach, and is shown in the table below.

Table G 1: Scaling of Channel Width variable.

	Channel Width (m)				
	Gavins Point	Lewis & Clark	Fort Randall	Garrison	Fort Peck
Score	Width	Width	Width	Width	Width
10	975	All	800	693	327
9	945		778	686	319
8	914		756	679	311
7	884		734	672	303
6	853		711	665	295
5	822		689	658	287
4	792		667	651	279
3	761		645	644	271
2	731		623	637	263

	Channel Width (m)				
	Gavins Point	Lewis & Clark	Fort Randall	Garrison	Fort Peck
Score	Width	Width	Width	Width	Width
1	700		600	630	255
0	< 700		< 600	< 630	< 255

Elliott and Jacobson (2006) reported mean channel widths that had sustained sandbars and transition zone channel widths below which sandbars are not likely to exist for Gavins Point and Fort Randall reaches. Biedenharn et al. (2001) reported similar information for Garrison and Fort Peck reaches. Channel widths that are the mean value for sustained sandbars or higher for a given reach receive a score of 10, while widths that are less than the transition zone width receive a score of 0. Because Lewis & Clark reach is a lake, erosion is not an issue and all potential restoration sites in that reach receive a score of 10 for the variable. Variable scaling for the remaining scores was determined according to a linear distribution of widths between the mean high value and the transition zone value.

Limitations: Scaling is based on channel widths that were determined by Elliott and Jacobson (2006) and Biedenharn et al. (2001). Although some spot checking was done, these widths may not always correspond with the channel widths that were calculated in this model.

2.2. Total Cumulative Historical Tern and Plover Nests

Relevant Module: ESE

Data source and processing: Nest counts were based on field surveys done from 1998 to the present. Only points with a high location accuracy (meaning a GPS position of the point was taken) are used in this analysis. Nests per site are calculated using the Spatial Join geoprocessing function to join the nest points input shapefile to the potential restoration sites input shapefile.

Purpose: It is assumed that sites with more nests historically will also have more nests in the future, once the area is restored. Additionally, one of the two target species (piping plover) is known to give preference to previously used sites when undertaking nest site selection (Haig and Oring, 1988).

Scaling: The scaling of this variable is specific to each reach, and is shown in Table G 2.

Table G 2: Scaling of Total Cumulative Tern and Plover Nests variable.

	Total Cumulative Historical Tern and Plover Nests				
	Gavins Point	Lewis & Clark	Fort Randall	Garrison	Fort Peck
Score	Nests	Nests	Nests	Nests	Nests
10	308	35	129	79	33
9	274	31	115	70	29
8	240	27	101	62	26
7	206	24	86	53	22
6	172	20	72	44	19
5	137	16	58	36	15
4	103	12	44	27	12
3	69	9	29	18	8
2	35	5	15	10	5
1	1	1	1	1	1
0	0	0	0	0	0

For each reach, the maximum number of cumulative historical nests that were found at a single site was measured. Potential restoration sites within the reach that have this many historical nests or greater receive a score of 10. Potential sites with no historical nests receive a score of 0, and sites with at least one nest receive a score of 1. Variable scaling for the remaining scores was determined according to a linear distribution of historical nests between 1 and the maximum number of historical nests.

Limitations: None

C.5.1.1.2 2.3. Size of Potential Restoration Area

Relevant Module: ESE

Data source and processing: Areas are determined within ArcGIS, based on the estimated footprint of the potential restoration site.

Purpose: Larger restoration sites provide the potential to construct sandbar complexes of optimum size. Additionally, there is increased cost efficiency with larger construction projects as a large percentage of construction costs are attributable to mobilization of equipment. This means it is less expensive to construct one 60 acre complex when compared to two geographically separate 30 acre complexes.

Scaling: The scaling of this variable is shown in Table G 3.

Table G 3: Scaling of Size of Potential Restoration Area variable.

Size of Potential Restoration Area (Acres)	
ALL Segments	
Score	Acres
10	60
9	54
8	48
7	41
6	35
5	29
4	23
3	16
2	10
1	4
0	< 4

The USFWS 2003 Amended Biological Opinion recommends 60 acres as the optimum size and 4 acres as a minimum size for emergent sandbar habitats. Therefore, potential sites 60 acres or larger receive a variable score of 10, and sites smaller than 4 acres receive a score of 0. The rest of the variable scaling was determined according to a linear distribution of sizes between the minimum and optimum site sizes among the remaining scores.

Limitations: Due to the dynamic nature of the Missouri River, potential site polygons may not accurately reflect the actual footprint of a complex at the time of construction.

C.5.1.1.3 2.4. Primary Site Condition

Relevant Module: ESE

Data source and processing: This score is manually assigned to potential restoration sites based on its existing characteristics as derived from site visits and/or the most recent available aerial photography.

Purpose: This variable is an indicator of the amount of work and cost (adding sand and removing vegetation) that would be required to restore or create a site, as well as previous levels of success that have been achieved in restoring sites of a given condition.

Scaling: The scaling of the variable is shown in Table G 4.

Table G 4. Scaling of Primary Site Condition variable.

Primary Site Condition		
ALL Segments		
Score	Condition	Code
10	Shallow Water	SW
7	Sparsely Vegetated Existing Bar	SVB
5	Existing Vegetated Bar	EVB
0	Open Water	OW

The shallow water condition would require a medium amount of sand for construction but would not require initial vegetation removal, and there has been previous success under these conditions. Sparsely vegetated and existing vegetated bars would require minimal sand for construction, but would require initial vegetation removal, and there has been no previous success in restoring these condition types. Open water areas would require a maximum amount of sand, and there have been no previous successes in this condition type.

Limitations: None

2.5. Distance to Existing Nest Site Complexes

Relevant Module: ESE, ERE

Data source and processing: Existing nest counts were based on field surveys done in the prior year (i.e., a 2009 site evaluation would be based on 2008 nest counts). Existing nests that were part of a complex that included at least 5 total nests were selected, and the "Euclidian Distance" function was used to determine the distance from each cell in a reach to the nearest one of these nest complexes. Defining a complex as having a minimum of 5 nests was based on best professional judgment, using the rationale that this number would eliminate outliers and would be some indication of nesting site quality and/or preference.

Purpose: One of the priorities for restoration is to restore habitats in areas that do not have an abundance of existing nesting habitat.

Scaling: The scaling of the variable is shown in Table G 5.

Table G 5: Scaling of Distance to Existing Nest Site Complexes variable.

Distance (miles) to Existing Nest Site Complexes
ALL Segments

Score	Distance
10	20
9	18
8	16
7	14
6	12
5	10
4	8
3	6
2	4
1	2
0	0

In the reach with the most distance between nest sites, Fort Peck, nests can be 20 miles apart or greater. Therefore, cells that are ≥ 20 miles away from existing nest site receive a score of 10. Cells that are adjacent to existing sites (less than 2 miles) receive a score of 0. The rest of the variable scaling was determined according to a linear distribution of distances between 1 and 20 miles among the remaining scores.

Limitations: None

2.6. Presence of Wetlands

Relevant Modules: ESE, ERE

Data source and processing: Wetlands were identified in the 2005 habitat delineations. For potential restoration sites, the percentage of the site that consisted of wetlands was calculated within ArcGIS.

Purpose: ESH restoration should ideally minimize impacts to wetland areas, as they are protected under Section 404 of the Clean Water Act. With regard to this variable alone, the ideal ESH project would not impact any existing wetlands.

Scaling: The scaling for the ESE module is shown in Table G 6. For the ERE module, a simple presence/absence scale is used: if a cell contains wetland a score of 0 is assigned, if a cell does not contain wetland, a score of 10 is assigned.

Table G 6: Scaling of Presence of Wetlands variable for ESE module.

Presence of Wetlands	
	ALL Segments
Score	Percentage of Wetland
10	0%
9	10%
8	20%
7	30%
6	40%
5	50%
4	60%
3	70%
2	80%
1	90%
0	100%

Potential restoration sites that contain no wetlands receive a score of 10, while sites that are entirely wetland receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of percentages between 0 and 100.

Limitations: Habitat delineations indicating the presence of wetlands at a proposed site do not necessarily indicate the presence of jurisdictional wetlands subject to the provisions of the Clean Water Act.

2.7. Distance to Protected Shoreline

Relevant Modules: ESE, ERE

Data source and processing: Protected areas were identified from the National Park Service Landowner Database, and will be updated in the near future with lands owned by States, the Federal government, and conservation groups that limit development. The “Euclidian Distance” geoprocessing function was run to determine the distance from each cell within a reach to nearest one of these features.

Purpose: Human disturbance of nesting sites is a concern for the ESH program, as is public perception of erosion caused by the placement of projects. While there has been no conclusive evidence of erosion being caused by the restoration of ESH, restoration activities adjacent to publicly owned lands or parcels protected by easements are seen as preferable because this is seen to limit the potential for disturbance due to human development as well as reducing the potential for perceived erosion issues.

Scaling: The scaling of the variable is shown in Table G 7.

Table G 7. Scaling of Distance to Protected Shoreline variable.

Distance to Protected Shoreline (m)	
	ALL Segments
Score	Distance
10	402
9	764
8	1,127
7	1,489
6	1,851
5	2,213
4	2,575
3	2,937
2	3,299
1	3,661
0	4,023

A general assumption was made that sites within ¼ mile (402 meters) of a protected shoreline are more likely to be bordered by this type of shoreline on at least one bank, while sites greater than 2.5 miles (4,023 meters) from a protected shoreline are unlikely to be bordered by this type of shoreline on either bank. Therefore, cells that are ≤ 402 meters away from a protected shoreline receive a score of 10, and cells that are ≥ 4,023 meters from a protected shoreline receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 402 and 4,023 meters.

Limitations: This variable acts as an approximate surrogate for a "percentage of adjacent shoreline that is protected" variable. That variable was not used in the model due to the difficulty of automating the calculation.

2.8. Potential for Backwater Restoration

Relevant Module: ESE

Data source and processing: Potential restoration sites were manually designated as being either associated or not associated with historic backwater areas, based on field determinations and/or analysis of aerial photography.

Purpose: The presence of historic backwaters provides the potential for floodplain features to be restored in conjunction with ESH restoration. While these features are beneficial to the general riverine ecosystem, they also represent a habitat type important to the food source of one of the two target species, least tern. When coupling backwater restoration with ESH creation, it is assumed that least terns will benefit from this increase in foraging habitat adjacent to the nesting site.

Scaling: Sites that have the potential for backwater restoration are given a score of 10, sites without that potential are given a score of 0.

Limitations: None

2.9. D50 Sediment Size

Relevant Module: ESE

Data source and processing: This variable was generated based on sediment samples that had been taken at various locations within the reaches between 1984 and 2007. The "Near" geoprocessing function is used to determine the sample that is closest to the potential restoration site, and the sediment size of that sample is assigned to the site.

Purpose: This variable is assumed to be representative of the abundance of "suitable" material in the vicinity of a proposed restoration site. In areas where suitable material is not abundant, targeted surveys have been necessary in order to identify potential borrow areas. This leads to increases in project cost and time needed for construction activities.

Scaling: The scaling of this variable is specific to each reach, and is shown in Table G 8.

Table G 8. Scaling of D50 Sediment Size variable.

	D50 Sediment Size (mm)				
	Gavins Point	Lewis & Clark	Fort Randall	Garrison	Fort Peck
Score	D50	D50	D50	D50	D50
10	> 0.38		> 0.27	> 0.21	> 0.25
5	0.30 - 0.38		0.20 - 0.27	0.20 - 0.21	0.22 - 0.25
0	< 0.30	All	< 0.19	< 0.20	< 0.22

Biedenharn et al (2001) reported by reach the average D50 sediment sizes for both plover habitat and non-plover habitat sandbars. For the Gavins, Fort Randall, Garrison, and Fort Peck reaches, sites that are associated with D50 sediment sizes that are greater than the reach average for habitat sandbars receive a score of 10, sites with sediment sizes less than the reach average for non-habitat sandbars receive a score of 0, and sites with sediment sizes that are between the habitat and non-habitat averages are given a score of 5. All potential sites within the Lewis and Clark reach are given a variable score

of 0, since previous efforts in that reach have required surveys in order to identify borrow sources with suitable material.

Limitations: The assumption is being made that the sediment size at the closest sediment sample point is representative of the borrow area adjacent to the potential restoration site. Due to the sporadic distribution of sediment points, this assumption may not always be accurate.

2.10. Distance to Mainstem Dam

Relevant Module: ESE, ERE

Data source and processing: River distance from each reach cell to the nearest mainstem dam was calculated using the "Cost Distance" geoprocessing function on a rasterized version of the 2005 reach habitat delineations, with all cells assigned a value of 1.

Purpose: Directly downstream of dams there is limited nesting activity and potential for restoration is limited due to degradation and/or increased influence of power-peaking flows.

Scaling: The scaling of this variable is specific to each reach and is shown in Table G 9.

Table G 9. Scaling for Distance to Mainstem Dam variable.

	Distance to Mainstem Dam (m)				
	Gavins Point	Lewis & Clark	Fort Randall	Garrison	Fort Peck
Score	Distance	Distance	Distance	Distance	Distance
10	17,678	9,449	49,987	28,651	93,299
9	16,256	8,568	45,375	27,059	84,728
8	14,834	7,688	40,762	25,468	76,156
7	13,411	6,807	36,149	23,876	67,584
6	11,989	5,927	31,537	22,284	59,013
5	10,566	5,046	26,924	20,693	50,441
4	9,144	4,166	22,311	19,101	41,869
3	7,722	3,285	17,699	17,509	33,298
2	6,299	2,405	13,086	15,917	24,726
1	4,877	1,524	8,473	14,326	16,154
0	< 4,877	< 1,524	< 8,473	< 14,326	< 16,154

For each reach, the river distance from the dam to the first major mainstem tributary was measured. Cells that are this distance or greater from a dam receive a score of 10. For each reach, the closest recorded nest to each dam was also determined. Cells that

are less than this distance away from a dam receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between the closest nest distance and the distance to the nearest major tributary.

Limitations: None

2.11. Historic Predation Events

Relevant Module: ESE

Data source and processing: Field survey nest counts also contain a record of which nests experienced predation. This information is used to determine the number of historical nests that had been predated at each potential restoration site.

Purpose: It is assumed that sites with less historical predation will likely experience lower levels of future predation.

Scaling: The scaling of this variable is specific to each reach and is shown in Table G 10.

Table G 10. Scaling for Historic Predation Events variable.

	Historic Predation Events				
	Gavins Point	Lewis & Clark	Fort Randall	Garrison	Fortt Peck
Score	Events	Events	Events	Events	Events
10	0	0	0	0	0
9	4	2	2		
8	8	5	5		
7	13	7	7		
6	17	10	9	1	
5	21	12	12		
4	25	14	14		
3	29	17	16		1
2	34	19	18	2	
1	38	22	21		
0	42	24	23	3	2

For each reach, the highest number of predated nests at any one historical site was determined. Proposed restoration sites that had this many events or more receive as score of 0. Sites with no historical predation receive a score of 10. Variable scaling for the remaining scores was determined according to a linear distribution of predation events between 0 and the historical maximum.

Limitations: As nest surveys at individual sites may be conducted a week apart or more, it is difficult to accurately capture when a nest is predated. Thus, predation records may not be entirely representative of the rate of predation at various sites.

2.12. Distance to Treeline

Relevant Module: ESE, ERE

Data source and processing: For all reaches with the exception of Lewis & Clark, treelines were obtained from the DMA sensitive resources data. For Lewis & Clark reach, the treeline was defined by the riverine forest habitat class due to unavailability of the treeline shapefile for this reach. The "Euclidian Distance" geoprocessing function is used to determine the distance of every cell within a reach to the nearest treeline.

Purpose: Analysis of nesting data conducted as part of the Programmatic Environmental Impact Statement for the Emergent Sandbar Habitat Program (PEIS) indicate that terns and plovers displayed preferential nesting site-selection of areas farther away from treelines. It is assumed that nests on restored sites that are further away from a treeline will be less susceptible to predation from raptors.

Scaling: The scaling of this variable is shown in Table G 11.

Table G 11. Scaling for Distance to Treeline variable.

Distance to Existing Tree Line (m)	
	All Segments
Score	Distance
10	290
9	249
8	208
7	168
6	154
5	141
4	128
3	115
2	102
1	88
0	< 88

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to a treeline. Cells that are the average separation distance or further from a treeline receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from

a treeline) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between the minimum and 95% separation distance, and the 95% separation distance and average distance.

Limitations: None

2.13. Distance to Boat Ramp

Relevant Module: ESE, ERE

Data source and processing: Boat ramps were identified from the DMA sensitive resources data. The "Euclidian Distance" geoprocessing function is used to determine the distance of every cell within a reach to the nearest boat ramp.

Purpose: Boat ramps are a source of human disturbance, and plovers and terns tend to nest further away from these areas. It is assumed that selecting potential sites farther away from boat ramps will reduce the potential for human disturbance at a restored site.

Scaling: The scaling of this variable is shown in

Table G 12. Scaling for Distance to Boat Ramp variable.

Distance to Boat Ramp (m)	
	All Segments
Score	Distance
10	743
9	571
8	400
7	229
6	209
5	189
4	170
3	150
2	130
1	111
0	< 111

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to a boat ramp. Cells that are the average separation distance or further from a boat ramp receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from a boat ramp) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Variable scaling for the remaining scores was

determined according to a linear distribution of distances between the minimum and 95% separation distance, and the 95% separation distance and average distance.

Limitations: None

2.14. Distance to Boat Dock

Relevant Module: ESE, ERE

Data source and processing: Boat docks were identified from the DMA sensitive resources data. The "Euclidian Distance" geoprocessing function is used to determine the distance of every cell within a reach to the nearest boat dock. Selecting potential sites farther away from boat docks will reduce the potential for human disturbance.

Purpose: Boat docks are a source of human disturbance, and plovers and terns tend to nest further away from these. It is assumed that selecting potential sites farther away from boat docks will reduce the potential for human disturbance at a restored site.

Scaling: The scaling of this variable is shown in Table G 13.

Table G 13. Scaling for Distance to Boat Dock variable.

Distance to Boat Dock (m)	
	All Segments
Score	Distance
10	542
9	417
8	292
7	168
6	157
5	146
4	136
3	125
2	115
1	104
0	< 104

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to a boat dock. Cells that are the average separation distance or further from a boat dock receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from a boat dock) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Variable scaling for the remaining scores was

determined according to a linear distribution of distances between the minimum and 95% separation distance, and the 95% separation distance and average distance.

Limitations: None

2.15. Distance to Domicile

Relevant Module: ESE, ERE

Data source and processing: Domiciles were identified from the DMA sensitive resources data. The "Euclidian Distance" geoprocessing function is used to determine the distance of every cell within a reach to the nearest domicile.

Purpose: Domiciles are a source of human disturbance, and plovers and terns tend to nest further away from these. Potential sites farther away from domiciles are assumed to have a reduced potential for human disturbance.

Scaling: The scaling of this variable is shown in Table G 14.

Table G 14. Scaling for Distance to Domicile variable.

Distance to Domicile (m)	
	All Segments
Score	Distance
10	682
9	541
8	400
7	259
6	251
5	243
4	235
3	227
2	218
1	210
0	< 210

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to a domicile. Cells that are the average separation distance or further from a domicile receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from a domicile) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between the minimum and 95% separation distance, and the 95% separation distance and average distance.

Limitations: None

2.16. Distance to Water Intake

Relevant Module: ESE, ERE

Data source and processing: Water Intakes were identified from the DMA sensitive resources data. The "Euclidian Distance" geoprocessing function is used to determine the distance of every cell within a reach to the nearest water intake.

Purpose: It is desirable to avoid restoration in areas that have the potential to impact water intakes through either sedimentation or changes in water quality.

Scaling: The scaling of this variable is shown in Table G 15.

Table G 15. Scaling for Distance to Water Intake variable.

Distance to Water Intake (m)	
	All Segments
Score	Distance
10	713
9	562
8	410
7	259
6	253
5	246
4	240
3	234
2	228
1	221
0	< 221

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to a water intake. Cells that are the average separation distance or further from a water intake receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from a water intake) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between the minimum and 95% separation distance, and the 95% separation distance and average distance.

Limitations: None

2.17. Distance to Recreation Area

Relevant Module: ESE, ERE

Data source and processing: Recreation areas were identified from the DMA sensitive resources data. The "Euclidian Distance" geoprocessing function is used to determine the distance of every cell within a reach to the nearest recreation area.

Purpose: Recreation is a source of human disturbance, and plovers and terns tend to nest further away from these areas. Potential projects farther away from recreation areas have a higher potential for reduction in human disturbance.

Scaling: The scaling of this variable is shown in Table G 16.

Table G 16. Scaling for Distance to Recreation Area variable.

Distance to Recreation Area (m)	
	All Segments
Score	Distance
10	398
9	336
8	275
7	213
6	189
5	164
4	139
3	114
2	90
1	65
0	< 65

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to a recreation area. Cells that are the average separation distance or further from a recreation area receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from a recreation area) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between the minimum and 95% separation distance, and the 95% separation distance and average distance.

Limitations: None

2.18. Distance to Urban Zone (Bismarck)

Relevant Module: ESE, ERE

Data source and processing: The "Euclidian Distance" geoprocessing function is used to determine the distance of every cell within a reach to the heavily urbanized zone of the river near the city of Bismarck, ND.

Purpose: Heavily urbanized areas along the river present the highest risk of human disturbance. The only heavily urbanized area relevant to this tool is that of Bismarck, ND. Projects located away from this urban zone are assumed to have a decreased risk of human disturbance.

Scaling: The scaling of this variable is shown in Table G 17.

Table G 17. Scaling for Distance to Urban Zone (Bismarck) variable.

Distance to Urban Zone (m)	
	All Segments
Score	Distance
10	32,187
9	28,968
8	25,750
7	22,531
6	19,312
5	16,093
4	12,875
3	9,656
2	6,437
1	3,219
0	0

Anecdotal evidence suggests that recreational boaters will travel up to 20 miles (32, 187 meter) along the river away from Bismarck. Cells farther than 32,187 meters away receive a score of 10, while cells adjacent to Bismarck receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 0 and 32,187.

Limitations: None

2.19. Distance to Bald Eagle Nest

Relevant Module: ESE, ERE

Data Source and Processing: The "Euclidian Distance" geoprocessing function is used to determine the distance between every cell within a reach to the closest bald eagle

nest. Bald eagle nest locations are from National Park Service field surveys and will be updated in the near future with records from states and other agencies.

Purpose: Restoration activities should avoid impacts to bald eagle nests, in accordance with the Bald and Golden Eagle Protection Act.

Scaling: The scaling of this variable is shown in Table G 18.

Table G 18. Scaling for Distance to Bald Eagle Nest variable.

Distance to Bald Eagle Nest (m)	
	All Segments
Score	Distance
10	1,609
9	1,448
8	1,287
7	1,127
6	966
5	805
4	654
3	503
2	352
1	201
0	< 201

Written comments by the USFWS (2004) to the Omaha District recommended a separation distance of 1 mile (1,609 meters) between bald eagle nests and construction activities. Following the removal of the Bald Eagle from the Endangered Species List, the USFWS National Bald and Golden Eagle Management Guidelines (2007) recommended separation distances of ½ mile (805 meters) for construction activities producing loud noises, and 1/8 mile (201 meters) for construction activities that would be visible from a nest. Based on the 2004 and 2007 guidelines, cells that are ≥ 1,609 meters from a bald eagle nest receive a score of 10, cells that are 805 meters from a nest receive a score of 5, and cells < 201 meters from a nest receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 805 and 1,609 meters, and between 201 and 805 meters.

Limitations: None

2.20. Distance to Cultural Resources

Relevant Module: ESE, ERE

Data Source and Processing: The "Euclidian Distance" geoprocessing function is used to determine the distance between every cell within a reach to the closest cultural resource. Cultural resource locations are from internal USACE databases.

Purpose: Cultural Resources and historic properties are protected by numerous federal and state laws, and impacts to known sites should be avoided if possible. Potential sites that are farther from known cultural resources would require less intensive efforts to comply with applicable laws, resulting in reduced time and cost for program implementation.

Scaling: The scaling of this variable is shown in Table G 19.

Table G 19. Scaling for Distance to Cultural Resources variable.

Distance to Cultural Resources (m)	
	All Segments
Score	Distance
10	1,609
9	1,448
8	1,287
7	1,127
6	966
5	805
4	704
3	604
2	503
1	402
0	< 402

Based on expert opinion (Barnum 2009), activities greater than 1 mile (1,609 meters) away from a cultural resource are unlikely to have any impact on it; activities half a mile (805 meters) away are also unlikely to have an impact but on-site investigations may be warranted; activities within a quarter-mile (402 meters) would likely warrant an on-site investigation and potentially the supervision of construction activities. Based on these recommendations, cells ≥ 1,609 meters away from a cultural resource receive a score of 10, cells 805 meters away receive a score of 5, and cells < 402 meters away receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 805 and 1,609 meters, and between 402 and 805 meters.

Limitations: None

2.21. Distance to Bridges

Relevant Module: ESE, ERE

Data Source and Processing: Bridges were identified from the DMA sensitive resources layer. The "Euclidian Distance" geoprocessing function is used to determine the distance between every cell within a reach to the closest bridge.

Purpose: Restoration projects should avoid bridges in order to prevent any accidental damage that may occur to the bridge during construction. Bridges also present a form of potential noise and visual disturbance to nesting birds.

Scaling: The scaling of this variable is shown in 20.

Table G 20. Scaling for Distance to Bridges variable.

Distance to Bridges (m)	
	All Segments
Score	Distance
10	823
9	741
8	658
7	576
6	494
5	411
4	329
3	247
2	165
1	82
0	0

On the Missouri River, the closest distance a successful nest on record was to a bridge was 823 meters. Cells that are this distance or further away from a bridge receive a score of 10. Cells adjacent to a bridge receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 0 and 823 meters.

Limitations: None

2.22. Distance to Industrial Facilities

Relevant Module: ESE, ERE

Data Source and Processing: Industrial facilities were identified from the DMA sensitive resources layer. The "Euclidian Distance" geoprocessing function is used to determine the distance between every cell within a reach to the closest industrial facility.

Purpose: Restoration projects should avoid industrial facilities in order to prevent any accidental damage that may occur to the facility during construction. Industrial facilities also present a form of potential disturbance to the habitat.

Scaling: The scaling of this variable is shown in Table G 21.

Table G 21. Scaling for Distance to Industrial Facilities variable.

Distance to Industrial Facilities (m)	
	All Segments
Score	Distance
10	205
7	168
1	160
0	< 160

DMA calculated across all reaches the average, minimum, and 95% separation distance of all recorded historical nests (from 1998-2006) to an industrial facility. Cells that are the average separation distance or further from an industrial facility receive a score of 10, cells that are at the 95% separation distance (95% of historical nests were this distance or further away from an industrial facility) receive a score of 7, and cells at the minimum separation distance or below receive a score of 0. Due to the limited range of distance values, additional scores were not utilized for this variable.

Limitations: None

2.23. Distance to Power Stations

Relevant Module: ESE, ERE

Data Source and Processing: Power stations were identified from the DMA sensitive resources layer. The “Euclidian Distance” geoprocessing function is used to determine the distance between every cell within a reach to the nearest power station.

Purpose: Restoration projects should avoid power stations in order to prevent any accidental damage that may occur to the station during construction. Power stations also present a form of potential disturbance to the habitat.

Scaling: The scaling of this variable is shown in Table G 22.

Table G 22. Scaling for Distance to Power Stations variable.

Distance to Power Stations (m)	
	All Segments
Score	Distance
10	3,810
9	3,598
8	3,387
7	3,175
6	2,963
5	2,752
4	2,540
3	2,328
2	2,117
1	1,905
0	< 1,905

The Montana-Dakota Utility agency has requested a separation distance of at least 3,810 meters between power stations and restoration sites. Also, the closest distance a successful nest on record was to a power station was 1,905 meters. Therefore, cells that are ≥ 3,810 meters away from a power station receive as score of 10, while sites < 1,905 meters away receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 1,905 and 3,810 meters.

Limitations: None

2.24. Distance to Utilities

Relevant Module: ESE, ERE

Data Source and Processing: Utilities (pipelines, powerlines, and cables) were identified from the DMA sensitive resources layer. The "Euclidian Distance" geoprocessing function is used to determine the distance between every cell within a reach to the nearest utility.

Purpose: Restoration projects should avoid utilities in order to prevent any accidental damage that may occur to the station during construction. Utilities also present a form of potential disturbance to nesting birds.

Scaling: The scaling of this variable is shown in Table G 23.

Table G 23. Scaling for Distance to Utilities variable.

Distance to Utilities (m)	
	All Segments

Score	Distance
10	1,609
9	1,456
8	1,303
7	1,149
6	996
5	842
4	689
3	535
2	382
1	229
0	< 229

A separation distance of one 1 mile (1,609 meters) was deemed a reasonable separation distance for avoiding accidental impacts to utilities from construction activities as this represents the maximum distance dredged material can be transported before an additional "booster" pump is needed and is also likely to be the maximum extent of a borrow area in any one direction from a restoration site. Additionally, this distance should be adequate for reducing impacts to birds from overhead power lines. Also, the closest distance a successful nest on record was to a utility was 229 meters. Therefore, cells that are ≥ 1,609 meters away from a utility receive as score of 10, while sites < 229 meters away receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of distances between 229 and 1,609 meters.

Limitations: None

2.25. Pallid Sturgeon Samples Within ½ Mile

Relevant Module: ESE

Data Source and Processing: Pallid sturgeon locations are based on field sampling data from 2003-2009, provided by the Pallid Sturgeon Population Assessment team. A ½ mile radius buffer, representing an average sediment borrow area at an ESH construction site, is created around each of the potential restoration sites, and then the Spatial Join geoprocessing function is used to determine the number of pallid sturgeon samples located in each buffer zone.

Purpose: Pallid sturgeons are a federally endangered species. Construction of restoration sites should avoid impacts to pallid sturgeon habitat. This variable uses the presence of multiple pallid sturgeons in a limited area (or recurring use by a single individual within the same area) as an indicator of pallid sturgeon habitat.

Scaling: The scaling of this variable is shown in Table G 24.

Table G 24. Scaling for Pallid Sturgeon Samples variable.

Number of Pallid Samples	
	All Segments
Score	Distance
10	0
9	9
8	17
7	26
6	35
5	44
4	52
3	61
2	70
1	78
0	87

A GIS analysis was performed to determine the highest number of pallid sturgeon samples found within any half-mile radius area surrounding a single pallid sturgeon sample. The half-mile radius was used to represent a typical borrow area for an ESH project. The highest number of samples found within one of these areas was 87, which represents the least desirable situation with regard to this variable. Therefore, potential restoration sites that have 87 or more samples within ½ mile receive a score of 10. Sites with no samples within ½ mile receive a score of 0. Variable scaling for the remaining scores was determined according to a linear distribution of samples between 0 and 87.

Limitations: The assumption is being made that the repeated presence of pallid sturgeon in a given area is indicative of that area having some degree of suitability as habitat for the species. However, this assumption has not been tested. This variable is being used because data on locations of actual pallid sturgeon habitat and spawning areas is not currently available; if these data do become available in the future the variable should be modified in order to incorporate it.

2.3 Variable Weighting

The primary ESHER user interfaces (ESE and ERE) allow the user to give weights to each of the variables described in this chapter. Weights are a way of assigning relative importance or priority values to each of the model variables.

The initial variable weights used for the first model run will be decided upon by the PDT, using a multi-step process. Initially, a survey of PDT members will be conducted to gauge the group's general sentiment as to the importance (low, medium, high) of each of

the variables. The survey results will be used as starting point for discussion at a future PDT meeting, where numerical weights will be assigned to each of the variables. ESHER will then be run using these weights, and the results will be reviewed and discussed by the PDT to determine if any changes to the weights should occur. The weights decided upon in the initial year will be used as the basis for generating a weighting scheme in subsequent years. Weights may change in future years due to such things as shifts in management priorities, availability of new scientific/technical information, and level of success of previous year restoration efforts.

G.6.16. ESHER Outputs

All final ESHER output files are saved in the C:\ESHER\ESHER Outputs folder. The first output, created by the "Pre-Processing 1 – Calculate Variable Values" module, is the "pot_sites_values" shapefile. This shapefile contains the raw variable values (i.e. distances) for all the proposed restoration sites that were input into the module. The following is a description of fields in the attribute table:

Acres: Size of restoration site
Condition: Primary site condition – shallow water (SW), existing vegetated bar (EVB), sparsely vegetated bar (SVB), open water (OW)
SiteName: Site identification number (river mile)
Backwater: Potential for backwater restoration (0 = no potential, 1 = potential)
C_Width: Channel width (meters)
Nests: Number of historical nests on site
Condition2: Condition coded as numbers(0 = OW, 5 = EVB, 7 = SVB, 10 = SW)
Nest_Dist: Distance to nearest nest complex (meters)
Cottonwood: Distance to cottonwood restoration sites. This variable is currently not included in ESHER, the intention is to add it when the location of cottonwood restoration sites becomes available.
Wetlands: Percentage of site that is wetland
Protected: Distance to protected shoreline (meters)
D_50: Sediment size (mm)
Dam: Distance to mainstem dam (meters)
Predation: Number of predated nests
Pallid: Number of pallid sturgeon samples within ½ mile buffer.
Tree_line: Distance to nearest tree line (meters)
Boat_ramp: Distance to nearest boat ramp (meters)
Dock: Distance to nearest dock (meters)
Domicile: Distance to nearest domicile (meters)

Intake: Distance to nearest water intake (meters)
Recreation: Distance to nearest recreation area (meters)
Urban: Distance to Bismark (meters)
Eagle: Distance to nearest bald eagle nest (meters)
Cultural: Distance to nearest cultural resource (meters)
Industrial: Distance to nearest industrial facility (meters)

Utilities: Distance to nearest utility
Wet_acres: Number of acres of wetland on proposed restoration site
Bridges: Distance to nearest bridge
Power_st: Distance to nearest power station
Size: Size of potential restoration site, rounded to nearest whole number (acres)

Distance values in the table of 0 mean that the resource is not in the reach (or there is no spatial data for the reach on that resource) where the restoration site is located. These sites receive a scaled score of 10 for that variable.

A second output ("ESH_site_scaled_values" shapefile) is created by the "x(Optional) – Create Site Scale Variable Output, Part 2" module. The Pre-Processing 1, Pre-Processing 2, and Create Site Scaled Variable Output, Part 1 modules all need to have been previously run before the Part 2 module will work. The output attribute table contains the scaled variable values (0-10) for all the proposed restoration sites. The attribute fields are identical to those in the "pot_sites_values" file, except there are no "Acres" or "Condition2" fields.

The "ESHER Site Evaluation" module creates the "ESH_site_scores" shapefile output. This output contains the final scores (0-100) of all the potential restoration sites being evaluated.

The "ESHER Reach Evaluation" module creates a separate raster output for each of the reaches (ft_peck, garrison, gavins_pt, land, randall). Cell scores can range from 0-100. An example of a reach evaluation output for Gavins Point reach is shown in Figure G 11.

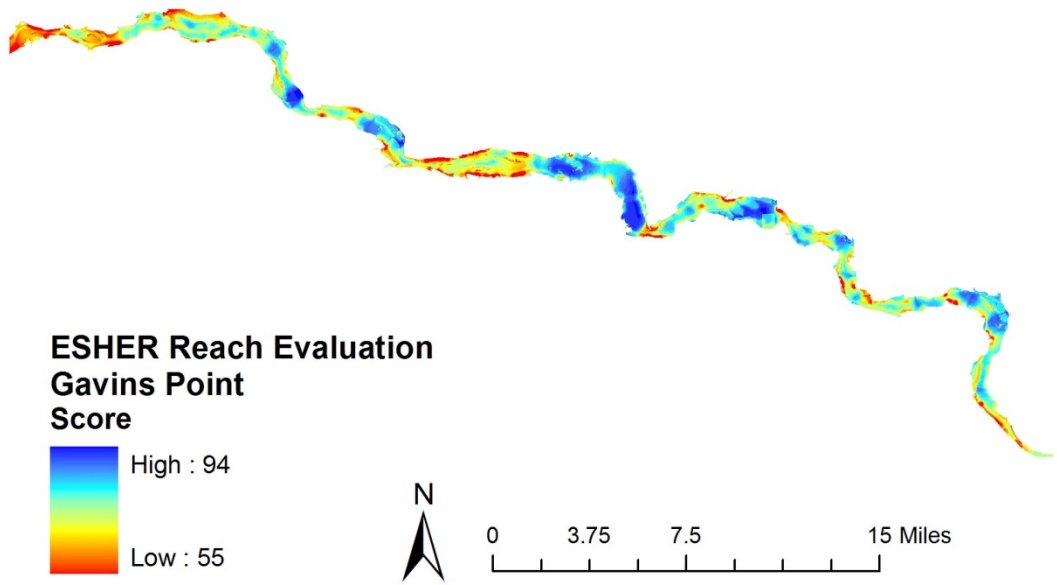


Figure G 11. Example of reach evaluation output for Gavins Point reach.

G.6.17. Modifying ESHER

Modifications to ESHER may occasionally need to be made. This chapter details the process for making changes such as changing input files and re-scaling variables, and provides general information on adding variables to the model. All these changes are made within the ArcGIS ModelBuilder environment, and this chapter assumes the reader has experience building models within ArcGIS ModelBuilder.

G.6.17.1. Changing Input Files

ESHER is hardwired to look for input files that have a specific name and are located in a specific folder. All input files are located within subfolders of the C:\ESHER main folder. Additionally, the model will occasionally select attributes based on specific field names and attribute codes within these input files. Therefore, it is suggested that when these input files are updated that they maintain the same file name and location, as well as keeping relevant field names and attribute codes the same. However, if for some reason these need to be changed, Figures 11-14 indicate where within the model structure the various inputs are located, as well as the original file names and locations, and attribute selection information if relevant. Two caveats, with the potential restoration sites input file, the name and location can be changed, but do not change any of the field names or attribute codes. Also, do not change the following shapefiles

located in the C:\ESHER\ESHER Inputs\ folder: “Peck_analysis_area.shp” “Garrison_analysis_area”, and “Gavins_randall_LC_analysis_area”.

With the exception of the potential restoration sites file and the habitat delineation files, all changes to input files are made in the “Pre-Processing 1” module. If the name or location of the potential restoration sites file changes, these changes need to be made in the “Pre-Processing 1”, “Optional…Part 2”, and “ESHER Site Evaluation” modules. Changes to the habitat delineation files need to be made in the “Pre-Processing 1” and “ESHER Reach Evaluation” modules. To make changes to an input file, find the number in the diagram (Figures 11-14) that corresponds to the appropriate input file, and then zoom into that area in the model editing screen. The circles/rectangles that need to be edited should be obvious once the appropriate area is zoomed in on.

1. Potential Restoration Sites Formatting needed - this page & next page

:\ESHER\pot_sites\pot_sites.shp

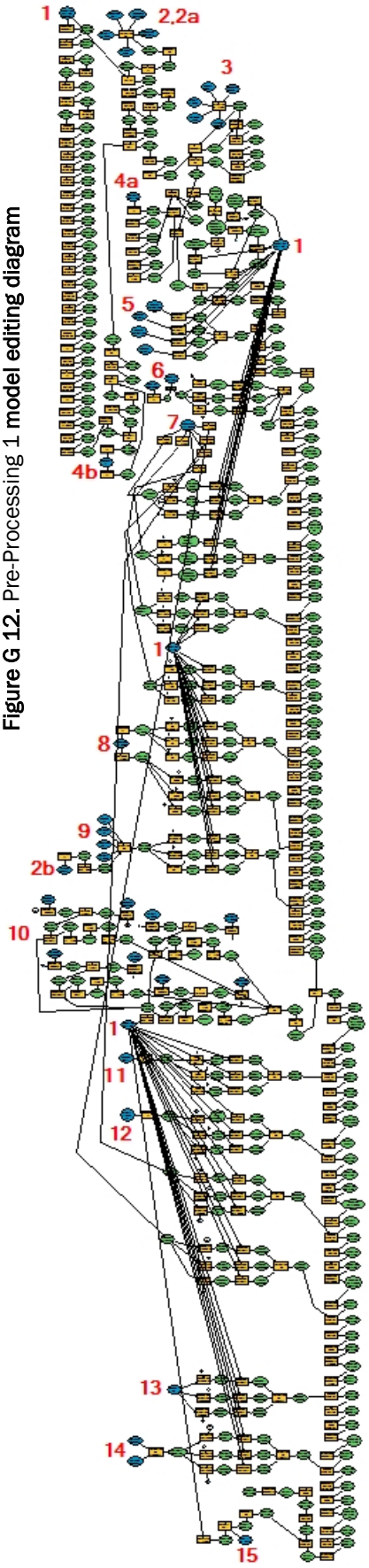


Figure G 12. Pre-Processing 1 model editing diagram

2. Habitat Delineations

Names and Locations:
C:\ESHER\DMA_Final\Ft Peck\Hab Delin 1998-2005\PeckDelin021507.shp
C:\ESHER\DMA_Final\Ft Randall\Hab Delin 1998-2005\RDL_2005_DELIN.shp
C:\ESHER\DMA_Final\Garrison\Hab Delin 1998-2005\GSN2005_050207.shp
C:\ESHER\DMA_Final\Gavins Point\Habitat Delin 1998-2005\Gavins_2005_050207.shp
C:\ESHER\DMA_Final\Lewis & Clark Lake\Hab Delin 1998-2005\L&C2005_DLN.shp
a) Select Attribute [Select] based on "TYPE" = 11 (Wetland).
b) Select Attribute [Select (11)] based on "TYPE" = 9 (Riverine Forest).

3. Sediments

Names and Locations:
C:\ESHER\sediment\Ft_Peck_1984Sediment.shp
C:\ESHER\sediment\Ft_Randall_2007Sediment.shp
C:\ESHER\sediment\Garrison99sediment.shp
C:\ESHER\sediment\Gavins_point_2002Sediment.shp
C:\ESHER\sediment\Lewis_Clark_2007Sediment.shp

4. Historical Nests

Name and Location: C:\ESHER\tp_nests\allnests.shp
a) Select Attribute [Select (13)] based on field "SURVEY_YR" = 2008. Value will likely need to be changed every year.
b) Select Attribute [Select (14)] based on field "LOC_QUAL" = 1.

5. Dam Distances

Names and Locations:
C:\ESHER\ESHER Inputs\damdist_garr
C:\ESHER\ESHER Inputs\damdist_gavn
C:\ESHER\ESHER Inputs\damdist_peck
C:\ESHER\ESHER Inputs\damdist_ranlc

6. Cultural Resources and Shipwrecks

Names and Locations:
C:\ESHER\cultural resources\cultural_resource.shp
C:\ESHER\shipwrecks\riv_boat_accidents_1839_to_1934.shp

7. Sensitive Resources

Names and Locations:
C:\ESHER\DMA_Final\sensitive\allfeatures.shp
Select Attribute [Select (3)] based on field "Feature" = 'Boat Ramp'.
Select Attribute [Select (4)] based on field "Feature" = 'Boat Dock'.
Select Attribute [Select (5)] based on field "Feature" = 'Domicile'.
Select Attribute [Select (6)] based on field "Feature" = 'Recreation Area'.
Select Attribute [Select (7)] based on field "Feature" = 'Irrigation Pump'.
Select Attribute [Select (8)] based on field "Feature" = 'Industrial Structure'.

8. Sensitive Features Lines

Names and Locations:
C:\ESHER\DMA_Final\sensitive\lines.shp
Select Attribute [Select (9)] based on field "type" = '1' (Bridges).
Select Attribute [Select (10)] based on field "type" = '2' (Utilities).

9. Tree Lines

Names and Locations:
C:\ESHER\DMA_Final\Ft Peck\Sensitive_Resources\Peck_Forest_Line.shp
C:\ESHER\DMA_Final\Gavins Point\Sensitive Features\Gavin_Forestline.shp
C:\ESHER\DMA_Final\Ft Randall\Sensitive Features\RNDL_Forest.shp
C:\ESHER\DMA_Final\Garrison\Sensitive Features\Forrest_Lines2.shp

10. Channel Banks

Names and Locations:
C:\ESHER\ESHER Inputs\Peck_channel_top.shp
C:\ESHER\ESHER Inputs\Peck_channel_bottom.shp
C:\ESHER\ESHER Inputs\Garrison_channel_top.shp
C:\ESHER\ESHER Inputs\Garrison_channel_bottom.shp
C:\ESHER\ESHER Inputs\Gavins_channel_top.shp
C:\ESHER\ESHER Inputs\Gavins_channel_bottom.shp
C:\ESHER\ESHER Inputs\Randall_channel_top.shp
C:\ESHER\ESHER Inputs\Randall_channel_bottom.shp

11. Power Stations

Name and Location:
C:\ESHER\power\powerstations.shp

12. Urban Area

C:\ESHER\DMA_Final\Garrison\Sensitive Features\GarrisonEXCLS.shp
Select Attribute [Select (12)] based on field “Feature” = ‘Bismark Urban Zone’.

13. Eagle Nests

Name and Location:
C:\ESHER\BE_nests\2008.shp

14. Protected Shoreline

Names and Locations:
C:\ESHER\Real_Estate\mn39_stewardship_020409_completed
C:\ESHER\Real_Estate\mn59_stewardship_020409_completed

15. Pallid Sturgeon

Name and Location:
C:\ESHER\pallid\pallid.shp

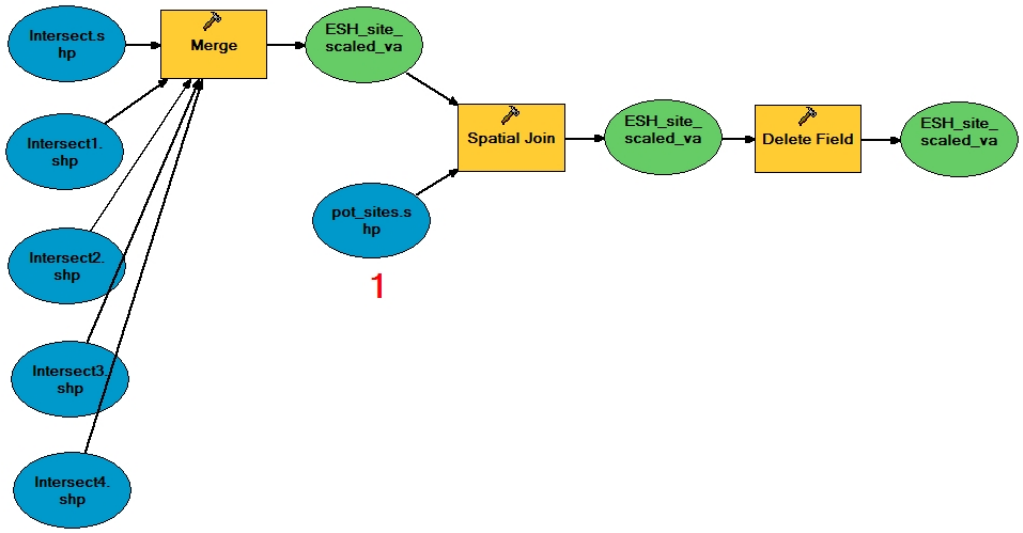


Figure G 13. Optional – Part 2 **model editing diagram.**

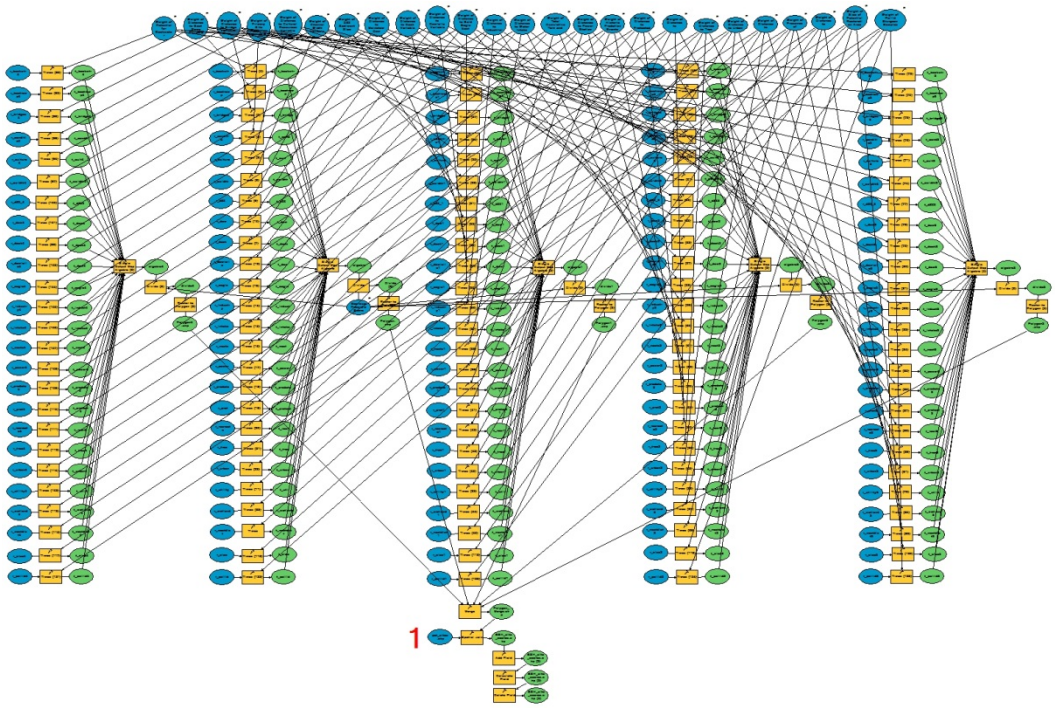


Figure G 14. ESHER Site Evaluation **model editing diagram.**

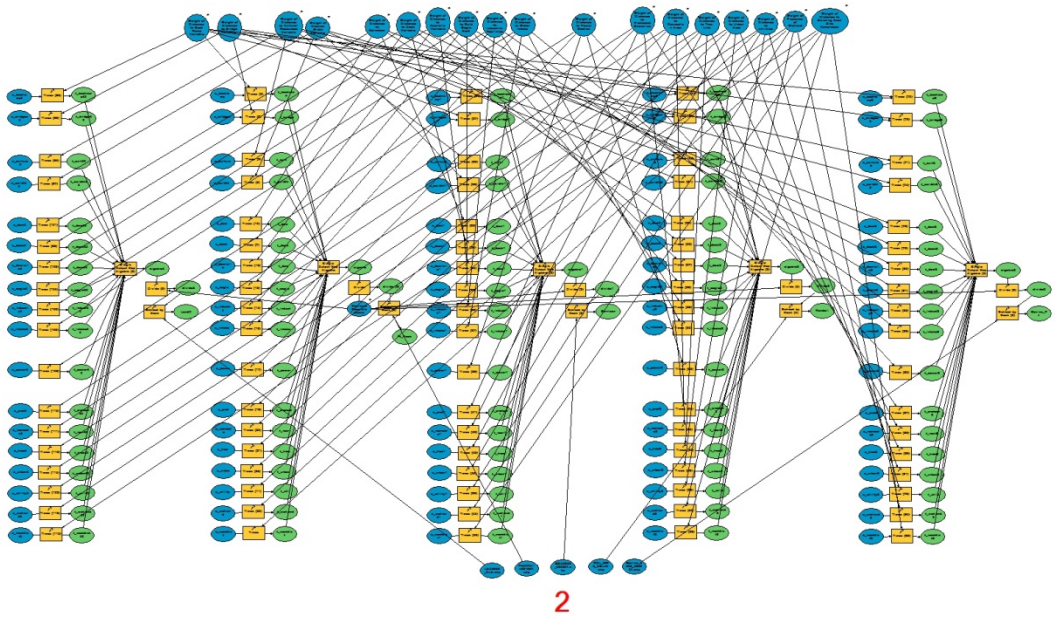


Figure G 15. ESHER Reach Evaluation **model editing diagram.**

G.6.17.2. Scaling Variables

Changes to the default scaling of variables can be made by editing the Pre-Processing 2 and Pre-Processing 3 modules. Variable scaling is assigned using the "Reclassify" tool, and each variable is associated with its own "Reclassify" tool. In both modules, each variable is replicated five times, once for each of the reaches. Therefore, for a variable where the scaling is identical across reaches, changes to that scaling need to be made in each of the replicates. If the scaling of a variable is unique to a specific reach, then a change in scaling only needs to be made in the "Reclassify" tool for that variable in that particular reach.

G.6.17.3. Adding Variables

Adding variables to ESHER should be done by someone who is well experienced with building models within the ModelBuilder environment. Adding a variable requires editing of all 7 modules (or 5 – if the variable is not being used in the reach evaluation then the ESHER Reach Evaluation and Pre-Processing 3 modules do not need to be changed). The structure of the existing modules can be used as a guide for how additional variables should be incorporated. There are two important things to be aware of when adding a variable – 1) when adding a variable to the "Pre-Processing 1 module" the variable field name in the output table should be added during the creation of the variable, rather than at the beginning where many of the existing field names are being created (upper left corner of diagram in Figure 3). Otherwise, the new field name will be lost during several Spatial Joins processes that occur in the module. The alternative is to delete and then re-add these Spatial Join processes in the module. 2) In order to include the new variables in the "ESH_site_scaled_values" output, in the "Optional – Part 2 module", the Merge and Spatial Join processes should be deleted and then re-added to the module.

G.6.17.4. Creating new Potential Restoration Sites

It is anticipated that ESHER will be run on an annual basis in order to analyze a group of potential restoration sites generated by the ESH PDT. This will involve updating the Potential Restoration Sites shapefile (C:\ESHER\pot_sites\pot_sites.shp) on an annual basis. The following steps outline the process of completing this task.

1. Use a combination of field knowledge from site visits, aerial/satellite imagery, and the outputs of the ESHER ERE tool to select locations with a high potential of restoration success.

2. Edit the pot_sites.shp file by using the most current imagery to draw a polygon over the most likely footprint of an ESH complex at the potential restoration site.

3. Fill out all the attributes for the polygon as follows:

Acres: Calculate the acreage of the polygon utilizing the measure tool.

SiteName: Nearest Whole Missouri River Mile

Condition: Indicate the primary (>50%) site condition within the polygon based on the imagery, habitat delineations, field knowledge or other sources of information using the following codes: **SW** –Shallow Water, **OW** –Open / deep Water, **EVB** –Existing Vegetated Bar consisting of dense vegetation, **SVB** – Sparsely Vegetated Bar

Backwater: Based on imagery or site knowledge, assess the potential for restoring a backwater or other floodplain feature in conjunction with the potential ESH restoration site. Backwater restoration sites should be within 1 mile of the potential ESH restoration site. Assign the following codes to the attribute: **0** – No potential for backwater / floodplain restoration, **1** – Potential exists for restoration of a backwater / floodplain feature.

Attachment G.7 Piping Plover Cages, Nest Moving/Raising, Chick Relocation & Chick Platform

In addition to surveying the birds, monitoring crews will often perform management actions to increase the productivity of the two species. Other actions will be performed to learn more about the two species, including measures to protect the birds from predators, relocating nests endangered by rising water or erosion, and collecting specimens for research and necropsy.

G.7.18. Piping Plover Cages

Construction: The cages should be constructed using wire mesh with two inches by four inches openings. Bird netting may be used for the top of the cage. The cage dimensions should be three feet by three feet by three feet and constructed so that they fold down flat for easy transportation. The cage will be anchored to the ground using stakes.

Where and When to Place a Cage: Tern nests should never be caged. Piping plover nests at risk of inundation on riverine or reservoir segments may be caged prior to nest moving. Caging nests prior to a nest move gives the adults time to habituate to the cage, which may aid in their finding the nest after it has been moved to a new location. Cages may also be placed over plover nests if crews have documented losses to predators during the current or past years or if it is suspected that a predator may be in the vicinity of a nesting site. These situations should be addressed on a case by case basis, as there is some evidence that the presence of a cage attracts predators. In situations where nesting habitat is limited, however, a cage may be an effective tool to protecting the nest.

When cages are used, they should generally be placed over a plover nest that has a full clutch (generally four eggs for first nests) and where incubation has been started. Nests with incomplete clutches and no incubation should not be caged on the initial visit. The reason for waiting for a complete clutch is that the more time the plovers have spent on the nest, the more likely it will be that they will return to a nest that has had a cage placed over it.

How to Place a cage: Cages and anchors need to be cleaned before placement around a nest. This can be done by placing the cages and anchors in the water near the shore upon arrival at a site in order to remove any foreign materials and odors that may have been picked up while transporting the cages and anchors.

Before removing the cages and anchors from the water, the person or persons handling the cages needs to wash their hands with no-scent soap or use a no-scent towelettes to preclude human scent being transferred to the cages.

The cage should be assembled near the boat or ATV away from the nest site and then carried to the nest. The cage is placed over the nest so the nest is centered in the cage. Anchors (metal stakes) should be placed at each of the four corners of the cage and driven flush into the ground.

After the cage is secure, the cage should be watched through binoculars to determine if the adult will return to the nest. If the adult will not go inside the cage and resume sitting on the nest within fifteen minutes, the cage is to be removed. In the Comments Section of the Nest Record a note should be written stating that the attempt to cage the nest failed.

After the nest has been terminated, the cage will be removed from the nest.

G.7.19. Nest Moving

No matter which method is used to move the nest, there are certain procedures that need to be followed. Hands and any tools used for nest moving need to be washed in biodegradable scent-free soap. Footprints and other signs of nest moving activities need to be removed by brushing the area with a hand or with a whisk broom. In moving nests this work needs to be done quickly to minimize stress both to the eggs and the attending parents. However, do not be in such a hurry that the eggs may be damaged or destroyed during the move.

After moving, a nest needs to be watched from a distance to see if the adult returns to the nest. Least terns generally do not have a problem finding the new nest. Plovers, being ground oriented, tend to have greater difficulty in finding the new nest location. If this occurs, the plover can be gently “herded” toward the nest site so that it can relocate the nest.

If the adult cannot relocate the nest or will not go to the new nest site, the nest may need to be relocated again back closer to the original nest site. However, a nest will not be relocated to an area that will subsequently be inundated or eroded.

G.7.19.1. Obliterate/Recreate Method

In this method the original nest bowl is destroyed and a new nest bowl is created at a safe site. First, a new nest bowl is created by scooping out a shallow depression. This new nest bowl should be in a location safe from sandbar erosion and high enough to prevent loss from inundation. Piping plover nest moves should be no greater than fifteen feet from the original nest bowl. Because least terns are flight oriented, a new nest site can be located at greater distances.

After a new nest bowl has been created the eggs are removed from the original nest bowl and placed at a secure temporary location. Anything in the original nest bowl, such as twigs and debris in tern nests and pebbles in plover nests are collected and put in the new nest bowl. Also any visual cues around the original nest bowl, such as rocks, sticks, vegetation, are removed and placed in the same orientation around the new nest bowl. If the nest was caged before the move, the nest needs to be re-caged after the move. The original nest bowl is then completely obliterated and the eggs are placed in the new nest bowl.

G.7.19.2. Obliterate/Platform Method

This method is similar to the obliterate/recreate method with the major difference being that the nest is re-created on top of a buried wooden platform. The platform should be at least twenty inches, but not more than thirty inches square and should be made of ¼ to ½ inch thick plywood. Small holes need to be drilled into the platform to allow water to drain through. The platform needs to be buried from 1½ to 3 inches deep at the new nest site with excavated material. The new nest is then reconstructed on top of the platform. The advantage of this method is that if more moves are subsequently needed the platform can be excavated and the nest can be moved intact to a new location.

G.7.19.3. Cylinder/Plate/Platform Method:

This method uses a cylinder made from a coffee can, or similarly shaped object, with both the top and bottom cut out, and an eight to fifteen inch square aluminum plate (or a restriction sign could also be used). The cylinder is pressed or screwed into the substrate around the nest to a depth of 1½ to 3 inches. The substrate is then excavated from one side of the cylinder. The plate is slid under the nest and cylinder with the plate remaining perpendicular to the cylinder. Once the plate is positioned under the nest to form a platform, the remaining substrate may be removed from around the cylinder and

the cylinder and plate is lifted from the ground and transported to the new nest site location.

At the new location, material is excavated and the plate is slid out from underneath the cylinder. Substrate is then built up around the can and the can is removed. Substrate material is sprinkled over the new nest site to blend it into the landscape.

If it is anticipated that the nest may have to be moved again, the cylinder and plate is placed on a platform at the new nest site and the plate is carefully slid from under the nest. Substrate material is then placed on the platform and around the cylinder. The cylinder is then removed from around the nest. As with the other methods, substrate material is used to blend the new nest into the surrounding landscape. If additional moves are needed to relocate the nest, the platform can be excavated and moved as described in the obliterate/platform method.

G.7.20. Nest Raising

Nest raising is used when it is not possible to move the nest. Before the nest can be raised, the eggs need to be removed from the present nest site. The preferred method is to use the cylinder/plate method described above. Once the eggs are safely set aside, the nest location should be built up to a height to withstand the anticipated increase in water. After the mound has been built, the nest is recreated on top of the mound as described before. All of the visual surroundings to the nest such as driftwood, rocks and small vegetation are relocated on top of the mound in their same orientation. For plovers, there may need to be a more gradual slope up to the top of the mound and they may need to be herded toward the top of the mound.

Staking down the Cage

Moving a Nest using the Cylinder/Platform Method

Attachment G.8 Human Deterrence Measures

There are several measures that can be done to reduce disturbance of the birds, including gating and fencing off beaches to prevent vehicle access, restricting access to nesting grounds, law enforcement, and public education.

G.8.21. Restricting Access

To protect nesting and brood rearing sites from the public, sometimes access needs to be restricted. This is most commonly done by the placement of barricades and endangered species restriction signs.

1. **Barricades:** Barricades are used to prevent vehicular access to nesting sites located along reservoir shorelines, and are most commonly placed next to recreation areas to prevent off road vehicle access to the beaches. Barricades can be constructed using natural features such as rocks and logs. If a more permanent deterrent is required, a fence with a gate should be constructed to restrict access. Endangered species restriction signs should be placed in combination with the barricade. Crews need to consult with their supervisor and receive approval before any barricade construction is done.

2. **Endangered Species Restriction Signs**: The need to place restriction signs should be evaluated on a case-by-case basis. If a site is remote with little chance for human disturbance, it usually is better not to put up signs, as signs at a remote location might attract a person to the site out of curiosity.

   Generally, all river sites that contain five or more nests should be posted with restriction signs. All reservoir sites that have the potential for human visitation, especially those adjacent to recreation areas should be signed.

   The restriction signs should be visible to the public at all entry points to the nesting area. For sandbar and beach shorelines, the signs need to be placed near the water to forestall boaters from landing.

   The restriction signs need to be monitored constantly throughout the nesting season. Restriction signs that are down need to be re-installed before a crew leaves a site. When the birds have completed nesting and chick rearing and have left a site, the restriction signs should be removed and stored back at the office.

Endangered Species Restriction Sign

G.8.22. Law Enforcement

The USACE position on law enforcement is to use only the amount necessary to correct the problem. If a minor violation is observed such as people inside a restricted area, contact the individuals, ask them to leave the restricted area and explain to them the importance of not disturbing the birds.

If a major violation is observed, for example a person is pulling up the restriction signs, overturning predator exclosures, driving in the nesting area or smashing eggs, action needs to be taken. This does not necessarily mean that the individual is to be confronted. At all times the personal safety of the crew is of primary importance. If it is deemed not safe to approach the person or persons, observation should be done from a safe distance and as much information as possible should be gathered including a description of the individual or individuals, the boat or vehicle license number and what the individual is doing. If a camera is available, pictures of the violation should be taken. At the same time, crews should contact their supervisor or office via a radio or cell phone and advise them of the incident. The crew should also contact via the cell phone a law enforcement officer to report the incident.

If an ESA violation has been found after it has happened, all pertinent information will be recorded including who, what, where, when, why and how in regard to the incident. Take pictures of the violation and write a brief caption for each picture. The crew's supervisor will be contacted and informed of the incident. If circumstances warrant at the scene, the appropriate law enforcement officer will be contacted to determine if the officer should come out to the site. Upon returning to the office an incident report will be written, including a map of the site. The report will be given to the supervisor for review. The supervisor will send copies of the report to the TPMP coordinator and to the U.S. Fish & Wildlife Service special agent for the area.

G.8.23. Education & Outreach:

An important part of human deterrence measures is educating the public. This can be as simple as one-on-one conversations with people at the boat ramp, handing out endangered species materials, giving campground talks, putting up endangered species information signs and public service messages broadcast via television and radio stations. Another avenue to get the word out on endangered species is to contact the local media, such as newspapers, radio and TV stations, to set up interviews about the importance of the work.

Attachment G.9 Egg Floating

Determining the egg incubation stage provides valuable data both short and long term for least tern and piping plover recovery. In the short term, knowing the egg incubation stage provides a probable nest hatch date. The egg incubation stage, when combined with the clutch size, can be used to calculate a nest initiation date (the date the female laid the first egg of the clutch). This data is important in determining long-term nesting trends.

G.9.24. When to float an Egg

Upon nest discovery, one egg from the clutch should be floated to determine incubation stage. There is one exception to this rule - an egg will not be floated if any of the eggs in the clutch are pipping. A pipping egg is an egg that is close to hatching. Do not touch a pipping egg as the egg shell has fractured and could easily break if handled.

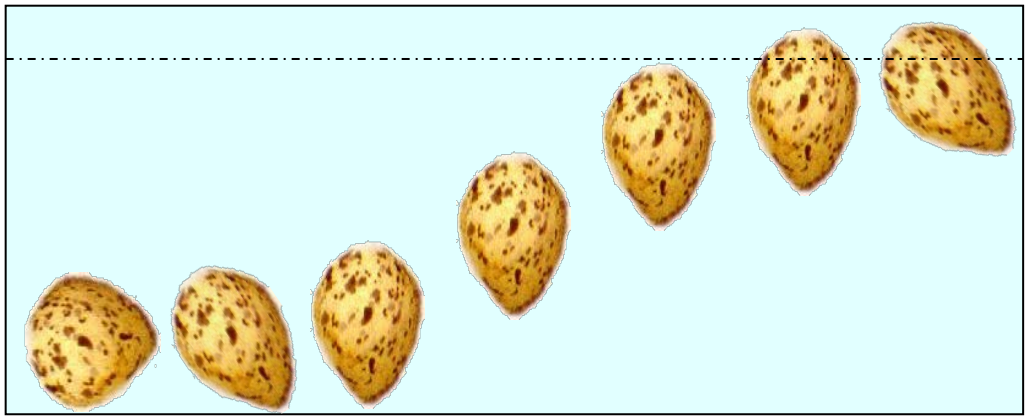
G.9.25. How to Float an Egg

Prior to handling an egg, hands must be washed with no-scent soap or a towelette to ensure human scent is not left on the egg. The preferred method is to use a no-scent towelette that can be carried during the survey and used to wipe hands prior to egg handling. A second method is to wash hands with no-scent soap where water is available.

Float cups should be made of transparent plastic (a glass cup should never be used). The cup should be filled three-quarters full with water taken from the river or reservoir and allowed to warm up for a few minutes. The cup of water should be good for all the nests on the site; it does not have to be refilled for each new egg.

Select an egg that is free of fecal or any other foreign material. When transferring the egg to the cup, have the cup a short distance above and to the side of the nest. Place the egg at the bottom of the cup and let it float. **Do not drop the egg into the cup.** After the egg stabilizes, compare its position to that of the egg float chart. Determine the incubation stage by looking at the number below the position selected on the float chart. After the incubation stage has been determined, gently remove the egg from the cup and place it back in its original position in the nest. It is not necessary to dry the egg before returning it to the nest; never shake the egg to remove excess water.

Egg Incubation Stage Float Chart



Plover 0 4 8 12 16 20 24

Generally, one egg will be floated from a nest. There are circumstances however where it may be necessary to float more than one egg. If the egg selected for floating floats to the top of the water with the pointed end up rather than down, this indicates an addled egg (an egg where the embryo has died). The egg should then be placed back into the nest and another egg should be floated. If this occurs, include this information in the nest comment.

Additional eggs may also be floated if a tern or plover lays an unusually large amount of eggs in the nest. The maximum clutch size for least terns is usually three eggs, and for piping plovers, four eggs. If a tern nest is found with four eggs or a plover nest with five or more eggs, the additional egg or eggs may have been laid by a different bird and could have a different incubation stage from the rest of the clutch. In the case of oversized clutches at least two eggs and possibly three should be floated. If, after floating two eggs, the eggs have the same incubation stage; record that as the incubation stage for the clutch. If the two eggs have different incubation stages, float a third egg and if its incubation stage agrees with one of the two previous eggs, record that as the incubation stage for the clutch.

After the incubation stage has been determined it is not necessary to re-float an egg on subsequent nest visits.

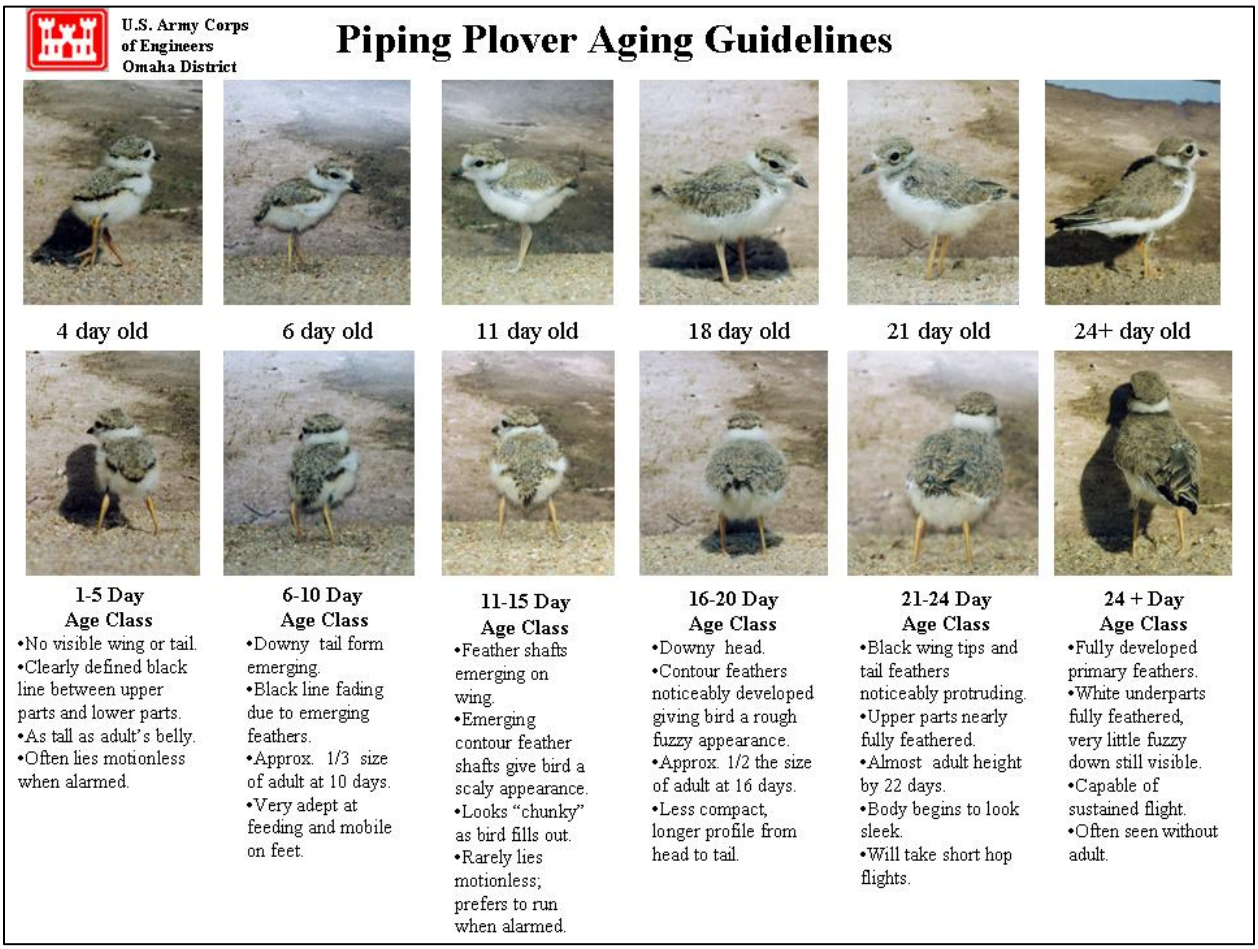
Attachment G.10 Tern and Plover Chick Aging

After hatching, it takes from 21-28 days for piping plover chicks to fledge (able to fly). Least tern chicks begin to fly at 18-22 days after hatching.

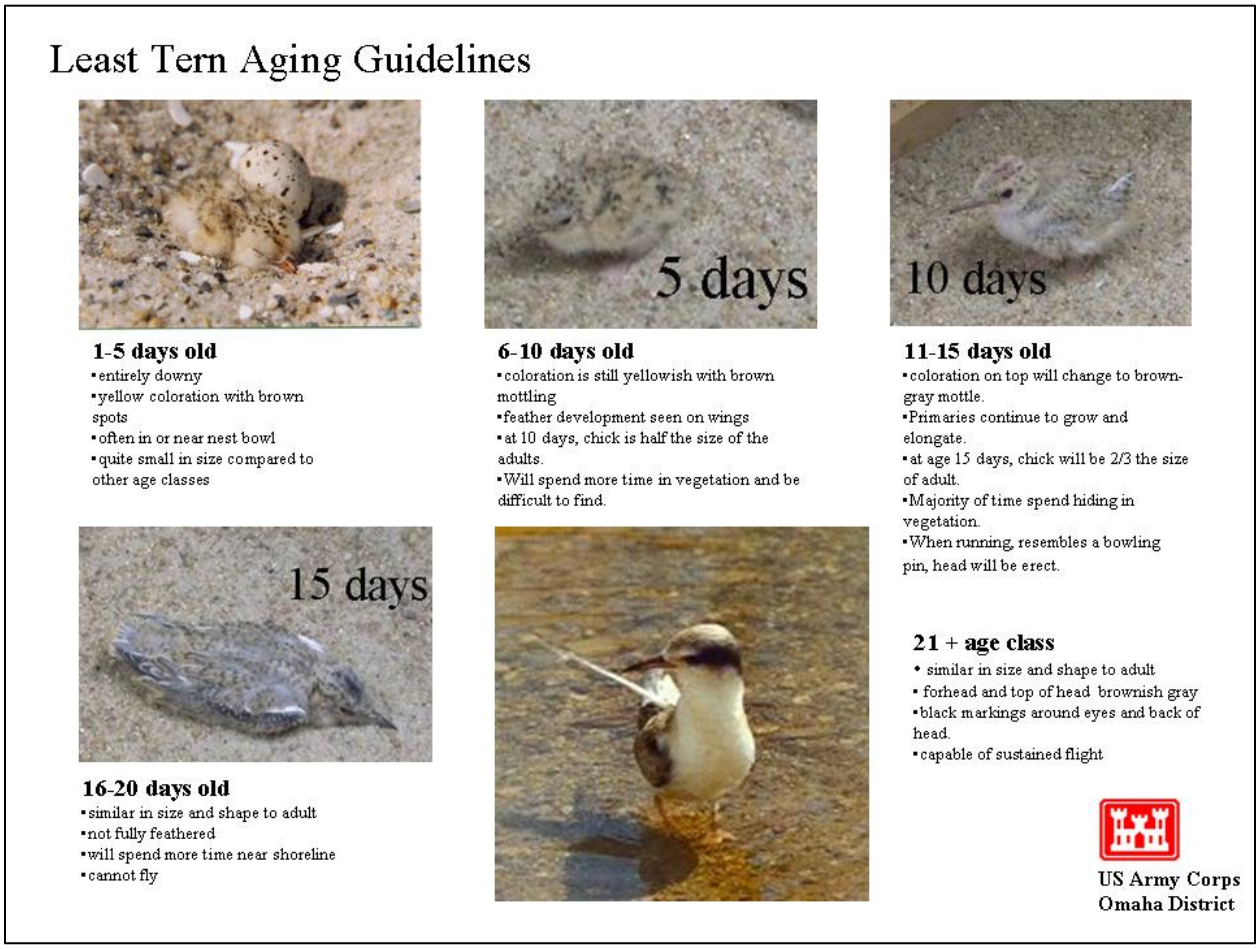
In addition to counting chicks, crew members need to determine the approximate ages of the chicks. Piping plover chicks are divided into five age classes: 1-5 days, 6-10 days, 11-15 days, 16-20 days and 21-24 days. Least tern chicks are divided into four age classes: 1-5 days, 6-10 days, 11-15 days and 16-20 days.

G.10.26. How to Determine if a Chick has Fledged

A chick is considered fledged when it is able to fly. There are two ways to determine if a chick is fledged. The first is straightforward— the chick is observed flying. This need not be sustained flight. A juvenile that performs short-hop flights is considered fledged. Do not harass a chick in any way to force it to try to fly by running toward the chick, making noises, throwing objects in the direction of the chick, or doing anything to disturb the chick.



The second way of determining fledging is more subjective and based on the size of the chick. If the chick appears to be the correct size of a fledgling, comparable in size to an adult, then the chick should be counted as fledged.



Attachment G.11 2015 Adult Band Resighting Plan

Banding has occurred on the Missouri River (MR) system for the last ten years and over 5000 plover and tern adults and chicks have been banded during that time period. Just last year 95 adult plovers and 400 plover chicks were banded on Gavins and Lewis and Clark Lake as well as 17 tern adults and 296 tern chicks. Band resighting data is used from the MR for a multitude of reasons including tern and plover adult and juvenile survival estimates, predicting plover population size and growth, and for an ongoing piping plover metapopulation study. It is important to continue to resight these birds in order to get tern and plover adult and juvenile survival estimates for the flood science study and the effects analysis, to get estimates of movement between the upper and lower rivers for the metapopulation study, and to attempt to estimate plover population size and growth in order to estimate carrying capacity.

G.11.27. Methods

We will attempt to resight least tern and piping plover adults from May through August of the 2015 field season with the majority of the work occurring from May 11-July 3. We will resight piping plover adults using high resolution point and shoot cameras and we will attempt to camera trap each nesting tern and plover adult using Kodak PixPro video cameras and Reconyx game cameras at least once during the nesting season. Our methods have been adapted from those developed by USGS Northern Prairie Wildlife Research Center and the Virginia Tech Shorebird program for tern and plover band resighting. All resighting and camera trapping efforts will comply with USFWS permit conditions outlined in Appendix 1.

We will deploy two resight crews of two individuals to conduct surveys and camera trap nests. For large sandbars, the two crews will combine in order to cover the sandbar in the time allowed. The river segments have been broken up into reaches based on number of nests in 2014 and boat ramp locations. There are three reaches on Gavins and two on Lewis and Clark Lake (LCL). Resight crews will operate separately from the Tern and Plover Monitoring Program (TPMP) crews although the TPMP crews may be utilized to retrieve game cameras on occasion. Camera Standard Operating Procedures (SOP's) have been developed and are attached in Appendix 2. Crews will be trained and required to adhere to camera protocol, permit conditions, and TPMP protocol. All resight crew members will carry a GPS displaying the location of nests to reduce the risk of accidentally stepping on a nest. If new nests are found by the resight crew they will record the location and collect data on the nest following the TPMP protocol. They will also share fate evidence such as chicks in bowl or predated egg shells with the TPMP program manager who will provide that information to the TPMP crews.

Resighting Methods

All sandbars on the Gavins Point and Lewis and Clark Lake segments will be searched for banded piping plovers at least three times during the between May 11-July 3 and ideally once a week. If time allows we may resight on the Fort Randall segment if the TPMP crews identify sites with banded birds. We will walk line transects through each sandbar, the number of transects will depend on sandbar size and number of surveyors. One crew member will use a spotting scope to locate banded individuals and direct the other crew member(s) to those groups to take pictures. Crew members with cameras will attempt to get within 25-50 meters of adults, choose a location to stop at, and take as many photos as time allows. Crew members actively photographing will not move while taking photos to prevent accidentally stepping on a nest. Number of photos will depend on the skill of the crew member and the activity level of the birds.

Camera trapping Methods

Camera trapping will occur once nesting begins which will be under way as we start our field season. In 2014 the majority of the plover nests were initiated the second and third weeks of May while the majority of tern nests were initiated during the fourth week of May and the first week of June. There is some overlap in nest initiation between terns and plovers although the majority of nest initiation occurred at different times. In the case where there are not enough cameras to trap all nests that require trapping, priority will be given to plover nests and nests that are further along in incubation and could potentially hatch prior to the next visit. Cameras will only be set on nests that have a full clutch, where incubation is more than 48 hours and the eggs are not pipping. We will rely on nest locations from the TPMP to locate nests that require trapping. Crew members will set video camera traps at a predetermined set of nests and then conduct resighting while the cameras capture video for a minimum of 30 minutes. Cameras will be mounted to stakes that can be easily placed in the ground. It should take no longer than one minute to place the camera and focus in on the nest. Camera traps will be retrieved after finishing the resighting survey. After resighting is complete trap cameras may be moved to another part of the sandbar or if the trapping effort is complete they will be completely removed from the sandbar. Video cameras will be placed on a maximum of 10 nests per sandbar at any one time. Permit conditions and sandbar layout will dictate the number of nests that can be trapped on any given visit.

We will attempt to video trap both adults associated with each nest. For this effort trapping is defined as capturing video of the adults, birds will not be handled. We will make a maximum of two attempts with the video cameras to trap each nest. After reviewing the video, if we determine both adults were not trapped on the first attempt

we will return the following week and make a second attempt. If after the second attempt we still have not trapped both adults we will deploy a game camera. In the event that too many nests are failing/hatching prior to trapping using this two attempt approach we may switch to one attempt with the video camera or only use the game cameras. As with the video camera setup, camera placement will take no longer than 1 minute as they will be set up prior to deployment. The game cameras are activated by motion and capture still photos. They will be deployed at the nest for a minimum of 48 hours. We will attempt to retrieve the cameras within 72 hours however that may not always be possible depending on weather and schedule. We will deploy up to 15 game cameras at any one time but will not place more than three game cameras per sandbar at a time. Due to high predation risk, use of still cameras on LCL will be limited. If necessary we will only use them if we are unable to get a band reading after two attempts using the video camera and we will only place one per sandbar. We may utilize the Virginia Tech research crews working on the upper portion of Lewis and Clark Lake to assist with camera deployment and retrieval.

G.11.28. Data Collection and Management

Data collected in the field will be limited to collecting site visit information using the GPS unit. All other data will be written on a white board and photographed or captured on video. The River mile of the site, the date, the camera type, and the operator of the camera will be written on a white board and each camera will take a photo of it prior to resighting. At each nest prior to setting a trapping camera we will video/photograph a whiteboard that displays the site river mile, set date, set time, camera type, and camera operator. When the trap is retrieved another photo or video will be taken that includes the retrieval time.

Photos and video will be viewed on a daily basis when possible. If viewing is not completed at the end of the day we will use weather days to complete viewing. If this proves to be unattainable we will utilize TPMP crew members once their season slows down or utilize seasonal staff that stay longer than the bird monitoring season. Band resight training will be provided to all individuals reviewing photos and video. Viewing video camera trap data will take priority over still photographs from both the Game Camera and the point and shoot cameras as that data is necessary to determine if a trap reset or a change in approach is required. Photos/video from each camera will be downloaded and stored in a folder labeled with the day's date. Any photos deemed unusable will be stored in a separate location.

Data will be recorded in an excel spreadsheet and will be loaded into a resighting table in the TPDMS. Data will be checked on a weekly basis to ensure band combos were accurately read. Where band combos prove difficult to read we will rely on the original

banders to provide clarification. All data, photos, and video will be provided to the original banders no later than Nov 1 2015.

Table G 25. Data fields for photos and video.

Field	Description
capture_date	The date the photo is taken/camera trap is set
set_time	The time the photo was taken or the time the video/game camera is set
retrieve_time	The time the video/game camera is retrieved
camera_operator	the initials of the person taking photos or setting the camera
segment_code	River segment where survey is being conducted; Gavins, LCL, Fort Randall
river_mile	River mile of the sandbar where the survey is being conducted
species_code	The host species of the nest; Least Tern, Piping Plover.
nest_id	A unique ID number assigned to each nest. Year|Segment|Unique ID
camera type	The type of camera used; Nikon, Canon, Lumix, video, game
resight_date	The date the photo/video is reviewed
viewer	The initials of the person viewing the photo/video
capture_time	The time in the video when the bands are readable for the first adult
capture_time2	The time in the video when the bands are readable for the second adult
alpha_numeric_code	the code on the alpha numeric flag or band
ULU	upper left leg, upper band
ULL	upper left leg, lower band
LLU	lower left leg, upper band
LLL	lower left leg, lower band
URU	upper right leg, upper band
URL	upper right leg, lower band
LRU	lower right leg, upper band
LRL	lower right leg, lower band
bands missing	Indicate if suspect bands missing; Y = bands missing
comments	Anything notable, e.g., faded bands, injury, feather wear, behavior
file_location	The path to the folder where the file is stored
file_name	The name of the file
checked	The initials of the individual double checking the band combo

Table G 26. Data collected for site visits.

Field	Description
observer	initials of the person entering the site visit
Office	The field office out of which surveys are being conducted.
segment_code	segment where survey is being conducted; Gavins, Lewis and Clark Lake, Fort Randall
river_mile	River mile of the sandbar where the survey is being conducted
signed	Mark "Y" if signs are placed on the site.
latitude	The Y coordinate of the site in decimal degrees.
longitude	The X coordinate of the site in decimal degrees.
elevation	The elevation of the site in meters.
start_time	The time the survey begins.
# of surveyors	The total number of people surveying
finished	Describes whether or not a survey was complete; Complete, Incomplete, Continuation
survey_method	Describes what type of survey was conducted; Stop & Scan, Targeted Search, Grid Search, Partial Grid Search, Resight and Trap, Resight, Trap
end_time	The time the survey ends
visit_comment	Comments about the survey
survey_date	The date of the survey
survey_time	The time of the survey

Table G 27. Band Colors

Color	Color code
Green Flag	GF
Yellow Flag	YF
Light Blue Flag	LF
Black Flag	KF
Red	R
Orange	O
Yellow	Y
Dark Green	G
Mint Green	M
Cobalt blue	C
Light Blue	L
Violet	V
Hot Pink	P
White	W
Black	K
Gray	A
Metal	X
Alpha Numeric Band	AN
Alpha Numeric Flag	ANF
Unknown Band Color	UC

G.11.29. USFWS Permit Conditions

1. If two or more nests are depredated on a single sandbar by the same type of predator, still cameras will be pulled from that sandbar. If this occurs on three or more sandbars, we will stop using still cameras. Camera traps will only be set on nests where adults have initiated full time incubation.
2. An individual bird may not be kept off of a nest for more than 30 minutes. Because of the size of some nesting colonies, an entire sandbar/alkali lake/reservoir shoreline may take much longer than 30 minutes, but surveyors should ensure that they move through quickly enough so that individual birds return to their nests within 30 minutes.
3. Surveyors shall not return to an area less than 120 minutes after previous departure.
4. No more than 40 minutes shall be spent in a nesting area in a 24-hour period, and no more than three visits shall be made to a nesting area daily.
5. Surveys for nests, chicks, and fledglings shall be conducted no more frequently than once every day and to the extent practicable, nests, chicks and fledglings shall be observed from a distance of 200 feet or greater to minimize disturbance. Nests may be checked daily when eggs are observed pipping or if eggs are expected to hatch within 24 hours to determine nest fate.
6. Surveys shall be conducted when the ambient temperature is between 40° and 90° Fahrenheit. Surveys shall not be conducted if it is precipitating. Surveys shall not be conducted if the wind speed is greater than 25 mph or if sand is blowing across the survey area.
7. To the extent possible during surveys, nesting least terns and piping plovers and those observed returning to their nests are not to be disturbed.
8. Incubation stage may be determined using egg floatation by those experienced with the technique. Prior to handling eggs, technicians shall wash their hands using unscented soap or wipe their hands using unscented wet wipes to reduce the risk of leaving residue or scent on eggs.
9. Surveyors may place nest cameras no closer than one meter from piping plover and least tern nests. Cameras shall be placed at a distance from the nest that shall not disturb the normal incubation of nests and shall not provide a perch for avian predators. Following placement, the nest shall be observed to ensure that the parents resume incubation activities. If adults do not resume incubation within 20 minutes, the camera shall be removed.
10. Nests may be marked using inconspicuous methods, e.g. tongue depressors, wooden dowels, driftwood, or rock cairns.

G.11.30. USACE BAND RESIGHTING CAMERA SOP

The following procedures and protocol have been adapted from procedures and protocols developed by USGS Northern Prairie Wildlife Research Center and the Virginia Tech Shorebird Program.

Resighting Camera

Introduction

- All crew members will read the manual for the camera/lens
- Practice these steps prior to doing it in the field

Equipment

- Nikon D5300 or Canon Powershot 50HS or Panasonic Lumix DMC FZ1000
- Fully charged battery
- SD card
- Monopod

Getting Started:

- Make sure the battery is charged nightly and the SD card is in the camera.

Camera Settings

- Nikon D5300
  - Shoot in either Auto mode or Sports mode. Use Sports mode for a rapid series of shots.
  - On the side of the lens turn on VR and put on normal. Use active mode in VR for rapid shooting while in sports mode shooting. Turn off VR at the end of the day.
  - If the satellite is flashing it has not obtained your location yet to embed GPS coordinates into the pictures. Wait for it to quit flashing to shoot.
- Canon Powershot 50HS
  - Shoot in Auto mode or Sports mode. Use Sports mode for a rapid series of shots.
- Lumix DMC FZ1000
  - Shoot in Auto mode “iA” with dial on upper left set to “multiple shot”.

Taking pictures and viewing on camera:

- Before shooting press the shutter button down half way to focus on your subject (On the Nikon, in Sports mode it will only focus on the first shot so try and be as steady as possible when shooting in this mode).
- To see pictures press on the play button and press the arrow keys to scroll through them.

Camera Basics and Maintenance:

- Never take the memory card out while the camera is on.
- Never aim the camera directly at the sun.
- Do not store the camera in the vehicles overnight or for long durations in hot weather.
- Limit exposure to direct sunlight and store in a dry, cool place when not in use.
- Nikon D5300
    - The “hood” attached to the lens can twist off and stored in the Pelican case if it is getting in your way from zooming the lens out. The hood’s use is to keep sand and dirt from blowing into the glass and on really sunny days will help in picture taking by preventing the pictures from looking washed out (too bright).
    - To attach the hood for lens protection or taking pictures, turn it around and align it correctly white dot to white dot and gently twist counter clockwise until it locks into place. Do not force the hood on, if it is not smoothly twisting it is not lined up correctly. The small open circle on the hood should now line up with the white dot on the lens.
    - Never take the lens off while the camera is turned on.

Downloading pictures onto computer:

- With the camera turned off and the memory card inserted, plug the camera into the computer with the supplied USB cable. Turn on the camera.
- When the dialog box pops up select import pictures and video.
- Tag the photos with the name of the camera. Ex Nikon.
- When done transferring pictures delete them from the memory card. On the computer browse to Removable Disc/DCIM/, select the appropriate folder, right click and select delete.
- Turn the camera off first and then unplug the camera from the computer.
- To save geotagged photos from the Nikon
    - Open up the Nikon Transfer 2 program on the desktop.

- Pictures should show up in the program. Unclick pictures you do not want to download and then click on Start Transfer.
- When done transferring pictures turn the camera off first and then unplug the camera from the computer.
- Once the pictures are downloaded, go rename each folder to the date of the pictures (5_20_2014) and then within each folder make additional folders for each segment and place the correct pictures in each folder.
- Pictures with a globe below the file name have embedded GPS coordinates.

Reviewing Photos

- View photos in any viewing software, zoom in to bird if necessary
- Enter band combos and other relevant data into the resight database.

Nest Trap Camera

Introduction

- All crew members will read the manual for the camera
- Practice these steps prior to doing it in the field
- Use bands or something with small lettering to focus on at the proper distance to make sure they are readable

Equipment

- Kodak PixPro SPZ1 HD video camera
- Fully charged battery
- Micro SD card
- Monopod
- A watch or phone to keep track of time

Getting Started

- Install micro-SD card and battery
- Attach camera to monopod/tripod
- Turn on HD Camera – power button is on the side

Camera Settings

- Click settings (top right button that looks like a list)
- Arrow right to the Macro setting (looks like a flower) and turn "ON"
- Click settings again to exit settings, or hit "enter" (center red button)

Deployment at Nest

- Turn the camera on.
- Place camera ~18-24inches from nest.
- Make sure lens is not dirty or smudged. Clean with lens brush or lens cloth before setting.
- Try to have the sun behind the camera (at your back) and, if possible, face camera away from wind or with a cross wind
  - Birds land into the wind so don't block their way
- Zoom in on nest so ~ 2 inches on either side of the eggs are visible. Use the up and down directional buttons to zoom in or out.
  - ***Make sure eggs are in focus*** and in center of the screen
- Click settings again
  - Arrow left to the far left setting and hit enter
- Navigate to "Continuous AF" (auto-focus), hit enter, scroll to "Off" and hit enter again.
- ***This step has to happen after the camera is zoomed in on the nest***
- Click settings again to exit settings
- Hit record button (Red button in center) and make sure it is still focused on the nest
  - Say Nest #, Rivermile, and date so the video will record (in case improper paper record keeping) and/or place a small whiteboard in front of the camera with the proper info
- Retreat from area and continue other activities
- Retrieve camera and hit record button again to STOP recording, then turn camera off.
- Knock the sand off the monopod before storing

Downloading pictures onto computer:

- Remove micro-SD card and place in adapter (or use USB cord to connect to computer)
- Insert SD card in computer and copy all video to computer (not necessary if using the USB cord)
- No special program is needed besides a video player

- Save video files to designated folder
- Delete videos from memory card

Video Review

- Play video and enter data into the resight database
- Record the occurrence of events as time into the video.
- Record any band combos obtained
- When viewing video, grab the "time" scroll bar on the video player
- Slide the "time" scroll bar until a bird or a change in substrate moving from a bird is seen

Reconyx Game Camera

Introduction

- All crew members will read the manual for the camera
- Practice these steps prior to doing it in the field
- Use bands or something with small lettering to focus on at the proper distance to make sure they are readable

Equipment

- Reconyx game camera
- Fully charged battery
- SD card

Camera Settings

- Turn the camera on.
- Make sure the memory cards are empty; this should come up when you turn the camera on (% Full, % Battery). You can also get this information by scrolling to 'Check Status' and hitting OK.
    - If not, scroll to 'Erase Card' – hit OK
    - Scroll to 'Yes' – hit OK
    - Wait for the card to be erased
- If the card is empty, scroll to 'Change Setup'.
    - Under Quickset, scroll to 'Advanced' – hit OK
    - Under Advanced Setup, scroll to 'Trigger' – hit OK
    - Under Motion Sensor, scroll to 'On' – hit OK

- Under Sensitivity, scroll to ‘Very High’ – hit OK
- Under Pics Per Trigger, scroll to ‘5’ – hit OK
- Under Picture Interval, scroll to ‘Rapid Fire’ – hit OK
- Under Quiet Period, scroll to ‘No Delay’ – hit OK
- Under Finished – hit OK

- Make sure these settings are correct before deploying cameras in the field the first time and check periodically throughout the season to make sure the settings didn’t get changed.

Deployment at Nest

- Turn the camera on.
- Right before placing, scroll to ‘Arm Camera’ – hit OK and deploy.
- Place camera 1.5-2m from nest cup
- Attempt to aim camera north for optimal lighting
- Pickup camera at following nest check (2-3 days)
- Remove memory card and mark card case with sticker, replace with a new card
- Deploy camera on next assigned nest

Downloading pictures onto computer:

- Remove micro-SD card and place in adapter (or use USB cord to connect to computer)
- Insert SD card in computer and copy all photos to computer (not necessary if using the USB cord)
- Save video files to designated folder
- Delete photos from memory card

Photo Review

- View photos in any viewing software, zoom in to bird if necessary
- Enter band combos and other relevant data into the resight database.

Appendix H. Monitoring and Assessment Protocols for Human Considerations

Note: This appendix will present common monitoring protocols employed by the program for HCs. Additional content is TBD, but may include discussion guiding development of protocols for specific projects, which may require preparation after the project objectives, location, design, etc., are known.

Populating this appendix with the appropriate information will be an ongoing objective for activities following AMP V5 and continuing to the Final Draft AMP.

I.1 Screening of HC Issues

I.2 Monitoring Protocols under the Preferred Alternative

I.3 Monitoring of Test Flows and Extreme Events

I.4 Assessments for HCs

Appendix I. Quality Assurance Project Plan (QAPP)

I.5 Overview

Quality Assurance Project Plans (QAPPs) are required for all data collection activities associated with the MRRP. Most data collections are covered by the programmatic QAPP (reference location). However, project-specific QAPPs may be needed for some activities, and it is the responsibility of all PIs, contractors, etc., to prepare, submit, and obtain approval for any project-specific QAPPs. This appendix provides an overview of the purpose and scope of the QAPPs, which are covered in detail in (reference).

Part I of the Uniform Federal Policy for Quality Assurance Project Plans (the UFP-QAPP Manual) is a consensus document prepared by the Inter-governmental Data Quality Task Force (IDQTF). It provides instructions for preparing QAPPs for any environmental data collection operation. The purpose of' the UFP-QAPP manual is to implement the project- specific requirements of American National Standards Institute / American Society for Quality (ANSI/ASQ E4), Quality Systems for Environmental Data and Technology Programs - Requirements with guidance for use, Section 6 (Part B), The Uniform Federal Policy for Implementing Environmental Quality Systems (UFP-QS) was developed by the IDQTF to implement Section 5 (Part A) of ANSI/ASQ E4.

I.6 Purpose

The purpose of a QAPP is to document the planned activities for data collection operations and to provide a project-specific “blueprint” for obtaining the type and quality of environmental data needed for a specific decision or use. The planning should include the data users, data producers, decision-makers and stakeholders to ensure that all needs are clearly defined and addressed. While time spent on such planning may initially seem unproductive and costly, the penalty for ineffective planning often generates greater conflict and extensive reworking, which results in increased cost and lost time.

The QAPP serves several purposes:

- As a *technical planning document*, it identifies the purpose of the project, defines the project quality objectives, and outlines the sampling, analytical, and quality assurance/quality control (QA/QC) activities that will be used to support environmental decisions.

- As an *organizational document*, it identifies key project personnel, thereby facilitating communication.
- As an *assessment and oversight document*, it provides the criteria for assessment of project implementation and for QA and contractor oversight.

I.7 QAPPs and Quality Management Plans

The *Uniform Federal Policy for Implementing Environmental Quality Systems* requires documentation of an organization's quality system in a quality management plan (QMP). A QMP is a formal document that describes the quality system in terms of the organization's structure, the functional responsibilities of management and staff, the lines of authority, and the required interfaces for those planning, implementing, and assessing all activities conducted. Organizations participating in the project (e.g., Federal agency, prime contractor, laboratory, etc.) must have a QMP or some other documentation of a quality system. The management, organization, and personnel responsibilities outlined in the QAPP should be consistent with that quality system.

I.8 Types of QAPPs

QAPPs can be of two types:

- A *generic QAPP* is an overarching plan that describes the quality objectives and documents the comprehensive set of standard operating procedures (SOPs) for sampling, analysis, QA/QC, and data review that are specific to a site (e.g., facility, base) or to an activity (e.g., compliance with an environmental program such as Safe Drinking Water Act, repetitive groundwater monitoring). A generic QAPP may be applicable to a single site with multiple activities (e.g., soil, groundwater, and surface water sampling) or to a single activity that will be implemented at multiple sites (e.g., same type of air monitoring at several Air Force bases) or at multiple times (e.g., a groundwater monitoring program that will sample the same locations every 3 months for 5 years).

  A generic program QAPP may serve as an umbrella under which project-specific tasks are conducted over an extended period of time. Project or task-specific information not covered by the umbrella is documented in detailed sampling and analysis plans (SAPs) or work plans, which use the generic QAPP as an informational reference whenever appropriate. The use of generic QAPPs, with supplemental project-specific QAPPs as needed, is a significant opportunity to use a graded

approach, reducing repetition and streamlining the QAPP development, review, and approval process (see Section 1.2.4).

When a generic QAPP is being developed that will apply across multiple EPA Regions or regulatory approval authorities, the scoping process must involve those entities early in the development of the QAPP. Receiving input early will help streamline review and approval of the generic QAPP.

- A *project-specific QAPP* provides a QA blueprint specific to one project or task. Project-specific QAPPs are used for projects of limited scope and time and, in general, can be considered the work plan for the project. A project-specific QAPP for each site or activity may be needed to supplement a generic QAPP.

I.9 Required QAPP Element Groups and Overview of Submittal/Approval Process

There are four basic element groups addressed in a QAPP: Project Management and Objectives, Measurement/Data Acquisition, Assessment/Oversight, and Data Review. The four basic element groups of a QAPP present a framework consistent with *EPA* Requirements for Quality Assurance Project Plans (EPA QA/R-5), which requires use of a systematic planning process.

Table I1. Required elements in a QAPP and list of supporting worksheets.

Required QAPP Element(s) and Corresponding QAPP Section(s)	QAPP Worksheet #	Required Information
Project Management and Objectives		
2.1 Title and Approval Page	1	- Title and Approval Page
2.2 Document Format and Table of Contents 2.3.1 Document Control Format 2.3.2 Document Control Numbering System 2.3.3 Table of Contents 2.3.4 QAPP Identifying Information	2	- Table of Contents - QAPP Identifying Information
2.4 Distribution List and Project Personnel Sign-Off Sheet 2.4.1 Distribution List 2.4.2 Project Personnel Sign-Off Sheet	3 4	- Distribution List - Project Personnel Sign-Off Sheet
2.4 Project Organization 2.4.1 Project Organizational Chart 2.4.2 Communication Pathways 2.4.3 Personnel Responsibilities and Qualifications 2.4.4 Special Training Requirements and Certification	5 6 7 8	- Project Organizational Chart - Communication Pathways - Personnel Responsibilities and Qualifications Table - Special Personnel Training Requirements Table
2.5 Project Planning/Problem Definition 2.5.1 Project Planning (Scoping) 2.5.2 Problem Definition, Site History, and Background	9 10	- Project Planning Session - Documentation (including Data Needs Tables) - Project Scoping Session Participants Sheet - Problem Definition, Site History and Background - Site Maps (historical and present)
2.6 Project Quality Objectives and Measurement Performance Criteria 2.5.3 Development of Project Quality Objectives Using the Systematic Planning Process 2.5.4 Measurement Performance Criteria	11 12	- Site-Specific PQOs - Measurement Performance Criteria Table
2.7 Secondary Data Evaluation	13	- Sources of Secondary Data and Information - Data Criteria and Limitations Table
2.8 Project Overview and Schedule 2.8.1 Project Overview 2.8.2 Project Schedule	14 15 16	- Summary of Project Tasks - Reference Limits and Evaluation Table - Project Schedule/Timeline Table

Measurement/Data Acquisition		
3.1 Sampling Tasks 3.1.1 Sampling Process Design and Rationale 3.1.2 Sampling Procedures and Requirements 3.1.2.1 Sampling Collection Procedures 3.1.2.2 Sample Containers, Volume, and Preservation 3.1.2.3 Equipment/Sample Containers Cleaning and Decontamination Procedures 3.1.2.4 Field Equipment Calibration, Maintenance, Testing, and Inspection Procedures 3.1.2.5 Supply Inspection and Acceptance Procedures 3.1.2.6 Field Documentation Procedures	17 18 19 20 21 22	- Sampling Design and Rationale - Sample Location Map - Sampling Locations and Methods/ SOP Requirements Table - Analytical Methods/SOP Requirements Table - Field Quality Control Sample Summary Table - Sampling SOPs - Project Sampling SOP References Table - Field Equipment Calibration, Maintenance, Testing, and Inspection Table
3.2 Analytical Tasks 3.2.1 Analytical SOPs 3.2.2 Analytical Instrument Calibration Procedures 3.2.3 Analytical Instrument and Equipment Maintenance, Testing and Inspection Procedures 3.2.4 Analytical Supply Inspection and Acceptance Procedures	23 24 25	- Analytical SOPs - Analytical SOP References Table - Analytical Instrument Calibration Table - Analytical Instrument and Equipment Maintenance, Testing, and Inspection Table
3.3 Sample Collection Documentation, Handling, Tracking, and Custody Procedures 3.3.1 Sample Collection Documentation 3.3.2 Sample Handling and Tracking System 3.3.3 Sample Custody	26 27	- Sample Collection Documentation Handling, Tracking, and Custody SOPs - Sample Container Identification - Sample Handling Flow Diagram - Example Chain-of-Custody Form and Seal
3.4 Quality Control Samples 3.4.1 Sampling Quality Control Samples 3.4.2 Analytical Quality Control Samples	28	- QC Samples Table - Screening/Confirmatory Analysis Decision Tree
3.5 Data Management Tasks 3.5.1 Project Documentation and Records 3.5.2 Data Package Deliverables 3.5.3 Data Reporting Formats 3.5.4 Data Handling and Management 3.5.5 Data Tracking and Control	29 30	- Project Documents and Records - Table - Analytical Services Table - Data Management SOPs
Assessment/Oversight		
4.1 Assessment and Response Actions 4.1.1 Planned Assessments 4.1.2 Assessment Findings and Corrective Action Responses	31 32	- Assessments and Response Actions - Planned Project Assessments Table - Audit Checklists - Assessment Findings and Corrective Action Responses Table

4.2 QA Management Report	33	- QA Management Report Table
4.3 Final Project Report		
Data Review		
1.1 Overview		
1.2 Data Review Steps 1.2.1 Step I: Verification 1.2.2 Step II: Validation 1.2.2.1 Step IIa: Validation Activities 5.2.2.3 Step IIb: Validation Activities 1.2.3 Step III: Usability Assessment 1.2.3.1 Data Limitations and Actions from Usability Assessment Activities	34 35 36 37	- Verification (Step I) Process Table - Validation (Steps IIa and IIb) Process Table - Validation (Steps IIa and IIb) Summary Table - Usability Assessment
5.3 Streamlining Data Review 5.3.1 Data Review Steps To Be Streamlined 5.3.2 Criteria for Streamlining Data Review 5.3.3 Amounts and Types of Data Appropriate for Streamlining		

Appendix J. Integrated Science Program Requirements and Procedures

Attachment J.1 – Research Project Management Plan (PMP) Template

MRRP Research Program
Project Management Plan Template

Background: A project management plan (PMP) is a formal, living document used to define requirements and expected outcomes and guide project execution and control. All continuing MRRP projects are required to develop and maintain a PMP (5- 10 pages). Yearly updates of the PMP will be due at the fall IPR for the program (generally occurring in September). However, the ISP Manager should be informed of significant deviations from the PMP at the earliest possible opportunity during the course of the FY.

1. Project Title and PMP Version Date

2. Project Origin and Purpose
   - 2.1 List the Statement of Need(s) this project is addressing and/or how the need for this project was identified
   - 2.2 Describe the problem or opportunity
   - 2.3 Project Value Statement (concise, 1 or 2-sentence statement on what value the project will create for the MRRP)

3. Objectives and Products
   - 3.1 Describe the objectives of the project (i.e., the capability to be developed or knowledge learned)
   - 3.2 Identify the products (ex. tools, reports, guidance, etc.) that will be delivered
   - 3.3 Detail the scope of benefits (what and for whom) that are expected to be gained from the project

4. Technical Approach
   - 4.1 Provide a detailed, chronological narrative of the tasks, subtasks, and activities to be accomplished to meet the project objectives
   - 4.2 Identify the tools that are expected to be utilized including models, technical equipment, specialized software, etc.

5. Knowledge/Technology Transfer Plan
   - 5.1 Include a description of the strategy to transfer the knowledge gained from the effort or the technology developed and support its use for the MRRP (e.g. technical reports, guidance documents, internet tools, conference presentations, on-site trainings, reach-back support plans). The plan should encompass a three to five-year outlook related to project deliverables and capability.

6. Schedule and Funding

6.1 Schedule:

- Identify the start and end dates of all tasks, subtasks, by using a Gantt-style or similar format, or at a minimum, a basic table may be used (see below).
- Identify planned deliverable completion dates.
- Be sure to provide information regarding any expected overlap into the following fiscal year.

Tasks, Subtasks, Deliverables	Start Date	Task End Date or Deliverable Completion Date

6.2 Funding:

- Identify the proposed budget for current year and any anticipated out years. This section should include listing and description of all leverage and collaborative funding contributing to the project. Your total proposed budget must be listed utilizing the following categories:
  - Labor-Lead Agency/Entity
  - Labor-Other Entity
  - Contracts
  - Other Expenses (Burdens, Travel, Purchases, etc.)
- Present your obligations and expenditures plan for the project. At a minimum, a basic table may be used (see below).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Obl	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K
Exp	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K	$K

7. Risk and Change Management Plan
   7.1 Identify the assumptions, dependencies, and critical risks which may impact execution of the technical approach and maintenance of the schedule and budget.
   7.2 Describe contingency plans associated with identified risks
   7.3 Describe your plan to communicate major changes to the project such as significant schedule adjustments, funding constraints, key personnel modifications, etc.

8. Project Delivery Team (PDT) Roles/Responsibilities
   8.1 Principle Investigator
   8.2 Members
   8.3 Collaborators (Active project participants such as Districts, Federal Agencies, Academia, etc.)
   8.4 Stakeholders (Customers and/or other interested agents)

PDT Member	Org. Code or Agency	Project Role	Financial POC (if project funded)

9. PMP Point of Contact: Name, E-mail, Contact Number

Attachment J.2 – Guidelines for Technical Publications

Note: This section is under development. The information provided below is a strawman to work from in developing guidelines for subsequent versions.

Introduction

Research reports and findings of monitoring and assessments constitute important products of work under the MRRP. They influence important decisions regarding program implementation. Money, facilities, and talent devoted to research should always result in a formal technical communication of some kind. In addition to the responsibility to the program, there is a duty to the scientific/technical community at large. Whatever new knowledge has been revealed must be made available to all. The only exceptions to this are cases where restrictions are required because of security classification or proprietary rights.

It is important that reports be published in a timely fashion, be clearly and concisely written, and be technically correct. The content of a report and the manner of presenting data are governed by the objectives of the investigation and the distribution intended. The ISP Manager and/or Program Manager are entitled to prescribe the level of detail of a report prepared for their specific needs. However, if the study provides information of broad applicability, the Project Investigators (PIs) should see to it that a complete record is made available. When an investigation consists of several phases and extends over a long period, reports may be prepared on each phase to provide the information as promptly as possible. This sequential reporting often yields additional benefits, such as a better perspective on the total investigation. Phase reports and progress reports can be planned to stand by themselves temporarily, and ultimately to be incorporated into a final or summary report.

The MRRP Web site is the primary means for distributing MRRP products. This method is faster, cheaper, and more flexible than traditional hard-copy printing. However, it doesn't meet all needs, so limited numbers of hard copies of select reports will be printed for archival purposes and limited distribution when there is sufficient justification. Moreover, some study results merit publication in Journal papers, and some PIs are obligated to publish results in agency reports (e.g. USGS reports). Guidance in this appendix is focused on MRRP requirements and are the minimum requirement; publications with other requirements are supplemental to those on the following pages.

Report Categories

Reports prepared under the MRRP will be published in one of the following series. The same report categories are used independent of the species, subject, or funding source.

Supplemental (non-MRRP) reports that result from a collaboration between researchers from more than one agency will be a product of the lead PI's agency. The responsibility for editing, producing, approving, and distributing the report will belong to the first author's agency.

Technical Report (TR)

A Technical Report documents the results of "a completed notable scientific and technical effort" sponsored by DoD (AR 70-31, para 6.a). It is a required tangible product of investigations performed under basic research, applied research, and advanced development programs (DoDI 3200.12). In addition to providing the final record of a project, the TR is also appropriate for documenting significant technical milestones achieved during a multi-year project. The author may prepare two or more technical reports as a series designated by a single publication number.

The content of a Technical Report is based on the objectives and standards given in AR 70-31 (para 5, 6, 8, and 9). However, the Military Standard presentation format specified in paragraph 6.a of the regulation is superseded by ANSI/NISO Z39.18-2005 (see DoDI 3200.12), which has been in use since 2006.

The Army technical reporting requirement for a sponsored project can be met by publishing the results in a recognized peer-reviewed science or engineering journal (AR 70-31, para 6.d). The procedure for accomplishing this involves management approval from the MRRP.

Technical Note (TN)

A Technical Note is an information- or technology-transfer publication that researchers can use to

- offer prospective users a reader-friendly synopsis of work fully documented in a Technical Report
- document supplementary or spinoff project results of interest to the MRRP
- present user-friendly instructions or specifications for applying or procuring MRRP technology products (e.g. models, design guidance, etc.).

The Technical Note is no more than 15 pages. For purposes of corporate branding, a standardized MRRP design is established. However, when the visual requirements of the technical information warrant, the author can develop MRRP-compatible design variations. (Design variations should be approved by the MRRP Manager, however.)

The TN will not generally serve as the sole documentation of a sponsored research project (see AR 70-31, para 8.a). Also, it is intended for technical topics only, not program work plans, annual reports, outreach, or other nontechnical purposes.

Special Report (SR)

The purpose of this series is to report the conclusion of work within the MRRP that was not the product of a science or engineering research investigation and does not serve the purposes of a Technical Note. The Special Report documents significant applications of MRRP technical expertise and effort outside the scope of a sponsored research, monitoring or assessment project. The following represent examples of Special Reports:

- Proceedings of conferences hosted or co-hosted by the MRRP
- A computer program user guide
- An instruction report
- A consulting study capturing MRRP technical expertise that may be of interest to a wider audience
- A literature review or annotated bibliography
- A white paper on technology applications, innovative designs, monitoring study designs, etc.

The SR is prepared and edited using the standards and formats applied to a Technical Report.

Contract Report (CR)

Studies performed for MRRP under contract are typically incorporated into a final Technical Report. However, there are two reasons a project manager may wish to publish a contractor deliverable as a separate Contract Report:

- to rapidly disseminate partial research results that may independently be of immediate use to technical proponents or peers
- to make a significant contractor study available for use as a formal reference in a Technical Report without labor-intensive reprocessing by authors or technical editors.

Publication of a research deliverable as a Contract Report is an option if the content meets the objectives of the contract's Scope of Work and the document is prepared to a high level of consistency and professionalism. The authors of record are exclusively non-governmental personnel. The individual responsible for accepting the contractor deliverable functions as the technical monitor on behalf of the MRRP.

Miscellaneous Paper (MP)

The purpose of this series is to officially recognize work by MRRP authors that has been published or presented outside of an official federal government publishing program. Examples include articles published in a nontechnical journal, conference presentations, book chapters, and technical reports prepared by MRRP researchers, including those from other agencies using MRRP funding.

Letter Report (LR)

The LR is correspondence pertaining to a research study, but it is not a published MRRP research product. The body of the LR is prepared in accordance with AR 25-50, Preparing and Managing Correspondence (May 2013), and it may be accompanied by one or more technical attachments. The LR may be used to

- summarize project status or interim findings
- present the results of a narrowly focused engineering study performed for operational purposes or as support for others.

When a researcher wishes to have technical correspondence numbered as a Letter Report, that document is subject to distribution limitations and other special handling requirements that can be explained by the MRRP PM. Tracking research correspondence as a Letter Report may be warranted by its relation to matters such as administrative procedure, policy formation, intellectual property protection, vulnerability information, or legal proceedings. However, because Army policy specifies the Technical Report as "the principal document representing the culmination of a completed notable scientific and technical effort" (AR 70-31, para 6.a), a Letter Report may not serve as the MRRP's closeout documentation for any DoD-sponsored research study.

Uniform Content Requirements

The basic content, presentation format, and literary style of MRRP reports are modeled on two widely accepted industry-standard references:

- American National Standard Z39.18-2005, Scientific and Technical Reports—Preparation, Presentation, and Preservation (ANSI/NISO Z39.18-2005
- The Chicago Manual of Style – 15th Edition (University of Chicago Press 2003).

ANSI/NISO Z39.18-2005 and the Chicago Manual shall prevail in all matters of report content and style. However, supplementary industry or government manuals may be consulted to resolve issues that are not addressed either by the ANSI standard or the Chicago Manual. A report should be organized to suit the specific requirements of the topic and the audience. However, all MRRP reports must include the basic content elements specified in ANSI/NISO Z39.18-2005, as described below. Included in the discussion are several optional components, which are clearly designated as such.

Front matter

This is the term for pages that carry information identifying the document, its authors, the funding authorization, report contents, etc. Collectively it includes the cover, title page, table of contents, Figure and table lists, preface, unit conversion factors, and other explanatory text. Page numbering is tracked with lowercase roman numerals. The cover presents basic information about a report's topic, authorship, and authorized distribution. A report number and date are printed on the cover to indicate that the document is an official MRRP technical publication. The title page includes the same information that appears on the cover plus detail about project sponsorship, funding, and author affiliation. The title page is counted as the first numbered page in the report, but the page number is not displayed.

The abstract appears on the reverse side of the title page. It summarizes the research problem, project objective, and outcome of the investigation. It should run no more than 200 words. Also on the reverse side of the title page is the standard disclaimer of any implied government endorsement of products discussed in text.

The distribution statement is a critical component of both the cover and the title page. Every MRRP technical publication must be imprinted with one of the seven primary distribution statements required by Department of Defense Directive (DoDD) 5230.24. Most reports published by the MRRP are intended for unrestricted public access and carry Statement A: "Approved for public release; distribution is unlimited."

The contents pages include the table of contents and lists of figures, tables, plates, etc. The table of contents will usually include the titles and page numbers for at least two levels of text organization (chapter and section). A preface is included in all MRRP reports to present essential non-technical documentation of the project, such as funding

authorization, sponsorship, technical contributors to project execution, chain of supervision, and the authors' acknowledgments.

A unit conversion factors table is included in all reports that do not use metric units or dual units. The table should include only those U.S. customary units used in the report. A notation list also may be included to define characters, symbols, and abbreviations used to express technical facts or quantities. It appears after the unit conversion factors.

Introductory chapter

In the introductory chapter the page numbering system changes from roman to arabic numerals, with the numbering restarting at page 1. This is the first chapter in which technical content is introduced. The required sections are background, objective, and approach. ANSI/NISO Z39.18-2005 does not prohibit additional sections in the introductory chapter.

The *background* section defines the problem addressed by the research and its impact on the MRRP. It cites related previous studies and explains why the current research, monitoring or assessment effort is necessary. It also may present other background information that provides essential context for the reader.

The *objective* is a concise statement of what the research or monitoring & assessment effort is intended to accomplish. The *approach* section explains the research methodology. If the methodology is complex or otherwise warrants a chapter of its own, the approach section may simply cross-reference the reader to the appropriate chapter. For example, a scope section may be helpful to explain any limitations, caveats, etc., of which the reader should be aware. In some cases, supplementary technology transfer or contact information also may be appropriate for the intended audience.

Technical reporting and discussion

This portion of the report begins with Chapter 2 and may include any number of additional chapters. It reports all details that the reader needs to understand how the research was conducted, how the findings were documented, and how the results were validated. The technical discussion will often include a chapter of the author's in-depth analysis or interpretation of results to provide a clear context for the concluding chapter.

Concluding chapter

The concluding chapter is the last chapter in the main body of the report before the reference list. The chapter is usually called “Summary,” “Conclusions,” or “Conclusions and Recommendations.” A technical report may conclude with a summary chapter if its purpose is to document empirical observations or straightforward research findings such as the results of a field demonstration or a laboratory test series. A summary typically reviews the research results in more detail than the abstract.

A chapter of *conclusions* differs from a summary chapter in that it presents or reviews the author’s technical interpretation of the research results. Conclusions concisely help the reader to understand how the research objective was met and what the results mean in terms of the MRRP objectives or implementation needs. Conclusions should be included for every secondary objective stated in the introductory chapter.

Most reports will include *recommendations* for the program. Recommendations generally will pertain to (1) how the research product or results should be used to address the problem defined in the first chapter or (2) what the MRRP may do to transition a Level 1 product into Level 2 or 3 efforts.

References

A reference list is presented immediately after the final numbered chapter of the report, but before any appendixes. Formats and styles prescribed in the Chicago Manual of Style should be used. The reference list should include every information source cited in text plus any uncited sources that were drawn upon. The reference list for this Guide, presented on page 56, may be used as a model.

Back matter

This category of report content encompasses appendixes and the report documentation page. Some reports may have other optional types of back matter such as a glossary or a list of acronyms. Appendixes consist of any supporting text, illustrations, or data necessary to clarify or verify research findings but are too detailed or long to incorporate into the main body of the report without distracting the reader. Each appendix is customarily designated by a letter rather than a chapter number.

The report documentation page is prepared by filling out a Standard Form (SF) 298 using information provided by the author. It is the last page in the report, presented

after all other back matter. The report documentation page is usually completed by the PI during final draft preparation, after an official report number has been assigned.

Formatting References and Samples

- Technical Note

  Fleming, C., J. Bonneau, and A. Quinn. 2016. *The role of research in adaptive management.* MRRP Technical Notes Collection. MRRP TN-16-1. Omaha, NE: U.S. Army Corps of Engineers.

- Journal Article

  Knocke, W. R., and P. Trahern. 1989. Freeze thaw conditioning of chemical and biological sludges. *Water Research* 23(1):35-42.

- Proceedings of Symposium

  Kovacs, A. 1989. Freezing ice in a harbor. In *Proceedings, 10th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC '89),* 12–16 June, Luleå Sweden, ed. K. B. E. Axelsson and L. A. Fransson, 6:235–242. Luleå Sweden: Univ. of Technology.

- Book

  Sanks, R. L. 1978. *Water treatment plant design*. Ann Arbor, MI: Ann Arbor Science.

  Beranek, L. K., and L. Leo. 1982. *Acoustics*. New York: McGraw Hill.

- Article in Book

  Gillham, R. W., and S. F. O'Hannesin. 1990. Sorption of aromatic hydrocarbons by materials used in construction of ground-water sampling wells. In *Ground water and vadose zone monitoring*. ASTM STP 1053, 108-122. Philadelphia: American Society for Testing and Materials.

  Kling, R., and R. Lamb. 1996. Analyzing alternate visions of electronic publishing and digital libraries. In *Scholarly publishing*, ed. R. P. Peek and G. B. Newby, 17-54. Cambridge, MA: MIT Press.

- Thesis

  Altamirano, M. R. 1991a. Experimental investigation of high and low impact energy absorption of AS-4/3502 graphite/epoxy panels. MS thesis, Univ. of New Orleans.

  _____. 1991b. Experimental investigation of high and low impact energy absorption of AS-4/3502 graphite/epoxy panels. PhD diss., Univ. of New Orleans.

- Foreign Language

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  Green, M. P. 1995. A history of learning institutions. http://www.ccs.neu.edu/home/distancelearning.html

Style guide for MRRP reports

Table J 1 presents the style tags for material used in MRRP reports.

Table J 1: Principal style tags used in MRRP reports.

Style Tag Name	Application
Block Text	Direct quotation of three or more lines; other text to be emphasized
Body Text	Regular narrative text
Caption	Default style when any caption is created using Insert menu
Caption Figure	For manual application to unnumbered figure caption
Caption Table	Provides correct paragraph drop after a table caption
Equation	Provides correct paragraph spacing for inline equations
Equation Terms	Variation of Body Text with tabs suitable for aligning equation terms
Graphic Callout	For “labels” applied to figures inside movable text boxes
Graphic Inline	For standardized positioning of inline (but not floating) graphics
Heading 0	Chapter title (unnumbered) for appendix, appears in TOC
Heading 02	Appendix main section heading, does not appear in TOC
Heading 03	Appendix subsection heading; does not appear in TOC
Heading 04	Appendix sub-subsection heading; does not appear in TOC
Heading 1	Chapter title (numbered)
Heading 2	Main section heading, appears in TOC
Heading 3	Subsection heading, appears in TOC
Heading 4	Sub-subsection heading, appears in TOC
Hyperlink	Use mainly for formatting URLs
List Bullet	Standard bulleted list
List Number	Standard numbered list
Reference Text	Reference list entries
Sub-paragraph	First-level subparagraph, numbered alphabetically: a., b., etc.
Sub-paragraph 2	Second-level subparagraph, numbered numerically: (1), (2), etc.
Table Column Heading	Variant of Table Text for table column headings
Table Text	Preferred style tag for data presented in a table
Table Text Compact	Alternative style tag for fitting wider tables to page constraints

Attachment J.3 – Template for Study Progress Reports

MRRP Research & Monitoring **Date**

FYXX QX Progress Report

1. PROJECT TITLE:

2. PI NAME:

3. STATUS:

- o
- o Provide an update on the project
- o

4. PRODUCTS & MILESTONES:

Product or Milestone	Scheduled Delivery Date (mm/dd/yy)	Actual Delivery Date (mm/dd/yy)	Percent Complete

5. FISCAL STATUS:

Present your obligations and expenditures plan for the project.

Current FY	1Q	2Q	3Q	4Q
Obligations	$K	$K	$K	$K
Expenditures	$K	$K	$K	$K

Attachment J.4 – Science Procurement Policy

Introduction

This appendix describes the process for acquiring MRRP-funded science services, predominantly research and monitoring, within the Integrated Science Program. The process outlined below, which is applied and overseen by the ISP Chief, is intended to ensure sound business practice and compliance with applicable laws and policy as well as address the following objectives:

Objectives

1. To the extent possible and reasonable, provide full and open competition for research activities to allow consideration of proposals across the spectrum of qualified entities. This process will allow comparison of technical competence and cost efficiency of potential contractors (e.g. state and federal government, colleges and universities, and the private sector).
2. Maximize consideration of multiple research approaches. This process will allow the ISP (and independent reviewers) to evaluate the relative potential of different research proposals to meet study objectives.
3. Provide needed consistency for longer term monitoring efforts while still allowing for competition and opportunity to increase efficiency and effectiveness (e.g. current approach is to utilize a 5-year contract vehicle for monitoring).
4. Provide a clear and transparent process for acquiring monitoring and research.
5. Enable award of science contracts within the timelines dictated by budget cycles and decision-making needs.

In general, procurement of science services will be the result of open competition. In rare circumstances, unique qualifications or other factors may result in necessary deviations from this approach. In such cases, the rationale for deviation will be clearly articulated. The acquisition approach will likely vary some depending on the type of science activity being contracted. Science activities can be grouped into one of two main categories which differ from each other in several important aspects.

Monitoring

Monitoring efforts typically require longer term consistency (the contractor can't reasonably change on an annual basis) in order to efficiently and effectively accomplish monitoring objectives. Monitoring efforts follow a monitoring plan that, although not

static, must remain consistent over time and the execution of that plan must also remain consistent. Monitoring plans are developed by USACE, with input from partners and independent experts, prior to acquisition of monitoring contractors. Contractors will develop proposals to accomplish the predetermined monitoring needs. Differences in proposals will focus predominantly on cost and expertise of the contractor, not on different views of how the monitoring could be conducted since the monitoring plan is not subject to significant modification by individual proposals. Currently, monitoring contracts are awarded as 5-year IDIQ contracts or MIPRs depending on the recipient of the award.

Research

Research efforts are discrete experiments or studies which are often relatively short term (i.e. 1 to 3 years). Unlike longer term monitoring efforts, study designs for research projects will be subject to individual proposals. Although the objectives of the research will be dictated by AM needs (as described in the AM Plan), potential researchers will likely propose differing approaches to meeting those objectives. This will allow the ISP, and independent reviewers, to consider and compare the merits and costs of those multiple approaches in meeting research objectives.

For most research, the ISP will utilize a competitive proposal solicitation process open to government agencies, public sector contractors, and universities through an open Request for Proposals. Only research proposals which address high priority needs will be sought. Research proposals which are submitted to the ISP which do not address a high priority need will not be considered for funding. Research projects will be selected on the basis of their support of MRRP AM needs, demonstrated capabilities of proposers, and cost effectiveness. Selections will be made by USACE but informed by proposal reviews from an independent panel. The review process will vary depending on funding thresholds and/or relation of the research to management decisions and the potential impact of those decisions (see Funding thresholds and review/selection process below). The selected researcher will then become the principal investigator for that particular research project. Solicitation of proposals must occur far enough in advance so that information on potential costs and timelines is available as budgets are being developed. The Integrated Science Program is committed to the use of peer review and will refine peer review guidelines for reviewing research proposals, publications, and other products or deliverables. Further discussion is needed with Contracting and OC to determine what outside review is permissible when reviewing research proposals.

Types of contracts and agreements for procurement of science services

Acquiring the necessary science support from a range of entities including state and federal entities, colleges and universities, and private enterprises will likely require a suite of acquisition tools in addition to those previously utilized by the ISP. Availability of additional acquisition tools should be assessed both within the Districts and through ERDC when needed tools are not available to the Districts. Potential types of useful contracts and agreements may include but are not limited to the following:

1. Military Interdepartmental Purchase Request (MIPR)

MIPRs may be used as a vehicle to obligate funds to other federal agencies for purchasing equipment and services. The process for using a MIPR is described below.

<u>MIPR (Military Interdepartmental Purchase Request)</u>:

1) Complete Federal Agency Independent Government Estimate (IGE);
2) Complete a USACE IGE (determine if it would be cheaper to hire internally);
3) Complete A&E Contract IGE (determine if it would be cheaper to put out for bids);
4) Prepare Scope of Work (SOW) (must have an MOA with the Agency that allows work between both);
5) Receive Federal Agency Proposal;
6) Review proposal with Agency IGE;
7) Complete Determinations & Findings (D&F) document, MIPR document (Form 448) and Interagency Support Agreement (Form 4914-R);
8) Once the Proposals are received and D&F complete, send the complete package (D&F, proposals and all IGEs) for internal review and signature (Supervisor, Budget, Contracting, Office of Council). Then send signed chop sheet with other documents to NWD to review/sign;
9) Award for funding.

2. Indefinite Delivery/Indefinite Quantity (IDIQ) term contract

This type of contract provides for an indefinite quantity of services over a fixed period of time (3-5 years). The government places task orders against a basic contract for individual requirements which are individually negotiated. Minimum and maximum funding limits are specified in the base contract. The government uses an IDIQ contract when it cannot predetermine, above a specified minimum, the precise quantities of services that it will require during the contract period. This process includes creation of a base contract. Market Research is completed in the first year and then precluded for the remainder of the contract. Progress payments are made continuously on annual task orders. This is an exceptionally time-consuming process for the first year of long-term contracts but reduces Market Research requirements for successive years of the contract life.

3. Firm Fixed Price Contract

Under this type of contract, the contractor is required to perform the work described in the contract. The price is not subject to any adjustment on the basis of the contractor's cost experience in performing the contract. The total requirement has a fixed price for satisfactory delivery or complete performance. Progress payments can be made based on completion of predetermined deliverable milestones and percentage of contract amount for each. Upon satisfactory completion of the work and delivery of all items required, the contractor is paid the remaining contract amount.

4. Blanket Purchase Agreement (BPA)

A BPA is a simplified acquisition method that government agencies use to fill anticipated repetitive needs for supplies or services. The agreement is for specific line items with a provider who is intermittently called upon for those goods or services; terms and conditions are negotiated up front and any orders against the BPA must comply. This type of contract has been used by the ISP for recurring water quality analyses, for example, where the costs of each analysis is negotiated up front and individual call orders were issued as analysis needs warranted.

5. Grant/Cooperative Agreement

An agreement with a non-profit or public entity which shares interest in the Program's goals to provide services which benefit the interests of both parties. A cooperative agreement is an instrument for basic or applied research that will require substantial Government involvement and the end result benefits the public. A grant is an instrument for basic or applied research that benefits the public, but there will NOT be substantial Government involvement. In either case, the organization doing the work cannot be for profit, or if it is for profit, it waives the fee/profit. The Legal Office reviews every cooperative agreement to ensure that the work is R&D; there will be substantial Government involvement; there is a public benefit; and the funds are appropriate. There are additional reviews if the dollar amounts are >$500,000. And more reviews if the dollar amounts are >$1M.

6. Cooperative Ecosystem Studies Units (CESU)

The Cooperative Ecosystem Studies Units (CESU) Network is a national consortium of federal agencies, tribes, academic institutions, state and local governments, nongovernmental conservation organizations, and other partners working together to support informed public trust resource stewardship. This agreement allows full competition among cooperating universities. To initiate a project with a member CESU University requires the following steps:

1. Identify project and appropriate CESU
2. A statement of interest (SOI) is prepared by the ISP
3. ERDC posts SOI to a CESU website
4. SOI is posted to the CESU website for a minimum of 10 days
5. Initial proposals are reviewed for technical competency and a full proposal is sought from the most qualified entity
6. Technical review by ISP and Contracting representatives
7. Invoicing and reporting requirements determined by the ISP
8. Proposals may include multiple year funding options

Further description of these contracting tools (and potentially others) including availability and usefulness will be provided in AM Plan v6 following further discussions with District and ERDC contracting staff. Acquisition of products and services will be made in the most appropriate manner based on Federal Acquisition Regulations (FAR), USACE Policy and input from Contracting and OC.

Funding thresholds and review/selection process - TBD

This section will describe an increasing level of review and need for independent review as cost increases. The impact research has on major decisions and the potential impact of those decisions will also affect level of review.

Debriefing of unsuccessful contractors and protest procedures - TBD

Appendix K. List of Pallid Sturgeon Metrics

Table K1. Metrics for monitoring status and trend of populations, action effectiveness and ecosystem condition. Some metrics will be measured directly, while others are derived variables (some based on models). Some metrics are used as key performance measures while others are covariates to help explain the observed variability in key performance measures.

Metrics used to monitor Pallid Sturgeon status & trends, action effectiveness, or ecosystem condition	Both Upper and Lower Missouri		Upper Missouri	Lower Missouri		
	Population / Ecosystem Status and Trends	Augmentation (U & L)	Intake	IRCs	Spawning Habitat	Spawning Sync Flows
Hydrology, water quality and geomorphology						
Water temperature	X	X	X	X	X	X
Water velocity	X	X	X	X	X	X
Water depth	X	X	X	X	X	X
Discharge	X	X	X	X	X	X
Cross-section profile			X	X	X	
Spawning flow characteristics (timing, magnitude, longitudinal spatial distribution)*			X		X	X
Water year conditions (e.g., total inflow, peak flows)*	X	X	X		X	X
Turbidity	X	X				
Suspended sediment			X	X	X	X
Dissolved oxygen (particularly Lake Sakakawea)	X		X	X		
Nutrient loads	X					
Contaminant loads	X					
Habitat						
Spawning habitat chosen vs. habitat available			X	X	X	X
# and area of spawning sites created with suitable characteristics (depth, velocity, substrate, and derivative hydraulic variables)					X	X
Fraction of habitat area with suitable habitat characteristics for IRCs; and trends in these attributes				X		
Habitat complexity in IRCS (e.g. diversity indices, patch shape, patch connectivity)				X		

Metrics used to monitor Pallid Sturgeon status & trends, action effectiveness, or ecosystem condition	Both Upper and Lower Missouri		Upper Missouri	Lower Missouri		
	Population / Ecosystem Status and Trends	Augmentation (U & L)	Intake	IRCs	Spawning Habitat	Spawning Sync Flows
Production of food / area in IRCs and control sites				X		
Effective acreage (acre-days/yr of available IRC habitat)				X		
Fish Numbers and Survival						
Density of free embryos and larvae in IRCs, control areas, navigation channel, etc.	X	X	X	X		
Actual survival of hatchery-reared first-feeding pallid sturgeon larvae	X	X	X	X		
Number and survival rates (to age-0, age-1[1], and juvenile stage) for stocked pallid sturgeon by stocked size, hatchery of origin, and condition	X	X	X	X	X	X
Numbers of pallid sturgeon free embryos collected	X	X	X	X	X	X
Capture of age-0 and older juvenile pallid sturgeon (e.g., present / not present, CPUE)	X	X	X	X	X	X
Number of pallid sturgeon by age class and origin (wild vs. hatchery)	X	X				
Survival probabilities for stocked pallid sturgeon by stocked size, age, condition, and hatchery of origin	X	X				
Yearling equivalents (stocking performance based on 3-year running average of annual yearling equivalents)	X	X				
Modelled long-term change in population	X	X	X	X	X	X
Population size structure analysis	X	X	X	X	X	X
Fish Condition and Genetics						
Pallid sturgeon condition – length, weight, Kn, health metrics	X	X	X	X	X	X
Length frequency distribution of age-0 fish	X	X	X	X		
Condition of age-0 fish – % empty/full stomachs, lipid content	X	X	X	X		
Genetics	X	X	X	X	X	X

[1] Age-0 fish become age-1 fish on January 1st

Metrics used to monitor Pallid Sturgeon status & trends, action effectiveness, or ecosystem condition	Both Upper and Lower Missouri		Upper Missouri	Lower Missouri		
	Population / Ecosystem Status and Trends	Augmentation (U & L)	Intake	IRCs	Spawning Habitat	Spawning Sync Flows
Bioenergetic metrics				X		
Levels of disease	X	X	X		X	X
Fish Movement and Spawning						
Telemetry data showing movement and aggregation of adult fish in reproductive condition			X		X	X
Numbers of adult pallid sturgeon passing over/around Intake Dam (moving upstream)	X		X			
Successful passage of pallid sturgeon downstream over Intake Dam			X			
Telemetry data on selection for created spawning sites vs. control sites					X	X
Measures of fish aggregation and spawning behaviors (e.g. optimum male : female ratios in spawning aggregations)			X		X	X
Confirmed spawning through telemetry and acoustic video			X		X	X
Frequency and location of pallid sturgeon spawning events	X		X		X	X
Site characteristics of pallid sturgeon spawning locations			X		X	X
Spawner selection of different spawning substrates			X		X	X
Site confirmation that eggs are not buried			X		X	X
Hatch rate as a function of habitat availability	X		X		X	X
Capture of eggs and embryos downstream of sites with apparent spawning	X		X		X	X
Confirmed egg release through recapture of female pallid sturgeon			X		X	X
Recruitment (field monitoring & model estimation) to age-1,2,3	X	X	X	X	X	X
Estimated improvement in spawning and recruitment due to management action		X	X	X	X	X

Metrics used to monitor Pallid Sturgeon status & trends, action effectiveness, or ecosystem condition	Both Upper and Lower Missouri		Upper Missouri	Lower Missouri		
	Population / Ecosystem Status and Trends	Augmentation (U & L)	Intake	IRCs	Spawning Habitat	Spawning Sync Flows
Augmentation						
Number, size, age, location, habitat and origin of captured pallid sturgeon	X	X				
Pallid sturgeon capture method and intensity		X				
Hatchery of origin of released pallid sturgeon		X				
Number, size, age, location, hatchery of origin and date of released pallid sturgeon	X	X				
Proportion of pallid sturgeon from different release groups		X				
Effective population size, empirical and projected		X				
Catch rates of pallid sturgeon/catch efficiency/CPUE		X				
Ecosystem Condition						
Abundance/biomass of direct or indirect competitors	X					
Abundance/biomass of predators of pallid sturgeon	X					
Abundance/biomass of key food sources for each life history stage of pallid sturgeon	X					

1

Appendix L. Reserved

2

Appendix M. Distributed Systems Data Management Requirements