Green Sturgeon Habitat Mitigation and Monitoring Plan

As set forth and described in the following National Marine Fisheries Service Biological Opinions:

West Sacramento General Reevaluation Study (NMFS File No. WCR-2014-1375)

American River Watershed Common Features (NMFS File No. WCRO-2020-03082)

Sacramento River Bank Protection Project Post Authorization Change Report (NMFS File No. WCRO-2019-01893)

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Acronyms

AM	Adaptive Management
ARCF	American River Common Features
BMP	Best Management Practices
BO	Biological Opinion
CDFW	California Department of Fish and Wildlife
CDWR	California Department of Water Resources
CFS	Cubic Feet per Second
CESU	Cooperative Ecosystems Studies Unit
Corps	US Army Corps of Engineers
CV	Central Valley
CVFPB	Central Valley Flood Protection Board
DPS	Distinct Population Segment
DWR	CA Department of Water Resources
EJB	Economically Justified Basin
ESU	Ecologically Significant Unit
FHAST	Fish Habitat Assessment and Simulation Tool
FRM	Flood Risk Management
GRR	General Re-evaluation Report
GRS	General Re-evaluation Study
GS HMMP	Habitat Monitoring and Management Plan
IEP	Interagency Ecological Program
IWM	Instream Woody Material
JSAT	Juvenile Salmon Acoustic Telemetry
kHz	kilohertz
LAR	Lower American River
LF	Linear feet
LIDAR	Light Detection and Ranging
NEMDC	Natomas East Main Drainage Canal
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
O&M	Operations and Maintenance
ODFW	Oregon Department of Fish and Wildlife
PACR	Post Authorization Change Report
PWT	Project Work Team
RM	River Mile
SAFCA	Sacramento Area Flood Control Authority
SAM	Standard Assessment Methodology model
sDPS	southern Distinct Population Segment
DSWC	Sacramento Deep Water Shipping Channel
SMART	specific, measurable, attainable, realistic, and timely
SRBPP	Sacramento Riverbank Protection Project

SRFCP	Sacramento River Flood Control Project
SWRCB	State Water Resources Control Board
USACE	US Army Corps of Engineers
USBR	US Bureau of Reclamation
USEPA	US Environmental Protection Agency
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
WDFW	Washington Department of Fish and Wildlife
WRDA	Water Resources Development Act
WSG	West Sacramento GRR
West Sac	West Sacramento Flood Control Project
WSAFCA	West Sacramento Area Flood Control Authority

GREEN STURGEON HABITAT MITIGATION AND MONITORING PLAN STATUS AND IMPLEMENTATION STRATEGY

1.0 INTRODUCTION

The U.S. Army Corps of Engineers (Corps) and its non-Federal partners are in various stages of planning and implementation for three flood risk management projects within the Sacramento River Basin. Biological Opinions (BO) issued for each project included conservation measures that recommended development of a Green Sturgeon Habitat Mitigation and Monitoring Plan (GS HMMP).

1.1 Existing Consultation Requirements

Conservation measures exist for developing a GS HMMP and updating the Fish Habitat Assessment and Simulation Tool (FHAST), formerly known as Simulation Assessment Methodology (SAM) model. The new FHAST will help to assess impacts more accurately from civil works projects on Green Sturgeon (*Acipenser medirostris)* and associated critical habitat. The Corps has recently consulted with National Marine Fisheries Service (NMFS) under the Endangered Species Act for projects that may impact green sturgeon habitat. These projects and associated BOs include the American River Watershed Common Features Project (ARCF) General Reevaluation Report (GRR) (Appendix A, NMFS 2015 WCR-2014-1377; NMFS 2016, ARN 151422-WCR2014-SA00133), West Sacramento Flood Control Project (West Sac) GRR (Appendix B, NMFS 2015 WCR-2014-1375; NMFS 2017, WCR-2017-7990; NMFS 2018, WCR-2018-9430) and Sacramento River Bank Protection Project (SRBPP) Post Authorization Change Report (PACR) (Appendix C, NMFS 2019, WCRO-2019-01893). Current measures under these BOs also include the tagging, and monitoring of green sturgeon and associated habitat.

1.2 Purpose

The purpose of the GS HMMP is to describe the process by which the Corps will implement green sturgeon southern Distinct Population Segment (sDPS) mitigation and monitoring commitments made in the latest decision documents for the ARCF Project, West Sac Project, and SRBPP. The GS HMMP study area consists primarily of Sacramento River Miles (RM) 0-80 (Figures 1 & 2). The GS HMMP describes effects of civil works projects occurring within the study area, and the Best Management Practices associated with activities that may minimize impacts. The goal of developing the GS HMMP is to ensure that adverse impacts of these three flood risk management projects on sDPS green sturgeon are sufficiently mitigated to allow for the growth, survival, and recovery of the species in those areas impacted by the Corps projects. This is a living document to serve as a tool to adaptively manage mitigation and monitoring strategies proposed in this plan.

Pursuant to the biological opinions, the Corps is working in collaboration with NMFS, the Central Valley Flood Protection Board (CVFPB), Department of Water Resources (DWR), West Sacramento Area Flood Control Agency (WSAFCA) and Sacramento Area Flood Control Agency (SAFCA) to establish the management and financial framework necessary to implement the GS HMMP-related actions. The Corps, with assistance from its non-Federal partners, have begun a process to fund, plan, and implement actions to benefit green sturgeon. To date these actions

include: monitoring activities, mitigation site selection and contracting to develop the FHAST model and grant funding opportunities local universities to better understand green sturgeon. The updated FHAST model will replace the existing SAM model and will include modules for Federally listed salmonids as well as sDPS green sturgeon This document is a coordinated effort between multiple districts within the Corps, US Fish and Wildlife Service (USFWS), NMFS, US Geological Survey (USGS), SAFCA, DWR, CA Department of Fish and Wildlife (CDFW), UC Davis, UC Santa Cruz, consulting firms, green sturgeon experts and the Interagency Ecological Program (IEP) sturgeon work team.

The GS HMMP describes activities for ARCF, SRBPP and West Sac to document any potential take occurring during and post-construction through observation of green sturgeon behavior in the project area via acoustic telemetry tracking. Telemetry data will provide information about green sturgeon habitat use and transit time in the project area compared to other reaches of the rivers. Post-construction monitoring will occur as required in associated biological opinions for each project, many civil work flood projects being 3-5 years post constructions, Sac Weir may be 5–8-year post construction.

1.3 Conservation Measures

The conservation measures identified in Table 1 summarizes the previous green sturgeon conservation measures for ARCF, SRBPP, and West Sac BO's.

The Corps is developing this GS HMMP in coordination with several BO's including: American River Common Features (ARCF, NMFS File No. WCR-2014-1377), (ARCF Re-initiation NMFS File No. WCRO 2020-03082) Sacramento Riverbank Protection Project (SRBPP, NMFS File No. WCRO-2019-01893), and West Sacramento GRR (WSG, NMFS File No. WCRO-2014-1375). The Corps has proposed the minimization measures for the ARCF (USACE 2021, NMFS 2015), that are also applicable to the SRBPP (NMFS 2019), and West Sac (NMFS 2015). The conservation measures include mitigation to minimize effects of the projects on federally listed fish species. Several measures may be applied to entire projects, or as species-specific actions, while other measures may be appropriate at specific locations within the project area. These avoidance activities are to be implemented during final design and construction.

The ARCF Project, part of the larger Supplemental Program funding package issued to the Corps in 2018, was required to commence designs in 2019 with the goal of construction to begin in 2022. Without the green sturgeon habitat model, it is challenging to accurately estimate the impacts to green sturgeon. Therefore, the Corps has coordinated with NMFS to develop the following alternative measure to minimize effects to green sturgeon.

1.3.1 FHAST

The Corps through a Cooperative Ecosystems Studies Unit (CESU) research grant with Fisheries Science Center at UC Santa Cruz is working on the FHAST to replace the SAM model created for salmonids. FHAST will develop an alternative green sturgeon survival and response model component that reflects green sturgeon preference for benthic habitat. It will account for the physical loss of habitat from revetment footprints instead of the convention used by the SAM which evaluates the fish response at the intersection of seasonal water surface elevations. Existing limitations of the existing SAM model is that it does not produce appropriate green sturgeon

functional assessments and mitigation recommendations based on species' use of aquatic habitats in the area during different life stages or times of the year.

The new FHAST green sturgeon model is anticipated to provide a more realistic effects assessment and reduce the mitigation requirements for future projects (ex. West Sacramento and potentially later contracts of ARCF erosion on the Sacramento River).

The objective set forth for updating the FHAST is to use the best available scientific expertise and information to develop a functional assessment methodology that can model the effects of future ARCF GRR actions, SRBPP actions, West Sacramento actions and future Sacramento District civil works actions. In addition, the FHAST needs to evaluate the performance of mitigation actions relative to the survival and growth of sDPS green sturgeon that are exposed to such actions. The new model will include hydraulic parameters and will be capable of evaluating project effects on all habitat conditions, not exclusively flow changes. The newly developed FHAST model with the green sturgeon module (summer 2023), would mostly benefit future flood risk reduction erosion protection activities as a part of the West Sacramento GRR and Sacramento Bank projects, but also could benefit later erosion action contracts under ARCF in 2023 and 2024.

1.3.2 Monitoring

Acoustic fish monitoring is occurring at ARCF sites pre-construction where feasible, during and post-construction. Telemetry data will document green sturgeon habitat use and transit time in the project area to estimate effects of project construction. For erosion prevention features along the Sacramento River, the Corps would conduct telemetry monitoring of green sturgeon for 3 years post-construction, or longer as required in BO's. Since the new Sacramento Weir fish passage structure would not be expected to operate annually, adding a reasonable amount of monitoring time to post-construction monitoring of the fish passage structure is warranted for the Sacramento Weir Widening Project. Acoustic telemetry will occur in the ARCF study area and would involve staff monitoring of the real-time telemetry data available online.

To coincide with the need for the GS HMMP, the Corps will continue to implement a benthic substrate sampling monitoring program to estimate food availability for green sturgeon. The data will inform habitat quality metrics in the green sturgeon model. The ARCF action areas will include both pre-construction, during, and post-construction sampling within study areas. If opportunity allows visual monitoring maybe conducted as well utilizing side scan sonar type technology.

Table 1. Summary of GS HMMP conservation measures from BO's for the American River Common Features (ARCF), Sacramento River Bank Protection Project (SRBPP), and West Sacramento GRS (general re-evaluation study) (WSG).

GS HMMP Conservation Measures	American River Common Features (2015)	West Sacramento GRS (2015)	Sacramento River Bank Protection Project (2019)	American River Common Features (2020)
The goal of the developing the HMMP conservation measure is to ensure that adverse impacts of future ARCF, SRBPP, and WSG projects on sDPS, green sturgeon are fully mitigated in order to maintain the growth, survival, and recovery of the species in the study area.	x	x	x	x
The GS HMMP shall be developed in coordination with the IEP green sturgeon project work team and consulted on with NMFS prior to the construction of any work within the designated critical habitat of sDPS, green sturgeon related to the ARCF, SRBPP, and WSG projects. The HMMP should focus on filling important data gaps on green sturgeon life history and micro and macro habitat ecology in both the Sacramento River drainage and the north Delta within the project impact area, in regard to how bank stabilization measures proposed in the ARCF, SRBPP, and WSG projects affect sturgeon ecology and survival, particularly in regard to juvenile rearing and survival. The goal of this conservation measure is to leverage the resources of the IEP to develop a HMMP that utilizes and applies the best available scientific expertise and information available.	x	x	x	x
The green sturgeon survival and growth response model shall reflect the green sturgeon preference for benthic habitat and that accounts for the physical loss of habitat from revetment footprints. The new modeling may include hydraulic modeling but must be capable of evaluating green sturgeon survival in response to levee repair projects in the project impact area and their effects on all habitat conditions, not exclusively flow changes. Development of the green sturgeon model shall be initiated at the start of the preconstruction engineering and design (PED) phase of the ARCF, SRBPP, and WSG projects and shall be peer reviewed by sturgeon experts on the IEP, other academia with sturgeon expertise and be consulted on with NMFS. The goal of this measure is to develop a functional assessment methodology using the best available scientific expertise and information available to model the effects of future ARCF, SRBPP, and West Sac project actions and evaluate the performance of mitigation actions relative to the survival and growth of sDPS green sturgeon that are exposed to such actions.	x	x	x	x
The HMMP will identify measures to restore or compensate for the area and ecological function of soft-bottom benthic substrate for sDPS green sturgeon permanently lost to project construction. The restored habitat must be capable of providing abundant benthic prey freshwater or estuarine areas; with adequate water quality, including temperature, salinity, oxygen content, and other chemical characteristics, is necessary for normal behavior, growth and viability of all life stages; and provide safe and unobstructed migratory pathways are necessary for timely passage of adult, sub-adult, and juvenile fish within the region's different estuarine habitats and between the upstream riverine habitat and the marine habitats. The restoration/mitigation shall be initiated prior to commencement of construction within the designated critical habitat of sDPS GS for the ARCF, SRBPP, and West Sac projects and the updated model should be used to validate performance. The restoration site and plan shall be developed in coordination with the IEP and be consulted on with NMFS. The goal is to ensure the spatial and temporal ecological impacts from project-related permanent loss of critical habitat for green sturgeon critical for juvenile green sturgeon are fully compensated.	x	x	x	x
The HMMP shall be developed with measurable objectives for completely offsetting all adverse impacts to all life stages of sDPS green sturgeon. The goal of this measure is to develop "SMART" objectives for mitigation. "SMART" objectives are specific (target a specific area for improvement), measurable (quantify or suggest an indicator of progress), attainable (specify who will do the work and if possible, how), realistic (state what results can realistically be achieved, given available resources) and timely (specify when the results can be achieved) habitat performance objectives for green sturgeon mitigation.	x	x	x	x
The sDPS GS HMMP will include measurable performance standards at agreed upon monitoring intervals. The HMMP will include adaptive management strategies for correcting any mitigation measures that do not meet performance standards. The goal of this measure it to provide a reasonable amount of time to measure performance standards after mitigation occurs to ensure that it meets the objectives of the HMMP.	x	x	x	x

1.4 Background

The West Sac GRR, ARCF GRR, and SRBPP PACR are described below.

1.4.1 West Sacramento Flood Control Project General Reevaluation Report

Current levee design criteria, revised based on studies over the past decade, indicate that the system around West Sacramento does not meet a 100-year level-of-performance (an event that has a 1 percent chance of occurring in any given year). Structural modifications to the levee system are proposed to address seepage, levee stability, erosion, and overtopping concerns along the existing West Sacramento levees and provide flood risk management to the City of West Sacramento.

The series of storms that struck California in February 1986 resulted in the flood of record for many areas in northern and central California. The estimated peak flows associated with the 1986 flood were nearly equal or exceeded the design flows of the Sacramento River, Sacramento Bypass, and the Yolo Bypass in the vicinity of West Sacramento. As a result of the problems experienced during the 1986 flood, the Corps initiated a study of the levees comprising the Sacramento River Flood Control Project (SRFCP) that were impacted by the flood. Due to the large scale of the study, the review was split into five phases. The first phase of this study included West Sacramento and was documented through an Initial Appraisal Report titled, Sacramento Urban Area Levee Reconstruction Project, California dated May 1988. This phase included the review of approximately 110 miles of levee and recommended the repair of 34 miles.

The 1986 flood also exposed structural problems and identified the inability of the existing levees to provide critical flood protection to the Sacramento metropolitan area. As a result, the Corps, in cooperation with the State of California, initiated the GRR titled, Sacramento Metropolitan Area, California, Feasibility Report. This report was published in February 1992 and indicated the existing flood control system in the study area provided significantly less than a 100-year level of protection. The study went on to recommend a program of improvements. The repairs recommended by the Sacramento Metropolitan Area, California, Feasibility Report were authorized in the Water Resources Development Act (WRDA) of 1992 (Public Law 102-580).

The Corps was preparing construction plans and specifications for the levee repairs authorized in the WRDA of 1992, when the 1997 New Year's Day Flood occurred. It was one of the largest experienced in northern California since the beginning of the measured record in 1906. In the wake of the 1997 flood, the Corps identified underseepage as an area of greater concern in the design and repair of levees. This resulted in a number of design revisions to the levee repairs recommended in the West Sacramento Project Design Memorandum. These design revisions and the associated increase to the total estimated project cost were captured in a supplemental authorization through the Energy and Water Development Appropriation Act of 1999 (PL 105-245).

In September 2015 NMFS issued a biological opinion concluding that West Sac, with the conservation measures proposed, is not likely to jeopardize the continued existence of the federally listed threatened Central Valley (CV) spring-run Chinook Salmon evolutionarily significant unit (ESU) (*Oncorhynchus tshawytscha*), endangered Sacramento River winter-run Chinook Salmon ESU (*O. tshawytscha*), threatened California CV Steelhead distinct population segment (DPS) (*O.*

mykiss), or the threatened sDPS of North American green sturgeon. In addition, the BO determined that West Sac work is not likely to destroy or adversely modify their designated critical habitats. It also concluded that West Sac would adversely affect the essential fish habitat of Pacific Salmon.

1.4.2 American River Watershed Common Features General Reevaluation Report

After the flood of 1986, Congress directed the Corps to investigate the feasibility of reducing flood risk to the City of Sacramento. The Corps completed that feasibility study in 1991. Congress authorized the ARCF in the WRDA of 1996. In 1999, Congress authorized improvements for Folsom Dam, and downstream levee improvements could be tied to the dam improvements in order to have a more cohesive project. Therefore, ARCF was modified by the 1999 WRDA to include American River improvements to safely convey 160,000 cubic feet per second from Folsom Dam. In February 2018, the Bi-Partisan Budget Act of 2018 (Public Law 115-123) appropriated funds to the Corps to implement project construction. The study area for the Common Features GRR includes: (1) approximately 22 miles of the north and south banks of the American River immediately upstream from the confluence with the Sacramento River; (2) the east bank of the Natomas East Main Drainage Canal (NEMDC), Dry, Robla, and Arcade Creeks and the Magpie Creek Diversion Channel (collectively referred to as the East Side Tributaries); (3) the east bank of the Sacramento River downstream from the American River to Freeport, where the levee ties into Beach Lake Levee, the southern defense for Sacramento; and (4) the Sacramento Weir and Bypass, located along the north edge of the city of West Sacramento.

In September 2015 NMFS issued a BO, concluding that ARCF, with the conservation measures proposed in the ARCF GRR, is not likely to jeopardize the continued existence of the federally listed threatened CV spring-run Chinook Salmon evolutionarily significant unit ESU (*Oncorhynchus tshawytscha*), endangered Sacramento River winter-run Chinook Salmon ESU (*O. tshawytscha*), threatened California CV Steelhead distinct population segment DPS (*O. mykiss*), or the threatened sDPS of North American green sturgeon. In addition, the BO determined that the ARCF is not likely to destroy or adversely modify their designated critical habitats. It also concluded that ARCF would adversely affect the essential fish habitat of Pacific Salmon.

1.4.3 Sacramento River Bank Protection Project and the Post Authorization Change Report

The Sacramento River Flood Control Project consists of more than 1,000 miles of levees plus overflow weirs, pumping plants, and bypass channels which protect communities and agricultural lands in the Sacramento Valley and the Sacramento–San Joaquin River Delta (Delta). The SRFCP was originally constructed pursuant to the Flood Control Act (Pub. L. 64-367, Section 2, 39 Stat. 948, 949 [1917]), which Congress enacted on March 1, 1917. Congress first authorized the Corps to provide substantial support for ongoing flood protection as applied to the existing SRFCP in 1960 (Flood Control Act, Pub. L. 86-654, Section 203, 74 Stat. 498 [1960]). The portion of the SRBPP completed pursuant to the original 1960 authorization was constructed from 1963 to 1975 and consisted of about 430,000 LF (linear feet) of bank protection.

In 1972, the Chief of Engineers found that "Although work under the initial phase (Phase I) has effectively controlled erosion at the critical sites, each year stream banks and levees at additional unprotected locations throughout the SRFCP are subject to erosion" (USACE 1972).

Accordingly, in 1974, repair of 405,000 LF was authorized in the River Basin Monetary Authorization Act, Pub. L. 93-252, Section 202, 88 Stat. 49 (1974) and is commonly referred to as Phase II of the SRBPP. The 1960 Act was further supplemented by an authorization passed on Dec 21, 1982 which provided "…that funds available or hereafter made available for the project for flood protection on the Sacramento River, California, authorized by the Flood Control Act of 1960, may be used for construction of bank erosion control works along the banks of the Sacramento River for Chico Landing to the upstream ends of the project levees." (Pub. L. 97-377, Section 140, 96 Stat. 1916). Phase II construction began in 1976 and as of 2019, approximately 403,450 LF have been repaired. There are approximately 1,550 LF remaining as part of the original Phase II authorization.

Through the WRDA of 2007, Phase II was modified to include an additional 80,000 LF of bank protection (Pub. L. No. 110-114, Section 3031). A PACR to support revisions to the SRBPP for the additional 80,000 LF was needed in order to avoid an interruption in levee repairs, and bank protection may only be considered economically justified in certain portions of the program area. There are currently seven economically justified basins (EJB) that are identified to satisfy the positive benefit-cost analysis criteria.

The number and extent of erosion sites can change from year to year because of various factors, including, but not limited to, newly identified sites, increased or decreased rates of erosion, repaired sites, reclassification of erosion sites to maintenance sites, and sites deemed to be no longer threatened by erosion. Due to the uncertainty about the number and size of erosion sites, a Programmatic BO limits the scope of the analysis and consultation to a total of 30,000 LF of bank protection on SRFCP levees within the seven EJBs. Implementation of the remaining 50,000 LF of authorized bank protection will be addressed in future consultations as necessary. Site specific consultations are tiered off of the Programmatic BO's and supplemental National Environmental Policy Act (NEPA) is completed as needed.

In August 2019, NMFS issued a biological opinion concluding that SRBPP, with the proposed conservation measures, is not likely to jeopardize the continued existence of the federally listed endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) ESU, the threatened CV spring-run Chinook salmon ESU (*O. tshawytscha*), the threatened sDPS of the North American green sturgeon, and the threatened California CV steelhead DPS (*O. mykiss*). In addition, the BO determined that SRBPP is not likely to destroy or adversely modify their designated critical habitats. NMFS also concluded that the program will adversely affect the Essential Fish Habitat of Pacific Coast Salmon in the action area.

1.5 Programs and teams working with the GS HMMP

The IEP (CDWR 2020) Sturgeon Project Work Team (PWT encourages, facilitates, and coordinates sturgeon monitoring, research, and information dissemination. In addition, it provides a technical forum for CV sturgeon issues and allows for participation from numerous academic institutions, State agencies and Federal to share telemetry data.

Objectives of the teams/groups include:

- Encourage, facilitate, and assist development of research on life history, distribution, population dynamics, abundance, and ecology of CV green sturgeon.

- Encourage, facilitate, and assist development of monitoring and research to evaluate the effects of water development/management and other stressors on CV green sturgeon.
- Identify research questions and data gaps.
- Provide technical review of sturgeon research, monitoring, and restoration proposals and recommendations on technical issues related to the protection, restoration, and management of sturgeon.
- Promote dissemination of project updates, research results, and current literature among scientists, resource managers, restoration specialists, and constituent organizations.
- Provide a forum for collaborative telemetry discussion and research on CV migratory fishes.
- Provide guidance and review of CV migratory fish telemetry research and monitoring.
- Increase linkages between telemetry research and application to allow for further development of detailed work plans for new studies.

2.0 PREVIOUS GREEN STURGEON-RELATED MONITORING

The GS HMMP study area consists primarily of Sacramento RM 0-80 (**Figure *1*** and **Figure *2***). The Corps began conducting telemetry monitoring in 2010 to better understand adult green sturgeon movement patterns and behavior. In 2016, the Corps began benthic substrate sampling to identify the macro-invertebrate community found in the Sacramento River. Long-term movement studies provide information on when and where adult green sturgeon move upstream and downstream to their spawning and feeding areas. The macro-invertebrate sampling identifies species, numbers, and biomass of the potential green sturgeon food supply.

2.1 Green Sturgeon Telemetry

2.1.1 Adult Green Sturgeon

The Corps began employing acoustic telemetry and collecting adult green sturgeon migration data in 2010 using Vemco VR2W 69-kHz receivers. The objective of the tracking efforts has been to leverage the available equipment inventory, past tagging efforts and ongoing tagging efforts (including those by other agencies) to passively collect migration data for adult green sturgeon passing though the lower Sacramento River. This migration data will help to provide an understanding of when and how adults travel through the lower Sacramento river during spawning migrations.

In 2010, 2011, and 2012, the Corps deployed a 2-D telemetry array at RM 85.6 on the Sacramento River, about one mile upstream of the Fremont Weir. The objective of this array was to provide 2-D tracks of salmonids moving past a constructed SRBPP repair site and determine if the Corps monitoring team could observe any behavioral responses to the constructed features of the site. Though 2-D tracks were not generated for green sturgeon, the monitoring team was able to peripherally collect sturgeon migration data as tagged green sturgeon were detected by the array.

In 2013 and 2014, the study area was expanded, and the migration station methodology was initiated. Receivers were deployed in pairs (one near each river bank) that functioned as acoustic gates from RM 15 near the confluence of the Sacramento River and the Sacramento Deep Water Shipping Channel (DSWC)to RM 90 near Knights Landing. There were additional gates placed in several sloughs throughout the Delta.

In 2015 an array of receivers was placed at RM 43.7, an SRBPP repair site, to generated 2-D tracks for salmonids. This also allowed the monitoring team to passively collect green sturgeon presence/absence data. Receivers were also deployed in an acoustic gate fashion between RMs 55 and 90.

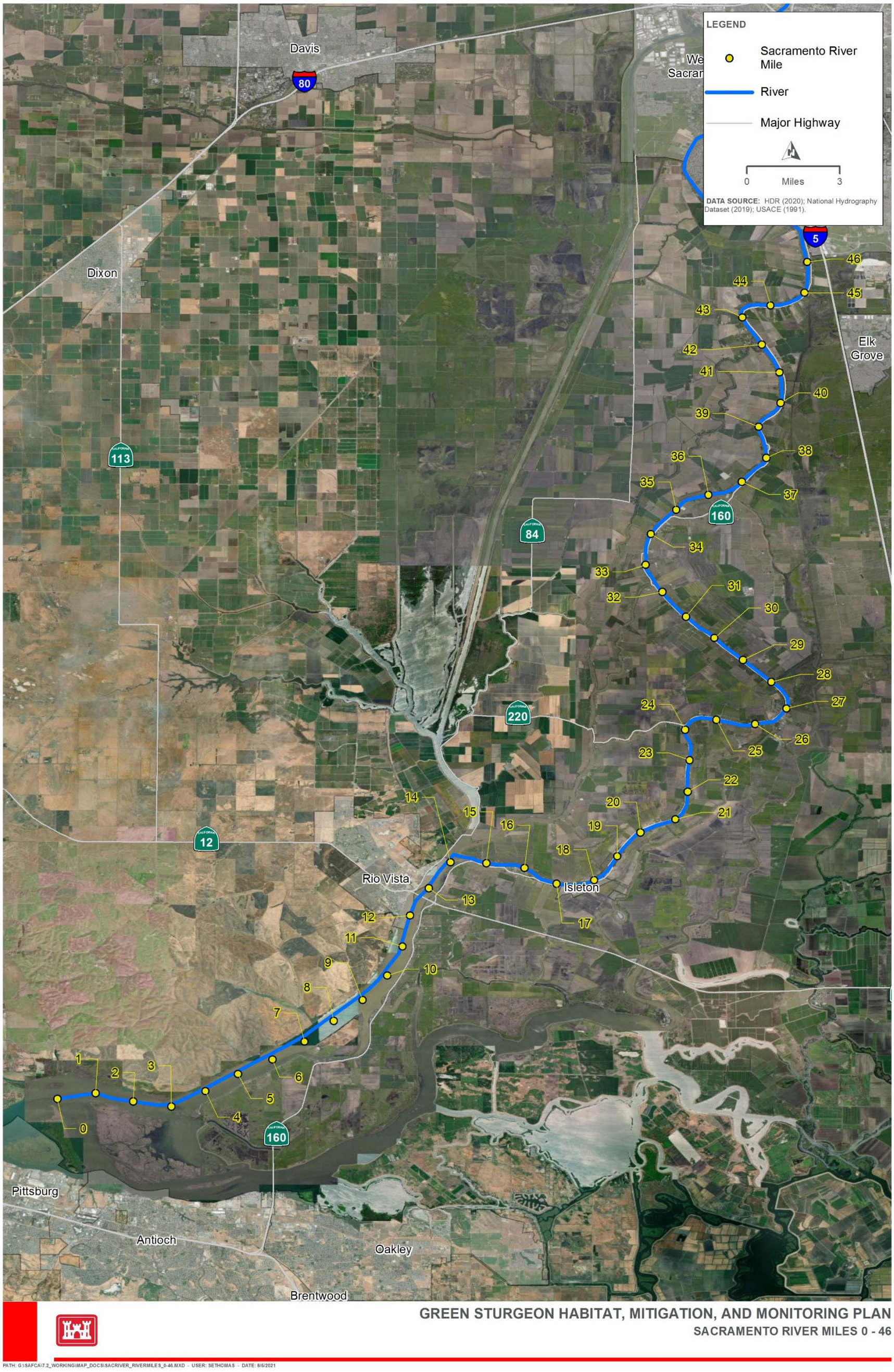


Figure 1. Map of the GS HMMP Study Range from rivermile 0 – 46.

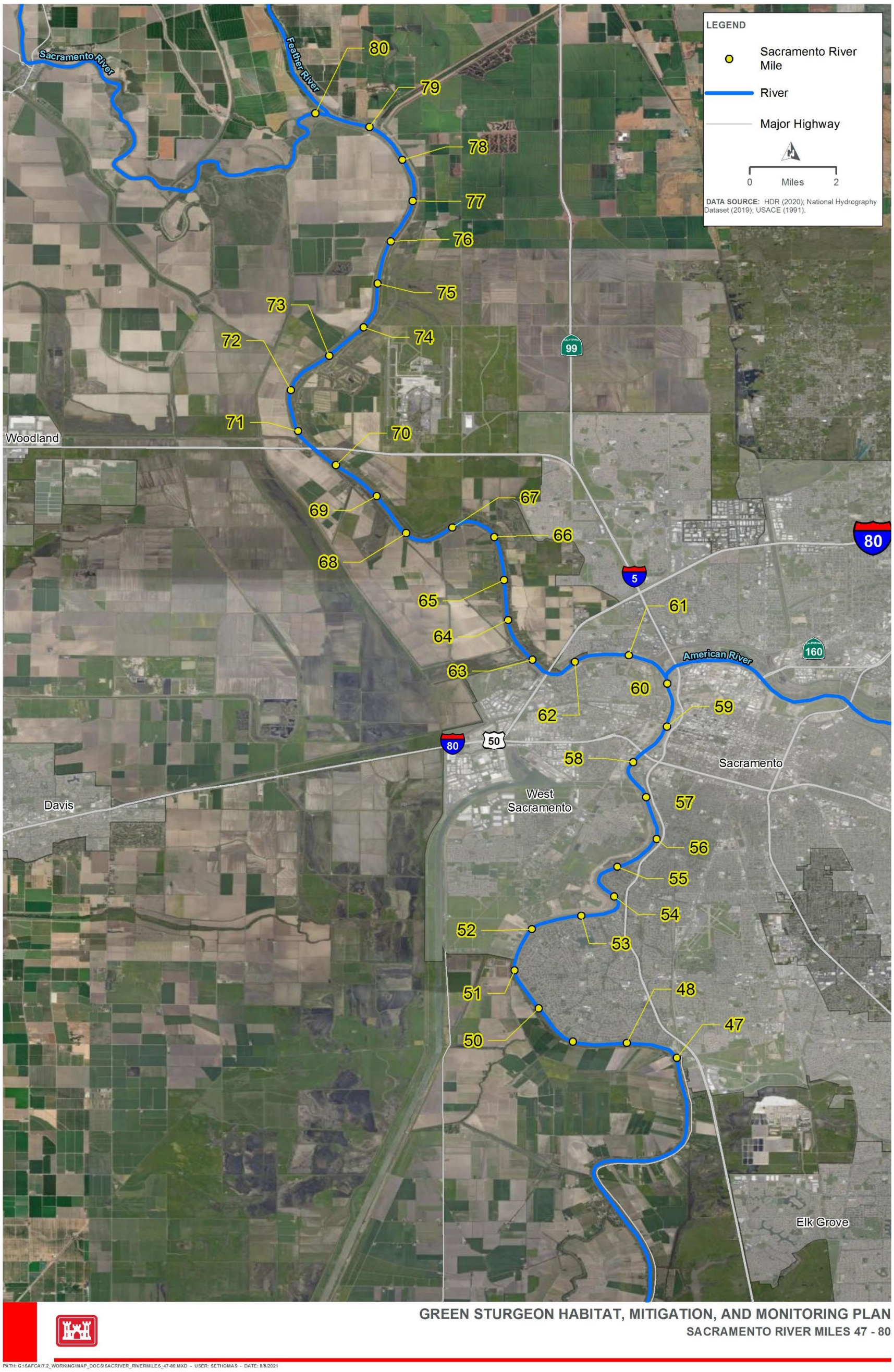


Figure 2. Map of the GS HMMP Study Range from rivermile 47-80.

In 2016 a two-dimensional array was deployed at RM 75 to examine the potential for habitat usage at a wing dam. The2-D tracks have not been processed yet. Additionally, four acoustic gates were placed lower in the system, between RMs 34.5 and 42.5.

In 2017, receivers were placed as acoustic gates at RMs 32 and 43.7.

In 2018, a series of six acoustic gates were placed from RM 32 to RM 85. The receivers at RM 32 were retrieved in July 2018 and not re-deployed because there were frequent problems with sediment burring mounts and because it was difficult to retrieve the receivers at that location.). The remaining five gates near RMs 43.7, 54.5, 65, 75 and 85 are still in place as of October 2021.

In 2018 a new study area was included above and below the city of Colusa to compare migration within a setback reach (upstream of Colusa) to a channelized reached (downstream of Colusa). While not directly in the project area, this could be valuable for understanding behaviors within differing physical conditions, thus providing additional data on juvenile green sturgeon habitat usage during migration.

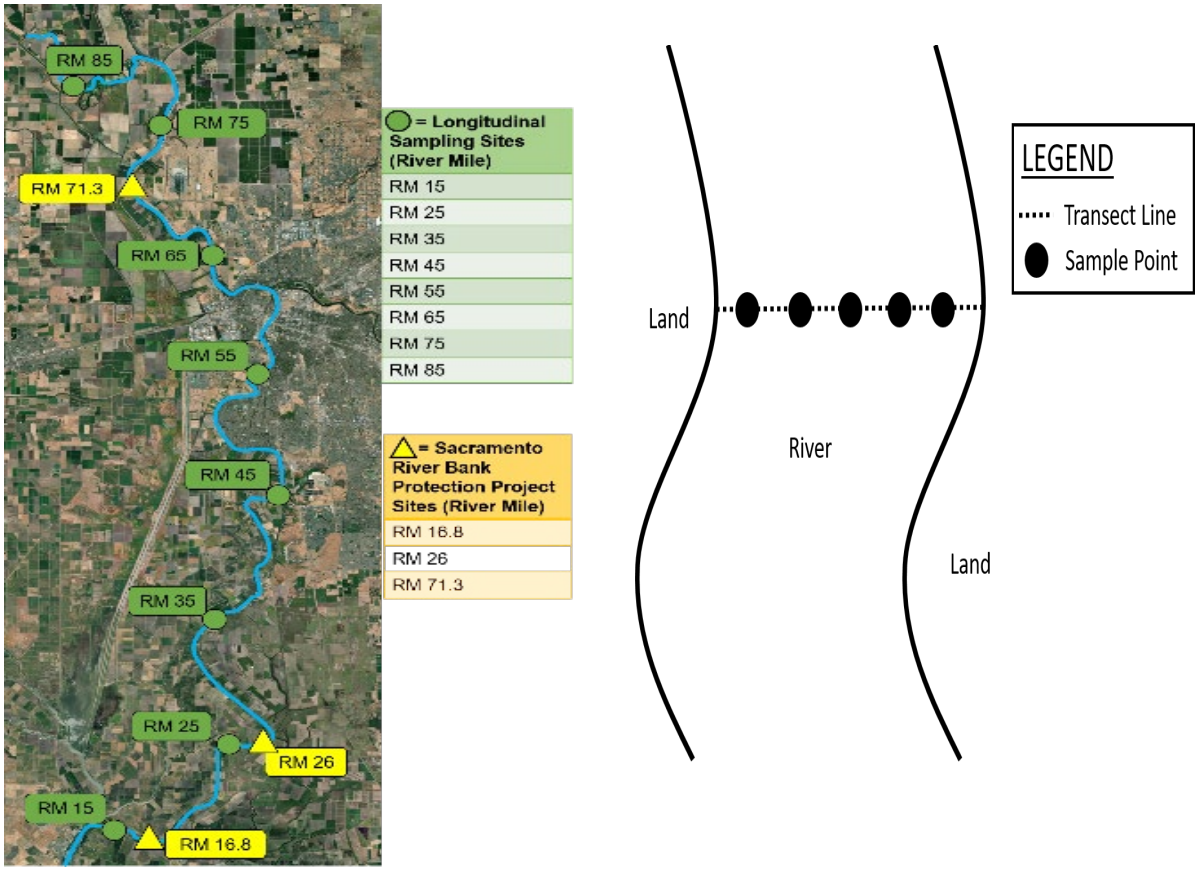
2.1.2 Juvenile Green Sturgeon

The two objectives for juvenile green sturgeon are 1.) Conduct further comparison of habitat use in relation to setback levees relative to the channelized river reaches. 2.) Determine what, if any, different behaviors juvenile green sturgeon are demonstrating in a natural bank setting versus a rip-rap or erosion repair setting. In collaboration with the NMFS Southwest Fisheries Science Center and USFWS the Corps deployed Juvenile Salmon Acoustic Telemetry Systems (JSATS) receivers in the fall and winter of 2016-2020, to monitor juvenile green sturgeon migration on the Sacramento River above and below the city of Colusa. The deployment was coordinated with wild juvenile green sturgeon tagging by USFWS from the Red Bluff field office. Stations were identified above and below the city of Colusa to fill gaps in NMFS and USFWS receiver coverage. This location was also ideal because the migration rates could also be compared above and below Colusa due to a predominately setback levee system above Colusa and a more channelized system below Colusa. In 2017, stations above the city of Sacramento were added and JSATS receivers were deployed at RM 65, RM 75, RM 85, and RM 54.5. JSATS receivers were also deployed below the city of Sacramento at RM 43.7. The 2016-2018 JSATS data is currently being analyzed by USFWS.

2.2 Benthic Macroinvertebrates

2.2.1 Benthic Sampling

The Corps conducts benthic sampling along the lower Sacramento River (Figure 3) with the objective of documenting food availability for migrating green sturgeon. Each location is sampled at five points along a transect perpendicular to river flow. Along these five-point transects, two petite ponar drops are conducted at each point to ensure adequate data for analysis. The ponar samples a six inch by six-inch section of the river bottom, and has a closed volume of 2.4 liters. Geographic coordinates are recorded for each drop site. Once the ponar is retrieved, it is emptied onto screen classifiers to sift through any collected substrate and remove any potential invertebrates or detritus that may house invertebrates. The substrate sample is classified as being made up of clay, sand, gravel, some combination thereof, or no substrate. Vertebrate presence is documented, but vertebrates are not retained for collection and subsequent processing.



(A) *(B)*

Figure 3. (A) Benthic substrate sampling locations by river mile; (B) sampling locations along transect line.

Table 2. Benthic Specimen Taxonomic Identification Levels.

Taxonomic Level	Taxa Identified
Phylum/Subphylum	Platyhelminthes (Flatworms) Nematoda
Class/Subclass	Oligochaeta Hirudinea (Leeches) Polychaeta (Bristle worms) Gastropoda (Snails)
Order	Amphipoda Odonata (Dragonflies/Mayflies) Coleoptera (Beetles) Diptera (Flies) Ephemeroptera (Mayflies) Plecoptera (Stoneflies) Trichoptera (Caddisflies)
Species	*Corbicula fluminea* (Asian freshwater clam)

Collected organisms or detritus are placed into labelled sample jars and filled with 90% ethanol for preservation until processing. Samples are processed later, with benthic macro-invertebrates identified down to varying levels of taxonomy (Table 2). Benthic sampling of the lower Sacramento River has occurred primarily in the spring and late fall, when adult and juvenile green sturgeon are expected to be active in this reach of the river. Any future modifications to the benthic monitoring program that may be made would be annotated in future reports. Future sampling will occur in March and November of each year. A sampling period may occur in June to further compare earlier study results. Further development of the GS HMMP may impact the future implementation of benthic monitoring.

3.0 IMPLEMENTATION STRATEGY AND FUTURE ACTIONS

Implementation of the GS HMMP consists of three major activities: monitoring and analysis, model development, and habitat mitigation (Figure 4). Environmental monitoring and analysis is done to assess green sturgeon ecological needs, and to provide data that informs conceptual and ecosystem models. Model development will begin with identifying existing conceptual models as the foundation for examining green sturgeon ecological habitat relationships. The ecosystem model will be developed based on the conceptual model and the SAM framework. The modeling framework will use monitoring data to identify preliminary mitigation measures for green sturgeon life stages. These measures can be further refined though the adaptive management process.

The conceptual and ecosystem models contribute information for designing appropriate mitigation features and monitoring the effectiveness of these features. Annual monitoring reports will be reviewed internally within the Corps and externally by either academic institutions, the NMFS Science Center, or other members of the green sturgeon IEP. This review will ensure adequate analysis to inform the green sturgeon model and allow any refinements that may be needed after the initial model is developed. The completed model will be used to inform adaptive management decision-making processes when assessing civil works impacts to green sturgeon in the lower Sacramento River.

The GS HMMP team has identified several different habitat types with attributes that occur within the Sacramento River (Figure 1 and Figure 2). The team recognized the GS HMMP study area functions primarily as a migratory corridor for adult green sturgeon. Further preliminary analysis conducted on juvenile green sturgeon movement data indicates juvenile green sturgeon may also utilize the HMMP study area primarily as a migratory corridor. Future monitoring studies beyond FY 2020 will focus on areas with possible green sturgeon effects including both the Sacramento River and Lower American River. Data synthesis should identify where to focus monitoring efforts in order to best to assess the civil work project impacts reaches of the river.

Additional monitoring activities such as the expansion of adult and juvenile green sturgeon hydro-acoustic monitoring will be added to the monitoring plan in the future as recommended in BO's. The hydro-acoustic monitoring portion of the monitoring plan would include both tagging and monitoring of adult and juvenile green sturgeon. This monitoring would also implement different types of acoustic technology to both accommodate life stages and more accurately define site fidelity within the study area. Also, the current benthic substrate sampling may need to be expanded to areas where anticipated project impacts may occur. In addition, data analysis may indicate that substrate sampling should be updated. The current sampling methods, techniques and sampling time periods are expected to remain the same as in previous years. Annual monitoring reports are expected to be completed and submitted to NMFS shortly after the previous monitoring calendar year. Initial results compiled and analyzed by the Corps will be discussed with NMFS and other agencies associated with the IEP Sturgeon PWT.

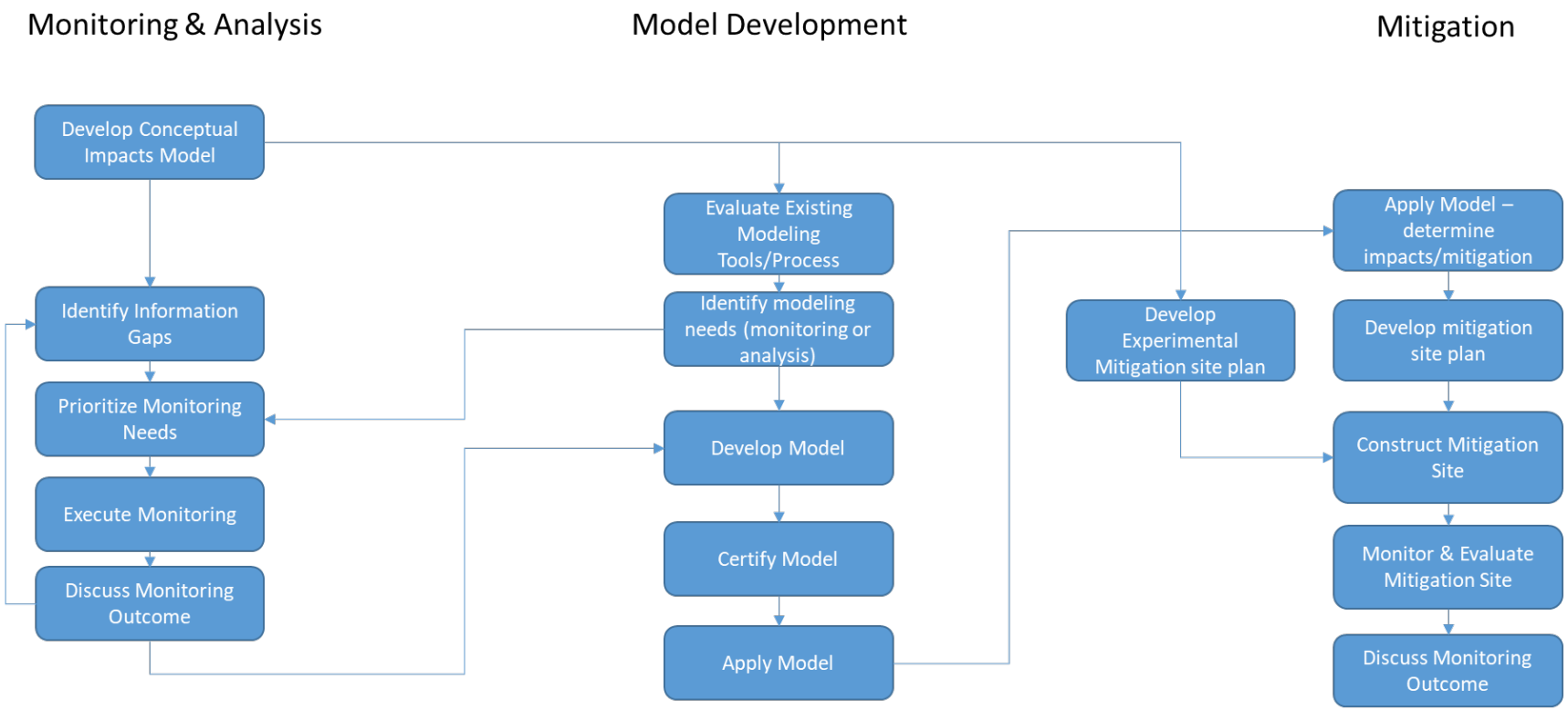


Figure 4. Draft Conceptual Diagram of Green Sturgeon HMMP Implementation

Table 3. Green Sturgeon habitat types.

Habitat Types	Attributes/Discussion
Spawning	• Spawning habitat attributes similar to holding area attributes. • Several known spawning areas in northern Sacramento River were documented using visual monitoring equipment. • Alteration of spawning areas is rare and generally due to illegal activity.
Foraging	• Can be associated with soft benthic substrate, also found on hardened substrate going after benthic macroinvertebrates. • Behavior can largely be defined by life stage or relative activity. During migration, foraging is less of a priority, but can become different behavior during rearing or holding.
Rearing	• Can be associated with soft benthic substrate, also found on hardened substrate going after clams. • Inundated floodplains can be used for feeding, with a possible loss associated with foraging. Existing research is less clear on floodplain usage. The only referenced peer reviewed literature identified an observation of an individual and not on the habitat usage. • Difficult to identify as data may be lacking based on current knowledge.
Migratory Corridor	• Telemetry data suggest that upstream movement/behavior is fairly rapid until adults reach known spawning/holding areas. • Duration and magnitude of any impediment should be considered for mitigation timing. • Telemetry data may inform key aspects for consideration (diurnal, timing of movement, seasonality, location of movement in the river relative to activity).
Holding Areas (adult lifestage)	• When rip rap is placed is it impacting holding areas such as deep holes? • Good documentation of specific holding areas where green sturgeon are frequently found from visual monitoring surveys. • Most Corps activity would occur below surveyed areas of known holding locations. • Telemetry data suggest that upstream movement/behavior is fairly rapid until adults reach known spawning/holding areas. • Velocity may play an important role to define usable or desirable habitat.

3.1 Adaptive Management

Adaptive management (AM) is a structured, active learning process for planning and implementing (Figure 7) specific actions to iteratively address hypotheses and uncertainties about the effects of management actions (USACE 2019b). The evaluation process is key to learning from previous actions to inform future management and planning. Each step contributes to reducing uncertainty to better inform management actions and decision-making. Every AM program starts by defining goals to guide the process and establishing milestones for the transitions between each stage. The three organizing principles of AM are plan, do, and learn.

Planning includes the assessment and design phases (USACE 2019b). Assessing the information available through the scientific process is essential for understanding resource dynamics and their

relationship to management. This step sets the foundation for the rest of the AM cycle as a continual learning process. The design phase identifies critical uncertainties to develop projects and studies that reduce those uncertainties and lead to informed management actions and decisions. Doing consists implementing and monitoring actions to document their effects on the system. Implementation is where a program carries out the management actions and decisions from the design stage. Monitoring plans provide a systematic approach to observe and document the effects of management actions on the ecosystem or species of interest.

Learning requires the program to evaluate the data and identify how to adjust actions. Evaluation is where data synthesis and analysis provide information on how management actions affect the system. Learning how management actions affect the system provides the program with information to adapt management actions. Ideally, the information will support development of actions that better address the multiple needs of management and the ecosystem.

Further Corps participation on the IEP PWT will provide a forum for identifying important mitigation habitat features and sturgeon life history uncertainties for AM. Discussion among the Corps, NMFS, USFWS, CDFW, and other stakeholders will refine the AM planning process for habitat mitigation features and the monitoring plan.

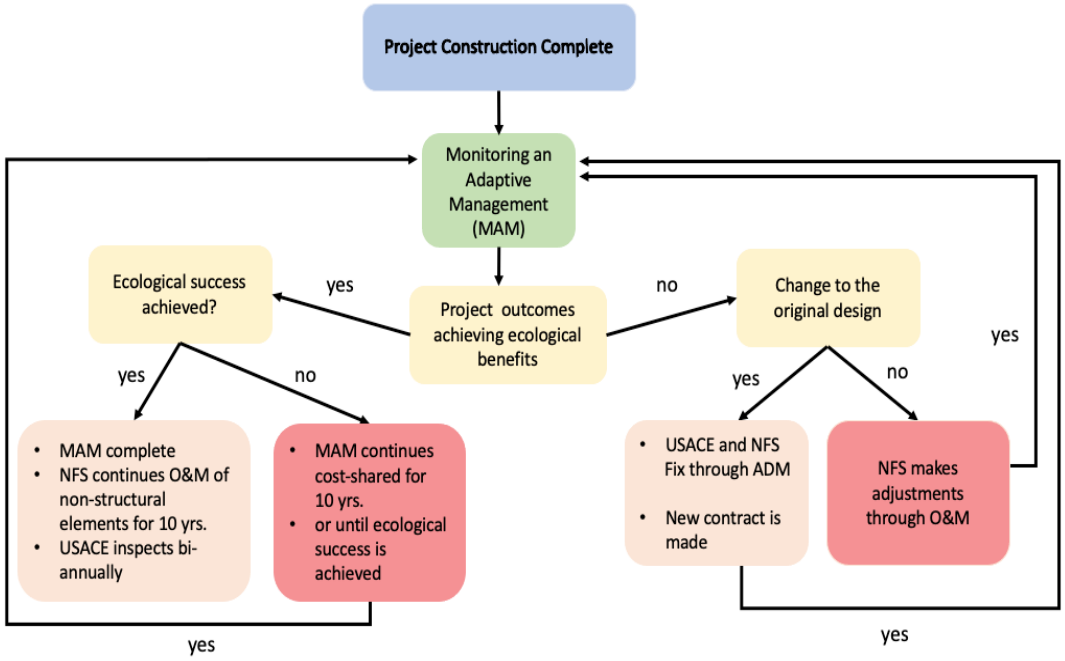


Figure 5. Civil works Adaptive Management model

3.1.1 Implementing Adaptive Management

Green sturgeon movement data in context with geomorphic trends for substrate and the distribution of macroinvertebrates provide a foundation for evaluating hypotheses that better define habitat use in the riverine corridor. Implementation of AM should start with study objectives to answer unknown variables within the BO's. The objective associated with this GS HMMP is to better understand how green sturgeon respond to project and construction activities in association with riverine habitat and management in the watershed (USACE 2019b). While the AM cycle may consist of a variable number of steps, these activities can be organized into planning, doing, and learning processes. The spatial and temporal scales for the activities and processes is a function of existing knowledge of system components, the understanding of the ecosystem and the potential project/construction impacts. Compilation and ranking problems of interest by the Sturgeon IEP would provide the starting point for initiating the AM process.

The availability of existing information supports AM at different steps, moving the process forward. Conceptual models are important tools for describing the Sturgeon IEP's understanding of project impacts to the species and their habitat. The graphical depiction of qualitative relationships between environmental and species parameters is an important framework for illustrating ecological relationships. Conceptual model development and review by the Sturgeon IEP will establish a common foundation of knowledge to select problems to move into the AM design step. The conceptual model should facilitate communication between the Sturgeon IEP and stakeholders.

Computer models like FHAST represent interactive conceptual models by formulating quantitative relationships between data parameters. Environmental parameters describing important species-habitat interactions provide insight into how management actions may affect species distributions and populations. The FHAST should provide support for quantifying species vital rates in computer models to simulate population in response to habitat availability and management actions. The data required for computer models may be derived from literature reviews or require the monitoring studies to be designed and implemented.

The learning phase of the AM cycle should identify how erosion protection features affect green sturgeon movement through the migration corridor, improve designs for appropriate habitat mitigation features, and refine the criteria for evaluating mitigation habitat success. These AM results in turn, support subsequent project planning, implementation, and monitoring for erosion protection and habitat mitigation features.

3.2 Future Green Sturgeon Telemetry

There are important uncertainties regarding green sturgeon habitat use in the Sacramento River. Preliminary movement data indicates rapid upstream and downstream transit times for adult green sturgeon, while juvenile green sturgeon appear to wait for elevated flow for out-migration down the river. These movement patterns suggest that feeding habitat in the migratory corridor may be less important than previously thought. The ongoing studies described below should begin to elaborate further on data gaps regarding green sturgeon habitat use.

3.2.1 Adult Green Sturgeon

Monitoring will continue within the current project reaches in the Lower Sacramento River. Adult monitoring efforts will also expand within the ARCF study area to better determine project impacts to the sturgeon behavior and impacts to surrounding critical habitat. It has been documented in previous monitoring studies that the Lower Sacramento River is a migratory corridor. The newly designed fish passage structure at the newly widened Sacramento Weir will provide adult sturgeon passage between the Sacramento River and Yolo bypass drain. This was identified as a key component in the 2021 green sturgeon recovery plan status review. Data sets have shown that adult green sturgeon migrate from Verona downstream to Clarksburg in under 24 hours. However, very little data exists over the potential impacts construction activities maybe having during migration. The Corps plans to further expand the acoustic receiver arrays in the lower Sacramento River to better identify green sturgeon data gaps, mitigation strategies and implementation. Data obtained from the newer, revised arrays in the Lower Sacramento River will better assess fish behavior to determine any adverse impacts that may be occurring prior to construction, during construction, or post construction. The Corps, with some participation from DWR, CDFW, and NMFS, anticipates tagging twenty adult green sturgeon each calendar year for the next five consecutive years (2020-2025). Annual tagging will maintain a robust sample size for future monitoring purposes of the adult population as older tags expire. The placement of new tags will have an expectant battery life of 10 years. In summary future sturgeon monitoring efforts may include:

- Develop a long-term plan for green sturgeon telemetry monitoring studies.
- Continue tagging adult green sturgeon with Vemco 69 kHz acoustic tags in coordination with CDFW, DWR, and NMFS to maintain a sufficient number of tagged fish for reasonable adult migration data.
- Use a portable Vemco VR100 to conduct live tracking of adult green sturgeon to identify habitat use and potential adult behavior.
- Continue operating telemetry arrays for tracking movement.
- Establish additional stations to be deployed just upstream and downstream of the Sacramento Weir.
- Deploy 2- or 3-dimensional acoustic receiver array to characterize adult green sturgeon movement related to construction activities.
- When adequate, investigate river channel features using bathymetry and hydraulic maps to identify river features that could be utilized by adult green sturgeon.
- Expand spatial analysis/synthesis of existing migration data in the project reach and the 2-dimensional arrays in AM process to inform future telemetry planning.
- Submit annual monitoring reports to NMFS at the end of each calendar year.

3.2.2 Juvenile Green Sturgeon

Previous field data is being regularly reviewed and analyzed as sample size increases. As new data is collected annually, and this additional data will also be incorporated into annual reporting as stipulated in the BO's. Additional monitoring began in 2020-2021. Over time monitoring efforts will increase and begin to focus on areas of proposed civil works, areas of impacts within the Sacramento, and areas of impact within the lower portion of the American River. The Corps plans to continue its current acoustic telemetry array stations upstream and downstream of Colusa for comparing setback reaches to channelized reaches, that include stations at RM 65, RM 75, RM 85,

RM 54.5, and RM 43.7. The Corps plans to expand its current array focused within the WRDA of 2016 Project Area (RM 43 to RM 85).

The Corps plans to expand the juvenile green sturgeon telemetry work by purchasing additional receivers to collect data on green sturgeon habitat utilization, movement pre-construction, movement during construction, and movement post-construction. This data will be used to assess impacts, identify data gaps, and identify mitigation strategies on sturgeon occupying the project areas. The additional receivers will be deployed to cover locations of interest, such as proposed construction impact areas, or features to help understand utilization by juvenile green sturgeon. These efforts are expected to be cost shared through ARCF, West Sac and SRBPP projects. The following were identified monitoring and reporting needs to be implemented.

- Identify transition areas and develop focused telemetry plans for determining use and function by juvenile green sturgeon.
- Focus effort at setback levees vs channelized levees with 2D or 3D arrays.
- Deploy receivers at existing mitigation sites (Bullock Bend) to identify if green sturgeon are using floodplains as intended.
- Deploy additional receivers within the lower and middle portions of the Sac River study area utilizing acoustic hyperbolic positioning telemetry technology.
- Submit annual monitoring reports to NMFS at the end of each calendar year.

3.3 Benthic Macroinvertebrates / Green Sturgeon Forage Study

A cumulative report summarizing previous annual reports for the benthic community monitoring study is being developed. An objective of this report is to document forage organisms that may inhabit the project areas. The report will also relate physical habitat characteristics that may determine forage opportunities between RM 15 and 85 (10-mile intervals) for Spring (March) and Winter (November- December). Analyses should identify key habitat features or trends associated with suitable benthic production of prey organisms, and document whether project actions affect green sturgeon foraging opportunities. The benthic monitoring milestone report will incorporate readily available historic data from other sources, examine presence/absence patterns of native mollusks, examine shifts in species composition, and document trends in distribution. The following below are future considerations for future benthic and foraging studies.

3.3.1 Geomorphology

- Construct a conceptual spatial model of sediment size distribution for the Sacramento River based on Singer 2015 and other references.
- Use existing hydraulic data to identify potential areas for low velocity and finer substrate habitat.
- Develop benthic substrate sampling protocol to validate hydraulic modeling for identification of low velocity, fine substrate habitat.

3.3.2 Benthic Sampling

- Continue current benthic substrate sampling with sampling site modifications to include ARCF study area and known areas of juvenile green sturgeon rearing/holding
- Investigate the correlation between flow conditions and food source availability.
- Continue sampling period in November with potential increase of sampling in October.
- Incorporate existing hydraulic, hydrologic and geomorphology information for the Sacramento and American Rivers into riverine habitat models.
- Potential to work with local universities to conduct lab diet trials to determine palatability and digestibility.

3.4 CESU Laboratory Work

Several studies that would advance the knowledge of green sturgeon have been previous identified by UC Davis, state, and federal regulatory and research resource agencies. These studies were identified to help answer life history model gaps and migration concerns to better implement future mitigation actions. The Corps is in the process of funding two of these studies costing 5 million dollars. The Corps was able to fund such studies through a CESU cooperative research grant to account for mitigation fulfillment for ARCF. The studies consist of hydraulic passage and substrate to better understand juvenile green sturgeon preferences. The studies will also assist refining screening criteria for juvenile green sturgeon. Award and implementation of work will begin in 2022.

3.5 Development of Green Sturgeon Habitat Model

As mentioned previously the new FHAST model will replace SAM (quantify salmon habitat values in terms of bank line weighted or area weighted species responses. The species responses are calculated by combining indices of habitat quality (i.e., fish response indices) with quantity (i.e., bank length or wetted area) for each season, target year, and relevant species/life stage. The FHAST conceptual model assesses changes to the quality and extent of the following six near-shore and floodplain habitat variables (i.e., fish response indices), considering habitat utilization and impacts to the growth and survival by life stage and season (USACE 2012). The following habitat variables that are used in the SAM will also be incorporated into the FHAST model:

- Bank slope — average bank slope of each average seasonal water surface elevation;
- Floodplain availability — ratio of wetted channel and floodplain area during the 2-year flood to the wetted channel area during average winter and spring flows;
- Bank/Channel substrate size — the median particle diameter on the bank or area to be excavated (i.e., D50) along each average seasonal water surface elevation;
- In stream structure — percent of shoreline coverage of instream woody material (IWM) along each average seasonal water surface elevation;
- Aquatic vegetation — percent of shoreline coverage of aquatic or riparian vegetation along each average seasonal water surface elevation; and
- Overhanging shade — percent of the shoreline coverage of shade.

Possible habitat inputs into the FHAST for the habitat module may include benthic habitat quality (substrate sampling), floodplain inundation (Ecosystem Function Model, USACE 2017), in stream depth and velocity habitat quality parameters (2D River Analysis System, USACE 2019 a), and water quality modules (under development). Green sturgeon telemetry data may identify existing habitat features to refine quality indices, and habitat use during migration. Development of other technologies for in stream monitoring of all life stages may contribute additional insights.

The CESU project for updating the FHAST model was awarded May 2021. The SAM model will be replaced by the agent based FHAST model. The development of the green sturgeon habitat model within FHAST will likely begin the third quarter of FY 2022. Input on habitat parameters and analyses from the Sturgeon IEP and Corps Project Delivery Teams is essential for model development. The work team identified specific recommended monitoring activities to inventory aquatic resources and create ecological baseline conditions within proposed construction areas.

Ecological and biological monitoring would occur prior to construction, during construction and/or post construction. Some monitoring activities may only occur during certain construction phases independently. Section 3.5.1 outlines the future modeling efforts to be identified and implemented.

3.5.1 Future Modeling Efforts/Attributes

- Compile previous SAM data for AM process (evaluation and design).
- Acquire existing light detection and ranging (LiDAR) data for project areas for inundation modeling with HEC-RAS (USACE 2019) or other software. Evaluate inundation frequency with HEC-EFM (USACE 2017).
- Develop FHAST metrics for green sturgeon migratory corridor habitat.
- Develop and evaluate methods for processing larger numbers of specimens or greater volume of benthic samples.
- Compile Corps previous monitoring data sets for FHAST model input.
- Secure university laboratory work with cooperative grant funding to university.

Table 4. Monitoring activities for GS HMMP.

Monitoring Activity	Related Parameter	Notes
General Monitoring or Documentation	Channel Capacity Flood Exceedance Curves Geomorphology	• Use hydraulic models to identify potential habitat based on depth and velocity. • Use existing geomorphic data to evaluate benthic substrate distribution from Singer 2015.
Hydrologic and Hydraulic Analyses	Velocity Suitability	• Define the hydraulic window green sturgeon will occupy. • M.T. Wyman et al. 2017.
Benthic Sampling (Soft Benthic Substrate)	Sediment Food Availability	• Current sampling efforts are occurring on the Sacramento River. • Known locations where juvenile green sturgeon occur will be a key sample location for comparison to other locations (potential baseline for comparison). • RM 15-85 were sampled every 10 river miles. Sites generally picked, not selectively. • RAS models (data contact could be Dave Smith, USACE) could be leveraged to predict locations of soft sediment (preferred sediment for green sturgeon). • Possible consideration of coarse substrate for juveniles as they may also be beneficial (under investigation).
Adult and Juvenile Monitoring (Could Include Telemetry, Larval Netting, Screw Traps, ARIS)	Index of Juvenile Abundance Behavior, Holding, and Movement	• Marking/tagging juvenile green sturgeon in lower Sacramento River area. • Battery life can challenge monitoring juveniles into lower river due to longer holding times. Good weather events may encourage movement but holding can limit data. • Identifying holding locations (holes) in the lower Sacramento River. Event was scheduled to do so in 2021 but was canceled.
Water Quality	Water Temperature Turbidity	• Consider network of temperature loggers along the river (efficient and cost effective). Installing with telemetry receivers is a good past approach. Could also utilize existing USGS temperature monitoring stations.

3.6 Biological Monitoring

It is anticipated technical agency annual reports will be submitted to NMFS at the end of each calendar year per monitoring program or as recommended in the NMFS BO's reporting requirements. The technical reports would consist of data collection efforts for that year, scientific analysis, results, findings, and conclusions. The reports are anticipated to inform management and the GS HMMP of any recommendations or AM changes needed to be made based upon findings. Any new substantial findings or discoveries may be submitted for professional publication review. Any preliminary data analysis completed by the Corps with unusual or precedent findings will be further discussed with NMFS.

3.7 Vegetation Monitoring

This monitoring occurs on any sites requiring biological compliance monitoring during the period of plant establishment. Annual monitoring can include up to 3-5 years post-installation and approximately 8 years post-installation by the non- federal sponsor. Annual reports are prepared and will be used to inform the update of the FHAST model once updated. This model may serve as a guide for the development of the green sturgeon model. Annual reports will be prepared and sent to NMFS.

3.8 Best Management Practices

The GS HMMP work team identified several civil work construction actions that are routinely conducted in the Sacramento district civil works program (*Table 5*). Best Management Practices (BMP)s were identified for future considerations while assessing construction actions during Section 7 consultations. Adequate BMP's could potentially alleviate or off set action impacts.

3.9 Habitat Mitigation

On-site specific habitat mitigation measures are currently being explored as more available habitat information and data becomes available. Due to the diverse habitat types used by the various life stages, creation of each habitat type can be very complex. Current mitigation measures include purchase of salmon/green sturgeon mitigation bank credits, creation of other species specific HMMP, cooperative research grant opportunities with local universities, and creation of sturgeon fish ladders for fish passage improvement. Other potential mitigation opportunities to offset construction actions discussed with the HMMP work team consisted of the screening of nearby water diversions that are currently unscreened, improvement to current dilapidated screened diversions, removal of abandoned concrete structures in the river that are known to cause predation cover, and further funding of additional university studies.

Table 5. Routine construction related actions with best management practices.

Actions	Possible BMP's Specific to Green Sturgeon	Notes
Installation and usage of coffer dams and pile driving	• Preference to vibratory hammer over impact hammer. Use metal cushion with impact hammer. Only use impact hammer after vibratory is not viable. • Impact hammer when used, implement with a slow start. Only use impact hammer within specific work window. Provide an onsite biological monitor for acoustic levels. • Use a bubble curtain. • Consider an upstream bubble curtain line to move fish prior to exposure to the pile driving. • Adult fish rescue plan to be approved by NMFS.	
Placement of fill, which can include both fine and larger materials such as rip-rap	• Pre-construction monitoring to establish baseline information for impact analyses and consideration. • Documentation or establishment of potential habitat usage (via telemetry) as pre-construction information to help understand sturgeon usage and possible habitat impact for the project area. • Consider channel morphology as part of the pre-construction monitoring (bathymetry) and post construction as well.	• Are there ways to implement or consider in levee design to improve upon them for sturgeon habitat or usage? • Is the lack of residency a function of the existing habitat quality? • Monitoring data, results, and trends may drive further pre-construction investigation.
When feasible creation of bench- or slope-back levees	• For design of bench- or slope-back levees, consider lower water stage features, undulations, etc. for greater access and more frequent usage.	• Increased area to forage, feed, hide, increased temperature with shape of these levees versus other shapes. • Consider action as a mitigation measure for future discussion.
General bridge construction (some of the other items in this list would be embedded into this general activity)	• Consider any lighting associated with construction or ongoing illumination of the bridge and its pertinent impact to phototaxis on sturgeon (notably juvenile life stages). Illumination thresholds, color, etc. all aspects for review.	• Action Item – Ally to further investigate on potential actions and discuss related California Department of Transportation activity with NMFS staff.
Night work (conducting activity when there is no daylight)	• Avoidance of nightwork is preferred when possible. • Pre-construction monitoring will help inform current trends in the area of interest. • Possible consideration of prioritizing night work if trends indicate that sturgeon are moving at night versus the day. Data would be required to support this action. • Community concerns for nightwork should be considered during planning. • Safety requirements such as lighting (candle-power), equipment, navigational markers, etc. should be reviewed to minimize impact to sturgeon. Shielding lights, considering angle of lights, etc. all should be considered and reviewed.	• Adults are more active at night. • Bill Poytress confirmed greater juvenile activity at night as well.
In-water work windows (while not an activity, an important aspect guiding activity)	• Stay within prescribed work window. • Prioritize shoreline activities earlier in the work window to allow for greater flexibility of activities later in the work window. • Coffer dam installed within the work window will allow for work behind the coffer potentially outside of the work window (greater flexibility). • Work windows flex with time and require AM. Typical work windows consist of July 1-October 31 for the Sacramento River.	• Factors include location, mainstem or tributary, water year type, etc. • Talk with contracting to identify financial incentives for completing work within the window and penalties for exceeding the work window. May reduce need for AM.
Dredging activity	• Storm events may limit work activity.	• The type of dredge will drive the BMP's utilized such as cutter head, clamshell, etc.

Actions	Possible BMP's Specific to Green Sturgeon	Notes
Dredging activity	• Location of dredge activity will modify work window. Sacramento and Stockton Ship channel locations have specific times: August 1 begin, end October 31 (Sacramento) and end of November (Stockton). • Dredge material should be placed on upland locations and monitor entrainment by investigating dredge material (~30 percent of the material). • Water quality must be monitored (turbidity, etc.) If material is not placed in upland site, additional monitoring activity may be required. • Presence of metals or other pollutants may require additional monitoring. • Ambient areas directly or indirectly impacted may require water quality monitoring.	
Exclusionary measures (activity to keep fish outside of work areas)	• Soft start when conducting pile driving is an approach to ensure fish are clear prior to more aggressive driving. • Guidelines for pump rates behind coffer dams can reduce impingement and pumps must have fish friendly screening.	

4.0 SUMMARY/DISCUSSION

As previously mentioned in Section 1, the GS HMMP is a living adaptive document for AM decision making. Further biological monitoring and analyses will better inform the Corps and its non-federal sponsors on activities involving monitoring, impacts and mitigation to green sturgeon and associated habitats. The plan's justification is driven by three biological opinions covering a vast area of the CV. One of the primary objectives of this plan is to determine the impacts of Corps civil works construction activities and post-construction features more accurately on green sturgeon resources. This GS HMMP is meant to determine what effects are occurring to the species and if they are fully mitigated for through what has already been done. If effects are not mitigated, this GS HMMP provides AM techniques or further mitigation approaches to ensure the species is mitigated for appropriately. Moving forward in the establishment of the GS HMMP and further monitoring will support development of conceptual models for better understanding of green sturgeon life history and habitat use for AM. The GS HMMP along with further monitoring and research will aid the development of the green sturgeon portion of the FHAST model.

4.1 Past, Current and Future Milestones

2021 – Finalized adaptive GS HMMP.
University research work continuing.
Continuous benthic, adult and juvenile acoustic monitoring.

2020 – University research work.
Re-initiation of ARCF program.
Implementation of GS HMMP meetings.
Revamped and more robust monitoring within ARCF study area (RM 41-64).

2019 – Continuous benthic, adult and juvenile acoustic monitoring. Re-initiation of SRBPP GRR.

2018 – Updated work plan for implementation of the HMMP elements that have been described in the NMFS 2015 BOs for the West Sac and ARCF GRRs. Continuous benthic, adult and juvenile acoustic monitoring.

2017 – Updated work plan for implementation of the HMMP elements that have been described in the NMFS 2015 BOs for the West Sac, SRBPP and ARCF GRRs. Continuous benthic, adult and juvenile acoustic monitoring

5.0 REFERENCES

CDWR (California Department of Water Resources) 2020. Interagency Ecological Program. Available online: https://water.ca.gov/Programs/Environmental-Services/Interagency-Ecological-Program.

National Marine Fisheries Service (NMFS) 2015. Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response, for the West Sacramento General Reevaluation Study (West Sacramento GRS). NMFS No: WCR-2014-1375. September 8, 2015.

National Marine Fisheries Service (NMFS) 2015. Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response, for the American River Common Features General Reevaluation Report (Common Features GRR). NMFS No: WCR-2014-1377. September 9, 2015.

National Marine Fisheries Service (NMFS) 2019. Endangered Species Act Section 7(a)(2) Biological Opinion, Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response, and Fish and Wildlife Coordination Act Recommendations for the Sacramento River Bank Protection Project Post Authorization Change Report. NMFS No: WCRO-2019-01893. August 30, 2019.

Singer, MB. 2015. Impact Scales of Fluvial Response to Management along the Sacramento River, California, USA: Transience Versus Persistence *in* P. F. Hudson, H. Middelkoop (eds.), Geomorphic Approaches to Integrated Floodplain Management of Lowland Fluvial Systems in North America and Europe, DOI 10.1007/978-1-4939-2380-9_4

USACE (U.S. Army Corps of Engineers). 1972. *Sacramento River Bank Protection Project, California—Second Phase*. Report of the Chief of Engineers, Department of the Army.

USACE (U.S. Army Corps of Engineers). 2012. Standard Assessment Methodology (SAM).

USACE (U.S. Army Corps of Engineers) 2017. Ecosystems Function Model (HEC-EFM). Documentation and software available at: https://www.hec.usace.army.mil/software/hec-efm/.

USACE (U.S. Army Corps of Engineers) 2019a. River Analysis System (HEC-RAS). Documentation and software available at: **https://www.hec.usace.army.mil/software/hec-ras/**.

USACE (U.S. Army Corps of Engineers) 2019b. A Systems Approach to Ecosystem Adaptive Management. A USACE Technical Guide. Editors J.C. Fischenich, S.J. Miller, and A.J. LoSchiavo. ERDC-EL SR-19-9, November 2019.

USACE 2021. American River Watershed Common Features Water Resources Development Act of 2016, American River Contract 2 Supplemental Environmental Impact Statement/ Supplemental Environmental Impact Report. State Clearinghouse Number 2005072046. June 2021.

Wyman, M.T., Thomas, M.J., McDonald, R.R., Hearn, A.R., Battleson, R.D., Chapman, E.D., Kinzel, P., Minear, J.T., Mora, E.A., Nelson, J.M., Pagel, M.D., and Klimley, A.P. (2017) Fine-scale habitat selection of green sturgeon (*Acipenser medirostris*) within three spawning locations in the Sacramento River, California. Canadian Journal of Fisheries and Aquatic Sciences. 75(5): 779-791. https://doi.org/10.1139/cjfas-2017-0072.

APPENDICES

APPENDIX A AMERICAN RIVER COMMON FEATURES BIOLOGICAL OPINION

APPENDIX B WEST SACRAMENTO GENERAL REEVALUATION STUDY BIOLOGICAL OPINION

APPENDIX C SACRAMENTO RIVER BANK PROTECTION PROJECT BIOLOGICAL OPINION