STATEMENT OF WORK
Central Valley Winter Run Chinook Life Cycle Model

Summary

To meet the goals of improving the reliability of water supply and improving the ecosystem health in California's Central Valley, we are proposing to continue the development of simulation models to evaluate the potential effects of water project operations and habitat restoration on the dynamics of winter-run Chinook salmon populations in the Central Valley. The winter-run life cycle model (WRLCM) couples water planning models (CALSIM II), physical models (HEC-RAS, DSM2, DSM2-PTM, USBR river temperature model, etc.) and a stage structured Chinook salmon life cycle model to predict how the salmon populations will respond to suites of management actions, including changes to flow and export regimes, modification of water extraction facilities, and habitat restoration. The WRLCM is of substantial benefit to society as a tool to evaluate the impacts of a critical water projects (the State Water Project and the Central Valley Project) on an endangered resource (Sacramento River winter-run Chinook salmon).

Period of Performance

This scope of work covers the period from September 1, 2018 through January 31, 2022, with three years of active work and a few additional months to allow for completion of invoicing.

Project Team and Collaborators

The project team, comprised of the following people, will work with USBR's Technical Lead, Katrina Harrison and Science Division Chief, Josh Israel to implement the following statement of work.

University of California, Santa Cruz

Peter Dudley, agent-based modeling; biophysical modeling
Miles Daniels, river and delta habitat capacity modeling; hydrologic modeling
Sara John, river and delta habitat capacity modeling; GIS and general modeling; data management
Kerrie Pipal, project coordination and data management
Vamsi Sridharan, hydrodynamics modeling
Programmer (TBD), model coupling; user interface development; data management
Communications specialist (TBD), user manual, report, and user interface development; general documentation

QEDA Consulting, Seattle, WA

Noble Hendrix, Quantitative Ecologist
(with additional staff as needed)

Project Tasks

The first three tasks (Quarterly Technical Input Meetings, Expanded Life Cycle Model Website and Documentation, and Collaboration and Reporting) are geared towards project communication and outreach. The remaining tasks (Reinitiation of Consultation Life-Cycle Modeling, Habitat Restoration and Growth Model Development, Flow-Survival Relationships, and Incorporation of updated egg mortality models) are oriented towards model application and development. Tasks 5 (Habitat Restoration and Growth Model Development) and 6 (Flow-Survival Relationships), and Task 7, include the development of study plans to be submitted to review bodies (CVPIA / IEP / CSAMP).

Task 1. Quarterly Technical Input Meetings

UCSC will work collaboratively with USBR to hold quarterly technical input meetings with stakeholders and interested parties. Over the project performance period, the project collaborators will hold a total of 12 meetings (six to be held at UCSC in Santa Cruz, CA and six to be held in Sacramento, CA). These meetings will be interactive, user friendly and allow for broad participation from interested parties. As appropriate, the collaborators will adjust the content and focus of the meetings to make them user-friendly for higher-level policy and decision-maker audiences and/or seek out other opportunities to reach out to this audience. At least one planning meeting will be held with the primary collaborators prior to each of the technical input meetings and at least one planning meeting will be held with a select group of stakeholder representatives who will provide input on content prior to the technical input meeting. Presentations or other materials used in the meetings will be posted on the expanded website described below in Task 2.

Deliverables	**Due by**
Planning meetings with USBR (total of 12)	Once per quarter 10/1/2018 - 9/30/2021
Planning meetings with stakeholder representatives (total of 12)	
Quarterly Technical Input Meetings (total of 12)	

Personnel	**Task Role**	**Annual Level of Effort (%)**
Noble Hendrix, QEDA Consulting	Technical preparation for meetings and presentations - LCM	10
Miles Daniels, UCSC	Technical preparation for meetings and presentations - habitat capacity	5

Peter Dudley, UCSC	Technical preparation for meetings and presentations - growth and agent-based modeling	10
Sara John, UCSC	Technical preparation for meetings and presentations - habitat capacity	5
Kerrie Pipal, UCSC	Technical preparation for meetings and presentations - project coordination	10
Vamsi Sridharan, UCSC	Technical preparation for meetings and presentations - hydrodynamics modeling	5
Programmer (TBD) UCSC	Technical preparation for meetings and presentations - model coupling and data analysis	5
Communications specialist (TBD) UCSC	Technical preparation for meetings and presentations	20
Eric Danner	Project Management	0

Task 2. Expanded Life Cycle Model Website and Documentation

Project Collaborators will expand the current public Life Cycle Model website and host the site on UCSC web servers. The expanded site will include

- Winter Run Chinook Life Cycle Model User's Manual geared towards technical audiences
- Versions of model available for download for users to supply their own CalSim / DSM2 / other runs
- Documentation of future modifications to the life cycle model. This documentation will include attempted modifications to the model and whether the modifications were successful or not to increase the transparency of what has and has not worked
- Interactive Interface for the Life Cycle Model - expanded Shiny Application that is user friendly for both technical and policy level audiences.
- Communication documents providing
    - Information about what the model results tells us more generally or holistically about the system and which actions are the most influential
    - Periodic updates written for lay audiences highlighting what we are learning from the model

Deliverable	**Due by**
Expanded LCM Public Website	Ongoing Phase 1

Winter Run Life Cycle Model User's Manual for technical audiences	September 2020
WRLCM versions	September 2019 (and annually as needed)
Expanded Model Interface (i.e. Shiny App)	Version 2 - Jan 2019 Version 3 - Jan 2020
General Model Information Document for lay audiences (updated annually as appropriate)	September 30, 2019
Model/Project Updates (twice per year)	Twice per year

Personnel	**Task Role**	**Annual Level of Effort (%)**
Noble Hendrix, QEDA Consulting	User's manual and website development	5
Miles Daniels, UCSC	User's manual and website development	10
Peter Dudley, UCSC	User's manual and website development	10
Sara John, UCSC	User's manual and website development	10
Kerrie Pipal, UCSC	User's manual and website development	10
Vamsi Sridharan, UCSC	User's manual and website development	10
Programmer (TBD) UCSC	User's manual and website development	15
Communications specialist (TBD) UCSC	User's manual and website development	40
Eric Danner	Project Management	0

Task 3. Collaboration and Reporting

UCSC shall hold monthly coordinating calls with Reclamation to discuss progress, address any problems that may have arisen, and any actions items for the upcoming months.

UCSC will present progress on this work at up to (2) scientific conferences each year, such as the Bay-Delta Conference, the Interagency Ecological Program Conference, and the American Fisheries Society Conference. UCSC will also provide periodic updates – up to two (3) per year - to collaborative efforts such as the Collaborative Adaptive Management Team (CAMT).

UCSC will prepare annual progress reports that document progress on deliverables and highlight any challenges or delays in meeting deadlines.

Deliverable	**Due by**
Coordinating Calls (USBR/UCSC/others)	Monthly
Presentations at Scientific Conferences	Ongoing/Annually
Bay-Delta Conference	Nov, Years 1 and 3
Interagency Ecological Program Conference	April
American Fisheries Conference	August
CAMT	As requested
Presentations to CAMT	Ongoing
Annual Progress Reports	September (annually)

Personnel	**Task Role**	**Annual Level of Effort (%)**
Noble Hendrix, QEDA Consulting	Report preparation – LCM	5
Miles Daniels, UCSC	Report preparation - habitat capacity	10
Peter Dudley, UCSC	Report preparation - growth and agent-based modeling	10

Sara John, UCSC	Report preparation - habitat capacity	10
Kerrie Pipal, UCSC	Report preparation - project coordination	10
Vamsi Sridharan, UCSC	Report preparation - hydrodynamics modeling	5
Programmer (TBD) UCSC	Report preparation - model coupling	5
Communications specialist (TBD) UCSC	Report preparation – all aspects	20
Eric Danner	Project Management	0

Task 4. Reinitiation of Consultation Life-Cycle Modeling

The WRLCM was initially developed to evaluate alternative hydrologic management scenarios. These scenarios could be evaluations of alternative operations using the existing physical infrastructure of the Central Valley, or operations combined with modifications to the physical structure. The WRLCM has been used to evaluate the relative impacts of alternative actions with the goal of not adversely impacting the winter-run population relative to a baseline. Thus far, the generation and running of scenarios has proceeded in the following steps: 1) develop a set of operational and restoration actions as a scenario; 2) convert the operations into rules that are implemented in a CALSIM run; 3) develop DSM2 and temperature model results for incorporation into the WRLCM; 4) utilize information on the restoration actions, DSM2, and temperature outputs to run the WRLCM (including the ePTM); and 5) evaluate the WRLCM outputs to see if the intended results were obtained.

In this task, we would run the Life-Cycle Model for up to 20 separate / alternatives or scenarios, and an additional 6 sensitivity analyses that would only require minor model changes for a variety of different parameter sets for each sensitivity analysis. Any additional scenarios would be completed per the direction of Reclamation but would correspond with commensurate decreases in the scope of another task. We would use model outputs from Reclamation that represent scenarios in the Reinitiation of Consultation. Reclamation would accomplish items 1 through 3 above, providing the collaborators with the operational and/or restoration actions, model assumptions, CALSIM model results, DSM2 results, and temperature model results. The collaborators would then use these provided model results to run the WRLCM (including the ePTM) and evaluate the outputs.

Deliverable	Due by
Technical memorandum describing the actions, WRLCM model assumptions, underlying model mechanics and equations (or referring to existing detailed documentation), results and discussion	May 2019
Model results in excel spreadsheet or HEC-DSS	May 2019
Raw model input and result files	May 2019

Personnel	Task Role	Annual Level of Effort (%)
Noble Hendrix, QEDA Consulting	Model runs and analysis	15
Miles Daniels, UCSC	Habitat capacity modeling	25
Peter Dudley, UCSC	Growth and agent-based modeling	5
Sara John, UCSC	Habitat capacity modeling	15
Kerrie Pipal, UCSC	Project coordination	5
Vamsi Sridharan, UCSC	Hydrodynamics modeling	15
Programmer (TBD) UCSC	Model coupling and data management	10
Communications specialist (TBD) UCSC	Documentation	10
Eric Danner	Project Management	0

Task 5. Habitat Restoration and Growth Model Development

One of the potential benefits of habitat restoration and floodplain connectivity is the increase in growth rates that can occur for juvenile salmon using those restored habitats. There are several hypothesized mechanisms by which increased growth rates, and thus larger sized juveniles, could have higher survival rates: 1) larger fry have higher survival rates during rearing than smaller fry; 2) larger smolts have higher survival during migration to the ocean than smaller smolts, and 3) larger smolts at time of ocean entry in the Gulf of the Farallones have higher survival rates than smaller smolts. We will incorporate each of these hypothesized mechanisms into the WRLCM to evaluate how these changes in survival would scale up to

affect winter-run population dynamics (e.g., cohort replacement rate, relative levels of abundance, etc.). We will incorporate information from growth models to understand the ranges of growth that are attainable in different habitats under different restoration scenarios and evaluate their potential to affect winter-run population dynamics. Finally, we will use information obtained from studies in the Yolo bypass, Cosumnes River, and elsewhere to quantify the relationships between larger sized individuals and survival rates.

We will submit a study plan for inclusion of habitat restoration into the model to CVPIA, IEP, CSAMP / CAMT or the other appropriate forum(s) for scientific input and review. The collaborators will attend, in person, two (2) meetings of these forums as appropriate as part of their scientific study review processes. The collaborators will present their study plans and consider alternate scientific hypotheses and approaches. We will revise the study plans as appropriate based on the input from the review process.

We will take multiple approaches to incorporate growth terms into the model. These will include using Agent-Based Models (ABMs) such as "inSalmo" to construct matrices of growth values for varying densities of fish under a range of flows and temperatures. Similar matrices will be generated for different restoration scenarios. The resulting values can be applied in the WR LCM.

Deliverable	**Due by**
Draft study plan submitted to CVPIA / IEP / CSAMP	March-July 2019
Presentation to CVPIA / IEP / CSAMP	May 2019
Revised study plan submitted to CVPIA / IEP / CSAMP	August 2019
Technical memorandum describing the science reviewed, WRLCM model assumptions, underlying model mechanics and equations for incorporation of growth, results of any initial runs and discussion	Sep 2019
Raw model template input and executable files for Version 1.0 – all the files to run the model	Sep 2019
Raw model template input and executable files for Version 2.0 – all the files to run the model	Sep 2020

Personnel	**Task Role**	**Annual Level of Effort (%)**
Noble Hendrix, QEDA Consulting	Model development	10
Miles Daniels, UCSC	Habitat capacity modeling	10

Peter Dudley, UCSC	Growth and agent-based modeling	35
Sara John, UCSC	Habitat capacity modeling	15
Kerrie Pipal, UCSC	Project coordination	5
Vamsi Sridharan, UCSC	Hydrodynamics modeling	10
Programmer (TBD) UCSC	Model coupling and data management	15
Communications specialist (TBD) UCSC	Documentation	10
Eric Danner	Project Management	0

Task 6. Flow-Survival Relationships

We will develop a study plan for continued development of the ePTM with an emphasis on incorporating multiple water management components (exports, gate operations, etc.), generating results of fish movement and survival, and providing visualizations to illustrate how predictions change under various management scenarios. These results will quantify the effect of water operations on salmon migration, maps of entrainment risk into the pumps and estimates of salvage rates for various scenarios. The continued model development will occur in two phases. In Phase I, we will continue development of the ePTM using observed migratory behaviors from the literature, with simple hydrodynamics based on DSM2. During this phase, we will develop the methods for quantifying migration duration, route selection, survival rates and entrainment risk, as well as provide an ePTM repository for the model and results generated using it.

We will submit a study plan for inclusion of for continued development of the ePTM into the model to CVPIA, IEP, CSAMP / CAMT or the other appropriate forum (s) for scientific input and review. The collaborators will attend, in person, two (2) meetings of these forums as appropriate as part of their scientific study review processes. The collaborators will present their study plans and consider alternate scientific hypotheses and approaches. We will revise the study plans as appropriate based on the input from the review process.

A key aspect of the development of the ePTM will be to make it an accessible decision support tool. To this end, we will (i) host a public repository with the model as well as results obtained from it, (ii) continue to improve the user-friendliness of the code, (iii) standardize the visualization and analysis methods, (iv) hold workshops. In Phase II, we will focus on developing user-friendly interfaces and visualizations for the results of Phase I analyses. Concurrently, we

will also improve the manner in which ePTM estimates of survival are affected by habitat in the Delta.

Deliverable	**Due by**
Draft study plan submitted to CVPIA / IEP / CSAMP	March-April 2019, March-April 2020
Presentation to CVPIA / IEP / CSAMP	May 2019, May 2020
Revised study plan submitted to CVPIA / IEP / CSAMP	August 2019, August 2020
Technical memorandum describing the science reviewed, WRLCM model assumptions, underlying model mechanics and equations for ePTM updates, results of any initial runs and discussion	Sep 2019
Raw model template input and executable files for Version 1.0 – all the files to run the model	Sep 2019
Raw model template input and executable files for Version 2.0 – all the files to run the model	Sep 2020

Personnel	**Task Role**	**Annual Level of Effort (%)**
Noble Hendrix, QEDA Consulting	Model development	15
Miles Daniels, UCSC	Habitat capacity modeling	15
Peter Dudley, UCSC	Growth and agent-based modeling	10
Sara John, UCSC	Habitat capacity modeling	10
Kerrie Pipal, UCSC	Project coordination	5
Vamsi Sridharan, UCSC	Hydrodynamics modeling	10
Programmer (TBD) UCSC	Model coupling and user interface development	15
Communications specialist (TBD) UCSC		0
Eric Danner	Project Management	0

Task 7. Incorporation updated egg mortality models

Several potential collaborators are developing alternate egg mortality models, building upon the NMFS model of thermal tolerance (Martin et al. 2017). These models have the potential to improve our understanding of the timing of the thermal impacts of developing salmon embryos, and subsequently refine the timing of the temperature management season, conserve cold water, and alter flow management within the system. Once the model integration is complete, the revised model will undergo an external review process.

Deliverable	**Due by**
Next version of LCM incorporating revised egg mortality models	June 2019
Updated User Manual describing how the updated egg model was incorporated	Sep 2019
Raw model template input and executable files for Version 1.0 – all the files to run the model	Sep 2019
Raw model template input and executable files for Version 2.0 – all the files to run the model	Sep 2020

Personnel	**Task Role**	**Annual Level of Effort (%)**
Noble Hendrix, QEDA Consulting	Quantitative Ecologist - technical preparation for meetings and presentations	5
Miles Daniels, UCSC	Habitat capacity modeling	5
Peter Dudley, UCSC	Growth and agent-based modeling	10
Sara John, UCSC	Habitat capacity modeling	5
Kerrie Pipal, UCSC	Project coordination	5
Vamsi Sridharan, UCSC	Hydrodynamics modeling	0
Programmer (TBD) UCSC	Model coupling	5
Communications specialist (TBD) UCSC	Documentation	5
Eric Danner	Project Management	0