Proposal to Connect the Mokelumne River to the Sacramento River at the Delta Cross Channel to Improve Chinook and Steelhead Migration

Russ Brown, ICF International
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Introduction

Mokelumne River juvenile Chinook enter the Delta tidal channels immediately below Woodbridge Dam. The natural spawning and rearing of Chinook and steelhead are limited to the 25 mile reach between Camanche Dam (river mile 64) and the downstream end of Lodi Lake (river mile 39). The Mokelumne River Hatchery is located just below Camanche Dam (river mile 64); both were completed in 1964. Hatchery releases of smolts have been made in the Mokelumne River (downstream of Woodbridge Dam) and in the Bay-Delta (with some release of production fish in coastal pens). River rearing juveniles have been sampled with rotary screw traps (RSTs) at Vino (river mile 54) and at Golf (river mile 38.5), located just below Woodbridge Dam; juveniles are also collected at the Woodbridge ID diversion fish-screen bypass. Adults returning to the Mokelumne River are counted and identified (size, sex, adipose clipped) with video equipment at the Woodbridge ID Dam (river mile 39) and collected at the Mokelumne River hatchery. Figure 1a shows a map of the Mokelumne River above Frandy; the major fish sampling locations are indicated.

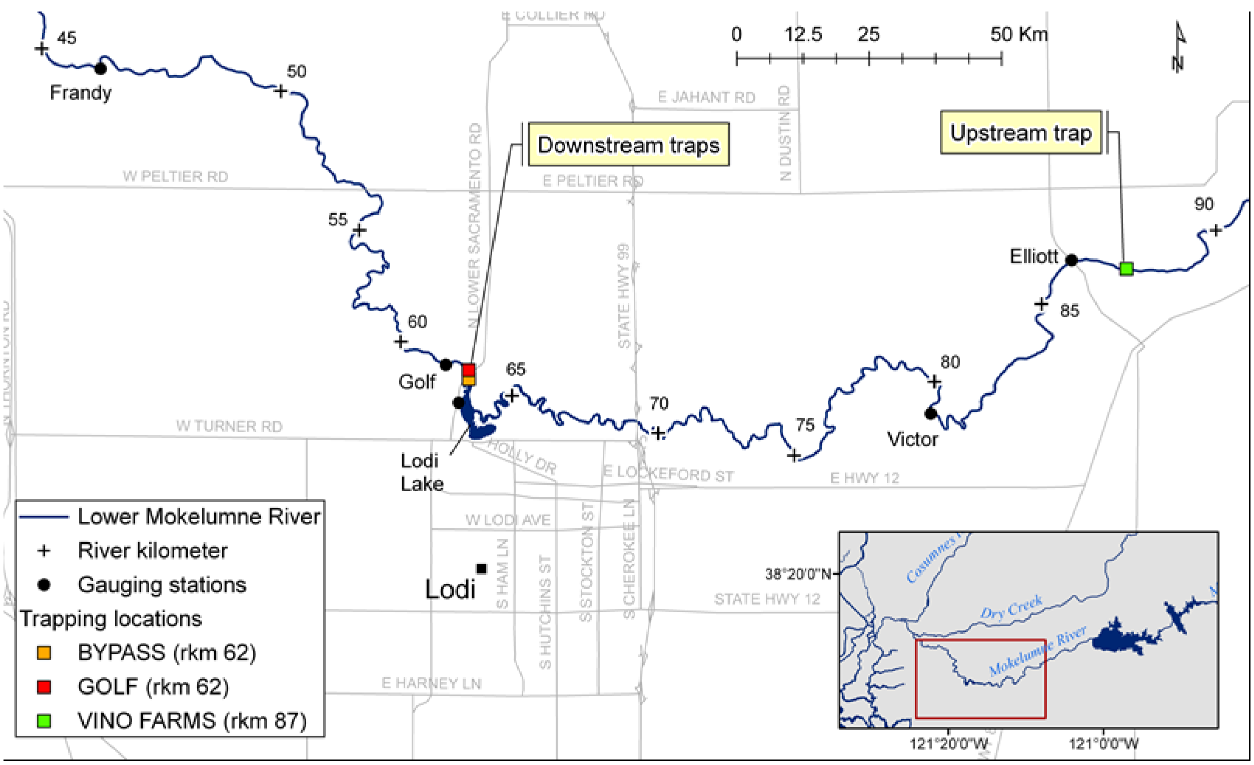


Figure 1a. Mokelumne River Juvenile Fish Sampling Locations with insert showing Delta channels.

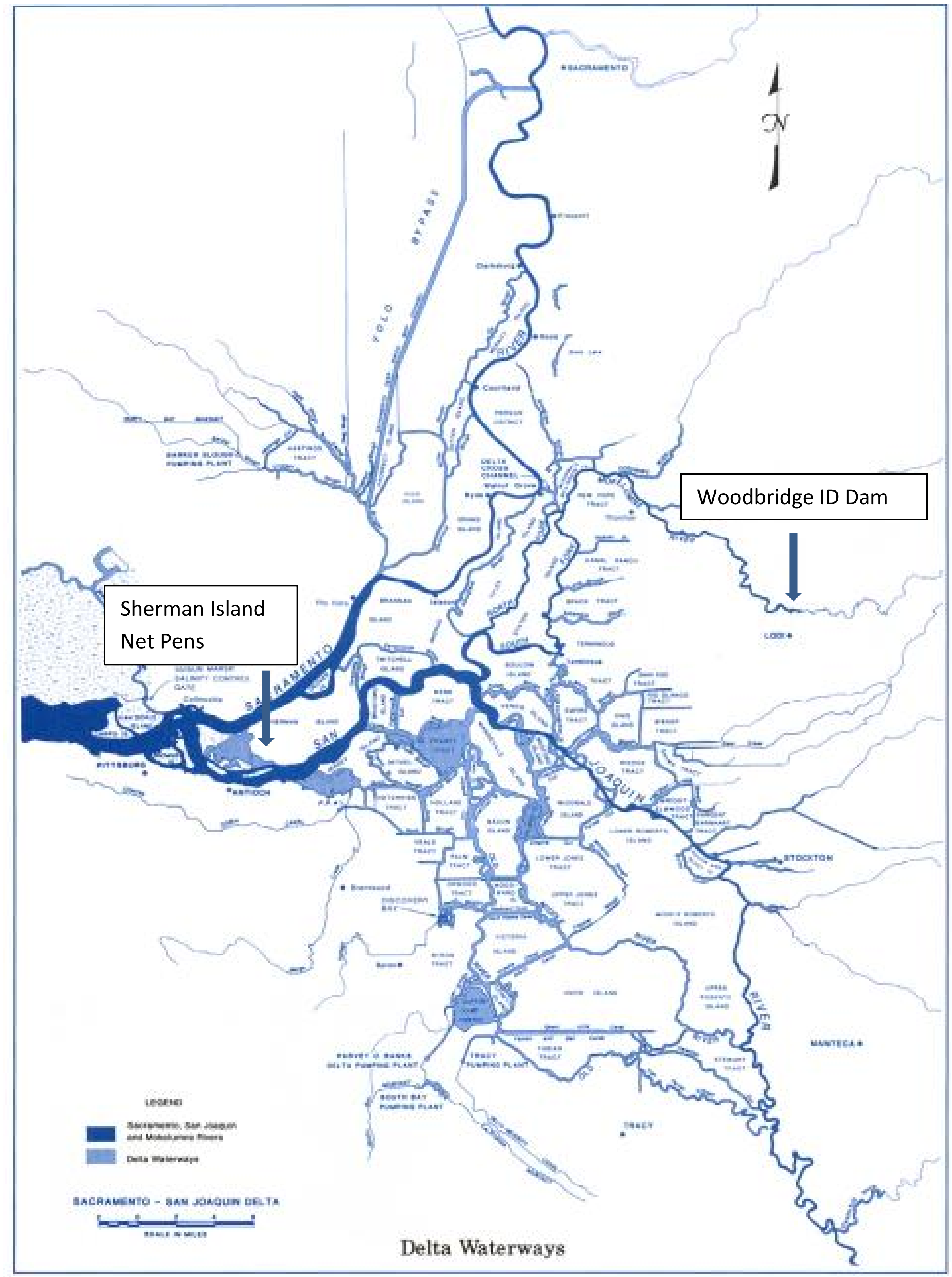


Figure 1b. Mokelumne River and Delta Channels for Migrating Juvenile Fish and Returning Adult Fish.

Figure 1b shows the Delta channels and the possible migration pathways for Mokelumne juvenile and adult fish. The extensive fish data from the Mokelumne River and hatchery can be used to provide an accurate understanding of the existing conditions of fish habitat, and to estimate river rearing success for smolts, Delta rearing success for river fry that pass Woodbridge Dam, juvenile passage through the Delta, ocean growth, harvest rate and return rates (2-yr old, 3-yr old and 4-yr old), and adult homing and straying. Some of these fish data can also be used to develop a biological monitoring program to evaluate the benefits of the proposed project for improved Delta passage (survival) and increased adult homing (reduced straying). Several examples of the available Mokelumne River Chinook fish data collection and analysis methods are described and discussed in the attachment. Many of these fish data collection and analysis methods can be used to evaluate the success (benefits) of the proposed project.

Releases from Camanche Dam are regulated to provide irrigation diversions from the Mokelumne River and from Lodi Lake to the Woodbridge ID canal (with fish screen) and to provide minimum flows below Woodbridge Dam. Flows and temperatures below Camanche Dam are normally adequate for Chinook spawning, egg incubation and rearing, although conditions may be unsuitable during drought (low flows, warm temperatures). During low runoff years, most of the releases from Camanche Dam are diverted at Woodbridge ID canal, with relatively low flows required below Woodbridge Dam. During higher runoff years, releases from Camanche Dam are sometimes higher than the required flows (i.e., flood control releases). Because the major irrigation diversion is located downstream at Woodbridge Dam, the river flows between Camanche Dam and Woodbridge Dam are much higher in most years than if the diversions were located immediately below Camanche Dam (e.g., Stanislaus, Tuolumne, and Merced River diversions). Although the Woodbridge ID diversions are seasonal with a maximum of about 400 cfs, these additional flows in the Mokelumne River (100 cfs to 400 cfs) during the irrigation season (March-October) likely provide improved habitat and higher survival of fry and smolts in the spring months (March-June).

The success of river spawning eggs, fry, and smolts can be evaluated from a comparison of the RST data collected at Vino and Golf and the fish screen bypass at Woodbridge (e.g., juvenile passage) with the estimated number of spawning females (egg production). Because of differences in the monthly patterns of spawning, fry emergence, growth, and movement from year to year, the use of smolt production as a measure of in-river rearing success (e.g., smolts per female) should include the potential effects of high winter flows on fry outmigration (with possible rearing in the Delta channels), as well as the effects of spring flows and temperatures on spring rearing conditions. Different responses to flows are expected in each month. Higher flows in January-March might flush small fry from the river; higher flows in March-May may increase suitable habitat (e.g., riparian and floodplain inundation) and increase growth and survival; higher flows in April-June may reduce water temperatures and thereby improve smoltification success (<65 F).

The juvenile smolts passing Woodbridge Dam must migrate downstream through the Delta channels to Chipps Island (USFWS Trawl) and to the ocean. Some hatchery smolts have historically been released at New Hope, and some of these CWT fish have been recovered at the CVP and SWP exports, or at the Chipps Island trawl. These CWT fish (recoveries) from different years may provide information about the migration success through the Delta channels. Unfortunately, recoveries of CWT fish at Chipps

Island for fish released at New Hope has been relatively low compared to CWT recoveries for Sacramento River releases of Nimbus or Coleman hatchery fish. The Mokelumne River juveniles (hatchery and river spawned) join the other Central Valley fall-run Chinook and are assumed to have similar ocean growth and survival and harvest.

Once the Mokelumne River adults leave the ocean, they must navigate the Delta channels and detect the Mokelumne River water (i.e., homing). CWT data indicate that straying from the Mokelumne River to the American River or to the SJR tributaries (Stanislaus, Tuolumne, and Merced) has been relatively high, especially for Mokelumne River (hatchery) fish released in the Bay-Delta (e.g., Sherman Island or San Pablo Bay). Similarly, straying of American River fish (Nimbus hatchery fish released in the Bay-Delta) to the Mokelumne River has also been relatively high, suggesting that the Mokelumne River homing signal (e.g., percent Mokelumne River water) has been relatively weak, with a moderate American River homing signal (percent American River water) in North Fork and South Fork Mokelumne River channels (Sacramento River water diversions to DCC and Georgiana Slough) .

Many Mokelumne River habitat restoration efforts (gravel placement, side channel enhancement) have likely improved the river spawning and rearing success. Gravel has been added to the river to increase spawning habitat quantity and quality; this action has been deemed successful by biologists based on spawning distribution and egg survival (EBMUD 2010). Hatchery management has also been improved, with less importation of American and Feather River brood stocks. While the hatchery fish are separated from the river fish, some hatchery releases of smolts have been made to the river near the hatchery (to reduce straying). The proposed action would likely improve the Delta passage survival for the river rearing smolts, increasing the fraction of the juveniles (fry and smolts) that survive and pass Chipps Island to the ocean in April and May. The proposed action would also likely improve the return rate (homing) of adult fish and reduce the stray rate of Mokelumne fish to other rivers, because all of the Mokelumne River water would enter the Sacramento River at the DCC (higher Mokelumne River water fraction) .

Proposed Action

A major improvement in the Mokelumne River Chinook (and steelhead) juvenile migration success through the Delta channels would likely result from the direct connection of the Mokelumne River to the Sacramento River at the Delta Cross Channel (DCC). The basic idea would be to divide the DCC (0.75 miles long) into two channels with a wall down the center that would extend about 0.5 miles down the center of Snodgrass Slough to Dead Horse Cut, which connects with the Mokelumne River near New Hope. This would allow the north DCC gate to connect to Snodgrass Slough and the Mokelumne River (through Dead Horse Cut). A channel barrier (with flood gate) across the South Fork Mokelumne (at the New Hope Bridge) and a channel barrier (with flood gate) across the North Fork Mokelumne (channel at the south edge of Dead Horse Island) would allow all juvenile Chinook (and steelhead) to reach the Sacramento River through the DCC, without migrating down the Mokelumne River Forks and SJR channel (See Figure 2). A boat lock should be included to allow boating access to Snodgrass Slough.

Figure 2. Mokelumne River and Sacramento River Channels in the Vicinity of the Delta Cross Channel with Proposed Project Facilities (DCC Dividing Wall and Channel Gates)

This would likely increase the survival of these smolts through the Delta channels to Chipps Island. The direct connection to the Sacramento River would also likely increase the benefits from fry rearing in the tidal marsh habitat of Snodgrass Slough and the lower Cosumnes River floodplains, because the juveniles rearing in these habitats would have a shorter migration route to Suisun Bay and the ocean. These potential benefits should be evaluated and tested with a demonstration project and fish monitoring plan.

Photo of DCC gates

The purpose of this proposed project is to increase the survival of juvenile smolts migrating through the Delta channels to Chipps Island and the ocean. Results from many paired CWT releases and acoustic-tag tracking experiments in recent years have indicated that migration survival in the Sacramento River channel to Chipps Island (pathway 1) provides a higher survival than migration through the DCC and N. Fork Mokelumne River or Georgiana Slough to the mouth of the Mokelumne at the SJR and downstream in the SJR channel to Chipps Island (pathway 2). The proposed project would allow most of the Mokelumne River smolts to migrate downstream in the Sacramento River channel, and avoid the additional mortality (i.e., predation) that is evident along the Mokelumne River and SJR channels. The CWT experiments estimate the relative survival (recovery ratio); many of the paired releases suggest the relative survival is about 0.5 for diversion from the Sacramento River (pathway 1) to the Mokelumne and SJR (pathway 2). Acoustic-tag tracking experiments estimate the overall survival of a smaller number of relatively large (105-120 mm) fish. Generally the survival from Walnut Grove to Chipps Island in the Sacramento River (pathway 1) is 0.4 to 0.8 (40-80% of tagged fish pass the Chipps Island detector array), while the survival through DCC or Georgiana Slough to the Mokelumne and SJR to Chipps Island (pathway 2) is 0.2 to 0.4 (about half of the Sacramento River survival).

The major goal for the proposed project is to increase the survival of Mokelumne River smolts from Woodbridge Dam to Chipps Island; releases of CWT hatchery smolts below Woodbridge Dam might be used to directly measure the effects of the Mokelumne River connection to the Sacramento River at the DCC; an increased recovery rate at Chipps Island would be expected. Paired releases might be used to test the effects each year during a demonstration period. A demonstration period could be evaluated with just two flood-gates at the Walnut Grove Road bridges on N Fork (below Snodgrass Slough) and S Fork (below New Hope), without the DCC dividing wall. The first release in early May could be made during a week when the DCC was closed (existing conditions), with the flood gates on N. Fork and S. Fork left open, so that the juveniles would migrate down the Mokelumne River channels. The second release could be made with the DCC north gate open and the flood gates on N. Fork and S. Fork closed, so that all of the Mokelumne River flow and fish would be tidally connected to the Sacramento River through the DCC (with one gate open). Initial results would be available the first year from CWT recoveries at Chipps Island and in the CVP and SWP salvage facilities; the final comparison of survival rates would be improved by ocean catch and hatchery return recoveries of CWT in subsequent years. A similar testing program (paired CWT releases) might be continued after the full project was completed; recoveries (ocean and river) for releases at Woodbridge Dam would be compared with releases in San Pablo Bay to determine if the relative recoveries (ocean and river) for the Woodbridge releases are higher with the connection project than the existing recovery ratio (e.g., generally less than 0.2) for hatchery releases at New Hope and San Pablo Bay or Sherman Island.

The adult migration of Mokelumne River fish would also likely be improved because the attraction (homing) to the Mokelumne River would be increased, with less straying from the Mokelumne River to the American River or the SJR tributaries. The fraction of Mokelumne River water in the Sacramento River downstream of the DCC (with north gate open) should provide a stronger olfactory signal (i.e., chemical homing, % river water) than with existing conditions, which requires a longer migration route up the SJR and up the Mokelumne River channels. Much of the Mokelumne River water in October and November is likely flowing south in the SJR and Middle River to the CVP and SWP exports; reducing the fraction of Mokelumne River water at Collinsville and in Suisun Bay, and increasing the straying of Mokelumne River fish to the SJR tributaries. With a direct connection through the DCC north gate, a greater fraction of the Mokelumne river water would reach Chipps Island and Suisun Bay.

Additional benefits for Mokelumne River juveniles (and other Sacramento River Chinook juveniles) would likely be provided with a fish screen in the Sacramento River at the DCC. The south gate of the DCC could remain open throughout the year if a wedge wire screen were constructed to allow 2,500 cfs of Sacramento River water to be diverted to Snodgrass Slough and North Fork Mokelumne without diverting any Sacramento River or Mokelumne River juvenile fish. A fish screen with 15-feet tall panels along the east levee of the Sacramento River could extend 500 feet (e.g., twenty 25-feet wide panels, mounted on a pier with 10 pairs of pilings spaced 50 feet apart to support the pier and fish screen panels) from the DCC gates to Walnut Grove (dock) would provide an approach velocity of 0.33 ft/sec. With the fish screen installed, most Mokelumne River juveniles would exit the DCC north gate and migrate downstream in the Sacramento River and past Chipps Island to the ocean. The benefits from a DCC fish screen could be increased if a similar (larger) fish screen were constructed in the Sacramento

River across the mouth of Georgiana Slough. This larger fish screen (e.g., 1,500 feet long, extending upstream and downstream of Georgiana Slough) would allow 7,500 cfs of water to be diverted into Georgiana Slough and protect about 20% of the juveniles in the Sacramento River that are currently diverted into Georgiana Slough to the North Fork Mokelumne and the SJR. The fish screen(s) would be operated (in place) during months when juvenile Chinook (fry or smolts) might be leaving the Mokelumne River (e.g., January-June) or when Sacramento River Chinook might be migrating downstream (e.g., winter-run in December- May). Because adult Chinook might also be migrating upstream during these months (e.g., winter-run), one of the screen panels should be opened to prevent trapping adults at the Georgiana Slough screen or at the south side of the DCC screen. An open panel would slightly reduce (e.g., 5%) the fish screen effectiveness, but should eliminate any adult delay or trapping.

The proposed project would include a biological monitoring program to confirm and quantify the project benefits. The effects of the proposed direct connection of the Mokelumne River to the Sacramento River through the divided DCC may be difficult to measure directly, because the juvenile Chinook (hatchery CWT) released below Woodbridge Dam would not likely be detected (i.e., sampled) until they were 2-year old fish (river returns). However, some CWT juveniles would be recovered at the CVP or SWP fish facilities or at the Chipps Island trawl. Tagged (hatchery) juveniles released from Woodbridge Dam and Sherman Island (paired releases) that were captured at Chipps Island and the CVP/SWP fish facilities might indicate a measurable improvement in survival to Chipps Island (for periods with and without the DCC connection); however, this would require a major release of hatchery CWT fish to the lower Mokelumne (at Woodbridge Dam or downstream of the New Hope barrier) and at Sherman Island (for comparison) for several years. Acoustic tag studies might be used for steelhead or larger juvenile Chinook (>100 mm) for several years with releases at Woodbridge Dam and below the New Hope barrier. Acoustic tag studies may provide a more rapid assessment of the project benefits (for larger juveniles). The attachment to this proposal describes the existing Mokelumne River fish monitoring program (part of the Joint Settlement Agreement) and identifies several data analysis methods that might be included in the proposed project biological monitoring program.

Project Feasibility Evaluation and Monitoring Plan Development

The proposed project is to connect the Mokelumne River to the Sacramento River at the DCC, so that all Mokelumne River smolts can migrate down the Sacramento River past Chipps Island to the ocean, and thereby increase their Delta passage survival. The proposed project may improve fry rearing success in Snodgrass Slough and connecting tidal sloughs, because fewer fry would be transported down the Mokelumne River channels to the SJR. The proposed project is also expected to increase the homing of Mokelumne River adults, and reduce the straying to the American River and SJR tributaries.

Before this project is implemented (constructed) and tested (demonstrated) to confirm the expected benefits, a more detailed evaluation of the engineering feasibility (costs) and biological effects (benefits) of the proposed project, along with the development of a biological monitoring plan to measure the benefits is recommended. The major tasks that could be included in the feasibility assessment and monitoring plan development are described in this section. If the project design appears feasible (i.e., could be constructed and operated at a reasonable cost) and the biological effects appear substantial and measureable (with proposed fish monitoring and special studies), the project could be implemented as a full-scale demonstration project. The demonstration project would be temporary (i.e., removable), but full-scale (connect the full flow of the Mokelumne River to the Sacramento River at the DCC). If the fish monitoring program and special studies during the demonstration period indicated that the biological benefits were not achieved, or if unanticipated biological consequences were identified, the demonstration facilities (e.g., dividing walls, channel gates, fish screens) could be modified or removed. However, if the demonstration project was successful (e.g., smolt migration survival increased, adult straying reduced), permanent facilities could be designed to modify, strengthen or replace the temporary facilities.

The feasibility and benefits evaluation and the monitoring plan development could be a joint effort between EBMUD engineering and biological staff, CDFW (hatchery) staff, USFWS, NMFS, and CDFW fish biologists, and selected EBMUD consultants. The feasibility and benefits evaluation might be conducted as a Joint Settlement Agreement (JSA) element. The basic tasks that would be included in the feasibility assessment and development of the biological monitoring plan and special studies to evaluate the benefits of the demonstration project are described below.

Task 1. Review Historical Fish Data from the Mokelumne River

As described in the previous sections, there are a wealth of fish data from the Mokelumne River that can be further evaluated and integrated to provide 1) an accurate understanding of river rearing and smolt survival, 2) estimate Delta passage survival, 3) track the annual survival in the ocean, 4) estimate the ocean catch, 5) evaluate the river and hatchery returns, and 6) estimate straying to other rivers as well as straying from other rivers (hatcheries) to the Mokelumne. All sources of fish data should be compiled and integrated, including the hatchery returns and releases; adult escapement at Woodbridge Dam, river carcass and redd surveys; CWT releases and recoveries from the ocean, hatcheries and rivers; RST catch and passage estimates at Vino and Golf, and the WID fish screen bypass catch and passage estimates. Other special studies of Mokelumne River habitat and fish behavior can be incorporated into this integrated compilation of fish data. Additional analyses of the fish data may be possible to further evaluate and understand this extensive collection of Mokelumne River fish data. The monitoring plan with special studies to evaluate the effects of the connection project will be based on this framework of fish data and analyses. Additional data collection may be needed to better understand fry rearing success in the Delta channels (e.g., beach seine or other sampling in Snodgrass Slough).

Task 2. Delta Tidal Flow Modeling of Existing and Project Conditions

The DSM2 Delta tidal flow model will be used to describe and evaluate the existing tidal hydraulics (elevations, velocities, flows) of the Mokelumne River and Snodgrass Slough channels. The tidal flows in the DCC, North Fork and South Fork Mokelumne, Georgiana Slough, and other sloughs connecting with the S. Fork Mokelumne are also important. All of these Delta channels are included in the DSM2 model, but there has not been extensive calibration of the model to match the available tidal elevations and tidal flow data in the Mokelumne River channels. More detailed channel geometry (bathymetry) may be available for the Mokelumne and Snodgrass Slough channels; this would allow more accurate tidal flows to be calculated in the north Delta channels. The DSM2 modeling results will be used to evaluate the engineering feasibility of the project facilities (e.g., dividing walls, channel gates, barriers, and fish screens), and will also be used to evaluate the hydraulic conditions (e.g., velocity, depth, water residence time) and to support the assessment of biological benefits for rearing and migrating juveniles and for returning adults (homing, straying).

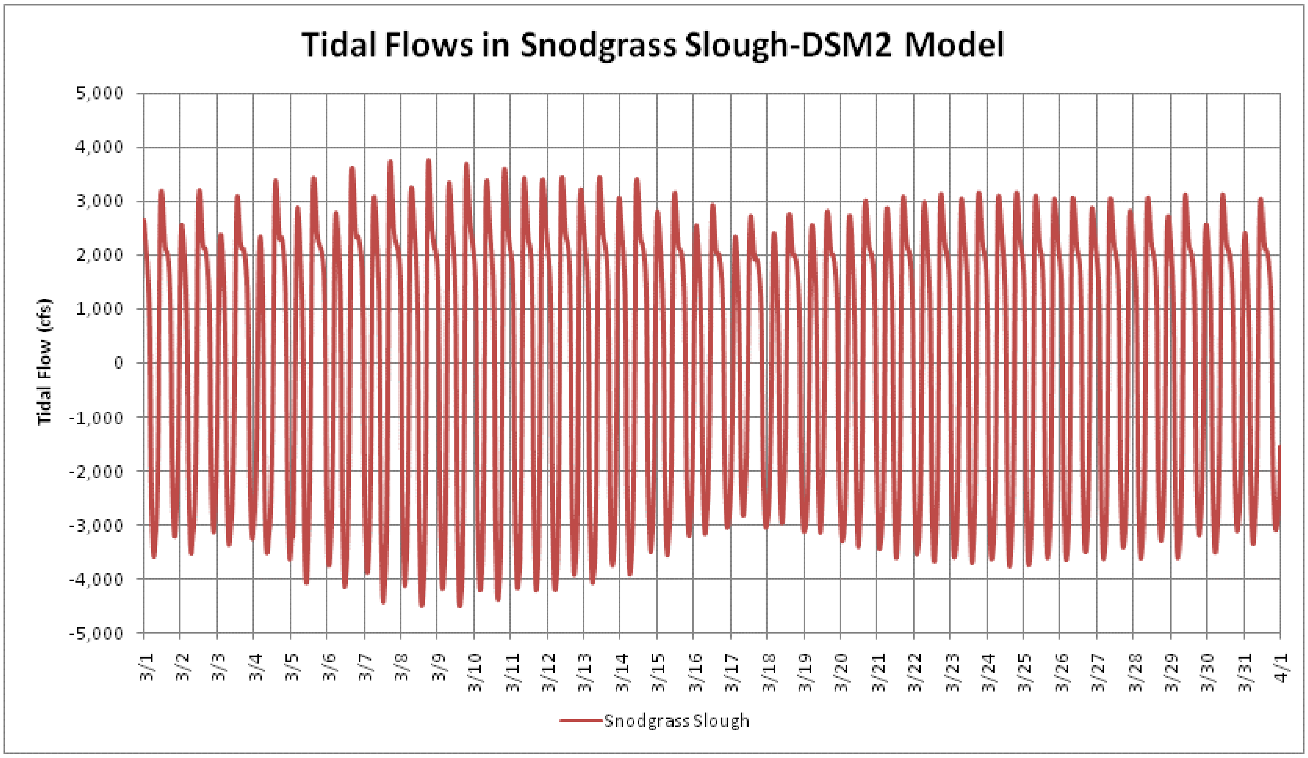
Modeling results will be used to describe the existing tidal flows (e.g., percent of time with positive and negative flow) and net (i.e., daily average) flows, water residence times, and fraction of Mokelumne River water (i.e., particle tracking) in the Mokelumne River channels and in other Delta channels over a range of potential hydrologic conditions (i.e., river flows and exports). The purpose for calculating tidal flows is to evaluate (compare) the passage conditions for juvenile Chinook, and the homing conditions for adult Chinook. The changes in the tidal and net flows that would result from the proposed project would be evaluated for the juvenile migration and for the adult migration periods. The DSM2 model can also be used to track the fraction of Mokelumne River water that is tidally transported into the various Delta channels, to support the evaluation of effects on homing and straying of adult fish. Closing the DCC gates changes the tidal elevations and flows in the Sacramento River, and increases the diversions from the Sacramento River to Sutter, Steamboat, and Georgiana Sloughs. In a similar way, dividing the DCC and connecting Snodgrass Slough and the Mokelumne River upstream of New Hope to the Sacramento River will greatly increase the tidal flows through the DCC north gate, and would also change the (screened) diversions through the DCC south gate to the N. Fork Mokelumne River and the (screened) diversions to Georgiana Slough. The tidal flow modeling for a range of Sacramento and Mokelumne (Cosumnes) River flow conditions will be used to evaluate the feasibility of the project facilities, and to evaluate likely changes in fish movement and migration survival (for juvenile and adult Chinook and steelhead).

As an example, Figure 3a shows DSM2 modeling results (tidal flows) for Snodgrass Slough upstream of the DCC in March 2001 (with DCC closed). Snodgrass Slough is the major tidal slough in the Mokelumne-Cosumnes River tidal channel complex, connecting with the N. Fork Mokelumne River just downstream of the DCC. Snodgrass Slough represents about half of the tidal area upstream of the DCC; the other half of the tidal area is along the Mokelumne and Cosumnes River channels. The maximum tidal flows (upstream and downstream) are about 3,000 cfs; most of this tidal flow moves upstream from or downstream to the N. Fork Mokelumne (when DCC is closed). The tidal flows in Snodgrass Slough and in the Mokelumne River upstream of New Hope would be similar with the proposed connection of the Mokelumne River to the Sacramento River, but all of this tidal flow would move from or to the Sacramento River through the divided DCC and north gate. Figure 3b shows the tidal volumes calculated (from the tidal flows) for Snodgrass Slough upstream of the DCC. With the proposed DCC connection project, the tidal volumes at the DCC north gate would be about twice as large because all of the tidal flows in Snodgrass Slough and upstream in the Mokelumne and Cosumnes channels would enter and leave through the north DCC gate and divided DCC. The tidal flows with the proposed project would therefore likely be about 6,000 cfs and the tidal volumes would be about 3,000 af. These tidal flows and volumes indicate a relatively large tidal habitat area (1,000 acres) that would connect with the Sacramento River through the DCC north gate; this area might be used for rearing Mokelumne River Chinook fry, as well as rearing Chinook and other fish from the Sacramento River (and tributaries).

Task 3. Engineering Feasibility of the Mokelumne River Connection to the Sacramento River

Alternative designs for the proposed facilities to connect the Mokelumne River to the Sacramento River through the divided DCC north gate will be thoroughly investigated and compared. The feasibility of a dividing wall in the DCC will be investigated so that the south gate could be opened and screened to allow higher Sacramento River diversions to the SJR and south Delta during the winter and spring months (DCC currently closed). This would reduce any reverse flows in the SJR at Jersey Point and Antioch, and thereby reduce the upstream movement of delta smelt from the confluence. The feasibility of a fish screen extending 500-750 feet downstream of the DCC to Walnut Grove will be thoroughly investigated, to prevent juvenile fish from being diverted into the south gate of the DCC. The feasibility of another (larger) fish screen on Georgiana Slough will also be investigated, to increase the benefits that would be achieved with the proposed project, by keeping all of the Mokelumne River smolts in the Sacramento River channel. One of the fish screen panels (sections) would remain open to allow any upstream migrating adult fish to pass through the fish screen(s) back to the Sacramento River.

The feasibility of flood-gates on the N. Fork and S. Fork channels (just downstream of New Hope) will be thoroughly investigated; these gates would remain closed most of the time, but would need to be opened during major flood events on the Cosumnes and/or Mokelumne Rivers. Appropriate operations guidelines (flow thresholds) would be developed. Various designs for a boat lock to allow boating access from the S. Fork to the Mokelumne River at New Hope and Snodgrass Slough via Dead Horse Cut will be investigated. A boat lock or other boat passage provisions would also be needed for a fish screen on Georgiana Slough. The possibility of initially testing the connection project with just two flood gates (on S Fork and N Fork at the Walnut Grove Road bridges), without the DCC dividing wall or fish screens, will also be investigated and designed as a pilot test (demonstration) of the proposed project. This initial design would allow the basic benefits of the project to be measured without building the DCC dividing wall and the DCC and Georgiana Slough fish screens. With the N. Fork and S. Fork Mokelumne River flood gates closed, the DCC gates could be opened to connect the Mokelumne River to the Sacramento River during the juvenile migration period (e.g., March-June) and adult migration period (e.g., October-December).



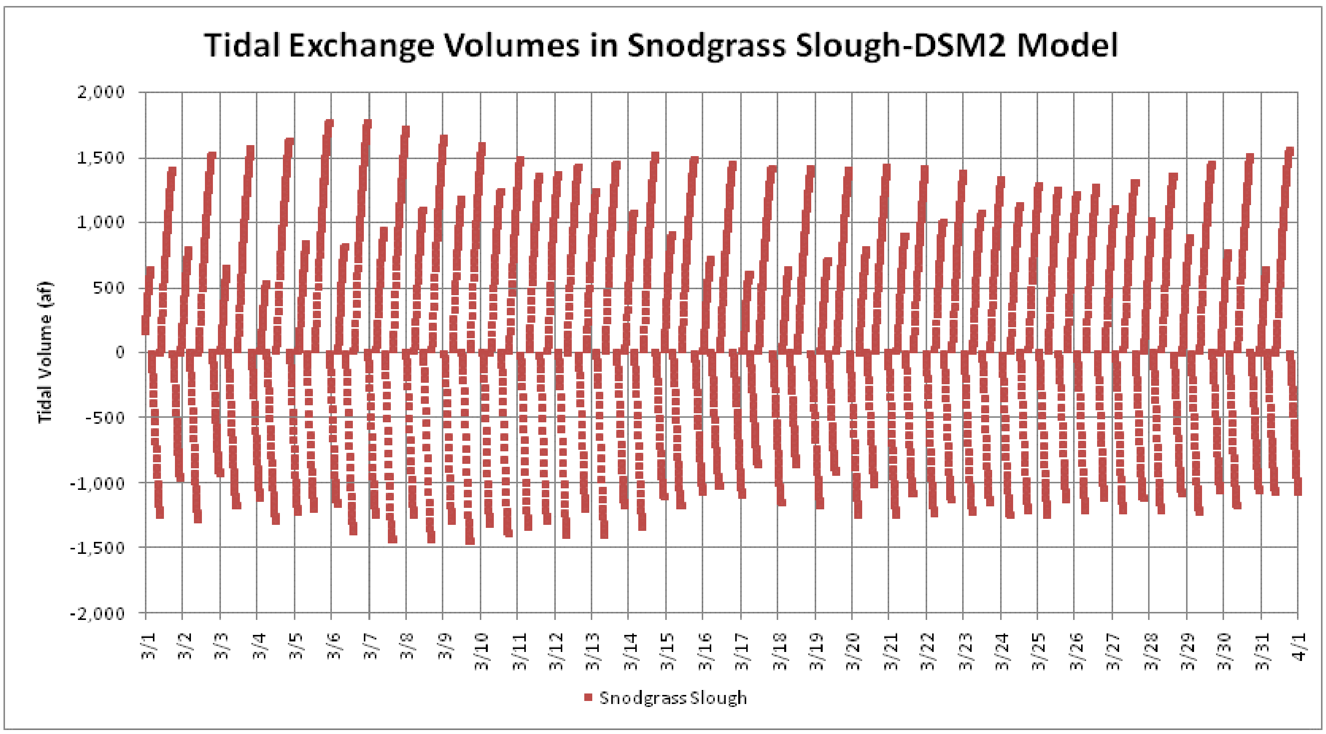


Figure 3. DSM2-Simulated Tidal Flows (cfs) and Tidal Volumes (af) for Snodgrass Slough upstream of the DCC Channel (DCC closed) for March 2001.

Task 4. Evaluation of Juvenile Migration Survival

The evaluation of existing Mokelumne River juvenile migration survival conditions would be conducted to establish the baseline for evaluating the likely benefits with the proposed project. The recent historical records from the Rotary Screw Traps and Coded Wire Tag (CWT) returns, as well as special studies on the Mokelumne River would be reviewed and described as migration timing and monthly survival percentages for the range of measured flow and temperature conditions. Data from other Delta fish studies (e.g., CWT release/recovery, acoustic tag tracking) would be combined to describe a quantitative migration and survival assessment for fish in the Sacramento River, the Mokelumne River, and the SJR through the Delta to Chipps Island or to the exports (e.g., Mokelumne River version of the Delta Passage Model). The Mokelumne River fish Delta passage survival evaluation for existing conditions (compared to the Delta passage survival of Sacramento River and SJR fish) is the primary basis (i.e., need) for the proposed project.

Some Mokelumne River juveniles passing through the DCC would likely be diverted into the south gate of the DCC and Georgiana Slough (unless screened); about 40% of the fish would likely be diverted (DSM2 model flow in Georgiana Slough with DCC closed for Sacramento River flows above 20,000cfs). Therefore, the evaluation of juvenile migration survival would likely indicate substantial additional benefits from constructing fish screens at the DCC (e.g., 2,500 cfs for south gate) and Georgiana Slough (e.g., 7,500 cfs), to fully protect Mokelumne River and Sacramento River juveniles. This Delta passage survival evaluation task would allow the likely benefits of the proposed project to be more accurately identified. The proposed project with fish screens on DCC and Georgiana Slough would be more costly but would allow all Mokelumne River Chinook and steelhead smolts to use the Sacramento River pathway (with the highest survival) to Chipps Island.

Task 5. Evaluation of Adult Migration Homing and Straying

The evaluation of existing Mokelumne River adult fish homing and straying would be conducted to establish the baseline for evaluating the secondary benefits of the proposed project to reduce straying of Mokelumne River fish (and reduce straying of other hatchery fish to the Mokelumne River). The recent historical records from the MRFH CWT releases at Sherman Island (upstream of Chipps Island) and in San Pablo Bay would be compared with the homing and straying rates for fish from other Central Valley hatcheries. The historical (before 2000) CWT recoveries for MRFH fish that were released at the hatchery or at locations along the Mokelumne River or in the Delta are of particular interest. The proposed project would increase the fraction of Mokelumne River water in the Sacramento River downstream of the DCC and reduce the fraction at the mouth of the Mokelumne River, thereby reducing straying of Mokelumne River adults. The actual reduction in straying would be measured in the years after the Mokelumne River connection to the Sacramento River was implemented. The lowest straying rates will likely be for hatchery releases below Woodbridge Dam. Because the juvenile migration survival to Chipps Island and the ocean would likely be increased substantially with the project, the project could allow all hatchery releases to be made below Woodbridge. If the proposed connection project is initially tested (i.e., pilot testing) with just the two flood gates on N. Fork and S. Fork Mokelumne River during the juvenile migration months (January-June), these gates should be closed in October and November to increase the homing (reduce straying) of adult Mokelumne River fish.

Task 6. Development of Biological Monitoring and Special Studies Plan

The proposed project to connect the Mokelumne River to the Sacramento River at the DCC could become a new biological monitoring and habitat restoration element in the Joint Settlement Agreement (JSA) for the Lower Mokelumne River with USFWS and CDFW; to improve juvenile migration survival through the Delta and increase adult attraction (homing) for Mokelumne River adult Chinook and steelhead. The demonstration project monitoring and special studies plan could be cooperatively developed by EBMUD, CDFW and USFWS staff under the JSA, with technical assistance from NMFS and selected EBMUD consultants.

An initial testing period could experimentally demonstrate (measure) the fish benefits from a direct tidal connection between the Mokelumne River and the Sacramento River. This would involve closing the flood gates on N. Fork and S. Fork and opening the DCC gates during the outmigration period (e.g., March-June) and adult migration period (e.g., October-December). Paired releases of CWT hatchery fish, with some acoustic tag tracking, would provide some initial estimates of the juvenile migration survival benefits. Similar initial testing during the adult migration period (e.g., October-November) would allow initial estimates of the adult homing benefits. Some Sacramento River fish would likely enter the DCC during flood tides, and may rear in the Snodgrass Slough habitat before returning to the Sacramento River on subsequent ebb tides. Some additional beach seines or other sampling in the Snodgrass Slough tidal habitat to evaluate fish growth and survival might be included in the demonstration project monitoring plan.

EBMUD staff in cooperation with CDFW and USFWS would plan the additional fish monitoring and data analyses that might be used to evaluate the project benefits, in addition to the already extensive fisheries evaluations under the existing JSA program. Paired releases of CWT hatchery fish might be a major component of the monitoring plan, to directly measure the survival of juveniles released below Woodbridge Dam to Chipps Island (recoveries) and losses at the SWP and CVP salvage facilities. Paired (or sequential) releases under existing conditions (DCC closed) and with the proposed DCC connection project could be compared (e.g., similar to the VAMP studies on the SJR). Additional monitoring for the demonstration project might include acoustic tag tracking down the Mokelumne and through the Delta; this might be implemented in cooperation with other acoustic tag studies, using tracking stations established for other studies. The feasibility of an additional RST in the north DCC gate (e.g., a tidal design, to allow sampling during downstream ebb tides and upstream flood tides) might be investigated to allow a direct measure of the survival of juveniles between Woodbridge Dam and the DCC connection. The project monitoring and special studies plan will include an assessment of the uncertainty in these fish measurements, to determine if the benefits are likely to be measureable.

Task 7. Project Feasibility and Monitoring Plan Report

The engineering design, feasibility assessment and biological monitoring plan development tasks will be described and documented in a report prepared by the selected EBMUD consultants. A draft report for EBMUD review and comments/suggestions would be followed by a final report incorporating all changes in response to review comments/suggestions. The draft report would also be reviewed by the JSA cooperating agencies. This project feasibility and biological monitoring report would serve as the project description document for the subsequent environmental documents and permit applications that would be required for the demonstration project. Reclamation would likely prepare an Environmental Assessment (EA) under NEPA, while EBMUD would likely prepare an Initial Study (IS) under CEQA. A Biological Assessment would likely also be needed for USFWS and NMFS approval under ESA. The project feasibility and monitoring plan report would provide all the information and analyses needed to prepare the environmental documents for the proposed project.

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Attachment: Mokelumne River Chinook Fish Data Analysis Methods

The extensive fish data from the Mokelumne River and hatchery can be used to provide an accurate understanding of the existing conditions of fish habitat, and to estimate river rearing success for smolts, Delta rearing success for river fry that pass Woodbridge Dam, juvenile passage through the Delta, ocean growth and survival, harvest rate and return rates (2-yr old, 3-yr old and 4-yr old), and adult homing and straying. Some of these fish data can also be used to develop a biological monitoring plan to evaluate the benefits of the proposed project for improved Delta passage (survival) and increased adult homing (reduced straying).

Mokelumne River Rearing and Delta Passage Survival Estimates

The primary measure of overall Mokelumne River Chinook production (survival) in the river, Delta and ocean is the total number of adults, observed in the ocean catch and escapement (adult returns) to the Mokelumne River and Mokelumne hatchery, as well as other Central Valley rivers and hatcheries (strays). The production of river spawning and rearing juveniles is obscured, however, by the hatchery production of smolts (released in San Pablo Bay or Sherman Island in the Delta), because the majority of ocean catch and returning adults are hatchery fish. Although the survival in the ocean may be similar for these two types of Mokelumne River fish, the survival of river rearing fry to smolts (e.g., 90 mm) is much lower than the hatchery production of smolts (i.e., smolt/female ratio). Hatchery smolts are released downstream of Woodbridge Dam or at Sherman Island, so their survival to Chipps Island and the ocean may be higher than river spawning and rearing fish migrating past Woodbridge Dam to Chipps Island and the ocean. Nevertheless, the ocean catch and escapement of CWT hatchery fish provides an initial estimate of the productivity (survival) of Mokelumne River hatchery fish in comparison to other Central Valley rivers with hatcheries (i.e., American River and Feather River), and may allow variations from year to year to be identified (Miyamoto and Hartwell 2001).

Because adult Chinook migration past WIDD, Mokelumne River hatchery returns, river spawning (carcass surveys and redd counts), and hatchery smolt releases have been carefully monitored for many years (since 1990), the success (e.g., production; ocean catch + Central Valley returns) of the hatchery releases and river rearing fish in each year can be generally determined. The Mokelumne River Hatchery has participated in the Regional Mark Information System (CWT program) and the CDFW constant fractional marking program that was initiated in 2007 to estimate the contribution of hatchery fall-run Chinook salmon to Central Valley escapement and evaluate the success of restoration actions. The CWT returns to the Mokelumne River hatchery and river can be evaluated to determine production (ocean catch + returns) and to evaluate straying (both from the Mokelumne River and to the Mokelumne River from other hatcheries). But separating the overall production into the river rearing success (smolts/female), Delta passage success (smolt survival to Chipps Island), and ocean survival is difficult. Interpreting the success of river rearing and Delta passage for each cohort might be improved by considering the ocean conditions, as reflected in adult returns to the river and CWT returns of hatchery fish in subsequent years (2-yr old, 3-yr old, 4-yr old). This comparison of hatchery CWT returns could allow the differences in ocean survival and return rates (2-yr old, 3-yr old, 4-yr old) for each cohort to be separated from the river rearing success and Delta passage survival (for releases of CWT fish at Woodbridge Dam).

Photo of Woodbridge Irrigation District Dam

To illustrate the difficulties of using the total Mokelumne River returns as an indication of river rearing success (in previous years), the annual escapement (returns) to the Mokelumne River and hatchery from 1974 to 2014 are given in Table 1, from the CDFW file of Central Valley Chinook escapement (CDFW 2014) called "GrandTab." The effects of river conditions on the juvenile rearing success in their first year is sometimes evaluated from the 3-yr replacement ratio, assuming that most fish return as 3-yr olds and that ocean conditions are relatively similar from year to year. The replacement ratio for brood year +3 escapement divided by the brood year escapement is given in brood year + 1 (to correlate with river conditions in brood year + 1). The average hatchery returns for 1974-2014 (41 years) was 3,315 fish, while the average river spawning escapement was 2,880 fish. But the Mokelumne River combined (hatchery and river) returns ranged from 250 fish in 1977 to more than 15,000 fish in 1983, 2005 and 2011. The average for the first 20 years (1975-1994) was 3,654 fish, while the average for the last 20 years (1995-2014) was 8,641. This appears to be a great improvement (i.e., habitat restoration success), except that the increase from the first half to the second half of the record was predominantly for hatchery fish; the hatchery returns increased from 954 to 5,593 fish, whereas the average for river spawning fish increased only slightly from 2,796 to 3,047 fish.

Because the mixture of hatchery and river spawning fish returning to the Mokelumne River is likely dominated by hatchery fish, and because the hatchery returns are a different fraction of the returning fish each year (the 25% CWT marking program improves this estimate), the success of the river spawning fish cannot be accurately determined from the overall number of returning fish. Because CWT returns indicate substantial straying of Mokelumne hatchery fish to other rivers and substantial straying of CWT fish from other hatcheries to the Mokelumne River (e.g., Nimbus Hatchery on the American River), the success of the Mokelumne River spawning (e.g., natural rearing) fish is even more difficult to evaluate. Figure 3 shows the Mokelumne River escapement (returns) for the hatchery and river spawning for 1974-2014.

Photo of Mokelumne River Fish Hatchery

Using escapement and ocean catch to evaluate river-rearing juvenile success (adults) is a difficult analysis, with several steps and necessary assumptions. The ocean harvest and return rates are estimated from the CWT returns. The ocean catch and returns of river-rearing fish are generally assumed to be similar. However, while the number of hatchery fish entering the ocean can be estimated from the hatchery releases times the assumed initial ocean survival rate, the number of river juveniles passing Woodbridge and the Delta passage survival are both unknown. The river rearing and Delta survival (smolts/female) in the first 6-8 months must somehow be separated to evaluate the potential benefits from the DCC connection project. The river and Delta survival in the first year (brood year + 1) might then be estimated from the production of river-rearing (unmarked) smolts, based on RST data, and the river returns plus estimated ocean catch of river fish and river-spawning fish for the cohort. Since CWT recoveries are the only method for tracking ocean catch and returns of each year class, the CWT patterns for each brood year must be assumed to apply to river rearing fish as well. Identifying the Mokelumne River rearing survival and Delta passage survival from the adult returns (and estimated ocean catch) of hatchery and river spawning fish will be both difficult and uncertain.

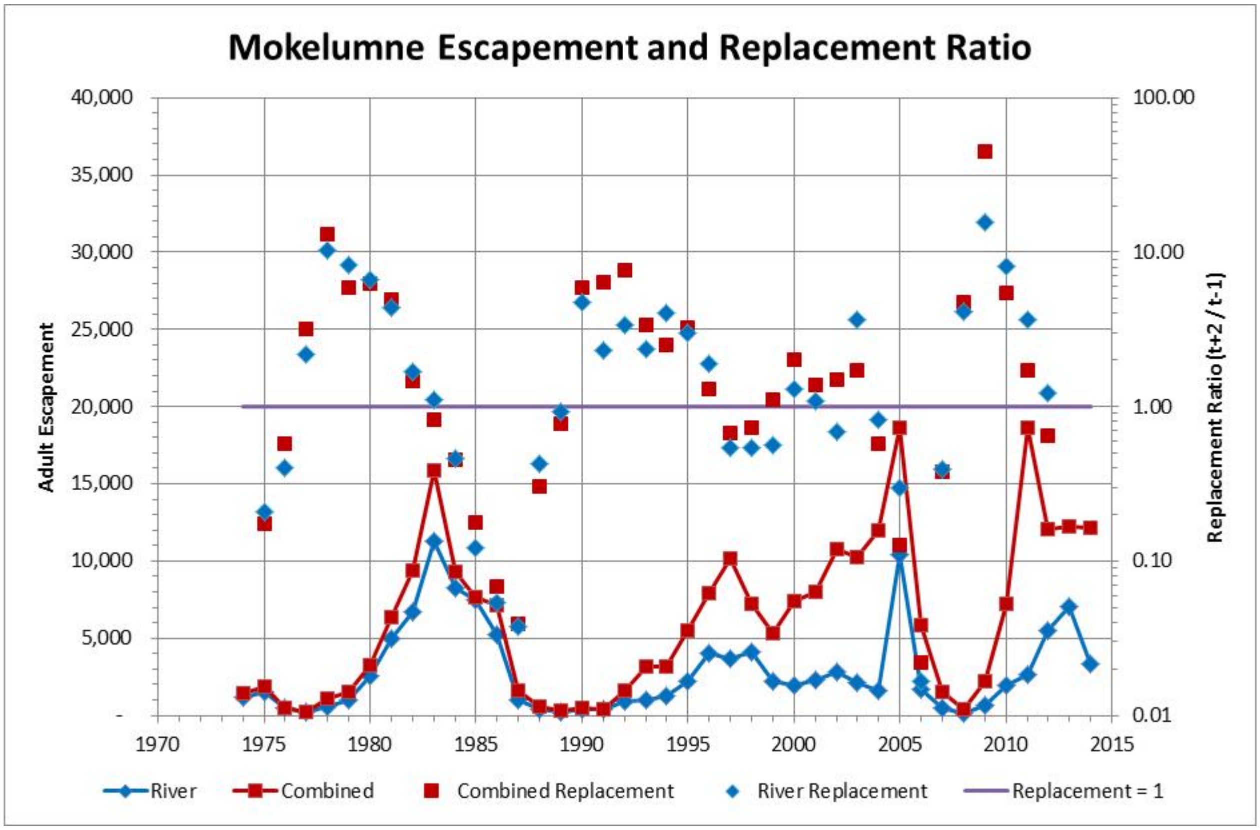

Figure 3. Mokelumne River Escapement (River and Hatchery) and Replacement Ratios for 1974-2014

A more direct and reliable method for evaluating river rearing success (growth and survival in different years) is to compare the monthly passage (expanded catch) of fry and juveniles in rotary screw traps (RSTs). The monthly passage can be compared to the river spawning females, to estimate the monthly fry/female or monthly smolts/female ratios. Based on RST data collected at Vino since 1990, the juvenile production of river-spawning females ranges from 50,000 to over 1 million juvenile fish per year. River conditions (flow and temperature) may have a large impact on juvenile production (fry rearing survival). At higher flows (e.g., >1,000 cfs), large numbers of juveniles apparently migrate from the Mokelumne River as small fry in January-March , although they may rear in the Delta tidal channels. An analysis of the monthly fry/juvenile passage data from several years might allow the effects of Mokelumne River flows on growth, survival and movement of fry and juveniles (smolts) to be identified. RST data provide the most accurate estimates of the number of fry and smolts that enter the Delta channels each year; this RST monitoring will be needed as part of the assessment of the proposed DCC connection project benefits.

Table 1. Mokelumne River Escapement (Hatchery and River) for 1974-2014 (Source: DFW GrandTab)

	Cosumnes River	Mokelumne Hatchery	Mokelumne River	Mokelumne Total	River Percentage	Total Ratio for River Conditions (t+2/t-1)
1974	285	222	1,200	1,422	84%	
1975	725	399	1,501	1,900	79%	0.18
1976		18	455	473	96%	0.57
1977		0	250	250	100%	3.19
1978	100	486	600	1,086	55%	12.92
1979	150	507	1,000	1,507	66%	5.84
1980	200	639	2,592	3,231	80%	6.22
1981		1,386	4,954	6,340	78%	4.91
1982		2,677	6,695	9,372	71%	1.46
1983	200	4,568	11,293	15,861	71%	0.82
1984	1,000	959	8,298	9,257	90%	0.45
1985	220	223	7,459	7,682	97%	0.18
1986		1,913	5,254	7,167	73%	0.07
1987	-	630	1,000	1,630	61%	0.04
1988	100	128	400	528	76%	0.30
1989		81	199	280	71%	0.78
1990		68	429	497	86%	5.88
1991		42	368	410	90%	6.35
1992		710	935	1,645	57%	7.70
1993		2,164	993	3,157	31%	3.35
1994		1,919	1,238	3,157	39%	2.51
1995		3,323	2,194	5,517	40%	3.22
1996		3,883	4,038	7,921	51%	1.31
1997		6,494	3,681	10,175	36%	0.67
1998	300	3,091	4,122	7,213	57%	0.73
1999	229	3,150	2,183	5,333	41%	1.11
2000	460	5,450	1,973	7,423	27%	2.02
2001		5,728	2,307	8,035	29%	1.38
2002	1,350	7,913	2,840	10,753	26%	1.49
2003	122	8,117	2,122	10,239	21%	1.73
2004	1,208	10,356	1,588	11,944	13%	0.57
2005	370	8,218	10,406	18,624	56%	0.13
2006	530	4,139	1,732	5,871	30%	0.02
2007	77	1,051	470	1,521	31%	0.38
2008	15	239	173	412	42%	4.73
2009	-	1,553	680	2,233	30%	45.14
2010	740	5,275	1,920	7,195	27%	5.41
2011	53	15,922	2,674	18,596	14%	1.70
2012	1,071	6,620	5,471	12,091	45%	0.65
2013	-	5,181	7,071	12,252	58%	
2014	373	8,816	3,301	12,117	27%	

Rotary Screw Trap Data Analysis to Evaluate River Rearing Success

The proposed project to connect the Mokelumne River to the Sacramento River at the DCC will improve the Delta passage survival and may improve the fry rearing success in the Delta channels, but will not change the Mokelumne River rearing success. Nevertheless, the monitoring of juveniles (RSTs) at Woodbridge is necessary to accurately estimate the increased Delta passage survival; an additional RST might be installed at the DCC north gate, to estimate the survival from Woodbridge to DCC. The productivity (ocean harvest + returns) of paired releases of hatchery CWT fish from Woodbridge and Sherman Island can also be compared to evaluate the benefits of the proposed project; the Woodbridge productivity should approach the Sherman Island productivity with the projext.

The 2013 juvenile outmigration report (Bilski et al 2013) is the latest available, and provides a good example of the trapping and analysis of the juvenile fish at Vino (river mile 54), 10 miles downstream of Camanche Dam and at Golf (river mile 39), 25 miles downstream of Camanche Dam and immediately below the Woodbridge Dam. There is also a juvenile fish trap in the Woodbridge ID fish screen bypass channel just upstream of Woodbridge Dam that operates during the irrigation season from April-June. The RSTs capture a fraction of the river flow and fish; the trap efficiency can be estimated from the RST flow fraction or by mark-recapture testing. Several trap efficiency tests are conducted with natural or hatchery fish each year. The measured trap efficiencies vary considerably, from 1% to 25%; the catch efficiency decreases with higher flow (i.e., lower flow fraction) and may be reduced for larger fish (i.e., avoidance). The Woodbridge ID fish screen bypass captures many more fish than the Golf RST because the trap efficiency is higher (i.e., flow fraction = diversion/river flow). The expansion of the catch at Vino and Golf to the estimated daily passage is more uncertain. A volumetric expansion (river flow/trap flow) with a linear increase with fish length (e.g., 1x for 30 mm fry, 3x for 90 mm fish) might provide a more uniform expansion of the catch data for each year, and allow differences between years to be further evaluated. The traps are generally operated four days each week, so the catch on weekends must be interpolated.

A good estimate of the river spawning females (from redd counts or carcass survey data) is needed to evaluate the number of fry and juveniles passing the Vino, WID and Golf traps. An average of 50% of the adult fish can be used, but grilse (2-yr fish, <70 cm, 27.5 inches) are usually males, so a higher grilse fraction will generally lower the female ratio (of total escapement). The fecundity may depend on the female size (length, age), but an average fecundity from the MRFH is about 5,000 eggs per female. The female ratio is not always 50%, and not all females produce redds; the measured redd/escapement ratio for the Mokelumne River has varied from about 25% to 65%.

Photo of Rotary Screw Trap

Assuming that the female spawners can be estimated, the river survival of fry and juveniles can be evaluated from the monthly fry/female (early emigrating) and the annual smolt/female ratio. Because smolts are 75-105 mm, they require 3-5 months of growth after they emerge from the gravels as fry (about 2.5 months after spawning). Mokelumne River fish generally spawn in November and early December, so the fry usually emerge in mid-January and February. Therefore, the earliest smolts (75 mm) are seen in mid-April, and smolts (75-105 mm) are caught in the Vino, WID and Golf traps in April, May, and June. Although the most common summary of RST data is the total number of juveniles (of any size), a more accurate accounting of river survival (production) would be the number of fry growing and surviving in the river and passing the traps as smolts in April, May and June. Some of the fry (30-75 mm) passing the traps in January, February and March may rear in the Delta channels and migrate to the ocean, but the fraction of the fry that survive to become smolts in the Delta channels is unknown. Nevertheless, the focus of this project is the improvement of the river-rearing smolt migration (survival) through the Delta to the ocean in April, May and June.

Table 2 gives the total monthly catch at Vino, Golf and the WID bypass for 2013. The river escapement in 2012 was 5,471 fish (with 6,620 hatchery returns), but the total observed adult females was 39% (2,133) with 5% female grilse (273). Furthermore, the total number of redds observed in November and December was only 1,287; this suggests that only about half of the returning females formed redds. These measurements also indicates the difficulty of estimating the number of spawning females (redds) and likely egg production for each year. Nevertheless, the 2013 escapement and redd counts were high compared to previous years (730 average redds for 1990-2012); only 3 other years had more than 1,000 redds. The total catch at Vino was 113,000 juveniles, the total catch at Golf was 2,526 juveniles (no sampling in June), and the total catch at the WID bypass was 35,000 juveniles. But as described above, the majority of these were fry caught in January, February and March. Focusing on the months of April-June, a total of 679 smolts were caught at Vino, a total of 639 smolts were caught at Golf (April and May), and a total of 35,000 smolts were caught at the WID bypass. Because the WID diversions are a large fraction of the river flow in the months of April-June when the smolts are migrating to the ocean, the sampling of the bypass trap should be emphasized in the future (with daily trapping?). Assuming a smolt expansion of the river flow divided by the diversion times 2 (sampling about half the days) for the bypass trap, a total of about 225,000 smolts passed WID and migrated through the Delta channels to the ocean in 2013. Assuming a redd count of 1,287 (females) and a fecundity of 5,000 eggs/female, the smolt/female ratio was about 175, and the egg/smolt survival at Woodbridge was 3.5%. This example year should be compared with other years and with other rivers to better understand how Mokelumne River rearing survival compares with other rivers and with other flow conditions.

Table 2. Monthly Catch and Passage in the Mokelumne River RSTs and WID Bypass Trap in 2013

Month	Camanche Release (cfs)	WID Diversion (cfs)	Vino Catch	Vino Passage	Bypass Catch	Bypass Passage	Golf Catch	Golf Passage
January	342	-	14,896	297,920	-		23	460
February	270	-	90,211	1,804,220	-		1,475	29,500
March	269	44	7,562	151,240	-		389	7,780
April	315	60	218	4,360	494	5,232	123	2,460
May	385	116	432	8,640	30,525	203,193	516	10,320
June	271	124	29	580	4,154	18,197	-	
Total			113,348	2,266,960	35,173	226,622	2,526	50,520

Note: Trap Expansion for Vino and Golf is about 20 (sampled for half the days with efficiency of 10%); Expansion for Bypass is River/WID

Mokelumne River rearing smolts may have lower survival rates to Chipps Island and the ocean than Sacramento River juveniles because the Mokelumne River juveniles are exposed to predation in the Delta channels for more days during their outmigration pathway and more may be entrained into the CVP and SWP exports (i.e., salvage). The proposed project to connect the Mokelumne River to the Sacramento River at the DCC would likely increase the outmigration survival of river rearing smolts (and hatchery smolts released below Woodbridge Dam). The increased survival might be evaluated with paired releases of hatchery CWT fish below Woodbridge Dam and at Sherman Island, or with acoustic tag tracking of larger smolts, with the DCC open (connected, proposed project) and with DCC closed (not connected, existing conditions).

Mokelumne River Adult Chinook Homing Success

The ability of Mokelumne River adults to return to the Mokelumne River for spawning is likely affected by the DCC gates being open in October and November; fish migrating upstream in the SJR and Mokelumne River channels may enter Georgiana Slough or Snodgrass Slough and DCC and "stray" to the Sacramento River rather than continuing their migration past New Hope to Woodbridge Dam and to the Mokelumne River and hatchery below Camanche Dam (Smith and Workman 2004). The annual escapement to the Mokelumne River is accurately determined with video recordings and a trap in the fish ladders at the Woodbridge Dam (Del Real and Saldate 2013). The hatchery returns (some with CWT) are subtracted from the total escapement to estimate the river spawning fish. Carcass surveys and redd surveys are also conducted on the Mokelumne River each year (Bilski and Rible 2013). All of this information should be integrated to provide an accurate assessment of the productivity of the Mokelumne River Chinook for each cohort or hatchery release group (CWT). Mokelumne River hatchery (CWT) fish returning to other rivers and hatcheries indicates the straying rate of Mokelumne River hatchery fish, for different release locations.

The straying of Mokelumne River fish to the SJR tributaries may be increased by Mokelumne River water flowing south in SJR and Middle River channels to the export pumps in October and November. Reclamation is conducting a 5-year study to close the DCC for 10-days in October (US Bureau of Reclamation 2012) in an effort to reduce straying of Mokelumne River fish to the American River (e.g., adults migrating up the Mokelumne River and through the DCC to the Sacramento River). The benefits of this 5-year study may be difficult to identify since the 10-day closure is only about 15% of the major migration period (October and November), and the annual straying of Mokelumne River fish to the American River is variable from year to year. The proposed project to connect the Mokelumne River to the Sacramento River at the DCC should provide a stronger homing signal (greater fraction of Mokelumne River water) and allow most Mokelumne River adult fish to migrate up the Sacramento River to the DCC and enter the Mokelumne River through the DCC. This should reduce the straying of Mokelumne River adults to the American River (upstream of the DCC) and also reduce the straying to the SJR tributaries (much lower fraction of Mokelumne River water in the SJR upstream of the Mokelumne River mouth).

The ability of returning Mokelumne River adults to locate the Mokelumne River mouth and continue upstream past Woodbridge Dam is partially determined by the fraction of Mokelumne River water in the downstream Delta channels. In most years the releases from Woodbridge Dam in October and November are relatively low (<500 cfs), so the fractions of Mokelumne River water in the tidal channels of the Delta are small. It is remarkable that many Mokelumne River Chinook find their way to Woodbridge Dam. The Mokelumne River and Cosumnes River flow connects with the South Fork Mokelumne at New Hope. The DCC diversion from the Sacramento enters Snodgrass Slough and connects with the North Fork Mokelumne; some fraction of the DCC water connects with the South Fork through Dead Horse Cut and the upstream section of the North Fork (See Figure 2). DSM2 modeling results indicate that about 25% of the combined flow (Mokelumne + Cosumnes + DCC), moves down the S. Fork and 75% moves down the N. Fork. The majority of the Mokelumne water is assumed to flow down S. Fork, but some fraction (e.g., 25%) was assumed to tidally mix with Snodgrass Slough and N.

Fork water. The majority of the Mokelumne water flows south in Little Connection Slough and Disappointment Slough to the SJR and down Middle River to the CVP and SWP exports. Only a fraction of the Mokelumne River water flows out of the mouth of the Mokelumne River to the SJR. Adults may locate the Mokelumne River geographically, but the olfactory cues are weak in the SJR at the mouth of the Mokelumne River.

Table 3 provides an example of the fraction of Mokelumne River water in several Delta channels, using historical flows in October 2009 (DWR 2015). The Mokelumne River flow was 381 cfs, the Cosumnes River flow was 29 cfs, the Sacramento River flow at Freeport was 12,876 cfs and the combined DCC and Georgiana Slough was 5,523 cfs (45% in Georgiana Slough). The fraction of Mokelumne River water in the S. Fork flow was 27% and the fraction of Mokelumne River water in the N. Fork flow was 4%. The fraction at the Mokelumne River mouth was about 2%, the fraction in the SJR at Threemile Slough was about 1.5%. Although the net flow in Threemile Slough is usually from the Sacramento River to the SJR, a fraction (e.g., 10%) of the SJR water was assumed to be tidally mixed into the Sacramento River through Threemile Slough. The fraction of Mokelumne River water in the Sacramento River below Threemile Slough was 0.1% and the fraction in Delta outflow at Chipps Island was 0.6%. A Mokelumne River fish could likely detect the fraction at Chipps Island, and could select the SJR fraction (1.5%) compared to the Sacramento fraction (0.1%). A Mokelumne River fish might not select the Mokelumne mouth (2%), because a higher fraction would be tidally mixed from the S. Fork (20%) in the SJR upstream of the Mokelumne River. Because greater fractions of Mokelumne River water were in the S. Fork, there might be some straying away from the Mokelumne River mouth into Potato Slough and the SJR channels upstream (south) of the Mokelumne River.

The proposed project to connect the Mokelumne River with the Sacramento River at the DCC should greatly reduce the staying of adults into the SJR tributaries. The Mokelumne River water fraction in the Sacramento River below DCC would be about 5%, likely providing a sufficient olfactory cue for fish migrating upstream in the Sacramento River to select the DCC connection to the Mokelumne River. The proposed project would divide the DCC and open the north gate to connect with Snodgrass Slough and the Mokelumne River through Dead Horse Cut, with flood gates blocking the S. Fork and N. Fork just downstream of New Hope. During the fall months, the south gate of the DCC should be closed, to minimize the amount of Mokelumne River water diverted back to the Mokelumne River channels. Diversion of Sacramento River water into Georgiana Slough would include Mokelumne River water, which would reach the mouth of the Mokelumne and might attract some adults into Georgiana Slough. However, these adults would likely move upstream in Georgiana Slough back to the Sacramento River and enter the DCC north gate to continue up the Mokelumne River to Woodbridge Dam. These expected fall attraction flow benefits for adult Mokelumne River chinook should be verified during the demonstration period (e.g., reduced CWT stray rates to American River and SJR Tributaries).

Table 3. Calculated Fraction of Mokelumne River Water in Delta Channels for October 2009 for Existing Conditions (Without the Mokelumne River Connection Project)

Mixing Fractions		Location	October Flow	October Mokelumne Fraction
		Woodbridge Dam	381	1.0000
		Cosumnes	29	
		Below Cosumnes	410	0.9287
		Sacramento at Freeport	12,876	
Freeport %	0.6	Sacramento at DCC	7,726	
	Maximum	DCC & Georgiana	5,863	
	Maximum	Georgiana	2,542	
		DCC & Georgiana	5,523	
Mokelumne %	DCC %	DCC	2,981	
0.75	0.25	South Fork	1,053	0.2713
0.25	0.75	North Fork	2,339	0.0407
		Mokelumne Mouth	4,880	0.0195
		Sac at Rio Vista	7,371	
		QWEST	3,402	
		OMR	(1,852)	
SJR % to Sac	0.1	Threemile (to SJR)	940	
		SJR at Threemile	4,342	0.0138
		Sac at Threemile	6,431	0.0010
		Delta Outflow	10,690	0.0062

Hatchery Releases and CWT Returns

The fall Chinook program at the CDFW-operated Mokelumne River Fish Hatchery (MRFH) has a goal to release (at Sherman Island or in San Pablo Bay) up to five million fall-run Chinook salmon smolts that average 60 fish per pound (fpp), equivalent to a length of about 85 mm. Approximately two million additional Chinook are raised to post-smolt size (45 fpp, 95 mm) in some years for an ocean harvest enhancement program. All of the enhancement salmon production is released into San Pablo Bay or reared in net pens on the coast. Juvenile fall Chinook are released between April and June and all fish are now marked at a rate of 25 percent (constant fractional marking) with an adipose fin-clip and coded wire tag. The CWT marking rate has been variable in previous years (Workman et al 2005).

The steelhead program at MRFH has a goal to release 250,000 yearlings at a size of 4 fpp (210 mm). The program has been experimenting with small releases (less than 2,000 fish) of two-year-old steelhead juveniles using a "natures" rearing strategy (i.e., presence of structure, low rearing density, shallow pond depth, cover and colored raceways). All steelhead are released in February or March and are marked with an adipose fin clip. Steelhead are normally released at New Hope Landing, approximately 10 miles downstream from the confluence of the Mokelumne and Consumes rivers (near the DCC) to avoid predation effects on Chinook fry.

Juvenile Chinook produced at MRFH have been released at various Mokelumne River, Delta, and SF Bay locations for many years. Most of the 2-3 million juvenile Chinook released annually have been released into the bay or in the Delta. Since 2011, all sub-yearling releases have been limited to the Mokelumne River Delta channels (downstream of natural spawning areas) instead of being released into the bay in an effort to reduce straying. Fall releases of Chinook (called yearling releases) are made in some years directly into the Mokelumne River at the hatchery.

Coded wire-tag (CWT) recoveries of MRFH fish (expanded for ocean and escapement sampling) show that bay releases have resulted in much higher stray rates than for fish released into the Mokelumne River (both at the hatchery and downstream releases). CWT recovery data for 1987-2007 indicate that the majority of Mokelumne Hatchery fish released in-river returned to the Mokelumne River (64% of expanded total river recoveries), but they were also found in the American River (26%), the Merced River (4%), the Sacramento River (2%), the Stanislaus River (1%), the Feather River (1%), and a variety of other locations in the Central Valley (California HSRG 2012). About half of the 64% of hatchery fish that returned to the Mokelumne River from the in-river juvenile releases were estimated to have returned to the hatchery (the others were assumed to spawn in the river). In contrast, only about 6% of the MRFH tagged fish released into San Francisco Bay were recovered in the Mokelumne River, and only half of those were recovered at the hatchery. Other watersheds receiving strays from bay releases were American River (31%), Merced River (20%), Stanislaus River (15%), Tuolumne River (11%), the Feather River (10%), Clear Creek (4%), Battle Creek (2%), and Butte Creek (1%).

CWT recoveries should be compared between the hatcheries to determine variations in ocean survival (production) and age-specific ocean catch and return rates for each cohort, and to evaluate straying from each hatchery (for river releases). Straying of Mokelumne hatchery fish released in the lower Mokelumne River or in the Bay-Delta appears to be greater than straying from other hatcheries, possibly because homing to the Mokelumne River is weaker than for the other Sacramento River tributaries (i.e., American, Feather, and Battle Creek).

A constant fractional marking program was implemented in 2006 to improve the estimation of hatchery contributions to ocean and inland harvest, in-river spawning escapement, and hatchery returns (Palmer-Zwahlen and Kormos 2013). The current practice of releasing most fall-run Chinook salmon hatchery production as smolts in the estuary avoids potential competition or predation between hatchery and river rearing juveniles. However, concerns remain regarding the potential effects of hatchery releases on the survival and growth of river rearing juveniles during their first year at sea, especially in years of low marine productivity (Williams 2006).

The California HSRG (2012) recommended that: "Transporting and releasing juveniles to areas outside of the Mokelumne River should be discontinued. Juvenile fish should be released at the hatchery, or if not possible, as far upstream in the Mokelumne River from the confluence of the Sacramento River as possible to reduce adult straying and increase the number of adult fish returning to the hatchery. Consider necessary facility modifications or equipment purchases that will facilitate on-site releases. Release locations for steelhead may take into consideration ecological and predation effects on other fish populations but should not compromise homing of adults to the hatchery." The proposed project to connect the Mokelumne River with Sacramento River at DCC would facilitate this recommendation by allowing more of the hatchery releases to be made below Woodbridge Dam. Because smolt survival through the Delta would likely be increased, the apparent benefits of Sherman Island or San Pablo Bay releases (i.e., higher ocean catch and returns) would be reduced. The increased percentage of Mokelumne River water in the Sacramento River downstream of the DCC would also likely increase the homing of adult fish and reduce the straying to the American River and SJR tributaries.

As an example of the suggested CWT analysis, Table 3 shows the brood year 2009 Mokelumne River CWT releases and recoveries. There were a total of about 2,115,000 CWT releases with 14 CWT codes. All of the smolts (2,015,000) were released from net pens located near the mouth of the SRJ on Sherman Island on April 21-23 and on June 1, 2010. Another release of about 99,000 yearlings was made from the hatchery to the Mokelumne River in November of 2010. These fish were considerably larger, but they had to migrate down the Mokelumne River and through the Delta to the ocean in November. The Mokelumne River hatchery provided 100% CWT adipose fin marking for brood year 2009 fish, so this was the total Chinook production from the Mokelumne River hatchery. Brood year 2009 fish were caught in the ocean during the 2011-2013 fishing seasons, and also returned to the rivers and hatcheries in 2011-2013 as 2-year old (grilse), 3-yr old and 4-yr old fish, but the age distribution (fractions) are not included in this example analysis. Table 3 is a final accounting of the total ocean catch and returns to each river for these 2009 brood year Mokelumne River hatchery fish.

Recoveries from the ocean catch and from Central Valley rivers (hatcheries and river spawning) are collected each year through very extensive sampling of the ocean catch (recreational and commercial fishing), returns to the five Central Valley Chinook hatcheries, and from river carcass surveys. All of the CWT data is compiled and evaluated by the Regional Mark Processing Center (RMPC), which provides regional coordination and maintenance of databases for CWT releases, recoveries, and sampling effort (expansion) data, as well as the dissemination of standard reports and individual database queries. These databases are known collectively as the Regional Mark Information System (RMIS).

Table 3A indicates that the total recoveries (expanded for partial sampling effort) from the brood year 2009 CWT releases was about 70,000 (3.3%). This is a relatively high (good) recovery rate; assuming that 4,000 smolts were released from each female (80% egg to smolt survival) this would suggest that 132 adults were produced (ocean catch or return), which is an extremely high production ratio of 66. The total ocean catch was about 31,500 (45%); therefore, if the Mokelumne fish were caught in proportion to the total Chinook fall run population, the ocean harvest rate was 45%, and about 55% of the total Mokelumne fish in the ocean returned to Central Valley Rivers.

Table 3B gives the recovery ratios, which are expressed as the number recovered per 1,000 CWT (i.e., a ratio of 10 represents a 1% recovery rate). Comparing the recovery rates for the two pen release dates, the April 21-23 releases (900,000) had ocean catch ratios of less than 5 (0.5%) and river return ratios of less than 10 (1%). The June 1 releases (1,100,000) had ocean catch ratios of 15-30 (1.5% to 3%) as well as river return ratios of 15-30 (1.5% to 3%). The similarity of the recovery ratios for the multiple tag codes (replication) was very high so these large differences between the two release dates are quite certain. The major differences between these releases was the five weeks of additional growth (17.5

mm) for the June 1 releases, and possible differences in the food resources as the smolts entered the ocean habitat (i.e., density of prey fish such as juvenile northern anchovy, herring, or shad). Table 3B indicates that the November 7 release of yearlings had an ocean catch ratio of 5 (0.5%) with a river return ratio of 10 (1%). The total recovery ratio of 14 (1.4%) was only about 25% of the average recovery of 53 (5.3%) for the June 1 releases. Although these yearling fish were 5 months older (75 mm larger) than the June smolts, they were released to the Mokelumne River at the hatchery and had to migrate down the Mokelumne River and through the Delta to Sherman Island, where the smolts had been released. Although CWT recovery ratios from other years should be evaluated, the river-Delta-ocean survival of the yearlings released at the hatchery in November 2010 (DCC open) was apparently only 25% of the ocean survival of the smolts released at Sherman Island on June 1.

CWT returns from routine hatchery releases cannot be used to indicate the juvenile growth and survival of river-rearing fish (i.e., smolts/female). Special studies with paired releases (100,000 CWT) of relatively small size fish (60-90 mm) from the hatchery and from Sherman Island might be used to indicate the river-Delta survival rates, and to compare the migration survival under existing conditions (DCC closed) with the proposed project . The migratory survival of larger smolts (90-120 mm) might be similarly tested using smaller releases (100-200) of acoustic tags during periods with the DCC connection and periods without the DCC connection. These fish tracking experiments are suggested as the primary methods for testing and evaluating the relative juvenile survival for the Mokelumne River fish for existing conditions and with the proposed project.

Some of these Mokelumne River fish monitoring programs can be modified or extended to provide additional information for evaluating the success of the Mokelumne River DCC connection project. For example, it might be possible to install an additional RST (or other fish trap) to measure the juvenile passage at the north gate of the DCC, during the same period that the Woodbridge ID bypass trap and the Vino and Golf RSTs are operated, to directly measure the passage (survival) from Woodbridge Dam to DCC north gate. This downstream trap might also indicate the rearing success for fry or Sacramento River juveniles that enter Snodgrass Slough tidal habitat. Paired releases of CWT hatchery juveniles might be used to determine the relative success of fish released at Woodbridge Dam with and without the DCC connection (or above and below the Channel gate at New Hope) compared to the survival of CWT fish released at Sherman Island. Because of the established fish data collection under the JSA, the biological monitoring of the proposed project will be easier to implement and more likely to identify the improved juvenile Delta passage and increased adult homing (reduced straying) with the proposed project.

Table 3. Mokelumne River Hatchery Brood Year 2009 CWT Releases and Recoveries in Central Valley River and Ocean Catch (in 2011-2014)

A. Mokelumne River Brood Year 2009 CWT Releases and Recoveries

Release Location	CWT Code	Release Date	Total Released	Total Recovered	Mokelumne River	American River	Yuba River	Feather River	Sacramento River	Stanislaus River	Tuolumne River	Merced River	Ocean Catch	River Return %	Mokelumne Homing %
Sherman Island	68613	21-Apr	221,003	2,877	1,057	415	37	14	56	162	29	120	987	0.9%	56%
Sherman Island	68639	21-Apr	385,466	4,572	1,986	359	30	49	88	205	17	173	1,665	0.8%	68%
Sherman Island	68683	23-Apr	97,748	717	293	47	18	1	6	69	7	32	244	0.5%	62%
Sherman Island	68684	23-Apr	98,469	821	343	64	10	1	-	16	6	25	356	0.5%	74%
Sherman Island	68682	23-Apr	99,100	1,005	401	142	-	-	25	36	8	44	489	0.7%	61%
Sherman Island	68666	1-Jun	3,668	174	53	22	-	1	-	15	4	2	77	2.6%	55%
Sherman Island	68664	1-Jun	10,333	351	85	42	-	-	-	7	4	31	181	1.6%	50%
Sherman Island	68687	1-Jun	100,965	6,303	1,758	577	79	23	297	374	43	254	2,898	3.4%	52%
Sherman Island	68686	1-Jun	101,181	6,192	1,514	514	23	24	350	250	45	298	3,174	3.0%	50%
Sherman Island	68688	1-Jun	102,476	6,127	1,583	710	46	22	288	322	32	197	2,927	3.1%	49%
Sherman Island	68673	1-Jun	114,298	3,734	1,017	460	50	23	130	125	11	131	1,782	1.7%	52%
Sherman Island	68641	1-Jun	285,045	9,925	2,826	1,348	98	37	288	322	73	288	4,743	1.9%	54%
Sherman Island	68708	1-Jun	395,978	26,198	8,653	2,660	178	72	930	1,170	162	924	11,458	3.7%	59%
Hatchery	68689	7-Nov	99,048	1,424	896	20	-	16	-	12	-	-	480	1.0%	95%
Total			2,114,778	70,420	22,465	7,380	569	283	2,458	3,085	441	2,519	31,461	1.9%	57%

B. Mokelumne River Brood Year 2009 CWT Recoveries per 1,000 CWT

[10 = 1%]

Release Location	CWT code Code	Release Date	Total Released	Total Recovered	Mokelumne River	American River	Yuba River	Feather River	Sacramento River	Stanislaus River	Tuolumne River	Merced River	Ocean Catch	River Return
Sherman Island	68613	21-Apr	221,003	13.02	4.78	1.88	0.17	0.06	0.25	0.73	0.13	0.54	4.47	8.55
Sherman Island	68639	21-Apr	385,466	11.86	5.15	0.93	0.08	0.13	0.23	0.53	0.04	0.45	4.32	7.54
Sherman Island	68683	23-Apr	97,748	7.34	3.00	0.48	0.18	0.01	0.06	0.71	0.07	0.33	2.50	4.84
Sherman Island	68684	23-Apr	98,469	8.34	3.48	0.65	0.10	0.01	0.00	0.16	0.06	0.25	3.62	4.72
Sherman Island	68682	23-Apr	99,100	10.14	4.05	1.43	0.00	0.00	0.25	0.36	0.08	0.44	4.93	6.62
Sherman Island	68666	1-Jun	3,668	47.44	14.45	6.00	0.00	0.27	0.00	4.09	1.09	0.55	20.99	26.44
Sherman Island	68664	1-Jun	10,333	33.97	8.23	4.06	0.00	0.00	0.00	0.68	0.39	3.00	17.52	16.36
Sherman Island	68687	1-Jun	100,965	62.43	17.41	5.71	0.78	0.23	2.94	3.70	0.43	2.52	28.70	33.72
Sherman Island	68686	1-Jun	101,181	61.20	14.96	5.08	0.23	0.24	3.46	2.47	0.44	2.95	31.37	29.83
Sherman Island	68688	1-Jun	102,476	59.79	15.45	6.93	0.45	0.21	2.81	3.14	0.31	1.92	28.56	31.23
Sherman Island	68673	1-Jun	114,298	32.67	8.90	4.02	0.44	0.20	1.14	1.09	0.10	1.15	15.59	17.03
Sherman Island	68641	1-Jun	285,045	34.82	9.91	4.73	0.34	0.13	1.01	1.13	0.26	1.01	16.64	18.52
Sherman Island	68708	1-Jun	395,978	66.16	21.85	6.72	0.45	0.18	2.35	2.95	0.41	2.33	28.94	37.25
Hatchery	68689	7-Nov	99,048	14.38	9.05	0.20	0.00	0.16	0.00	0.12	0.00	0.00	4.85	9.53
Average				33.30	10.62	3.49	0.27	0.13	1.16	1.46	0.21	1.19	14.88	18.54