PACIFIC STATES MARINE FISHERIES COMMISSION

Redd Dewatering and Juvenile Stranding in the Upper Sacramento River Year 2016-2017

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RBFO Technical Report No. 02-2017

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Cover photo: Fish rescue effort in an isolated stranding pool near the Sacramento River, Red Bluff.

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1/ This is the sixth year of this study on Sacramento River redd dewatering. This report and work described herein is funded in part by: the Central Valley Improvement Act Anadromous Fish Restoration Program and by the Federal Aid in Sport Fish Restoration Act (SFRA). Activities described in this report were undertaken through cooperative efforts with the California Department of Fish and Wildlife, the Pacific States Marine Fisheries Commission (PSMFC), and the U.S. Fish and Wildlife Service's Red Bluff Fish and Wildlife Office (USFWS), and were supported by various funding sources including: a U.S. Bureau of Reclamation (USBR) contract with the PSMFC, and a USFWS **Anadromous Fisheries Restoration Program (AFRP) grant (Agreement #F12AC00838)** with the PSMFC.

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SUMMARY

From the summer of 2016 to the spring of 2017 staff from the California Department of Fish and Wildlife (CDFW) and Pacific States Marine Fisheries Commission (PSMFC) working together from the CDFW's Red Bluff Fisheries Office (RBFO) conducted the sixth season of data collection to monitor redd dewatering and juvenile stranding-(fourth season) on the upper Sacramento River. This data provided information to fishery managers to guide management of flow releases from Keswick Dam to minimize impacts to the Chinook salmon redds and juveniles in the Sacramento River from the city of Tehama at river mile (RM) 229 upstream to Keswick Dam (RM) 302.

The Upper Sacramento River Basin experienced record precipitation during the winter and spring of 2016 and 2017. This large amount of rainfall in combination with summer and autumn flow release management from Keswick Dam led to no Chinook salmon redds being dewatered during this survey season.

Record breaking precipitation led to tributary flooding as well as large releases from Keswick Dam for flood protection. This resulted in a large number of fish stranded in isolated pools along the Sacramento River. During this period, 269 stranding sites between the Keswick Dam (the uppermost limit of anadromy on the Sacramento River) and the Tehama Bridge (a total of 73 river miles) were surveyed. A total of 240 juvenile winter-run Chinook, 19,892 juvenile fall/spring-run Chinook and late fall-run Chinook, 373 rainbow trout juveniles were rescued and returned to the Sacramento River. One adult winter-run chinook was observed dead in a stranding pool.

The nearly "real-time" reporting of shallow redd depth as flows were reduced provided fishery managers the ability to make management recommendations to avoid the dewatering of winter-run Chinook redds this season. Periodic meetings between fishery agencies and water agencies utilized the data generated by this survey to more effectively manage the water resources available.

INTRODUCTION

The Sacramento River is the largest river system in California, and yields 35% of the state's water supply. This river system supports the largest contiguous riverine and wetland ecosystem in the Central Valley. The Upper Sacramento River Basin (USRB) of California's Central Valley is unique worldwide because it has four separate spawning runs of Chinook salmon (*Oncorhynchus tshawytscha*) including federal and state listed endangered winter-run. Winter-run Chinook are endemic only to the USRB and historically thrived in the McCloud River. Chinook salmon populations of the Sacramento River provide the majority of the state's sport and commercial catch (Killam 2012). Each run of Chinook has adopted a different life history (spawning locations, and seasonal timing) that allows it to survive many different environmental conditions found over the course of a year in the USRB. Figure 1 shows the major spawning reaches of the Sacramento River, home to all four salmon runs.

Most of the Sacramento River flow is controlled by the U.S. Bureau of Reclamation's (USBR) operation of Shasta Dam, which stores up to 4.5 million acre-feet (maf) of water. The median historical unimpaired run-off above Red Bluff is 7.2 maf, with a range of 3.3-16.2 maf, (USFWS, 1995). During the winter of 2016-2017 water levels in Shasta Lake reached 4.28 maf on February 11, 2017. Resulting in emergency release for flood protection and ultimately resulted in widespread fish stranding downstream.

Population levels of Chinook salmon in the upper Sacramento River reached historically low levels over the last six years (Killam et al. 2016). In addition, California Central Valley steelhead (*Oncorhynchus Mykiss*) were listed as threatened under the Federal Endangered Species Act in 1998, and status was reaffirmed in 2006. The 2011 status review (Williams et al. 2011) for Central Valley steelhead indicates that their status has diminished since the 2005 status review (Good et al. 2005), with updated information indicating an increased risk of extinction.

The Anadromous Fish Restoration Program (AFRP) Final Restoration Plan (U.S. Fish and Wildlife Service (USFWS), 2001), recommended six specific actions to address the declines in anadromous fish that had been observed since 1970. Of specific relevance to this study is the need (as salmon population levels have continued to remain low in the years since the 2001 Plan) for river flows that support and restore salmon and steelhead populations. As outlined in the Final Restoration Plan:

> *Changes in the natural frequency, magnitude, and timing of flows - Reservoirs have changed the natural flow regimes of the Sacramento River by changing frequency, magnitude, and timing of flow. Flows need to be established that support the life history needs of all four races of salmon and steelhead: spawning flows, stable flows for early life stages, outmigration flows, and flushing flows for sediment transport.*

Stable and continuous river flows are important to the early life history (egg incubation to emergence from the gravel) of salmonids. If redds are dewatered or exposed to warm, deoxygenated water, incubating eggs/larval fish may not survive. After emergence from their redd, juvenile salmon can become stranded in shallow isolated water and be exposed to poor environmental conditions as well as increased predation. For eggs and juveniles to survive they need clean cool water at all times.

Action (A2) from the Final Restoration Plan addresses the concerns regarding flow management:

> *Upper Sacramento River, Action 2: 2. Implement a schedule for flow changes that avoids, to the extent controllable, dewatering redds and isolating or stranding juvenile anadromous salmonids, consistent with SWRCB Order 90-5.*

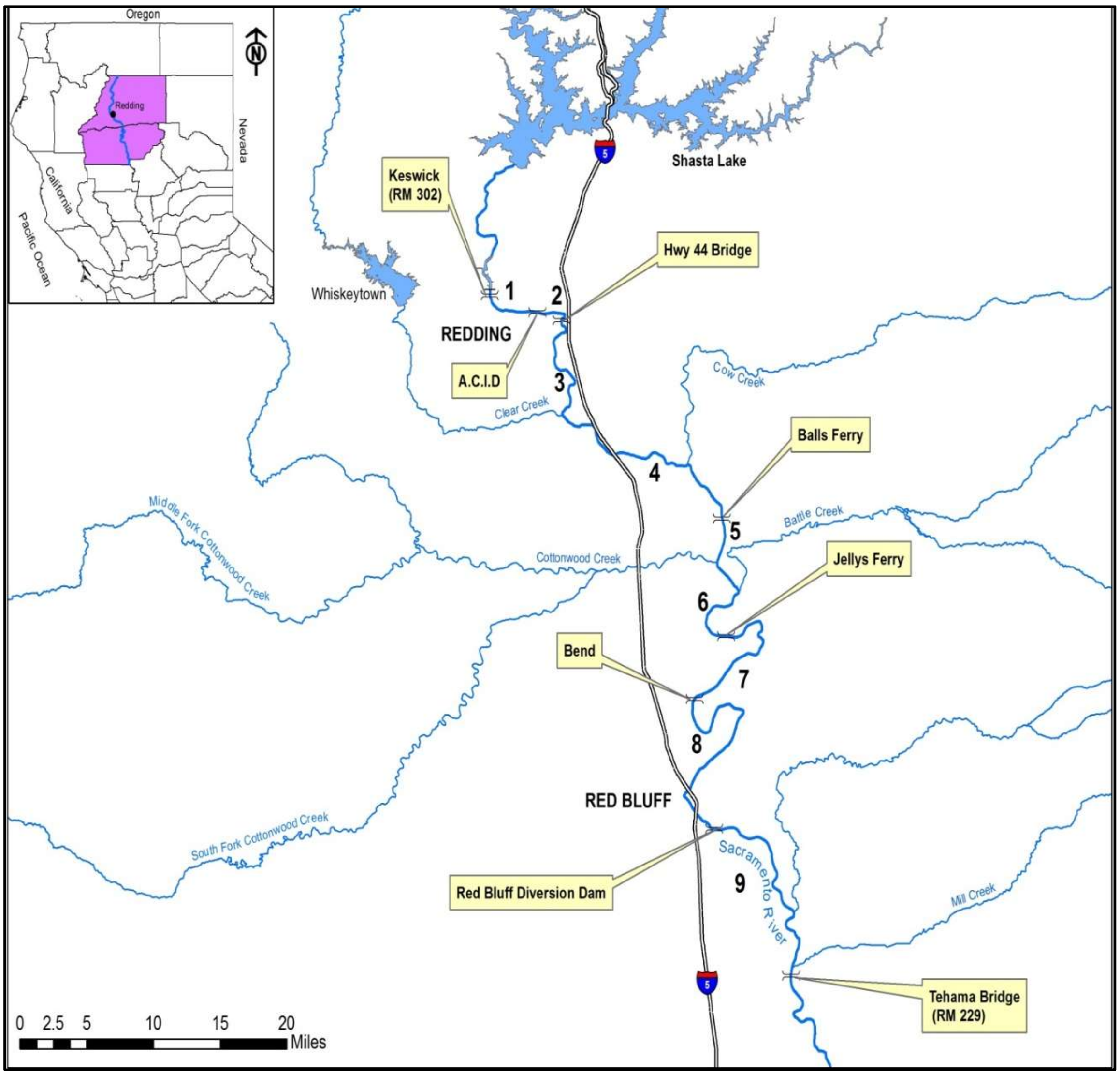

Figure 1. Map of the Upper Sacramento River Basin and study area from the Tehama Bridge to Keswick Dam (73 miles). River sections from study shown as numbers and based on river miles and landmarks.

Relevant actions (Reasonable and Prudent Alternatives, or RPA's) found within the Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and the State Water Project (OCAP BO) written by the National Marine Fisheries Service (NMFS 2009), state the following:

> *Action I.2.2. November through February Keswick Release Schedule (Fall Actions). Objective: Minimize impacts to listed species and naturally spawning non-listed fall-run from high water temperatures by implementing standard procedures for release of cold water from Shasta Reservoir. Action: Depending on EOS (End of September) carryover storage and hydrology, (Bureau of) Reclamation shall develop and implement a Keswick release schedule, and reduce deliveries and exports as detailed below.*

The OCAP BO identifies additional "sub" actions for implementation procedures when Shasta Reservoir has storage of various levels (2.4 million acre feet (maf) or higher, 1.9 maf to 2.4 maf, and below 1.9 maf, (Action I.2.2.A, B, and C respectively)). These actions include developing release criteria that addresses the need for stable Sacramento River level/stage in order to increase habitat for optimal spring-run and fall-run Chinook redds/egg incubation, and/or to minimize redd dewatering and juvenile stranding. Additional relevant excerpts from the OCAP BO are included in Appendix A.

In 2000, California Department of Fish and Wildlife (CDFW) staff collected data which when compared to the aerial redd survey counts, showed that 18 percent of the total fall-run Chinook salmon (hereafter fall-run) redds had been dewatered in December 2000 (CDFW, unpublished data). While this was not a comprehensive study, (aerial survey is not a total count of redds and effort varies annually) it should be considered a valuable "incidental observation", as it provides detail on the amount of redds that were dewatered in one year.

Redd dewatering and juvenile stranding relationships based on flow fluctuations for the thirty-one river miles between Battle Creek and Keswick Dam (Figure 1) are well described in a 2006 report by Dr. Mark Gard of the USFWS for the Instream Flow Investigations of the Central Valley Project Improvement Act (CVPIA), (USFWS, 2006). This report was part of a seven year investigation to describe instream flow needs of CVPIA managed streams for anadromous species. The report provides an in-depth analysis of Sacramento River salmon spawning habitats and stranding sites and their relationship to river flows. The relationships found in the report can be used to predict the consequences of flow fluctuations and their impact to spawning habitat, redd dewatering and juvenile stranding. An example table from Gard's 2006 report can be found in Appendix B. Data collection for the Gard study was from 1998 to 2001. The study did not focus on the biological consequences or actual impacts of the dewatering or the stranding. In contrast the purpose of this current monitoring effort is to better determine the present day impacts to flow reductions on a relatively real time basis (daily, weekly, or seasonal).

Real time monitoring of redd dewatering and stranding due to flow reductions is beneficial to managers to assist decision making based on actual conditions on the river. The timing of flow reductions can often be critical to the survival of large numbers of eggs or juveniles. Up-to-date information can provide fishery managers with the assurances they need to make decisions to mitigate flow changes, if the data shows that the biological consequences will be significant.

One source for flow reduction mitigation is to supplement Keswick Dam flows with water dedicated for environmental purposes. This "environmental water account" is commonly referred to as "the b2 water" and is part of the CVPIA, section 3406(b)(2). This directs the Secretary of the Interior to dedicate and manage annually 800,000 acre-feet of CVP water yield for the purpose of implementing the fish, wildlife, and habitat restoration purposes and measures as authorized by the CVPIA. Water from the b2 account can be used to supplement existing flows to prevent dewatering and stranding. This, in combination with up-to-date information on salmon in the river and close coordination between the different water and fishery agencies, can help reduce the impacts of flow management to salmon survival on the Sacramento River.

Winter-run Chinook salmon (hereafter winter-run) begin spawning in the upper reaches of the Sacramento River below Keswick from early May through August. Redd surveys are started in June to locate and monitor possible dewatering during flow reductions in late summer. Fall-run (and limited spring-run) begin spawning in the Sacramento River from the first week of September through mid-to-late November (Killam et al. 2016). Late fall-run Chinook salmon (late fall-run) spawning begins in early-December and peaks in mid-December to mid-January. Field surveys during the months of September through March provide opportunities to observe and collect data on current year fall and late-fall-run redds that are constructed in shallow water along the stream margins and in riffles. These surveys allow subsequent surveys to document dewatering with assurance that an active redd is being impacted. Dewatering can occur anytime a flow reduction is made. A typical reduction in flow, or "stepping down" of flow, occurs from September to November as less water is needed for agricultural purposes. When flow decreases coincide with large numbers of salmon spawning the impacts to spawning success can be significant. Figure 2 shows the stepping down of flow in both late summer and early winter of 2016. Figure 2 also depicts the large flood release from Keswick in late-winter 2017.

Redd dewatering on the Sacramento River can be observed during any month, but the biological significance of the dewatering depends on the timing of the flow decreases. When flows are increasing or maintained at a constant level there is minimal concern that new redds will be dewatered or juveniles stranded. Juvenile salmon will reside in the redd after hatching until their yolk sac is absorbed then "swim up" or emerge between the gravel and escape the redd structure into the water column. The development from egg to "swim up fry" depends on water temperature during development, (Beacham 1990), but can typically take up to100 days or more for water temperatures normal to the Sacramento River. Fall-run salmon spawning takes place in the fall when under natural conditions rainfall can be expected to maintain or increase natural flows. In the

Sacramento River, under USBR managed Keswick Dam flow releases, this flow regime can be reversed (Figure 2).

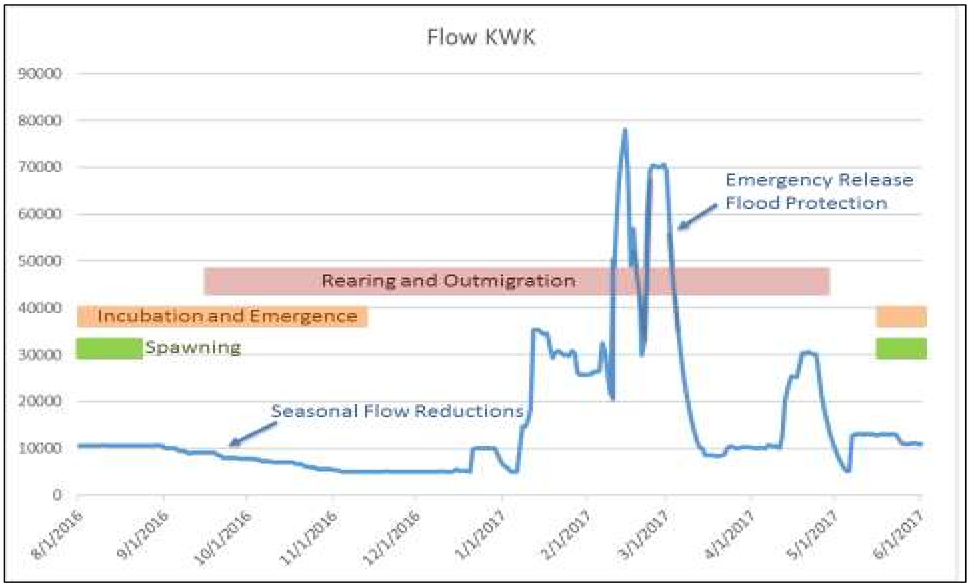

Figure 2. Flow releases from Keswick Dam on Sacramento River during selected periods in 2016 and 2017 and winter-run life history, KWK-USGS gauge (CDEC 2017).

Stranding of juvenile salmonids can also occur as a result of flow reductions throughout the Sacramento River. These stranding events have the potential to affect steelhead amd all four runs of the Sacramento Chinook salmon (fall, late-fall, winter and spring-run). The historical migration timing of all four adult Chinook salmon runs passing the Red Bluff Diversion Dam is provided in Appendix B Table B2. Spawning and juvenile rearing occurs year round in the USRB with spawning peaks occurring in October through January (fall and late-fall-runs) and again in June and July (winter-run) (Killam 2012).

Redd dewatering assessment can be challenging. For example, if dewatered redds are first observed out of water, these redds may be ones that were made by salmon that spawned in earlier runs or previous years, and from which the juvenile fish have already vacated. This creates difficulty in verifying if a dewatered redd contains eggs or juveniles, or if it is an older, inactive redd from a previous salmon run. Another challenge is that storm events can cause flow fluctuations downstream of Keswick Dam. Storm inflow from the many tributary streams below Keswick Dam (Figure 1) has the potential to re-water redds for various periods of time. The larger tributaries (e.g. Cow and Cottonwood Creek(s)), can contribute flows that increase main stem flows for a much longer time period. Therefore, the best time to observe potential dewatered redds is immediately after Sacramento River flows are dropping, but prior to large storms.

All winter-run redds observed in this study were marked before dewatering could occur and usually while adult female salmon were observed actively guarding the redd from other females (e.g., Figure 3). Frequent surveys through the spawning season allow biologists to estimate a construction date for each redd to determine the age and further provide an estimated fry emergence date for that particular redd.

This was the seventh season of redd dewatering monitoring and the fourth year of juvenile stranding monitoring. Prior year reports from 2011-2016 monitoring are available online through the RBFO's CALFISH internet link at this address:

http://www.calfish.org/Programs/CDFGUpperSacRiverBasinSalmonidMonitoring/tabid/222/Default.aspx) or by request from the authors.

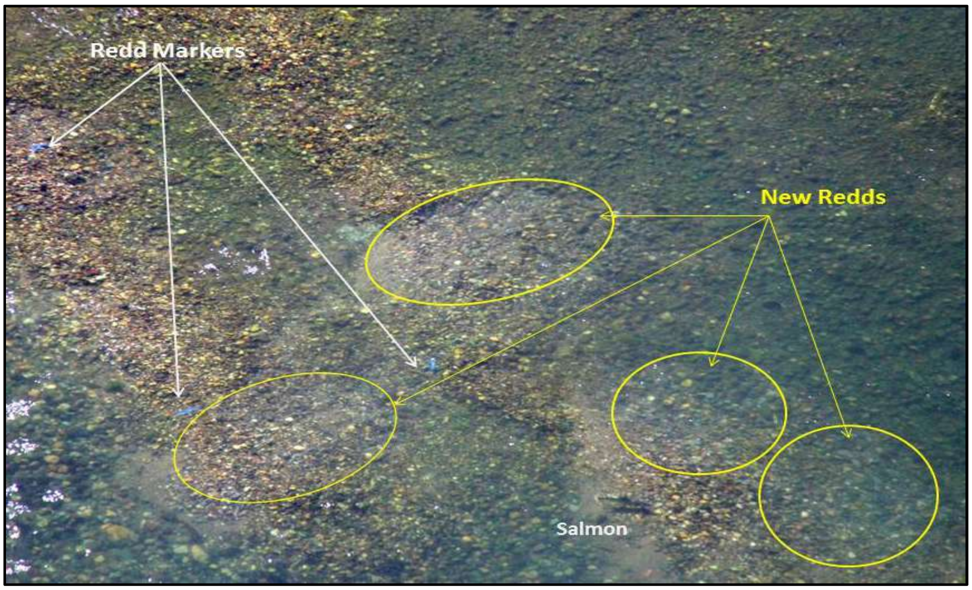

Figure 3. Aerial photograph of newly constructed spring/fall-run Chinook redds and previously marked redds (blue flagging).

Continued funding and interest made the 2016-2017 survey monitoring possible. The data collected from this year's survey provided resource managers a more accurate understanding of the impacts of redd dewatering and frequency of juvenile stranding occurring during this period. Daily "real-time" data collection for winter-run redd monitoring during late summer flow reductions was also made possible through AFRP funding.

METHODS

Redd Dewatering Field Survey Methods

Redd dewatering survey efforts were conducted primarily by boat and foot. Survey crews typically consisted of two staff members from the Red Bluff Fisheries Office (PSMFC or CDFW). Crews collected data on both active redds (adult fish recently present) or dewatered redds from the present salmon run. Crews marked and collected data on underwater or dewatered redds. Redds were marked with a Trimble® Geo7x handheld unit and with physical markers (flagged and weighted disk tags). The Trimble® unit utilized a highly accurate global navigation satellite system (GNSS) which allowed redds to be marked to an observed accuracy of nine to 32 inches (23 to 81 centimeters). This high level of accuracy allowed us to differentiate individual redds upon revisiting sites and to accurately recognize redd superimposition. The Trimble® unit also contained a digital data sheet which allowed for analyzation of data in Microsoft® Access® and ESRI®'s suite of mapping software.

Chinook salmon redds are constructed by female fish using their tails to excavate a depression in the streambed. As females lay on their side digging with their caudal fin, a vacuum force is created which lifts sediment into the current and shapes the pit of a redd. Once the pit is made, the male (or multiple competing males) and female salmon deposit eggs and milt side by side into the lowest point and the fertilized eggs sink to the bottom. The female then immediately covers the eggs with new gravel from just upstream of the pit. The female continues this process in an upstream movement until her eggs are deposited, (may take days). As the eggs are covered (normally up to 20 inches deep) in gravel a redd mound is created sheltering the eggs. When the female dies, the finished redd typically has an upstream pit (a.k.a. redd pot) that she has been using to cover her eggs located below the surface of the mound. This mound (called a tailspill) is the distinctive characteristic of salmon redds that the survey crews observed for dewatering and is shown in Figure 4 with other redd details.

Fish presence on or around spawning beds along with cleaned fresh gravel area are both defining characteristics of a redd that was recently constructed. Fresh redds are used to assist with aging and assigning a fry emergence date to that particular redd. Knowledge of fry emergence dates is utilized when making certain water management decisions. Water managers can determine the quantity of redds affected by future flow release reductions when identifying how many redds are currently containing eggs or fry. During the study, each observed redd was classified in the database from a list of five dewatering descriptors ranging from "not dewatered" to "totally dry". For the purposes of this study a dewatered redd was minimally identified as any active redd that had its highest section (the tailspill) exposed to the air. This would indicate that the river flow had decreased from the time when the redd was constructed and that impacts to egg or juvenile survival could be present.

Active redds (underwater with recent activity or fish near them) were identified by boat crews while surveying from the Tehama Bridge (RM 229) upstream to Keswick Dam (RM 302) near Redding. Figure 1 shows an area view of the survey area including the landmarks and river miles dividing the river sections used in the survey. Table 1 lists the survey sections with corresponding river miles. Redd surveys were conducted during spawning seasons on a regular basis, and after periods of Keswick flow decreases to allow crews to make observations of new redds and repeat observations of previously marked redds.

Active new redds were marked with round aluminum disc tags (1.25-inch diameter) attached by hog rings to a link of heavy steel chain placed underwater near the redd (Figure 4).

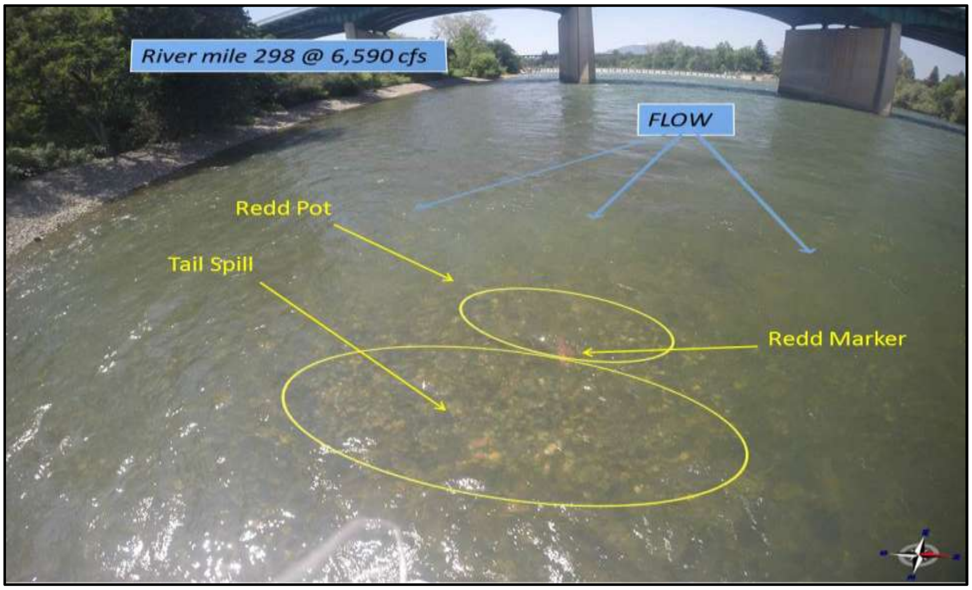

Figure 4. Winter-run Chinook redd observed during the 2016-2017 redd survey. Identifying features of Chinook redds are illustrated in the diagram.

A short length of surveyors flagging tape was added to the tag to increase visibility. Flagging was color-coded based on salmon run. Pink flagging was used during winter-run, blue for spring-run, and orange for fall-run and late-fall-run. Figures 3 and 4 show markers placed near active redds and the physical components of a finished redd.

Table 1. Dewatered Redd Survey river section numbers by river miles and landmarks for the 2016-2017 survey season.

Survey Section	River Miles	Landmarks
1	302-298	Keswick Dam **to** ACID Dam in Redding, CA
2	298-296	ACID Dam **to** Turtle Bay Brg (Hwy 44) in Redding, CA
3	296-288	Turtle Bay Brg (Hwy 44) **to** just below Clear Creek mouth
4	288-276	Clear Creek **to** Balls Ferry Brg near Anderson, CA
5	276-271	Balls Ferry Brg **to** mouth of Battle Creek near Cottonwood, CA
6	271-266	Battle Creek **to** Jellys Ferry Brg near Red Bluff, CA
7	266-257	Jellys Ferry Brg **to** Bend Ferry Brg near Red Bluff, CA
8	257-242	Bend Ferry Brg **to** Red Bluff Diversion Dam in Red Bluff, CA
9	242-229	RBDD downstream **to** Tehama Brg in Los Molinos, CA

An example datasheet is shown in Appendix C Figure C1-C2. Pertinent data collected for each redd included date, time, water temperature, crew, river section, water clarity, weather conditions, redd number, whether a salmon was present, dewatering status, sampling action, depth, and comments. Descriptions of each category are provided below.

a.) **Date:** This is the date that a redd is marked and recorded.
b.) **Time:** This is the recorded military time a redd is marked and recorded.
c.) **Water Temperature:** This is the river water temperature at the area where redds were being marked.
d.) **Crew Members:** This is the abbreviation of crew members who collected data during a survey.
e.) **River Section:** This is the section of river that the redds marked were located in.
f.) **Water Clarity:** This is the clarity of the river as gauged by a secchi disc. Clarity was an indication of how well redds could be identified during a survey.
g.) **Weather Conditions:** This is the weather conditions while the survey was conducted. Weather was an indication of how well redds could be identified during a survey.
h.) **Redd Number:** This is the unique number assigned to a redd and is obtained from the disc tag placed on the redd.
i.) **Salmon Present:** This is a range of options to help crews identify active redds. The four choices include: none, fish on redd, fish observed nearby, or redd dewatered.
j.) **Dewatered:** This is a range of options describing the extent of dewatering for each new redd encountered. The five choices include: no, top only, mostly, pot still wet, and pot dry.
k.) **Action:** This is a range of options to describe any actions taken at the redd location. The five choices include: depth and photo, measured, egg check, combination, or mark expired.
l.) **Depth:** This is a measurement in inches of water above the redd tail spill. Once a redd becomes "dewatered," a negative number is recorded.
m.) **Comments:** This allows crews to document any unusual qualities of each redd.

Once a new redd has been marked, repeat trips to that redd are made after flow changes to document any changes to the water conditions at the redd. These observations were treated similar to new redds with the exception of marker placement and Trimble® waypoint collection. The depth of each redd was measured in inches from the top of the tailspill to the existing water level. Dewatered redds received a negative number which corresponded to the distance of the tailspill out of water (Figure 4). A hand level and stadia rod were utilized to obtain depth measurements.

The depth of water over the highest point on the tailspill of the redd was measured for each redd. This provided data to compare water elevation at each redd with the flow in the river at each redd. This proves helpful in determining at what flow a certain area could be expected to be dewatered. For redds that had been dewatered the distance (elevation) from the redd's highest point to the nearest water surface was surveyed and reported as a negative number in the depth category for those dewatered redds.

Flows from Keswick Dam during periods of steady tributary inputs were compared with flows at other fixed monitoring stations along the river (CDEC: Bend station (BND), Red Bluff Diversion Dam (RDB), and Tehama Bridge (TEH)) to develop a relationship between time-distance and flows enabling crews to determine river flows at redds or stranding sites by recording time and the location during survey observations. Appendix E Table E1 provides the results of this time-distance-flow relationship.

Juvenile Stranding Field Survey Methods

Juvenile salmon can become stranded when decreasing river flows cause fish to become physically trapped in isolated pools or channels that at higher flows were previously connected (allowing free passage) to the Sacramento River. Stranding can lead to direct mortality when these areas drain or dry up. Indirect mortality can result through increased susceptibility to predators (otters, raccoons, birds, etc.) or water quality deterioration in shallow or stagnant stranding locations.

A juvenile salmonid stranding field datasheet (see Appendix C Figures C3-C4) was developed to document the presence and characteristics of stranding site locations on the Sacramento River for both rescue and restoration purposes. The datasheet categories were developed by RBFO staff to describe the unique characteristics of each potential site and provide information on the site's potential for impacting juvenile salmon survival. New stranding site locations were recorded on the field data sheet and a handheld Garmin GPS 78. Crews routinely carried both the Dewatered Redd datasheets and Stranding datasheets on surveys, completing the appropriate sheet if any observations were made. The Stranding datasheets included a similar river section to the one described for the Dewatered Redd sheet. Individual stranding sites were documented using the following categories:

a.) **Time:** This category allows determination of flows at the site by using a relationship between flow from Keswick Dam and the distance downstream.
b.) **Waypoint Number:** This is a number assigned to each potential stranding site using the GPS unit. The first digit corresponds to the site survey section number.
c.) **Picture Numbers:** These are photographs of the site for comparative purposes between visits.
d.) **River Mile:** Obtained from the online Sacramento River map atlas and represents distance from Sacramento River mouth, near Antioch, CA. Used to assist locating stranding sites during repeat observations and for flow calculations. (http://www.sacramentoriver.org/forum/index.php?id=atlases)
e.) **Connection:** This is a range of choices determined by crews at each site and describes the connection of the stranding site to the nearest flowing water of the river. Choices include: site open both up and downstream (crews

determine site likely to become isolated), downstream open only, upstream open only, and isolated completely.

f.) **Winter-run Number:** This is the estimated number of winter-run sized salmon observed in the stranding site. Size cut-offs are determined by each specific date using a screw trap developed length cut off chart for the Upper Sacramento River (example: Appendix B Table B3).

g.) **Fall-run Number:** This is same as winter-run above except for fall-run.

h.) **Late-fall-run Number:** This is same as winter-run above except for late-fall-run.

i.) **Habitat:** This is a range of choices describing the predominant habitat of the site and includes: pool, riffle, or combination.

j.) **Survival:** This a range of choices based on the crew's best judgment of the site and the knowledge of weather forecasts and future hydrological expectations based on the date and current environmental conditions. It describes the expectations for survival of salmon at the site and includes choices for: survival likely, death likely, and survival uncertain

k.) **Substrate:** This is a range of choices and describes the predominant substrate of the stranding site. Choices include: bedrock, cobble, small rock-sand, sand-silt-mud, or a combination of these.

l.) **Pool Temperature:** This is water temperature from a hand held thermometer or water quality meter.

m.) **Dissolved Oxygen:** This is dissolved oxygen level from a water quality meter.

n.) **Length:** Measured or estimated length of the stranding site.

o.) **Width:** Measured or estimated width of the stranding site.

p.) **Depth:** Measured or estimated depth of the stranding site.

q.) **Shelter:** This category describes the predominant type of shelter for stranded fish available in each site. It is a range of choices including: tree branches, submerged wood, aquatic vegetation, none, or combinations.

r.) **Reconnect:** This category describes a range of choices for the methods that could be used to reconnect the site to the river should that option be pursued. It is a simplified description of the type of work necessary to prevent stranding in future times at the site. Choices include: by hand, by power tools, by machinery, or not possible.

s.) **Rescue:** This category describes the level of effort (estimated by crews experienced in similar rescue efforts) that would be necessary to rescue the fish in the stranded site. Choices include: easy, moderate, difficult, or not possible.

t.) **Comments:** Allows crews to include other descriptions of each site.

Juvenile stranding events and stranding sites were observed while surveying the Sacramento River and side channels by boat and on foot. Efforts to locate and monitor stranding sites were conducted from the Tehama Bridge (RM 229) to Keswick Dam (RM 302). Isolated and partially or potentially isolated pools were observed and marked on a handheld GPS. Stranding sites are assigned a unique number that corresponds to the survey section the site is located within and typically increases in a downstream fashion. For example, site number 106 is located near the top (upstream) of Section one and site number 140 is located near the bottom (downstream) of Section one. All stranding sites were photographed and some examples are presented in Appendix D. Fish present were enumerated and identified by visual observation, including limited underwater observation and underwater photography. Juvenile salmonids were identified by species, and juvenile Chinook were classified by run based on approximate fork length relative to date. This is accomplished using the Central Valley Chinook length-at-date fork length table, an example of which is located in Appendix B Figure B3. Hard copies of this table were utilized in the field for size referencing observed salmon located in stranding pools. Figure 5 provides an example photo of a winter-run sized fish observed in a stranding pool. The site location and environmental conditions were also recorded. Some stranding pools were subsequently measured and environmental conditions such as temperature, substrate, type of shelter present, etc., were recorded. Likelihood of juvenile survival was assessed at observed stranding pools and was based on current and expected environmental conditions (e.g., if site was isolated and drying up and warm dry weather forecasted, then survival was probably unlikely for that site).

The feasibility of juvenile fish rescue and removal from the observed stranding site was also evaluated. This was based on the size and substrate of the stranding site, as well as surrounding habitat. For example, fish that were stranded in a wide shallow pool with little aquatic vegetation could be removed and relocated to adjacent flowing water using beach seines. Conversely, a deep bedrock pool with submerged debris such as downed logs or tree branches would be very difficult to effectively capture and remove juveniles for relocation. Other sites may require alternative methods such as electrofishing or using dip nets for small shallow water pools.

Stranding sites suitable for rescues containing juvenile salmonids were immediately rescued during observation. Rescues used seine nets of various lengths, dip nets and assorted tubs and buckets. Multiple passes were made with seine nets at each site and captured fish were transferred to buckets of water. Fish were then identified, tallied, and relocated to the nearest flowing river channel with minimal handling. Another characteristic assessed at each observed stranding site was the potential for reconnection. This was based on the substrate of the stranding site and the proximity to the nearest watered portion of Sacramento River.

The feasibility of reconnection included the potential for use of hand tools (e.g., shovels), power tools (e.g., jack hammers) and more aggressive reconnection using machinery such as an excavator, backhoe or other heavy equipment. Both permanent and temporary reconnection techniques were considered during assessment. Documented stranding sites were regularly revisited as resources allowed throughout the survey season. The status of each stranding site was evaluated to determine if and when the location reconnected or disconnected to the main river system. Fish numbers were estimated and species identified to assess mortality of stranded juveniles that were unable to be rescued sue to staffing limitations or pool characteristics.

Figure 5. Photo of a juvenile winter-run stranded in an isolated pool near Red Bluff Diversion Dam.

RESULTS

Dewatered Redd Data Summary

Northern California experienced record setting rainfall totals over the 2016-2017 season. The 2016-2017 dewatered redd monitoring season began with the winter-run Chinook spawning season that occurs from May through August each year. An estimated 1,409 winter-run spawned in the Sacramento River in the summer of 2016 (Killam et al. 2017). The first winter-run redds were located and identified during aerial redd surveys in early June. Survey crews identified 49 winter-run redds during the 2016-2017 survey that were thought to be susceptible to future dewatering before the eggs and juveniles within them had a chance to emerge from their redds. These redds were carefully monitored as seasonal flow reductions began to threaten four of these winter-run redds in late September, (Figure 2). No winter-run redds were dewatered.

Late spawning winter-run (from mid-July to mid-August) raised concerns with the fisheries agencies (CDFW, USFWS, and NMFS) that the redds of salmon would be dewatered with the typical flow reductions that occur in late August from Keswick Dam as agricultural water demands decrease. As a result, crews monitored shallow water winter-run redds in August and to report the results of this monitoring to the "b2 water" project work team. The b2 team is comprised of members from both fisheries and water agencies and is tasked with managing the b2 water account (supplemental water reserved for beneficial environmental purposes). The team is able to recommend on flow decisions made by water agencies responsible for Shasta Dam operations.

Redd dewatering surveys were conducted between June of 2016 and November 30, 2016. The Keswick (KWK-CDEC) flow gauge was used to determine flows in the 2016-2017 season. As a result of above average rainfall and high releases from Keswick Dam for flood protection, there was no danger of redd dewatering during the 2016-2017 season. Figure 6 provides a summary of Keswick Dam flow releases for the entire survey season.

The time of day was recorded for each redd observed. This allowed analysis of the flow at each marked redd based on redd's distance from Keswick Dam and the time it takes for flows to travel downstream. A multi-year time series of flow changes was analyzed using multiple linear regressions of flow changes coming from Keswick Dam and other points.

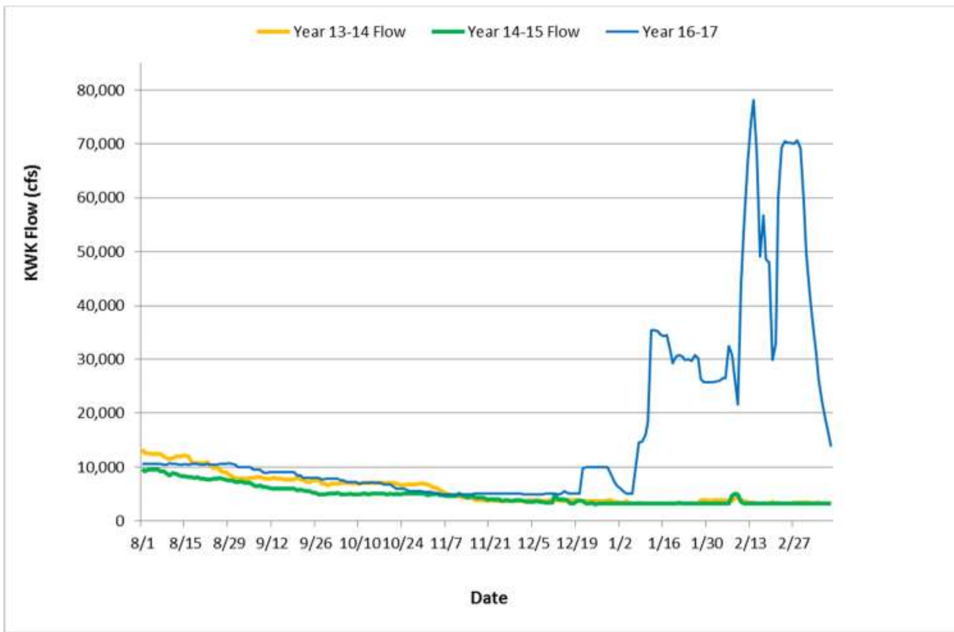

Figure 6. Sacramento River flow (obtained from the KWK gauge) by date for the 2013-2016 survey seasons.

Data from Appendix E Table E1 was used to calculate the flow at each given redd or stranding site. This enables comparison between water depths at redds and stranding site inlets and outlets. This data can be useful in predicting at what flow a certain area can become dewatered or isolated. For this study the Sacramento River was divided into half-mile segments based on the river mile designations available in the online CDWR atlas at the following link: *http://www.sacramentoriver.org/forum/index.php?id=atlases.*

Juvenile Stranding Data Summary

On February 14, 2017, the Bureau of Reclamation releases peaked at 82,100 cfs from Keswick Dam for flood protection. This and other high flow events caused the widespread stranding of adult and juvenile salmonids throughout the upper Sacramento River. There were 103 stranding surveys conducted from November 2, 2016 through May 15, 2017. Crews visited 269 potential unique stranding locations (Examples are shown in

Figure 7 and in Appendix D) between the Tehama Bridge (RM 229) and the Keswick Dam (RM 302). Figure 8 shows the distribution of stranded salmonid sites observed by river mile.

Figure 7. Aerial view of extensive flood that occurred on the Sacramento River during February 2017. The figure illustrates a few of these flooded areas, many of which stranded juvenile salmonids when flows receded.

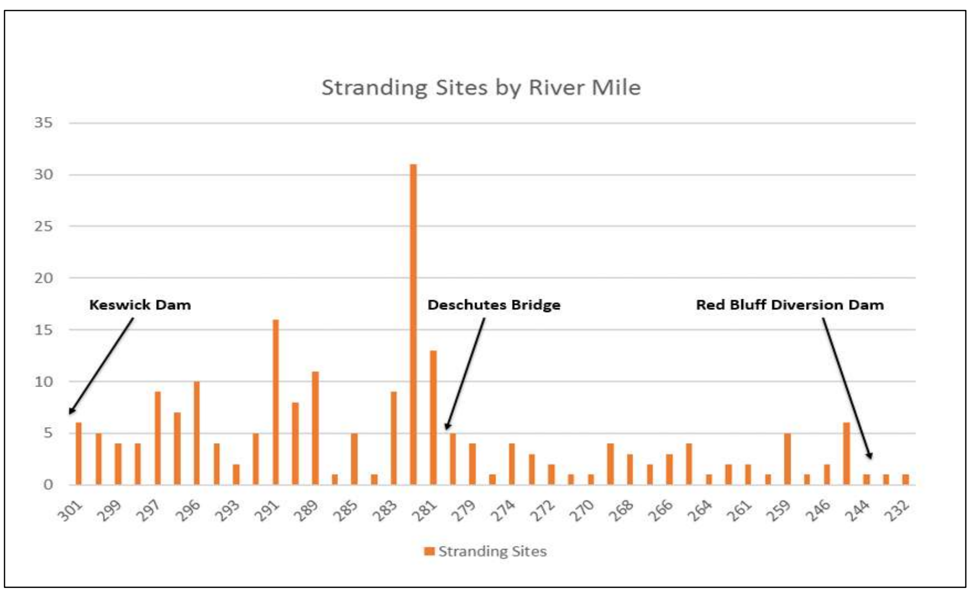

Figure 8. Graph of stranding sites by river mile as they occurred in between Keswick Dam (RM 302) and Tehama Bridge (RM 229).

There were several major stranding events that occured during the late-winter and spring of 2017. On February 9, 2017, flows from Keswick Dam were increased from 16,000 cfs to 82,100 cfs by February 14, and reduced back to 26,2000 cfs by February 21 (Figure 9). This major spike in flow from Keswick Dam resulted in widespread flooding and subsequent stranding thousands of juvenile salmon, and killed an unknown number of adult and juvenile salmon. At least one adult winter-run was found dead in a stranding pool. The numbers shown in Figure 9 are observational estimates and represent minimal numbers of stranded fish or fish mortality for the monitoring effort. This major stranding event repeated itself when flows were increased back up to 71,000 cfs on February 23, and were eventually reduced to 8,500 cfs by March 15. Crews recorded various data for each stranding site (Appendix C Figures C3-C4). The dominate substrates found at most sites were cobble and multiple substrates that include all categories (sand, silt, cobble, gravel) with the exception of section 8, where the dominate substrate consisted of bedrock. Most sites had aquatic vegetation, tree branches or both for shelter. River discharge was calculated using the same procedure as the dewatered redds (Appendix E Table E1.). This information was utilized to relate flow to the stage stranding sites become isolated and prevented fish passage.

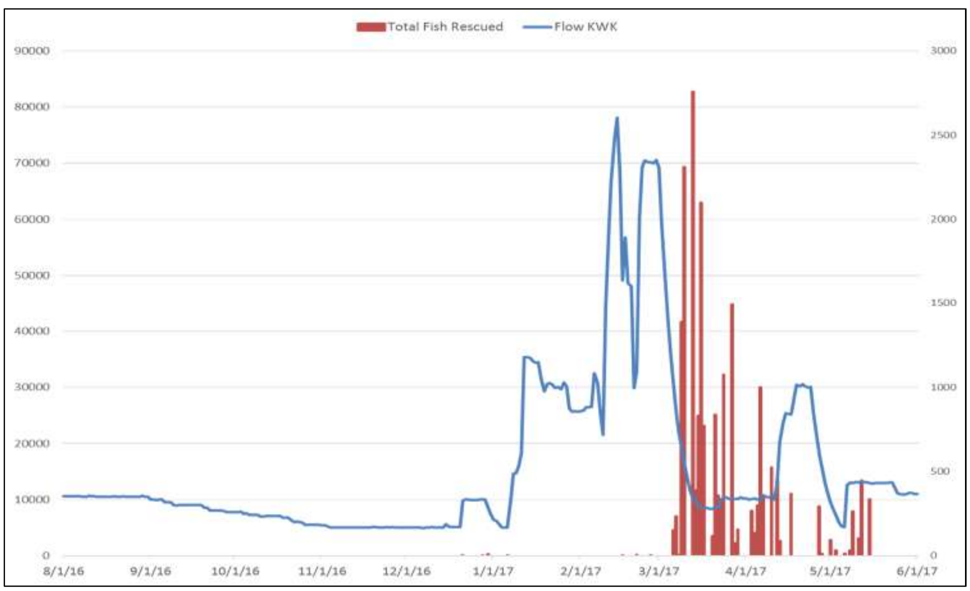

Figure 9. Graph comparing the number of stranded juvenile salmonids to Sacramento River flow (from the KWK gauge) by date for the 2016-2017 survey.

Fish Rescue Efforts

Stranded juvenile fish rescue efforts (example shown in Figure 10) using seine nets were conducted from December 21, 2016, through May 15, 2017. Backpack electrofishing and dip nets were also used where seining was not feasible. A total of 24,446 fish were observed and rescued from stranding locations on the Sacramento River during this period. There were a total of 240 winter-run and 19,892 spring, fall, late fall-run, sized salmon (based on data in Appendix B Table B3) and 372 rainbow trout (*Oncorhynchus mykiss*) rescued. Fishes of other families were also rescued during salmonid rescues (i.e.

Cyprinidae, Cottidae, Petromyzontidae, Centrarchidae, Catostomidae, etc.). An example of the fish rescue datasheet is provided in Appendix C Figures C5-C6. Beach seining and other rescue methods proved very successful and safe during these rescue attempts. An unknown number of fish mortalities resulted from these stranding events at sites that were not found or were surveyed too late. This includes one winter-run adult was observed dead in a stranding pool as well as 11 spring/late fall-run adults, and 20 rainbow trout adults.

DISCUSSION

The overall objective of this monitoring effort is to investigate and gain information on the extent and nature of impacts of river flow reductions and fluctuations to salmon populations in the upper Sacramento River. The monitoring effort provides data to water and fishery agency managers that allow them to better understand how flow changes affect salmonid resources. It also provides opportunities to protect these resources using real time information.

Survey crews identified some 49 winter-run redds during the 2016-2017 survey that were thought to be susceptible to future dewatering before the eggs and juveniles within them had a chance to emerge from their redds. These redds were carefully monitored as seasonal flow reductions began to threaten four of these winter-run redds in late September, (Figure 2). No winter-run redds were dewatered.

Figure 10. Fish rescue efforts to relocate juvenile from stranding pools near the Red Bluff Diversion Dam on the Sacramento River confluence (RM 243).

Anderson Cottonwood Irrigation District Dam (ACID) creates a deep water pool in the Sacramento River in Redding (RM 298). An additional management action taken to protect these upstream winter-run redds was to request that the ACID dam be kept in place until November 2, to prevent dewatering of those winter-run redds above the dam. The seasonal flashboard dam is normally taken out in October but by keeping the dam in place through November redds upstream remained flooded, allowing winter-run juveniles the opportunity to emerge without difficulties.

Following winter-run redd monitoring, staff transitioned into monitoring dewatering of spring, fall and late-fall-run redds as flows decreased when winter-run redds had “emerged” after November 1. No attempt was made to quantify the spring-run population in the Sacramento River (due to lack of funding for genetic testing). Some carcasses in early September of 2013 were genetically tested to separate the later spawning winter-run from other populations and the analysis found winter, spring and fall-run carcasses present in early September.

Observations during the 2016-2017 and prior years indicate that oscillating river flows have the potential to dewater redds and strand juvenile salmonids repeatedly in the same locations. Juvenile salmon move between shallow, slow moving waters to rest between venturing into swifter food carrying waters. This tendency makes them particularly susceptible to stranding as flows recede isolating the shallow river margin areas. During typical winter dry periods with steady or decreasing tributary inputs, small flow changes (up or down) from Keswick Dam can result in repeated flooding and dewatering of pool and side channels throughout the upper Sacramento River. The 2016-2017 season experienced significant winter rain events that resulted in flooding and major tributary stream influences as shown in Figure 11 that compares flows from Keswick Dam and flows downstream at the Bend gauging station. Although the increased tributary inputs substantially reduced redd dewatering below Clear Creek, many stranding sites became inundated then swiftly isolated as floods receded.

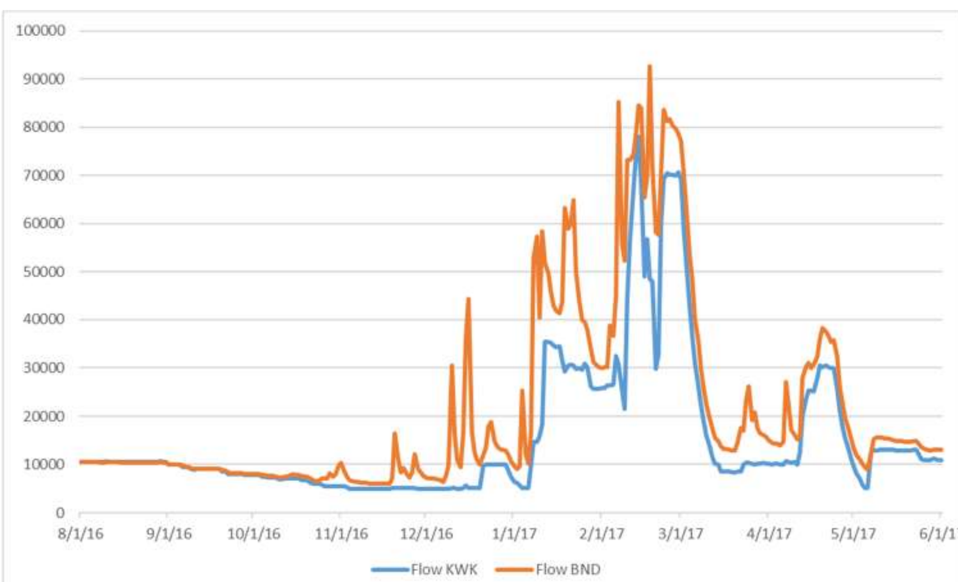

Figure 11. Graph of Sacramento River flow at KWK (below Keswick Dam) and at Bend Gage (located 42 miles downstream of Keswick) during year 2016-2017.

These flood events combined with decreased Keswick flow releases resulted in the bulk of observed stranded juvenile salmonids. The main objectives juvenile stranding surveys were to locate new stranding sites and to monitor the known sites for stranded juvenile salmonids. Later in the stranding season, fish rescues became the main priority. Future efforts will shift their focus towards monitoring, rescuing, and implementing preventive actions including possibly developing strategies for reconnecting stranding sites to the river.

Summary of Multi-Year Effort and Future Plans

Over the duration of this monitoring effort we have observed that constant river flows for a period of over 3 months following redd construction will prevent dewatering and prevent subsequent stranding of the young salmonids. The complexity of the Sacramento River below Keswick Dam makes determination of the impacts to juvenile salmon difficult to judge. Some of the issues this monitoring focused on are as follows:

a.) Determining the total percentage of redds dewatered and the impacts of superimposition to this percentage.
b.) Determining the impacts of salmon mortality from redd dewatering.
c.) Determining the survival of stranded juvenile Chinook in stranding sites.
d.) Determining the feasibility for reconnection of stranding sites to the Sacramento River mainstem.

The percentage of dewatered redds is calculated by comparing the estimated spawning females in the survey area (Killam et al. 2017) to the number of dewatered redds. It is not possible to count all redds (superimposition, depth, turbidity, staffing) so the number of female spawners based on other monitoring is used.

Superimposition of redds (typically during the fall-run) was observed in some high density spawning locations throughout the entire monitoring period (2011-2016). Redd superimposition occurs when early constructed redds are imposed upon by late spawning salmon that construct redds on top of or near the preexisting redds. This usually occurs in areas of high quality spawning habitat with adequate subsurface water flow and loose gravel provided by previous redds that are no longer guarded (S.J.R.P, 2008). Superimposition has been documented in many other streams and is known to have negative effects on previously deposited eggs (Fukushima M, et.1998). Counting redds in these high density areas during this study season was problematic due to the common occurrence of superimposed redds. Many redds were constructed in close proximity to one another and difficult to distinguish. The redd survey crew was asked to be conservative when marking and enumerating redds and was cautious not to overestimate redd counts.

Crews reported that the original redd markers were often missing from the redd locations on subsequent visits and had to rely on Trimble® to locate the original marked redd. This could happen when subsequent spawners kicked up new gravel that covered the marker, or by the public walking in the dewatered areas and removing them upon observation. If there was actually more than one redd for each marked redd location than the overall number of dewatered redds would increase. Crew ability to revisit marked redd sites was limited by staffing levels and the distance (73 miles) that redd dewatering occurred.

Salmon mortality in dewatered redds is variable and each redd is unique based on location and physical and environmental conditions around the redd. Dewatering of redds can occur due to small changes in flows and knowing the impacts (see Becker, et al., 1983) to the developing fish will need focused study. Determining what allows some salmon in dewatered redds to survive and others to perish should be a focus of future studies. Water velocity reduction and temperature increases are key components to the risks of salmon in redds during dewatering or simply in shallow water. Salmonid redds have specific water velocity, dissolved oxygen, and temperature requirements for embryo survival. Intragravel water flow transports dissolved oxygen, a biological requirement for salmon embryo production, to the eggs while removing silt and metabolic waste (Cordone and Kelley 1961). The observed ideal velocity requirements for chinook salmon redds are 30-80 cm/sec (1-2.6 ft/sec) while optimal temperatures range from 5-13°C or 41-55°F (Moyle, 2002). Although surface water levels and velocities may fall well below these ranges, sub-surface flow in the hyporheic zone may (or may not) be sufficient in providing dissolved oxygen for egg incubation. Further efforts to determine impacts to survival in the redds may focus on measurement of intragravel and surface water flows and water quality in and around dewatered redds.

Fish rescues are a regular component to juvenile stranding surveys but are limited to staff time and resources. Rescues are planned after significant flow reductions from Keswick Dam if juvenile fish are observed stranded in disconnected pools and survival in these pools is unlikely due to dewatering or long term expected dry conditions. Rescuing every stranding site with juvenile salmon by hand is not a viable long-term solution. Other options should be investigated such as deepening connections to known stranding sites to allow connection with the main channel at the current (agency established) minimum low flow from Keswick Dam of 3,250 cfs.

Future survival and behavioral studies of rescued juvenile salmonids are needed to better understand the effect of stranding on upper Sacramento River salmon and steelhead populations. Survivorship of juveniles in stranding sites depends on many factors. The connectivity to the river changes as Keswick Dam flows change or as tributary flows change so each stranding site is a dynamic balance of environmental inputs at any given time. Fish in some stranding locations are not necessarily lost as many even completely isolated sites were large and deep enough to support fish life for weeks possibly months and eventually would reconnect as flows increase in the spring for agricultural purposes. While fish may survive in some stranding pools, their ability to migrate is impaired and may lead to further survival problems later in life due to migration delays. Off channel rearing sites are a common natural occurrence and provide much needed rearing and resting habitat in the Sacramento River. They can become salmon death traps when conditions (flows) are managed opposite of the naturally occurring conditions. As natural flows increase from rainfall and flows from Keswick Dam are reduced, salmon in the upper river may become stranded and miss the opportunity to out-migrate during peak flows. Salmon out-migration during peak flows helps in predator avoidance and can help ensure the salmon find their way to the ocean past the confusion of alternate pathways in the Sacramento-San Joaquin Delta. The monitoring of salmonids rescued from stranding pools using acoustic telemetry will offer valuable information regarding the life history and behavior of salmon that may lead to stranding, as well as survival of rescued fish. This information will help lead management options such as Keswick pulse flows during dry years timed to rain events may trigger a migratory response in naturally spawned fish and allow stranded fish a chance to escape.

The past years of this study have demonstrated the need for flexibility and adaptability when studying the dewatering and stranding of redds and juveniles in the upper Sacramento River. To continue this effort in future years, staff should be in place in late summer but because of rainfall variability the study may or may not be able to occur on any given year. The variability experienced each year points to the challenge of managing river flows, predicting precipitation timing, and staffing human resources for this project. In some future years crews will be busy all year while in others the river might be flooding for months and crews will have little opportunity to collect data. In many years natural rainfall can swell the tributaries downstream of Keswick Dam. These natural inflows raise and lower the river levels and can both prevent, and lead to, dewatering and juvenile stranding depending on timing and salmon numbers.

From this effort, we know that Sacramento River flow reductions and flow oscillations have the potential to increase the mortality of naturally produced salmonids by dewatering and/or stranding thousands of juvenile Chinook. Stranding can affect juveniles of all runs, and can occur throughout the year at many different flows. It is now apparent that redd dewatering and stranding of juveniles has an impact all types of habitat and has the potential of being a major impact for juvenile salmonid survival throughout the upper Sacramento River.

Future efforts will allow efficient and extensive coverage of the study areas as well as almost real-time reporting of redd dewatering and juvenile stranding. Most notably this includes further monitoring of juvenile stranding sites to provide insight on future fish rescues. Future efforts will also begin to assess the potential to permanently reconnect stranding sites to the Sacramento River. With the use of advanced technology, further studies will provide resource managers with real-time data to make educated decisions on future flow allocations and the impacts these decisions will have on Central Valley Chinook salmon.

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APPENDIX A

Relevant Excerpts from the National Marine Fisheries Service (NMFS)-Operations and Criteria Plan (OCAP) Biological Opinion.

Page 587: Project operations of the Sacramento River Division affect winter-run, spring-run, CV steelhead, the Southern DPS of green sturgeon. In addition, project operations affect fall-run, which are not listed. Fall-run salmon are considered in developing the actions as a prey base for Southern Residents. This Division section of the RPA includes actions related to minimizing adverse effects to spring-run and steelhead spawning and rearing in Clear Creek and all species in the main stem Sacramento River. Actions include those necessary to reduce the risk to temperature effects to egg incubation in the upper river, especially to winter-run and spring-run spawning below Shasta Dam.
Page 590: Action Suite I.2. Shasta Operations, Introduction to Shasta Operations: Maintaining suitable temperatures for egg incubation, fry emergence, and juvenile rearing in the Sacramento River is critically important for survival and recovery of the winter-run ESU. The winter-run ESU has been reduced to a single population, which has been blocked from its historical range above Shasta Dam. Consequently, suitable temperatures and habitat for this population must be maintained downstream of Shasta Dam through management of the cold water pool behind the dam in the summer. Maintaining optimum conditions for this species below Shasta is crucial until additional populations are established in other habitats or this population is restored to its historical range. Spring-run are also affected by temperature management actions from Shasta Reservoir.

The effects analysis in this Opinion highlights the very challenging nature of maintaining an adequate cold water pool in critically dry years, extended dry periods, and under future conditions, which will be affected by increased downstream water demands and climate change. This suite of actions is designed to ensure that Reclamation uses maximum discretion to reduce adverse impacts of the projects to winter-run and spring-run in the Sacramento River by maintaining sufficient carryover storage and optimizing use of the cold water pool. In most years, reservoir releases through the use of the TCD are a necessity in order to maintain the bare minimum population levels necessary for survival (Yates et al. 2008, Angilletta et al. 2008).
The effects analysis in this Opinion, and supplemental information provided by Reclamation, make it clear that despite Reclamation's best efforts, severe temperature-related effects cannot be avoided in some years. The RPA includes exception procedures to deal with this reality. Due to these unavoidable adverse effects, the RPA also specifies other actions that Reclamation must take, within its existing authority and discretion, to compensate for these periods of unavoidably high temperatures. These actions include restoration of habitat at Battle Creek that may be support a second population of winter-run, and a fish passage program at Keswick and Shasta dams to partially restore winter-run to their historical cold water habitat.

Objectives*: The following objectives must be achieved to address the avoidable and unavoidable adverse effects of Shasta operations on winter-run and spring-run:*

Ensure a sufficient cold water pool to provide suitable temperatures for winter-run spawning between Balls Ferry and Bend Bridge in most years, without sacrificing the potential for cold water management in a subsequent year. Additional actions to those in the 2004 CVP/SWP operations Opinion are needed, due to increased vulnerability of the population to temperature effects attributable to changes in Trinity River ROD operations, projected climate change hydrology, and increased water demands in the Sacramento River system.

Ensure suitable spring-run temperature regimes, especially in September and October. Suitable spring-run temperatures will also partially minimize temperature effects to naturally-spawning, non-listed Sacramento River fall-run, an important prey base for endangered Southern Residents.

Establish a second population of winter-run in Battle Creek as soon as possible, to partially compensate for unavoidable project-related effects on the one remaining population.

Restore passage at Shasta Reservoir with experimental reintroductions of winter-run to the upper Sacramento and/or McCloud rivers, to partially compensate for unavoidable project-related effects on the remaining population.

Page 592: ***Action 1.2.1 Performance Measures.***

Objective*: To establish and operate to a set of performance measures for temperature compliance points and End-of-September (EOS) carryover storage, enabling Reclamation and NMFS to assess the effectiveness of this suite of actions over time. Performance measures will help to ensure that the beneficial variability of the system from changes in hydrology will be measured and maintained.*

Action: *The following long-term performance measures shall be attained. Reclamation shall track performance and report to NMFS at least every 5 years. If there is significant deviation from these performance measures over a 10-year period, measured as a running average, which is not explained by hydrological cycle factors (e.g., extended drought), then Reclamation shall reinitiate consultation with NMFS.*
Performance measures for EOS carryover storage at Shasta Reservoir:

87 percent of years: Minimum EOS storage of 2.2 MAF
82 percent of years: Minimum EOS storage of 2.2 MAF and end-of-April storage of 3.8 MAF in following year (to maintain potential to meet Balls Ferry compliance point)
40 percent of years: Minimum EOS storage 3.2 MAF (to maintain potential to meet Jelly's Ferry compliance point in following year)

Measured as a 10-year running average, performance measures for temperature compliance points during summer season shall be:
Meet Clear Creek Compliance point 95 percent of time
Meet Balls Ferry Compliance point 85 percent of time

Meet Jelly's Ferry Compliance point 40 percent of time
Meet Bend Bridge Compliance point 15 percent of time

Rationale: *Evaluating long-term operations against a set of performance measures is the only way to determine the effectiveness of operations in preserving key aspects of life history and run time diversity. For example, maintaining suitable spawning temperatures down to Bend Bridge in years when this is feasible will help to preserve the part of winter-run distribution and run timing that relies on this habitat and spawning strategy. This will help to ensure that diversity is preserved when feasible. The percentages are taken from those presented in the CVP/SWP operations BA, effects analysis in the Opinion, and NMFS technical memo on historic Shasta operations.*

P 592: ***Action I.2.2*.** ***November through February Keswick Release Schedule (Fall Actions)***

Objective: *Minimize impacts to listed species and naturally spawning non-listed fall-run from high water temperatures by implementing standard procedures for release of cold water from Shasta Reservoir.*

Action*: Depending on EOS carryover storage and hydrology, Reclamation shall develop and implement a Keswick release schedule, and reduce deliveries and exports as detailed below.*

Action I.2.2.A Implementation Procedures for EOS Storage at 2.4 MAF and Above
If the EOS storage is at 2.4 MAF or above, by October 15, Reclamation shall convene a group including NMFS, USFWS, and CDFG, through B2IT or other comparable process, to consider a range of fall actions. A written monthly average Keswick release schedule shall be developed and submitted to NMFS by November 1 of each year, based on the criteria below. The monthly release schedule shall be tracked through the work group. If there is any disagreement in the group, including NMFS technical staff, the issue/action shall be elevated to the WOMT for resolution per standard procedures.
The workgroup shall consider and the following criteria in developing a Keswick release schedule:

1) *Need for flood control space: A maximum 3.25 MAF end-of-November storage is necessary to maintain space in Shasta Reservoir for flood control.*

2) *Need for stable Sacramento River level/stage to increase habitat for optimal spring-run and fall-run redds/egg incubation and minimization of redd dewatering and juvenile stranding.*

3) *Need/recommendation to implement USFWS' Delta smelt Fall X2 action as determined by the Habitat Study Group formed in accordance with the 2008 Delta smelt Opinion. NMFS will continue to participate in the Habitat Study Group (HSG) chartered through the 2008 Delta smelt biological opinion. If, through the HSG, a fall flow action is recommended that draws down fall storage significantly from historical patterns, then NMFS and USFWS will confer and recommend to*

Reclamation an optimal storage and fall flow pattern to address multiple species' needs.

If there is a disagreement at the workgroup level, actions may be elevated to NMFS Sacramento Area Office Supervisor and resolved through the WOMT's standard operating procedures.

Rationale: *2.2 MAF EOS storage is linked to the potential to provide sufficient cold water to meet the minimum Balls Ferry Compliance point in the following year, and it is achievable approximately 85 percent of the time. Based on historical patterns, EOS storage will be above 2.4 MAF 70 percent of the time. The 2.4 MAF storage value provides a reasonable margin above the 2.2 level to increase the likelihood that the Balls Ferry Compliance Point will be reached while also implementing fall releases to benefit other species and life stages. Therefore, in these circumstances, actions should target the fall life history stages of the species covered by this Opinion (i.e., spring-run spawning, winter-run emigration). The development of a Keswick release schedule is a direct method for controlling storage maintained in Shasta Reservoir. It allows Reclamation to operate in a predictable way, while meeting the biological requirements of the species. The B2IT workgroup has been used in the past to target actions to benefit fall-run during this time of year using b(2) resources, and, because of its expertise, may also be used by Reclamation to develop this flow schedule. In the past, the B2IT group has used the CVPIA AFRP guidelines to target reservoir releases. Over time, it may be possible to develop a generic release schedule for these months, based on the experience of the work group.*

Action I.2.2.B Implementation Procedures for EOS Storage Above 1.9 MAF and Below 2.4 MAF

If EOS storage is between 1.9 and 2.4 MAF, then Reclamation shall convene a group including NMFS, USFWS, and CDFG, through B2IT or other comparable workgroup, to consider a range of fall actions. Reclamation shall provide NMFS and the work group with storage projections based on 50 percent, 70 percent, and 90 percent hydrology through February, and develop a monthly average Keswick release schedule based on the criteria below. The monthly release schedule shall be submitted to NMFS by November 1. Criteria for the release schedule shall include:

1) Maintain Keswick releases between 7000 cfs and 3250 cfs to reduce adverse effects on main stem spring-run and conserve storage for next year's cold water pool.

2) Consider fall-run needs per CVPIA AFRP guidelines, through January, including stabilizing flows to keep redds from de-watering.

3) Be more conservative in Keswick releases throughout fall and early winter if hydrology is dry, and release more water for other purposes if hydrology becomes wet. For example, release no more than 4,000 cfs if hydrology remains dry.

Reclamation, in coordination with the work group, shall review updated hydrology and choose a monthly average release for every month (November, December, January, February), based on the release schedule. In the event that the updated hydrology indicates a very dry pattern and consequent likely reduction in storage, the work group may advise Reclamation to take additional actions, including export curtailments, if necessary to conserve storage

If there is a disagreement at the work group level, actions may be elevated to NMFS and resolved through the WOMT's standard operating procedures.

***Rationale**: It is necessary to be reasonably conservative with fall releases to increase the likelihood of adequate storage in the following year to provide cold water releases for winter-run. This action is intended to reduce adverse effects on each species without compromising the ability to reduce adverse effects on another species. A work group with biologists from multiple agencies will refine the flow schedule, providing operational certainty while allowing for real-time operational changes based on updated hydrology. Over time, it may be possible to develop a generic release schedule for these months, based on the experience of the work group.*

Action I.2.2.C. Implementation and Exception Procedures for EOS Storage of 1.9 MAF or Below

If the EOS storage is at or below 1.9 MAF, then Reclamation shall:

> *1) In early October, reduce Keswick releases to 3,250 cfs as soon as possible, unless higher releases are necessary to meet temperature compliance points (see action I.2.3).*
>
> *2) Starting in early October, if cool weather prevails and temperature control does not mandate higher flows, curtail discretionary water deliveries (including, but not limited to agricultural rice decomposition deliveries) to the extent that these do not coincide with temperature management for the species. It is important to maintain suitable temperatures targeted to each life stage. Depending on air and water temperatures, delivery of water for rice decomposition, and any other discretionary purposes at this time of year, may coincide with the temperature management regime for spring-run and fall-run. This action shall be closely coordinated with NMFS, USFWS, and CDFG.*
>
> *3) By November 1, submit to NMFS storage projections based on 50 percent, 70 percent, and 90 percent hydrology through February. In coordination with NMFS, Reclamation shall: (1) develop a monthly average Keswick release schedule similar in format to that in Action I.2.2.B, based on the criteria below and including actions specified below; and (2) review updated hydrology and choose a monthly average release for every month, based on the release schedule. November releases shall be based on a 90 percent hydrology estimate.*

Criteria and actions: 1) Keswick releases shall be managed to improve storage and maintained at 3,250 cfs unless hydrology improves. 2) November monthly releases will be based on 90 percent hydrology. 3) Consider fall-run needs through January as per CVPIA AFRP guidelines, including stabilizing flows to keep redds from dewatering. 4) Continue to curtail discretionary agricultural rice decomposition deliveries to the extent that these do not coincide with temperature management for the species, or impact other ESA-listed species. It is important to maintain suitable temperatures targeted to each life stage. Depending on air and water temperatures, delivery of water for rice decomposition may coincide with the temperature management regime for spring-run and fall-run. This action shall be closely coordinated with NMFS. USFWS, and CDFG. 5) If operational changes are necessary to meet Delta outflow, X2, or other legal requirements during this time, then: a) CVP/SWP Delta combined exports shall be curtailed to 2,000 cfs if necessary to meet legal requirements while maintaining a 3,250 cfs Keswick release (or other planned release based on biological needs of species); and b) if it is necessary to curtail combined exports to values more restrictive than 2000 cfs in order to meet Delta outflow, X2, or other legal requirements, then Reclamation and DWR shall, as an overall strategy, first, increase releases from Oroville or Folsom; and c) in general, Reclamation shall increase releases from Keswick as a last resort. d) Based on updated monthly hydrology, this restriction may be relaxed, with NMFS' concurrence. 6) If the hydrology and storage have not improved by January, additional restrictions apply – see Action I.2.4.

Rationale: *Per actions I.2.3 and I.2.4 below, Reclamation is required to meet 1.9 MAF EOS. The BA's CALSIM modeling shows that during a severe or extended drought, 1.9 EOS storage may not be achievable. In this circumstance, Reclamation should take additional steps in the fall and winter months to conserve Shasta storage to the maximum extent possible, in order to increase the probability of maintaining cold water supplies necessary for egg incubation for the following summer's cohort of winter-run. Assessment of the hydrologic record and CALSIM modeling shows that operational actions taken during the first year of a drought sequence are very important to providing adequate storage and operations in subsequent drought years. The biological effects of an extended drought are particularly severe for winter-run. Extended drought conditions are predicted to increase in the future in response to climate change. While it is not possible to predict the onset of a drought sequence, in order to ensure that project operations avoid jeopardizing listed species, Reclamation should operate in any year in which storage falls below 1.9 MAF EOS as potentially the first year of a drought sequence. The CVP storage system is likely to recover more quickly in the winter and spring months if additional storage conservation measures are taken in the fall and winter. The curtailments to discretionary rice decomposition deliveries and combined export curtailment of 2,000 cfs are necessary to conserve storage when EOS storage is low. These actions were developed through an exchange of information and expertise with Reclamation operators. This action is consistent with comments from the Calfed Science Peer Review panel. That panel recommended that Shasta be operated on a two-year (as opposed to single year) hydrologic planning cycle and that Reclamation take additional steps to incorporate planning for potential drought and extended drought into its operations.*

APPENDIX B

Reference Tables of Salmon Biological Life History Traits.

Percentage of Fall-run Chinook Salmon Redds Dewatered - ACID Dam Boards Out

Spawning Flow (cfs)

Dewatering flow (cfs)	3500	3750	4000	4250	4500	4750	5000	5250	5500	6000	6500	7000	7500	8000	9000	10000	11000
29000																	
27000																	
25000																	
23000																	
21000																	
19000																	
17000																	
15000																	
14000																	
13000																	
12000																	
11000																	
10000																	0.9%
9000																2.2%	5.5%
8000															2.6%	6.6%	11.5%
7500														0.8%	4.4%	9.1%	14.1%
7000													0.9%	2.0%	6.6%	11.8%	17.3%
6500												1.3%	2.6%	4.2%	9.8%	15.6%	21.1%
6000											1.2%	2.8%	4.6%	6.5%	12.9%	19.7%	25.8%
5500										1.4%	3.2%	5.4%	7.7%	10.3%	17.6%	24.9%	31.0%
5250									0.7%	2.1%	4.2%	6.8%	9.4%	12.3%	19.8%	27.2%	33.1%
5000								0.7%	1.3%	3.2%	5.6%	8.6%	11.6%	14.7%	22.6%	30.2%	36.0%
4750							0.8%	1.6%	2.5%	4.8%	7.6%	10.8%	14.2%	17.6%	25.8%	33.2%	38.8%
4500						0.8%	1.7%	2.8%	4.0%	6.9%	10.4%	14.2%	18.2%	22.1%	30.9%	38.8%	44.2%
4250					0.8%	1.6%	2.7%	4.0%	5.4%	8.9%	13.0%	17.2%	21.6%	25.8%	34.9%	42.8%	48.0%
4000				0.9%	1.7%	2.8%	4.1%	5.7%	7.3%	11.4%	15.8%	20.3%	24.8%	29.0%	38.0%	45.7%	50.7%
3750			0.9%	1.6%	2.6%	3.9%	5.5%	7.3%	9.2%	13.6%	18.4%	23.1%	28.0%	32.4%	41.5%	48.7%	53.6%
3500		1.0%	2.1%	3.2%	4.6%	6.2%	8.1%	10.1%	12.2%	17.0%	22.2%	27.4%	29.2%	37.0%	45.9%	52.8%	57.3%
3250	1.0%	2.0%	3.4%	4.8%	6.6%	8.4%	10.6%	12.9%	15.3%	20.6%	26.2%	31.7%	37.0%	41.5%	50.2%	56.3%	60.4%

USFWS, SFWO, Energy Planning and Instream Flow Branch
Sacramento River (Keswick Dam to Battle Creek) Redd Dewatering and Juvenile Stranding Final Report
June 22, 2006 55

Appendix B Table B1. Example of a relationship table developed in Gard's USFWS 2006 report between salmon spawning flows and redd development flows shown in percentage of total redds dewatered, if development flows less than spawning flows.

Percentage and cumulative percentages

		Based on years--82-86		1970-1988		1970-1988		1970-1986		1970-1988	
		Winter Run		**Spring Run**		**Fall Run**		**Late-Fall**		**Steelhead**	
	Week	%	cum.%	%	cum.%	%	cum.%	%	cum.%	%	cum.%
JAN	1	1.70	3.45					6.50	55.39	0.97	91.84
	2	1.78	5.23					6.32	61.71	0.80	92.64
	3	0.35	5.57					3.07	64.77	0.61	93.25
	4	1.28	6.85					2.91	67.69	0.50	93.75
FEB	5	2.38	9.23					3.58	71.26	0.29	94.05
	6	3.12	12.35					4.08	75.34	0.45	94.50
	7	3.08	15.44					4.19	79.54	0.56	95.06
	8	0.97	16.41					4.38	83.91	0.53	95.59
MAR	9	6.35	22.76					3.29	87.20	0.49	96.09
	10	7.72	30.48					2.14	89.34	0.46	96.54
	11	9.23	39.70	start				1.74	91.08	0.38	96.92
	12	7.79	47.49	0.10	0.10			3.39	94.47	0.30	97.22
	13	4.91	52.40	0.25	0.35			2.08	96.55	0.28	97.50
APR	14	7.64	60.04	0.59	0.93			1.82	98.37	0.35	97.85
	15	8.26	68.29	0.96	1.89			1.39	99.76	0.28	98.12
	16	9.19	77.48	1.38	3.27			0.24	100.00	0.19	98.31
	17	3.47	80.95	1.63	4.90			end		0.17	98.48
MAY	18	2.02	82.98	1.60	6.50					0.16	98.63
	19	1.60	84.58	1.71	8.21					0.17	98.80
	20	2.17	86.75	2.16	10.37					0.23	99.03
	21	3.09	89.84	2.63	13.00	start				0.18	99.20
JUN	22	2.03	91.87	2.86	15.86	0.01	0.01			0.20	99.40
	23	1.63	93.50	2.61	18.47	0.00	0.02			0.13	99.54
	24	1.84	95.34	2.93	21.40	0.01	0.03			0.14	99.68
	25	0.51	95.85	3.50	24.89	0.03	0.06			0.15	99.82
	26	0.76	96.61	3.10	27.99	0.08	0.14			0.18	100.00
JUL	27	1.60	98.20	3.67	31.66	0.10	0.24			0.13	0.13
	28	0.31	98.52	6.02	37.68	0.29	0.53			0.18	0.31
	29	1.04	99.55	4.75	42.44	0.49	1.02			0.18	0.49
	30	0.44	99.99	3.21	45.65	0.70	1.72			0.22	0.72
AUG	31	0.01	100.00	4.12	49.77	0.96	2.68			0.26	0.98
	32	end		6.97	56.74	1.68	4.36			0.39	1.36
	33			6.07	62.81	2.95	7.31			0.68	2.04
	34			6.75	69.55	3.53	10.84			1.12	3.16
	35			5.74	75.29	3.91	14.75			2.36	5.52
SEP	36			7.22	82.51	4.54	19.29			3.82	9.34
	37			6.68	89.19	5.59	24.88			5.80	15.14
	38			5.23	94.42	8.58	33.46			7.54	22.67
	39			3.70	98.12	9.24	42.70			8.95	31.63
OCT	40			1.19	99.31	10.49	53.19	start		11.75	43.37
	41			0.69	100.00	10.59	63.78	0.26	0.26	11.27	54.65
	42			end		8.97	72.75	2.06	2.32	9.79	64.44
	43					6.99	79.74	2.33	4.65	6.51	70.95
NOV	44					6.70	86.44	3.27	7.92	5.17	76.12
	45					4.68	91.12	4.24	12.16	4.04	80.17
	46					2.71	93.83	3.42	15.58	2.44	82.61
	47					2.23	96.06	3.65	19.23	2.21	84.82
DEC	48	start				1.68	97.74	5.37	24.60	2.05	86.87
	49	0.17	0.17			0.90	98.64	5.27	29.87	1.44	88.31
	50	0.38	0.55			0.66	99.30	5.27	35.14	1.04	89.35
	51	0.49	1.04			0.51	99.81	6.94	42.08	0.69	90.04
	52	0.71	1.75			0.19	100.00	6.81	48.89	0.83	90.87

Appendix B Table B2. Average migration timing for the various salmonid runs passing the Red Bluff Diversion Dam 1970-1988.

Fork Lengths by day sampled not SID

RANGES OF FORK LENGTHS FOR THE VARIOUS CHINOOK RUNS BY DATE

	FALL	SPRING	WINTER	LATE-FALL	FALL	
1-Jan	0-41	42-55	56-111	112-202	203-270	1-Jan
2-Jan	0-41	42-55	56-112	113-230	231-270	2-Jan
3-Jan	0-41	42-56	57-112	113-205	206-270	3-Jan
4-Jan	0-41	42-56	57-113	114-206	207-270	4-Jan
5-Jan	0-42	43-56	57-114	115-207	208-270	5-Jan
6-Jan	0-42	43-57	58-115	116-209	210-270	6-Jan
7-Jan	0-42	43-57	58-115	116-210	211-270	7-Jan
8-Jan	0-43	44-58	59-116	117-211	212-270	8-Jan
9-Jan	0-43	44-58	59-117	118-213	214-270	9-Jan
10-Jan	0-43	44-58	59-118	119-214	215-270	10-Jan
11-Jan	0-43	44-59	60-119	120-216	217-270	11-Jan
12-Jan	0-44	45-59	60-119	120-217	218-270	12-Jan
13-Jan	0-44	45-59	60-120	121-218	219-270	13-Jan
14-Jan	0-44	45-60	61-121	122-220	221-270	14-Jan
15-Jan	0-45	46-60	61-122	123-221	222-270	15-Jan
	FALL	SPRING	WINTER	LATE-FALL	FALL	
16-Jan	0-45	46-61	62-123	124-223	224-270	16-Jan
17-Jan	0-45	46-61	62-123	124-224	225-270	17-Jan
18-Jan	0-45	46-61	62-124	125-226	227-270	18-Jan
19-Jan	0-46	47-62	63-125	126-227	228-270	19-Jan
20-Jan	0-46	47-62	63-126	127-229	230-270	20-Jan
21-Jan	0-46	47-63	64-127	128-230	231-270	21-Jan
22-Jan	0-47	48-63	64-127	128-232	233-270	22-Jan
23-Jan	0-47	48-64	65-128	129-233	234-270	23-Jan
24-Jan	0-47	48-64	65-129	130-235	236-270	24-Jan
25-Jan	0-48	49-64	65-130	131-236	237-270	25-Jan
26-Jan	0-48	49-65	66-131	132-238	239-270	26-Jan
27-Jan	0-48	49-65	66-132	133-239	240-270	27-Jan
28-Jan	0-49	50-66	67-133	134-241	242-270	28-Jan
29-Jan	0-49	50-66	67-133	134-243	244-270	29-Jan
30-Jan	0-49	50-67	68-134	135-244	245-270	30-Jan
31-Jan	0-50	51-67	68-135	136-246	247-270	31-Jan
	FALL	SPRING	WINTER	LATE-FALL	FALL	
1-Feb	0-50	51-67	68-136	137-247	248-270	1-Feb
2-Feb	0-50	51-68	69-137	138-249	250-270	2-Feb
3-Feb	0-50	51-68	69-138	139-251	252-270	3-Feb
4-Feb	0-50	51-69	70-139	140-252	253-270	4-Feb

1

Appendix B Table B3. Example of juvenile salmon fork length table allowing run classification by date and length developed for use in California Central Valley investigations.

APPENDIX C

Example of Field Datasheets used in 2015-2016 Redd Dewatering and Stranding Study.

SACRAMENTO RIVER REDD DEWATERING STUDY DATA SHEET

Date:_____/______/ 2014 Use new data sheet for each section River temp:________ Crew:_____,______,______

River Section _____________ Water clarity:_______ (nearest 1/2 foot) GPS #_________

Boat ____________ Weather:___________ 1-clear, 2-pt cloudy, 3-cloudy, 4-rain, 5-snow

carcass survey boat = 1 (and 2 if both doing redds), 3= specific boat redd survey, 4= redds only 2nd boat, 5= walking to redd areas SURVEY ID# from computer____________

COMMENTS:

REDD INFORMATION

	Redd #	Time	Pict #'s	Salmon Present	Dewatered	Action	Depth	Comments
1				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
2				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
3				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
4				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
5				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
6				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
7				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
8				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
9				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
10				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
11				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
12				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
13				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
14				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
15				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
16				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
17				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
18				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
19				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
20				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
21				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
22				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
23				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
24				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
25				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
26				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
27				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
28				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
29				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
30				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
31				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
32				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
33				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
34				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
35				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
36				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
37				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
38				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
39				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
40				0 1 2 3	0 1 2 3 4	0 1 2 3 4		

Codes:

Redd # = Disc Tag number and GPS waypoint #

Salmon Present = 0-none, 1-on redd, 2-seen in area, 3-redd dewatered

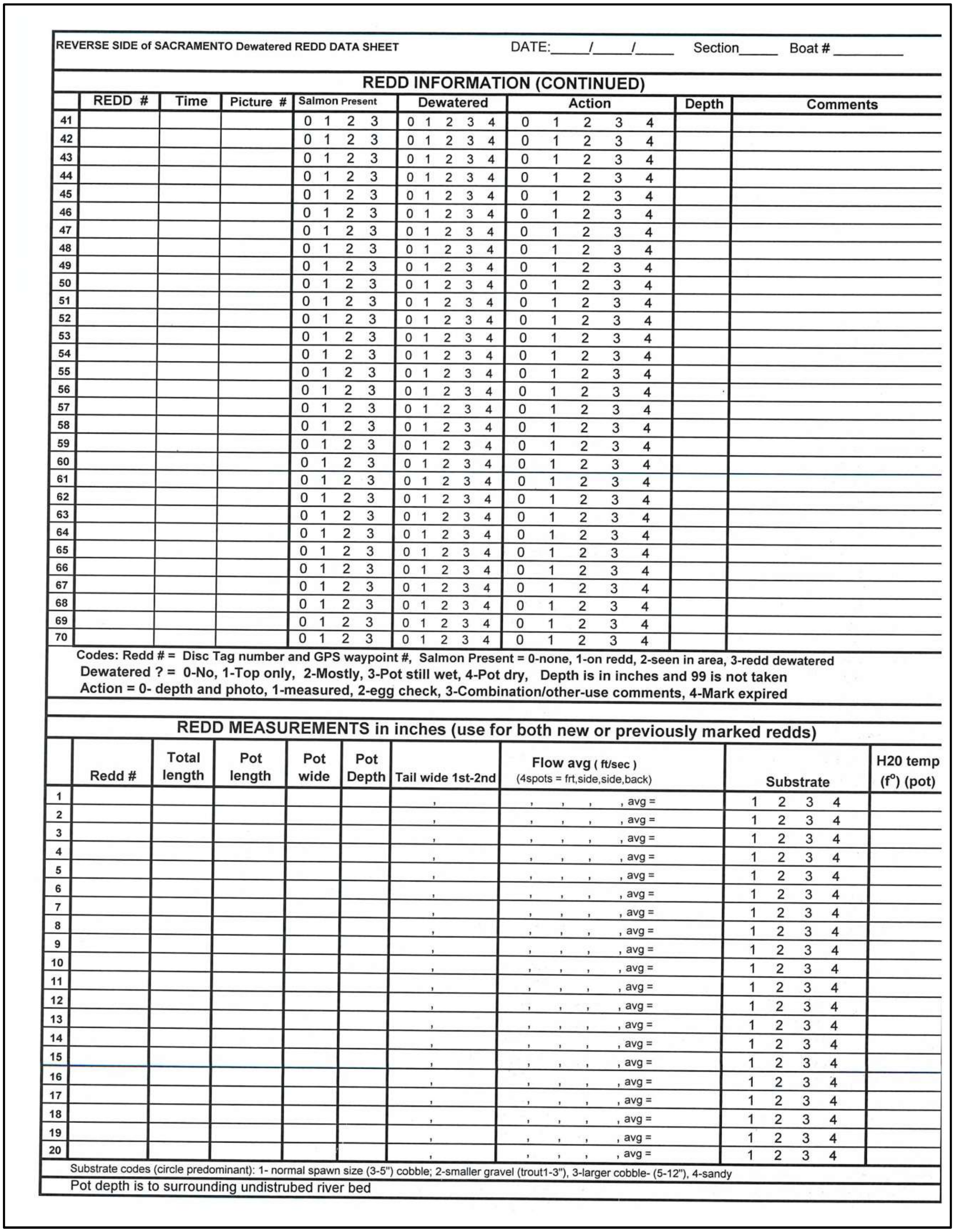
Dewatered ? = 0-No, 1-Top only, 2-Mostly, 3-Pot still wet, 4-Pot dry

Action = 0- depth and photo, 1-measured, 2-egg check, 3-Combination/other-use comments, 4-Mark expired (use back if measuring)

River Sections- 1= up from ACID, 2= up from Hwy 44, 3=up from Clear Pwr 4=up from Balls, 5=up from Battle, 6=up from Jellys, 7=up from Bend 8=up from RBDD, 9=up from Los Mo, 10=all down from Los Mo

DEPTH is inches of H20 of top of redd, can be negative (99 is no data collected)

Appendix C Figure C1. Front side of redd dewatering field datasheet.



REVERSE SIDE of SACRAMENTO Dewatered REDD DATA SHEET DATE:____/____/____ Section_____ Boat # _________

REDD INFORMATION (CONTINUED)

	REDD #	Time	Picture #	Salmon Present	Dewatered	Action	Depth	Comments
41				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
42				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
43				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
44				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
45				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
46				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
47				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
48				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
49				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
50				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
51				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
52				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
53				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
54				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
55				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
56				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
57				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
58				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
59				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
60				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
61				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
62				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
63				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
64				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
65				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
66				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
67				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
68				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
69				0 1 2 3	0 1 2 3 4	0 1 2 3 4		
70				0 1 2 3	0 1 2 3 4	0 1 2 3 4		

Codes: Redd # = Disc Tag number and GPS waypoint #, Salmon Present = 0-none, 1-on redd, 2-seen in area, 3-redd dewatered
Dewatered ? = 0-No, 1-Top only, 2-Mostly, 3-Pot still wet, 4-Pot dry, Depth is in inches and 99 is not taken
Action = 0- depth and photo, 1-measured, 2-egg check, 3-Combination/other-use comments, 4-Mark expired

REDD MEASUREMENTS in inches (use for both new or previously marked redds)

	Redd #	Total length	Pot length	Pot wide	Pot Depth	Tail wide 1st-2nd	Flow avg (ft/sec) (4spots = frt,side,side,back)	Substrate	H20 temp (f°) (pot)
1						,	, , , , avg =	1 2 3 4	
2						,	, , , , avg =	1 2 3 4	
3						,	, , , , avg =	1 2 3 4	
4						,	, , , , avg =	1 2 3 4	
5						,	, , , , avg =	1 2 3 4	
6						,	, , , , avg =	1 2 3 4	
7						,	, , , , avg =	1 2 3 4	
8						,	, , , , avg =	1 2 3 4	
9						,	, , , , avg =	1 2 3 4	
10						,	, , , , avg =	1 2 3 4	
11						,	, , , , avg =	1 2 3 4	
12						,	, , , , avg =	1 2 3 4	
13						,	, , , , avg =	1 2 3 4	
14						,	, , , , avg =	1 2 3 4	
15						,	, , , , avg =	1 2 3 4	
16						,	, , , , avg =	1 2 3 4	
17						,	, , , , avg =	1 2 3 4	
18						,	, , , , avg =	1 2 3 4	
19						,	, , , , avg =	1 2 3 4	
20						,	, , , , avg =	1 2 3 4	

Substrate codes (circle predominant): 1- normal spawn size (3-5") cobble; 2-smaller gravel (trout1-3"), 3-larger cobble- (5-12"), 4-sandy
Pot depth is to surrounding undistrubed river bed

Appendix C Figure C2. Reverse side of redd dewatering field datasheet.

SAC RIV JUVENILE FISH STRANDING SURVEY DATA USE NEW Pg per SECTION see reverse for more section codes, fish lengths

Date:_____/______/_______ **River temp:**________ **Weather:**__________ **GPS #**__________ SURVEY ID _________

River Section __________ 1-clear, 2-pt cloudy, 3-cloudy, 4-rain, 5-snow fill in at office

Boat ______________ **Water clarity:**_______ **Crew:**_____,_______,______ **Agency (s)**____________________

carcass survey boat = 1 (and 2 if both doing stranding), 3= specific boat stranding survey, 4= stranding only 2nd boat, 5= walking (no boat) to standing areas

COMMENTS: Fill out fish fork cutoffs before the survey based on date. Take pics of all stranding locations surveyed

	Time	Waypoint #	Picture #'s	Riv Mile	Connection	Winter run #	Fall run #	Late Fall #	Habitat	Survival	Substrate	Pool Temp	DO2	Length-ft	Width-ft	Depth-ft	Shelter	Reconnect	Rescue	Comments
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				
15																				
16																				
17																				
18																				

CODES: **Time**:-military **Waypoint #** is with gps zoomed to 80'- can have multiple small pools with same waypoint, if long take wp in middle

Pics- take mult pics show all, underwater fish, list numbers **Connection = 0**-open both up and down, **1**-up open only, **2**-down only, **3** = Isolated completely

Habitat = **0**-Pool, **1**-Riffle, **2**-Combo Both **Survival =** judgement and forecast of future conditions = **0**-Survival likely, **1**-Death likely, **2**- Survival is uncertain

Substrate = **0**-Bedrock, **1**-Cobble, **2**-small rocks-sand, **3**-sand-silt-mud, **4**-multiple **Shelter** = **0**-tree branches, **1**-submerged wood, **2**-aquatic veg, **3**-none, **4**-mult

Reconnect= 0-by Hand, **1**-by Power, **2**-by machine, **3**-not possible **Rescue** = **0**-easy, **1**-moderate, **2**-difficult, **3**-not possible

Appendix C Figure C3. Front side of juvenile stranding field datasheet.

FILL OUT FRONT FIRST this is Reverse side of JUVENILE FISH STRANDING SURVEY DATA

River Sections- 1= up from ACID, 2= up from Hwy 44, 3= up from Clear	Winter run size =	Date:____/____/____
4= up from Balls, 5= up from Battle, 6= up from Jellys, 7= up from Bend	Fall run size =	River Section ________
8= up from RBDD, 9= up from Los Mo, 10= all down from Los Mo	Late fall size =	Boat ________

	Time	Waypoint #	Picture #'s	Riv Mile	Connection	Winter run #	Fall run #	Late Fall #	Habitat	Survival	Substrate	Pool Temp	DO2	Length-ft	Width-ft	Depth-ft	Shelter	Reconnect	Rescue	Comments
19																				
20																				
21																				
22																				
23																				
24																				
25																				
26																				
27																				
28																				
29																				
30																				
31																				
32																				
33																				
34																				
35																				
36																				
37																				
38																				

CODES: **Time**:-military **Waypoint #** is with gps zoomed to 80'- can have multiple small pools with same waypoint, if long take wp in middle

Pics- take mult pics show all, underwater fish, list numbers **Connection = 0**-open both up and down, **1**-up open only, **2**-down only, **3** = Isolated completely

Habitat = **0**-Pool, **1**-Riffle, **2**-Combo Both **Survival** = judgement and forecast of future conditions = **0**-Survival likely, **1**-Death likely, **2**- Survival is uncertain

Substrate = **0**-Bedrock, **1**-Cobble, **2**-small rocks-sand, **3**-sand-silt-mud, **4**-multiple **Shelter** = **0**-tree branches, **1**-submerged wood, **2**-aquatic veg, **3**-none, **4**-mult

Reconnect= 0-by Hand, **1**-by Power, **2**-by machine, **3**-not possible **Rescue** = **0**-easy, **1**-moderate, **2**-difficult, **3**-not possible

Appendix C Figure C4. Reverse side of juvenile stranding field datasheet.

SAC RIV JUVENILE FISH RESCUE DATA see reverse for more section codes, fish lengths, codes

Date:_____/_______/________

SURVEY ID __________

River Section ___________

Datasheet for rescued fish only. Observed fish recorded on SAC RIV JUVENILE FISH STRANDING SURVEY DATASHEET

COMMENTS: Fill out fish fork cutoffs before the survey based on date. Take pics of all stranding locations surveyed

	Time	Waypoint #	Picture #'s	W-CHISAL	S-CHISAL	F-CHISAL	L-CHISAL	RAITRO adult	RAITRO juvenile	THRSTI	SAKPIK	RIFSCU	SACSUC	WESMOS	HARDHE	CALROA	Other Species Comments
1																	
2																	
3																	
4																	

Appendix C Figure C5. Front side of juvenile rescue field datasheet.

FILL OUT FRONT FIRST this is Reverse side of JUVENILE FISH RESCUE DATA

River Sections- 1= up from ACID, 2= up from Hwy 44, 3= up from Clear	Winter run size =	Date:______/______/______
4= up from Balls, 5= up from Battle, 6= up from Jellys, 7= up from Bend	Fall run size =	River Section __________
8= up from RBDD, 9= up from Los Mo, 10= all down from Los Mo	Late fall size =	Boat __________

Waypoint #	W-CHISAL	S-CHISAL	F-CHISAL	L-CHISAL	RAITRO adult	RAITRO juvenile	Other Species Comments

Blue Gill	BLUEGI	Lamprey Spp.	LAMSPP	Sacramento Sucker	SACSUC	catfish spp.	CATSPP	mosquito fish	WESMOS	Notes:
California Roach	CALROA	Largemouth Bass	LARBAS	Sculpin Spp.	SCUSPP	green sunfish	GRESUN	goldfish	GOLDFI	
Chinook Salmon	CHISAL	Minnow Spp.	MINSPP	Smallmouth Bass	SMABAS	largemouth bass	LARBAS	common carp	COMCAR	
Dace Species	DACSPP	ainbow Trout (Steelhea	RAITRO	Threespine Stickleback	THRSTI	riffle sculpin	RIFSCU	brown trout	BRWTRO	
Hardhead	HARDHE	Sacramento Pikeminnov	SACPIK	Unknown	FISUKN	prickly sculpin	PRISCU	american shad	AMESHA	

Appendix C Figure C6. Reverse side of juvenile rescue field datasheet.

APPENDIX D

Photographs of Redd Dewatering and Juvenile Stranding from the 2016-2017 Study on the Sacramento River.

Appendix D Figure D1. Stranding pool left behind in a city of Redding park near the Sacramento River following flood protection releases during spring 2017.

Appendix D Figure D2. Rescue efforts at stranding sites near the Sacramento River in Redding, March 23, 2017.

Appendix D Figure D3. Dead adult winter-run Chinook which became stranded during flow reduction from Keswick Dam, February 21, 2017.

Appendix D Figure D4. Flooded riparian woodland containing winter and fall-run Chinook. Sacramento River, February 2017.

Appendix D Figure D5. Stranding site in East Sand Slough, located in side channel above Antelope Blvd. bridge in Red Bluff, CA.

APPENDIX E

Relationship between Distance and Time and Flows for the Sacramento River between Keswick Dam (RM 302) and Tehama Bridge (RM 229).

Note to use this table: use recorded time of day and the river mile of your point of interest (redd, stranding site, etc). River miles are divided into half miles and segments begin at downstream edge. Subtract the time from this table from the actual time at site location. Compare this calculated time to the closest (15 minute) corresponding KWK or KES gauge time and use CDEC site to obtain a river flow value for the calculated time. This flow value is the actual flow at your point of interest, minus any tributary inputs.

Appendix E Table E1. Times for Sacramento River flows to travel downstream from Keswick Dam to Tehama CA. by half-river miles (RM). Green highlight indicates locations with flow measuring sites.

Miles	RM	KES Time	KWK Time	Location
0.0	302	0:00		KESWICK DAM (KES Gauge)
0.5	301.5	0:06		
1.0	301	0:11	0:02	KWK Gauge is 0.75 miles downstream
1.5	300.5	0:17	0:08	
2.0	300	0:23	0:14	
2.5	299.5	0:28	0:20	
3.0	299	0:34	0:25	Diestelhorst Bridge-Redding CA
3.5	298.5	0:40	0:31	
4.0	298	0:46	0:37	
4.5	297.5	0:51	0:43	
5.0	297	0:57	0:49	Turtle Bay-Redding CA
5.5	296.5	1:03	0:54	
6.0	296	1:09	1:00	
6.5	295.5	1:15	1:06	
7.0	295	1:20	1:12	Cypress Street Bridge-Redding CA
7.5	294.5	1:26	1:17	
8.0	294	1:32	1:23	
8.5	293.5	1:38	1:29	
9.0	293	1:43	1:35	
9.5	292.5	1:49	1:40	
10.0	292	1:55	1:46	Bonnyview Bridge-Redding CA
10.5	291.5	2:01	1:52	
11.0	291	2:06	1:58	
11.5	290.5	2:12	2:04	
12.0	290	2:18	2:09	
12.5	289.5	2:24	2:15	
13.0	289	2:30	2:21	Clear Creek mouth
13.5	288.5	2:35	2:27	
14.0	288	2:41	2:32	
14.5	287.5	2:47	2:38	
15.0	287	2:53	2:44	I5 close below Burbon Island

Appendix E Table E1. Continued:

Miles	RM	KES Time	KWK Time	Location
15.5	286.5	2:58	2:50	
16.0	286	3:04	2:55	
16.5	285.5	3:10	3:01	
17.0	285	3:16	3:07	I5 Bridge-Anderson CA
17.5	284.5	3:21	3:13	
18.0	284	3:27	3:19	Airport Road Bridge- Anderson CA
18.5	283.5	3:33	3:24	
19.0	283	3:39	3:30	
19.5	282.5	3:45	3:36	
20.0	282	3:50	3:42	
20.5	281.5	3:56	3:47	
21.0	281	4:02	3:53	Deschutes Road Bridge-
21.5	280.5	4:08	3:59	
22.0	280	4:13	4:05	Cow Creek mouth
22.5	279.5	4:19	4:10	
23.0	279	4:25	4:16	
23.5	278.5	4:31	4:22	
24.0	278	4:36	4:28	
24.5	277.5	4:42	4:34	
25.0	277	4:48	4:39	Ash Creek-Mouth
25.5	276.5	4:54	4:45	
26.0	276	5:00	4:51	Balls Ferry Bridge-Cottonwood CA
26.5	275.5	5:05	4:57	
27.0	275	5:11	5:02	
27.5	274.5	5:17	5:08	
28.0	274	5:23	5:14	
28.5	273.5	5:28	5:20	
29.0	273	5:34	5:25	Cottonwood Creek mouth
29.5	272.5	5:40	5:31	
30.0	272	5:46	5:37	
30.5	271.5	5:51	5:43	
31.0	271	5:57	5:49	Battle Creek mouth
31.5	270.5	6:03	5:54	
32.0	270	6:09	6:00	Barge Hole Fishing Access
32.5	269.5	6:15	6:06	
33.0	269	6:20	6:12	Lake California Area side channel
33.5	268.5	6:26	6:17	
34.0	268	6:32	6:23	
34.5	257.5	6:38	6:29	
35.0	267	6:43	6:35	Jellys Ferry Road Bridge
35.5	266.5	6:49	6:40	
36.0	266	6:55	6:46	
36.5	265.5	7:01	6:52	
37.0	265	7:06	6:58	
37.5	264.5	7:12	7:04	
38.0	264	7:18	7:09	Inks Creek mouth
38.5	263.5	7:24	7:15	

Appendix E Table E1. Continued:

Miles	RM	KES Time	KWK Time	Location
39.0	263	7:30	7:21	Massacre Flat BLM camp
39.5	262.5	7:35	7:27	
40.0	262	7:41	7:32	
40.5	261.5	7:47	7:38	
41.0	261	7:53	7:44	
41.5	260.5	7:58	7:50	BEND Gauge is at RM 260.4
42.0	260	8:05	7:57	
42.5	259.5	8:12	8:03	
43.0	259	8:19	8:10	
43.5	258.5	8:26	8:17	
44.0	258	8:33	8:24	Bend District Road Bridge
44.5	257.5	8:39	8:31	
45.0	257	8:46	8:38	
45.5	256.5	8:53	8:45	
46.0	256	9:00	8:51	
46.5	255.5	9:07	8:58	
47.0	255	9:14	9:05	China Rapids
47.5	254.5	9:21	9:12	
48.0	254	9:27	9:19	
48.5	253.5	9:34	9:26	
49.0	253	9:41	9:33	Paynes Creek mouth
49.5	252.5	9:48	9:39	
50.0	252	9:55	9:46	
50.5	251.5	10:02	9:53	
51.0	251	10:09	10:00	
51.5	250.5	10:15	10:07	
52.0	250	10:22	10:14	Powerlines in Iron Canyon
52.5	249.5	10:29	10:21	
53.0	249	10:36	10:27	
53.5	248.5	10:43	10:34	
54.0	248	10:50	10:41	
54.5	247.5	10:57	10:48	
55.0	247	11:03	10:55	Dibble Creek mouth
55.5	246.5	11:10	11:02	
56.0	246	11:17	11:09	
56.5	245.5	11:24	11:15	
57.0	245	11:31	11:22	Antelope Ave. Bridge-Red Bluff CA
57.5	244.5	11:38	11:29	
58.0	244	11:45	11:36	
58.5	243.5	11:51	11:43	Red Bank Creek mouth
59.0	243	11:59	11:51	RBD Gauge is at RM 242.9
59.5	242.5	12:07	11:58	
60.0	242	12:15	12:06	
60.5	241.5	12:22	12:14	
61.0	241	12:30	12:21	
61.5	240.5	12:38	12:29	
62.0	240	12:46	12:37	mouth of Salt Creek

Appendix E Table E1. Continued:

Miles	RM	KES Time	KWK Time	Location
62.5	239.5	12:53	12:45	
63.0	239	13:01	12:52	mouth of Craig Creek
63.5	238.5	13:09	13:00	
64.0	238	13:16	13:08	
64.5	237.5	13:24	13:15	
65.0	237	13:32	13:23	
65.5	236.5	13:40	13:31	
66.0	236	13:47	13:39	
66.5	235.5	13:55	13:46	Butler Slough mouth
67.0	235	14:03	13:54	
67.5	234.5	14:10	14:02	
68.0	234	14:18	14:10	Antelope Creek mouth
68.5	233.5	14:26	14:17	
69.0	233	14:34	14:25	Coyote Creek mouth
69.5	232.5	14:41	14:33	
70.0	232	14:49	14:40	Dye Creek mouth
70.5	231.5	14:57	14:48	
71.0	231	15:05	14:56	
71.5	230.5	15:12	15:04	Elder Creek mouth
72.0	230	15:20	15:11	Mill Creek mouth
72.5	229.5	15:28	15:19	TEH Gauge is at RM 229.3
73.0	229	15:35	15:27	Tehama CA