SCIENCE WORK PLAN

Shasta RPA Adjustment

VERSION

August 28, 2017 - Initial Drafting
September 1, 2017 - Coordination with NMFS and others
September 12, 2017 - Updated version incorporating NMFS and Reclamation Comments

Planned
1 week prior to workshop - slide deck for rollout
Date TBD - workshop rollout.
1 month following workshop- Input received
1 month following input received- Revisions for implementation in 2019 subject to sufficient appropriations, agreements, environmental compliance, and permits.

PURPOSE

This draft Science Work Plan (Work Plan), provided for discussion and public comment, is associated with the proposed amendment of Reasonable and Prudent Alternative Action Suite I.2. of the National Marine Fisheries Service (NMFS) 2009 Biological Opinion (BiOp) on the Coordinated Long-Term Operation (LTO) of the Central Valley Project (CVP) and State Water Project (SWP). The purposes of this Work Plan include:

1. Identify near-term monitoring, modeling, and analysis and synthesis needs to improve fish and water management decision-making regarding Action Suite I.2.
2. Reduce uncertainty on the conditions necessary to achieve desired fish and water management goals
3. Coordinate activities between agencies, stakeholders, and other interested parties.

Upon receipt of comments, Reclamation will meet with individual entities and small groups to revise and make available a final work plan. Activities will help guide use of budget in the remainder of Federal fiscal year 2018, if possible, and fiscal year 2019. Upon material progress of activities identified in this document, Reclamation will coordinate revisiting and updating this document, if necessary.

BACKGROUND

In 2014 and 2015, Reclamation and NMFS used Action I.2.3.C to manage Shasta Division operations due to drought conditions impacts to ESA-listed species in the Sacramento and San Joaquin river basins and Bay-Delta. Information developed during the drought showed poorer performance of ESA-listed species than expected based on the actions taken as part of the

BiOp's Action I.2.3.C and multiple Temporary Urgency Change Petitions. Based on new information related to multiple years of drought, recent data demonstrating extremely low listed-salmonid population levels for the endangered winter-run Chinook salmon, and new information available and expected to become available as a result of ongoing work through collaborative science processes, Reclamation requested reinitiation of consultation on the long-term operation of the CVP and SWP on August 2, 2016.

In 2017, NMFS provided Reclamation with a draft amendment to the 2011 amended RPA related to Action Suite I.2 in the LTO BiOp. NMFS cited work including drought operation of Shasta and Keswick reservoirs, drought conditions, and new science and temperature survival models. Reclamation reviewed the draft amendment and hydrologic indicators, suggesting 2017 would be well suited for conducting a study to evaluate if the CVP could be operated to meet a temperature target of 53.0°F daily average temperature at the CCR California Data Exchange Center temperature gage station as a surrogate for a target of 55.0°F seven-day average of the daily maximum temperatures at the most downstream winter-run redd during the 2017 temperature management season.

Part of the amendment included development of a science work plan to address uncertainties and areas of science-based controversy. This document provides the Shasta RPA Adjustment Science Work Plan for near term activities to improve understanding of how physical conditions relate to achieving the biological objectives for temperature management on the Sacramento River related to Shasta Dam facilities. It uses a conceptual model to focus on identifying relevant management questions, reviews the current status of compliance monitoring and special studies associated with the focal topics, and suggests a path forward to improve the information available for informing decisions regarding Shasta operational requirements for ESA-listed salmonids.

CONSIDERING ENVIRONMENTAL WATER FRAMEWORKS AND CONCEPTUAL MODELS

Conceptual models and frameworks provide a basis for understanding how decisions result in a desired outcome. Conceptual models and frameworks also describe the strategies for making decisions and navigating uncertainty. This section describes promising examples of frameworks and conceptual models for prioritizing management questions to be addressed in this Science Plan.

A framework that could be considered for managing environmental water in the Central Valley is the approach espoused in Victoria, Australia. This framework is described in PPIC (2016) and highlights environmental water as a portfolio that is accessed through differing objectives based on the planning scenario for water and fish. These scenarios vary from an ecosystem caught in a critical drought to very wet conditions. Ultimately, these scenarios should establish the potential consequences of these choices and are prioritized, but not bound, by recovery objectives. This model could inform prioritization by considering which of the management questions are likely to gain the most information from the seasonal conditions observed in the Shasta Division (*i.e.*, dry, wet). For examples, wetter conditions should provide an opportunity for restoring winter-run Chinook salmon population by avoiding many of the impacts caused by Shasta temperature and flow operations. Also, managers can consider whether these climatic and reservoir conditions are necessitating decisions for temperature management, flow release, and management of others stressors to protect, restore, or simply maintain winter-run Chinook salmon populations. For example, the current winter-run Chinook salmon population is very low, which places the population at a higher risk of extinction, and necessitates greater efforts to improve survival and growth of the remaining population.

From the past five years, it is clear that there will be years when the CVP and SWP have the capacity to maintain listed species performance, while in other years the CVP and SWPs will not be able to protect listed species performance. Each of these distinct environmental management strategies have distinct management questions. These management questions can be prioritized through many generations of recovering the species depending on the species' performance and water management focus as they move from spawning locations, rearing floodplains, and migration corridors.

On the Columbia River, the biological opinion on the federal power system utilized a framework of population scenarios to describe a strategy where ESA-population performance indicators led to managers adapting their activities. Managers used cohort-based biological objectives to trigger off-the-shelf contingencies when early predictions of significant declines were identified or these declines were observed. This framework could inform prioritization of management questions that lead to description and agreement of these cohort-specific predictors, off-the-shelf contingencies, and other potential activities to protect and restore winter-run Chinook salmon.

Windell *et al*. (2017) described a conceptual model for winter-run Chinook salmon, whose tiered linkages provide a foundation for developing hypotheses regarding ESA-listed species and Shasta Division operations. This model identified how management attributes on the landscape affect environmental drivers that create aquatic habitats. These aquatic habitats directly influence the response of fish (*i.e.*, growth, survival, behavior), which managers are interested in ensuring for protection, restoration, and population maintenance objectives.

This Science Plan leverages this conceptual framework (Appendix A) for relevant life stages and locations to identify remaining management questions found across multiple landscape attributes, environmental drivers, habitat attributes, and response. These include:

- Holding Adult to Spawning Adult

- Upper River Egg to Fry Emergence
- Upper River Rearing Juvenile to Outmigrating Juvenile

Protection of winter-run requires a focus on the egg to fry stage, and Shasta Division operations focus on water cold and oxygenated enough for negligible temperature dependent mortality over the most downstream winter-run redd for the duration of the egg incubation to emergence of the last winter-run redd. From the past few years, it is clear that there will be years when the Shasta Division will not be able to protect listed species performance, but also years that exceed a desired biological outcome. Restoring and maintaining the winter-run Chinook salmon population will require examining additional habitat attributes that may affect non-temperature related mortality to achieve even greater biological objectives. Depending on how climate influences Shasta Division operations, decisions regarding hatcheries, harvest, exports, and habitat can be better structured by reducing uncertainties surrounding ESA-listed species, Shasta Division, and temperature processes.

MANAGEMENT QUESTIONS

Management questions are developed in a tiered approach to identify areas of interest in an organized framework for directing the necessary scientific studies to the most relevant issues for decision making and for adding, improving, or rejecting all or portions of conceptual models.

- What is a reasonable biological objective for temperature-dependent mortality to maintain the winter-run Chinook population (percentage and year-to-year frequency)?
    - What is the relative significance of temperature-dependent mortality compared to other sources of mortality?
    - What levels of storage and releases is required from a prior year to maintain a reasonable level of protection for a subsequent year?

- What are the bounds of feasibility (Shasta storage, Climate) driving coldwater volume and storage?
    - What is a reasonable biological objective for temperature-dependent mortality to restore populations (percentage and year-to-year frequency)?
    - How might additional populations above Shasta and in Battle Creek change requirements for populations below Shasta?
    - What are the effects of a changing climate?

- What are the appropriate egg-to-fry survival biological mechanisms to model?
    - Are the eggs or fish oxygen deprived?
    - How does substrate influence egg-to-fry survival? Does substrate size affect the sensitivity to temperatures?

- How do we prioritize biological needs in situations of limited cold water?
    - What are the population level risks from different balances on the downstream compliance location, water temperature targets, and risk of running out of cold water at the end of the season?
    - Can we manage pre-spawning flows to minimize risks to populations?
        - What is the relationship between pre-spawn flow, temperatures, spawning location and density-dependent effects?
    - What are the trade-offs between temperature management and other flow-related survival?

- How can the following non-temperature dependent factors relieve (or increase) pressures on cold water management?
    - Disease
    - Predation
    - Spawning Habitat Quality
    - Rearing Habitat (Improve survival)
    - Migration Cues (Improve Survival)
    - What about multiple stressors interacting: temperature and pathogens; temperature and predation, temperature/food/energy

- What long-term monitoring infrastructure is necessary in order to track temperature-dependent mortality?
    - Have we appropriately characterized background mortality? Spatially, seasonally, and year to year?
    - Are we counting fish effectively at Red Bluff Diversion Dam?
        - Are there better ways to account for juvenile emigration during high flow events when traps are not in place?

- How can we best stretch cold water during the temperature management season when it is limited?
  - What is the effect of the proposed revised temperature management values, locations and metrics [per RPA action I.2.4] relative to operations described by the 2011 amended RPA?
  - Are there certain thresholds and temperature tolerances that would allow for better optimization to reduce temperature dependent mortality when cold water is limited?
  - How can optimization be done during times of high air temperatures? Are buffers in the modeling needed to get predicted outcomes?
  - What is the relationship between storage and available cold water (cold water pool)?
    - Are storage targets (*e.g.*, EOS, the April 1 – May 31 period [per RPA action I.2.3], or end-of-November flood control limits) effective means of ensuring there is enough cold water during temperature management season?
- How can we minimize the number of years where we need to stretch the cold water pool, which creates tradeoffs of adverse effects at different life stages, run diversity (timing) and temperature tolerances?
  - How can we appropriately assess risk in the spring, prior to any irretrievable expenditure of resources/allocations of water, in order to maximize the likelihood of an adequate cold water pool in end of June, without unnecessarily curtailing allocations/deliveries?
  - Is it possible to create a decision support tool that could display these risks and uncertainties and allow managers to then choose the risk tolerance level?
  - Are there spring metrics that can predict the stability of lake stratification, or lack thereof?
  - What is the relationship between carryover storage levels and likelihood of adequate cold water the next spring.
  - Are there certain conditions/thresholds where it is so unlikely that adequate cold water will be available that temperature management is not reasonable to attain in any circumstance/operation?

- Can this very endangered species be managed to have temperature dependent mortality that would lead to recovery years, versus protection only years, per the Australia model, and still allow for recovery?
  - Can the life cycle model be run to get at this?
  - (using the WRLCM) What is the effect of multiple Critically Dry years (targeting no more than 30% temperature-related mortality) on the population?
    - How many CD years are too many? Combination of CD and D years? (Or, how long can just “protection” last?)
    - What variables in temperature management (e.g., Shasta storage, cold water pool volume, EOS carryover storage, EOA storage, reduced early season diversions, etc.) are most necessary to sustain the WR population through multiple CD years?

- How do we develop effective tools that manage for recent conditions, and don't rely on past averages?

- Structural modifications or adjustments:
    - Establish permanent temperature logger at Shasta Reservoir and tailwaters below dam
    - Are changes to any of these "knobs" effective: TCD, Whiskeytown, Trinity, power peaking, power bypass, etc?
    - Permanently seal leaks in the TCD?
    - Elephant trunk in Shasta to tap into cold water currently unavailable/unreachable?

Not all questions may be addressed within this near-term Work Plan. Questions posed but excluded from the scope of this Work Plan are included as attachment XX.

STATUS OF SPECIAL STUDIES AND CORE MONITORING

This section describes recent and ongoing special science studies related to the Shasta Division, ESA-listed species, and temperature. These efforts focus on management questions, performance measures, and management tools in these areas of interest between agencies, stakeholders, and interested parties. These efforts have primarily included observational and modeling studies, but future efforts may also require laboratory investigation depending on the management question and desired performance measure. This information is useful for determining if recent and ongoing efforts may address management questions identified above.

Table X. Special Studies Activity, Topic and Category, Status

Category	**Type**	**Science Activities**	**Status**
Shasta Division, temperature	modeling	Sacramento River temperature modeling review	Currently reviewing 2 draft TMs
temperature, ESA listed fish	modeling	Implementing the individual based model, inSalmo, in the Upper Sacramento River	Project Completion Date: April 2018
ESA listed fish	observational	Tracking Migration and Survival in Juvenile Winter-Run Chinook Salmon in the Sacramento River and Delta over Drought Years	Project Completion Date: April 2018
Shasta Division, temperature, fish	observational and modeling	Sacramento River Temperature Management Decision Support Tools	CVTEMP site established; review panel scheduled Fall 2017

temperature, fish	observational	Genetic Signatures of Drought Conditions and Disease in Central Valley Salmonids	Project Completion Date: December 2017
Shasta Division, temperature, fish	observational and modeling	Sacramento River Salmonid Passage Model for Data Assessment in Real Time	SacPAS site established
ESA listed fish	observational	Sacramento River Basin Salmonid Monitoring	Enhanced habitat monitoring occuring
ESA listed fish	observational	Red Bluff Diversion Dam Rotary Screw Trap Juvenile Monitoring Project	USFWS-desired sampling effort occuring
ESA listed fish	laboratory and model	Linking Drought and Southern DPS Green Sturgeon Recruitment	Project Completion Date: April 2018
Shasta Division, temperature	model	Workplan for Shasta and Trinity Division Seasonal Operational Water Temperature Modeling	Technical Team meeting continuing in Fall 2017
		TBD	
		TBD	
		TBD	

CORE MONITORING

Red Bluff Diversion Dam Rotary Screw Trapping
Redd Dewatering Surveys
Escapement Surveys
Pathogen Testing
Juvenile Stranding Surveys
Sacramento River Water Quality Stations
Reservoir Water Quality Monitoring

TECHNICAL APPROACH AND COORDINATION STRATEGY

A framework for the use of this Science Plan in adaptive resource management of the coordinated operations of the CVP and SWP is described in relation to current and potential types of programs.

The technical approaches and coordination strategy describes the different initiatives, resources, and forums that may assist in addressing the management questions to identify the potential deficiencies.

Related Programs and Projects

2009 BiOp
SAIL
NCWA CE QUAL W2 (May be an initiative, may be separate?)
(b)(13)
Shasta Dam Fish Passage Improvement Project
NCWA Salmon Plan

Coordination Forums

Synthesis
Stakeholder Involvement
DSP Review Panel
SRTTG
WOMT
LOBO review in 2018

Data Access and Availability

[Added per Maria]

Methods and Study Design

Temperature Predictive Tools

- CEQUAL W2 Upgrade for Temperature Modeling (NCWA)
- Modeling Exploration of Stratification Predictions (Yong Lai U2RANS?) Would these types of efforts even be fruitful? Are the more efficient efforts that do not require predictions of stratification, e.g. Indexing approach? Uncertainty mechanisms on hydrology, temperature, mixing, etc.
- Desktop Analysis and Field Deployment of Monitoring Network Upgrades

Egg-Mortality Parameters

- Laboratory studies to refine and/or replace the 7DADM approach with relationships between temperature, oxygen demand, exposure duration and frequency, and sublethal effects.
- ?? Reach-specific carrying capacity analysis for background mortality
- Lit. review for FX of habitat quality, etc. on O2 flux

Population Level Effects

- LCM for population targets
- LCM for different survival strategies, e.g. sacrifice and pulse; removal of other stressors
- ?? Desktop analysis of prespawn effects and options on fish distribution.
- Mortality Model - Scenarios for temperature management, e.g. managing too early, too conservatively, not enough, falling back later in the season, etc.

Synthesis

- Real-Time Predictive Tools and Plans
  - Do we need super detailed space-time approaches or is Keswick sufficient?
- Independent Review

POTENTIAL ADDITIONAL ACTIVITIES

The following paragraphs describe additional activities necessary to augment the existing programs for the purpose of addressing management questions.

REFERENCES CITED

PPIC 2016
Windell et al. (2017)

APPENDIX A

From Windell et al 2017

Figure X.

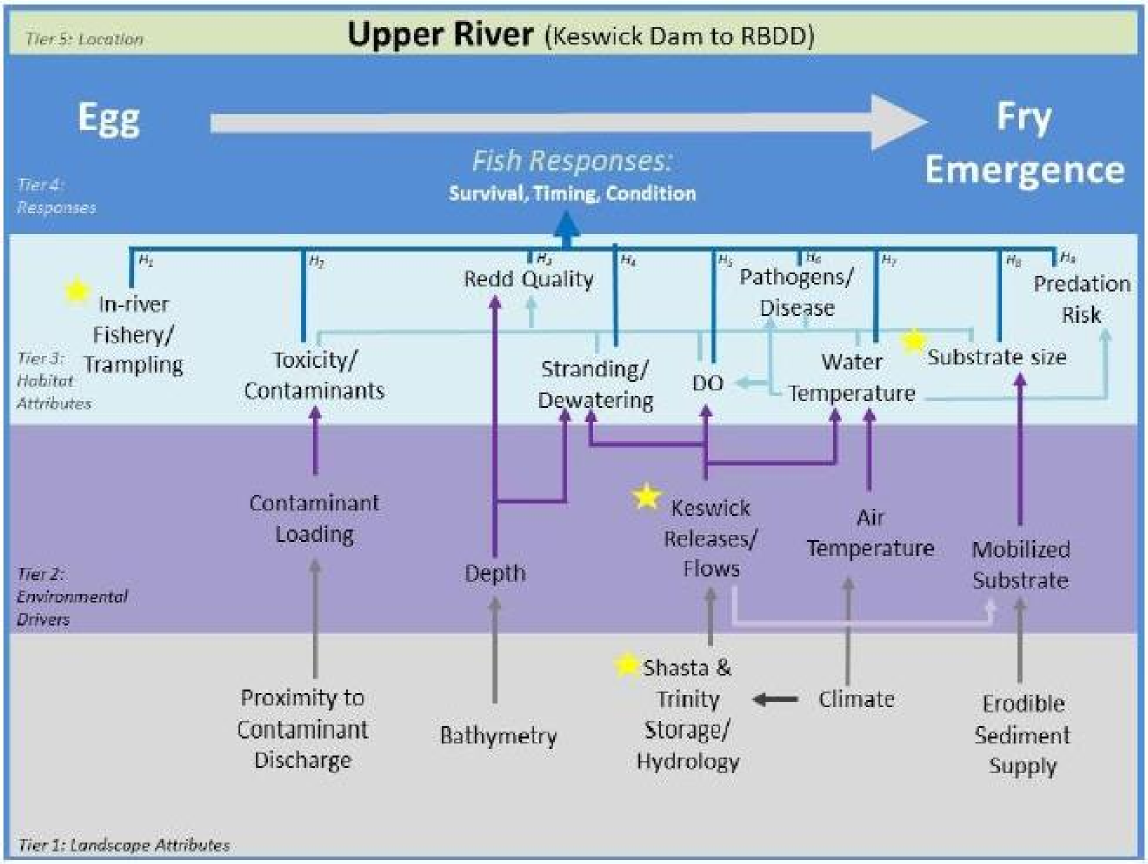

Figure 3. Conceptual model of drivers affecting the transition of SRWRC from egg to fry emergence in the Upper Sacramento River. Hypotheses referenced by the "H-number" are identified in the conceptual model 1 (CM1) narrative. Management actions are denoted by stars and are described in Table 1.

Figure Y.

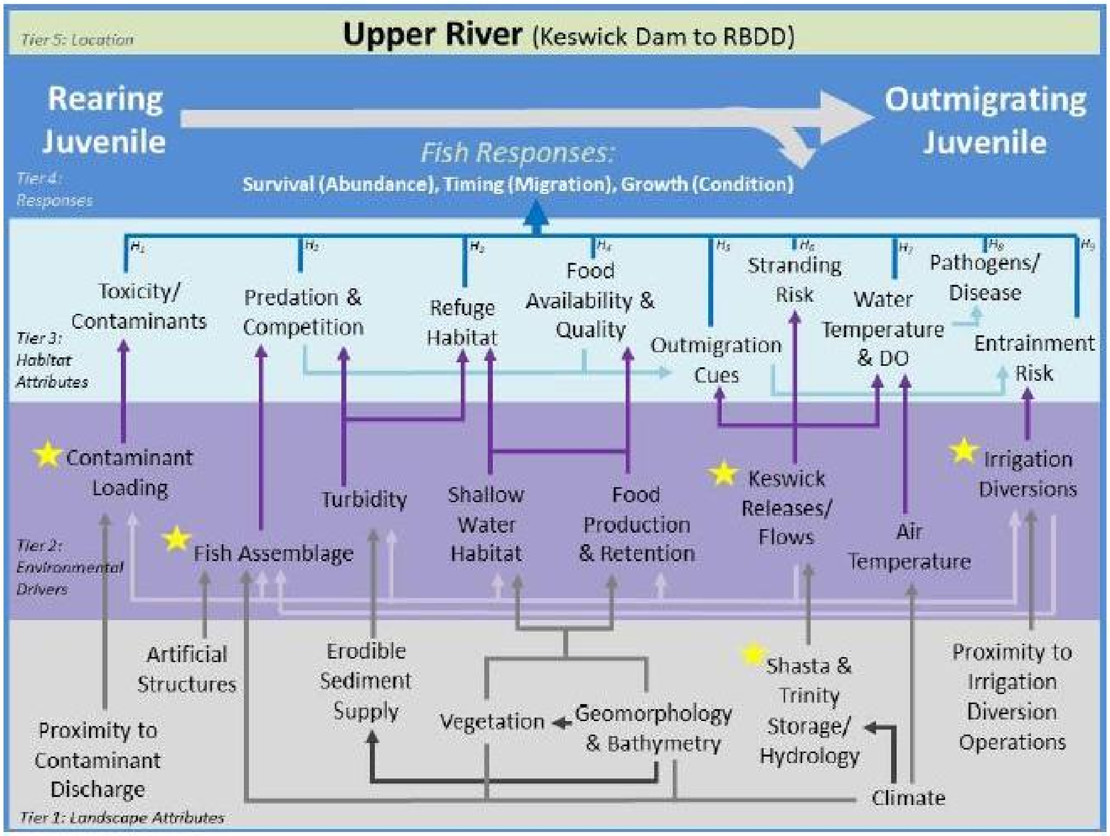

Figure 4. Conceptual model of drivers affecting the transition of SRWRC from rearing juvenile to outmigrating juvenile in the Upper Sacramento River. Hypotheses referenced by the "H-number" are identified in the conceptual model 2 (CM2) narrative. Management actions are denoted by stars and are described in Table 1.

Figure Z.

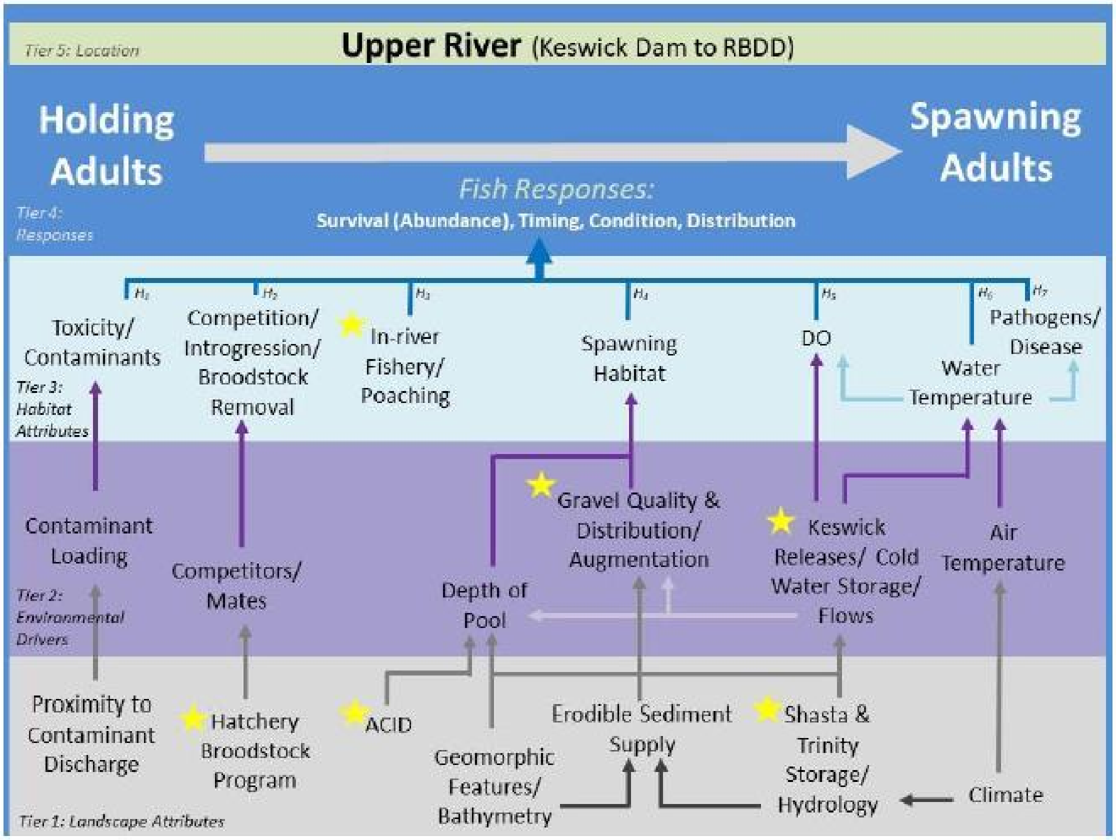

Figure 9. Conceptual model of drivers affecting SRWRC from holding adults to spawning adults in the Upper Sacramento River. Hypotheses referenced by the "H-number" are identified in the conceptual model 7 (CM7) narrative. Management actions are denoted by stars and are described in Table 1.