Resource Action: EWG-15A/B	**Task Force Recommendation Category: 2**

CHINOOK SALMON SPAWNING SEASON FLOW INCREASES TO REDUCE CHINOOK SALMON REDD SUPERIMPOSITION

Date of Field Evaluation: None, reformatting of previously delivered document

Evaluation Team: Allison Niggemyer, David Olson

Description of Potential Resource Action Measure:

Description of EWG-15A - Incrementally increase flows in the low flow channel from relatively low flows (for example, 400-600 cubic feet per second (cfs) or 600-800 cfs) to relatively high flows (for example, 800-1000 cfs or 1000-1200 cfs) throughout the Chinook salmon spawning season (for example, Sept 1 – Dec 1 or Sept 1 - Dec 15) in order change the lateral spawning habitat distribution from center of river channel during the early portion of the spawning season to margins of river channel in the later portion of the spawning season. Flows would be increased by some relatively consistent interval each week (for example, 25, 50, or 75 cfs/week) in order to increase usable spawning habitat and reduce superimposition of Chinook salmon redds. Once flows reach the high flow target, the high flow target would be maintained through May 30 in order to avoid dewatering Chinook salmon and steelhead redds through the incubation period for both species.

Description of EWG-15B - Increase flows in the low flow channel from relatively low flows (for example, 400-600 cfs or 600-800 cfs) during the early season spawning period to relatively high flows (for example, 800-1000 cfs or 1000-1200 cfs) for the period of the Chinook salmon spawning season after spring-run Chinook salmon are believed to have completed spawning. This flow change would be designed to be more beneficial to the early spawners (spring-run?) in order change the lateral spawning habitat distribution from center of river channel during the early portion of the spawning season to margins of river channel in the later portion of the spawning season. Flows would be increased one time in the spawning season. Once flows reach the high flow target, the high flow target would be maintained through May 30 in order to avoid dewatering Chinook salmon and steelhead redds through the incubation

Nexus to the Project:

The Oroville project influences flow regimes in the lower Feather River and controls releases that determine the quantity and quality of suitable salmonid spawning habitat**.**

Potential Environmental Benefits:

- Increased quantity of Chinook salmon spawning habitat;
- Increased quality of Chinook salmon spawning habitat;
- Reduced redd superimposition of Chinook salmon redds (EWB-15B would be more beneficial to early season spawners); and
- Decreased Chinook salmon egg mortality (EWB-15B would be more beneficial to early season spawners).

Potential Constraints:

Early spawning season flow releases would need to be sufficient to provide an adequate amount of suitable spawning area to support early season spawners and well as provide for suitable water temperatures for spawning. High flow targets to achieve lateral distribution changes in spawning habitat distributions may require substantial releases of water that may adversely affect water supply and power generation. The sustained high flows at the end of Chinook spawning could potentially adversely affect steelhead spawning and juvenile salmonid rearing habitat quality and quantity.

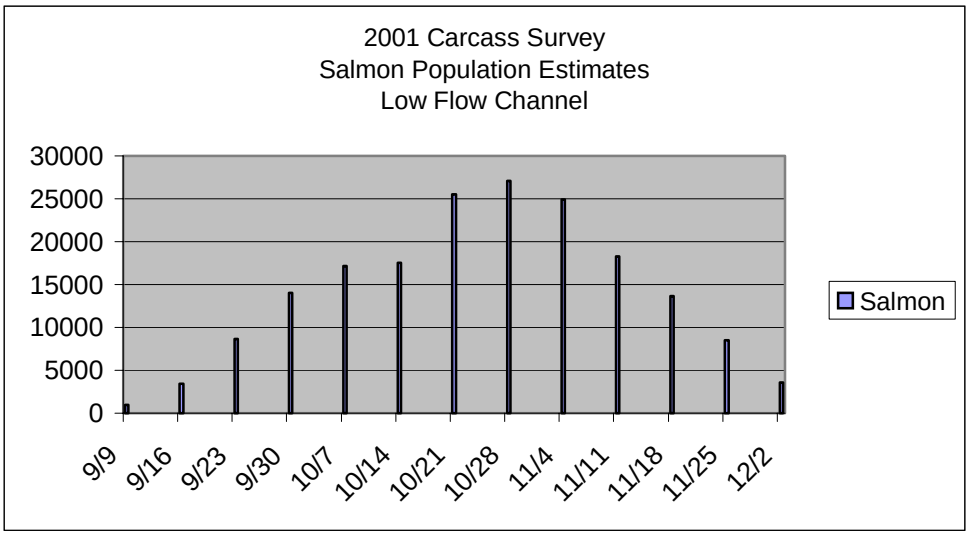
Existing Conditions in the Proposed Resource Action Implementation Area:

The low flow channel is heavily utilized by spawning adult Chinook salmon. Of the Chinook salmon spawning that occurs between the Fish Barrier Dam and Honcut Creek, approximately one-third occurs in the High Flow Channel, while approximately two-thirds occur in the Low Flow Channel. (DWR, Initial Information Package for Oroville Facilities Relicensing – P-2100) The intensive utilization of spawning habitat in the Low Flow Channel by adult Chinook salmon spawners results in redd superimposition, and is sufficiently intensive to prevent identification of individual redds in much of this reach of the Feather River. Historical study results suggest that superimposition reduces egg survival. Egg survival is thought to be reduced in the Low Flow Channel as a result of redd superimposition.

A superimposition index was calculated for the low flow channel and high flow channel in 1995. In 1995, CDFG estimated the number of adult Chinook salmon spawners in the low flow channel at 44,111 and in the high flow channel at 15,572. In 1995, the total spawning area was estimated in the low flow channel was estimated at 773,732 square feet and in the high flow channel, the total spawning area was estimated at 915,289 square feet. Using Bell's estimate of 55 square feet for the surface area of an average sized Chinook salmon redd, the superimposition index can be calculated using the following formula: superimposition index = [(escapement * 0.5) * 55ft^2]/ total spawning area. For 1995, the calculated superimposition index was 1.57 in the low flow channel and 0.47 in the high flow channel. As a result, the focus of this proposed resource action is to increase the quantity of spawning habitat by altering later spawning habitat distribution in the low flow channel only.

Chinook salmon spawning occurs in the Low Flow Channel from September – December, see Figure 1 below. The graph shows the temporal distribution of spawning from DWR's ongoing annual carcass survey. The number of spawning Chinook salmon is not evenly temporally distributed, with peak spawning activity occurring in approximately mid-October through mid-November.

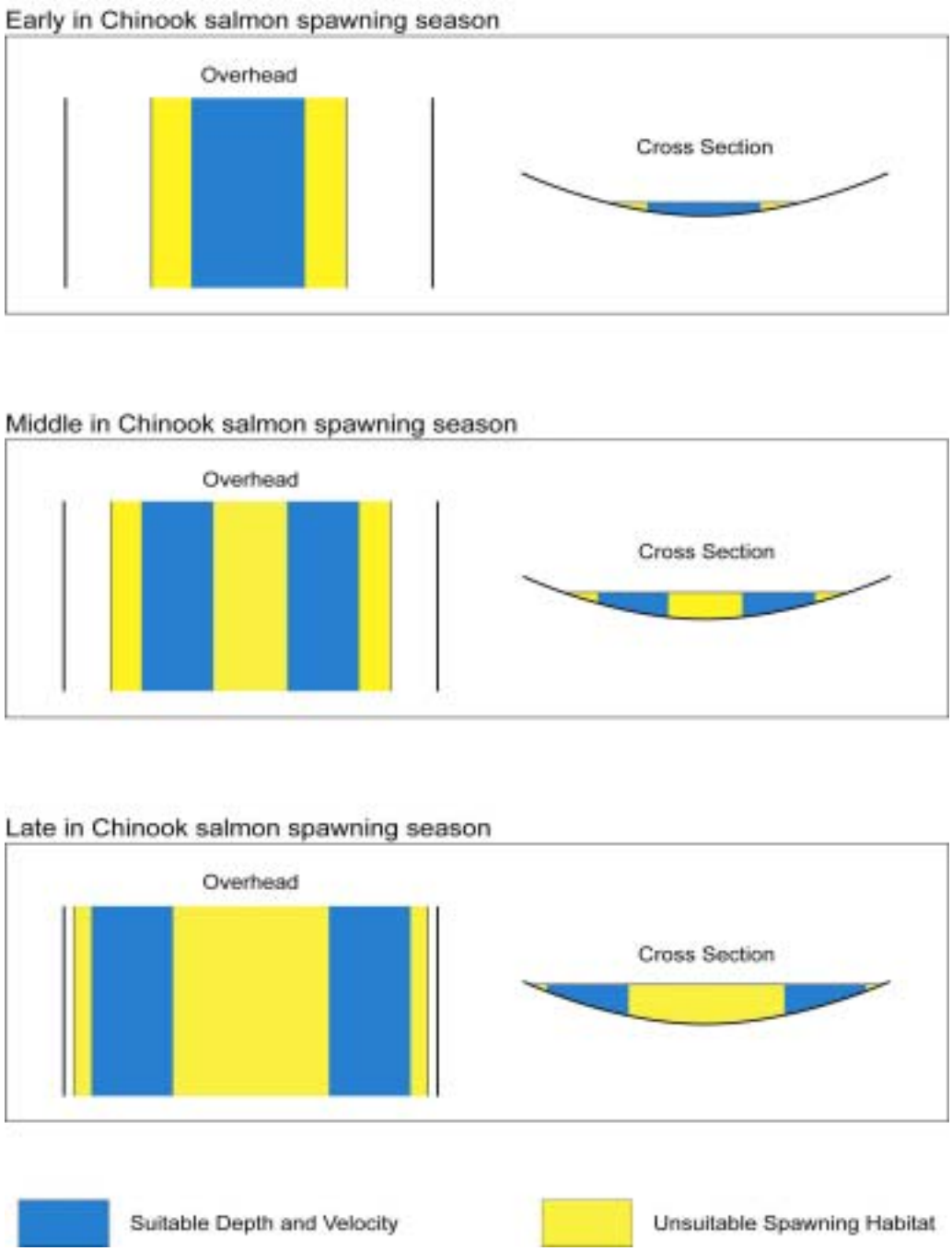
Figure 1: 2001 Carcass Survey Salmon Population Estimates - Low Flow Channel



Design Considerations and Evaluation:

Description of EWG-15A - Low flows (for example, 400-600 cfs or 600-800 cfs) during early part of the spawning season would require early Chinook salmon spawners to utilize the center portion of the river for spawning habitat. Increasing flows (for example, to 800-1000 cfs or 1000-1200 cfs) incrementally over the spawning season by some relatively consistent interval each week (for example, by 25, 50, or 75 cfs/week) in the later portions of the spawning season would encourage later spawners to utilize suitable spawning habitat on the margins of the river. Altering the location of the margin of the river within the river channel over the course of the spawning season may alter the lateral distribution of spawning over the season, resulting in decreased redd superimposition.

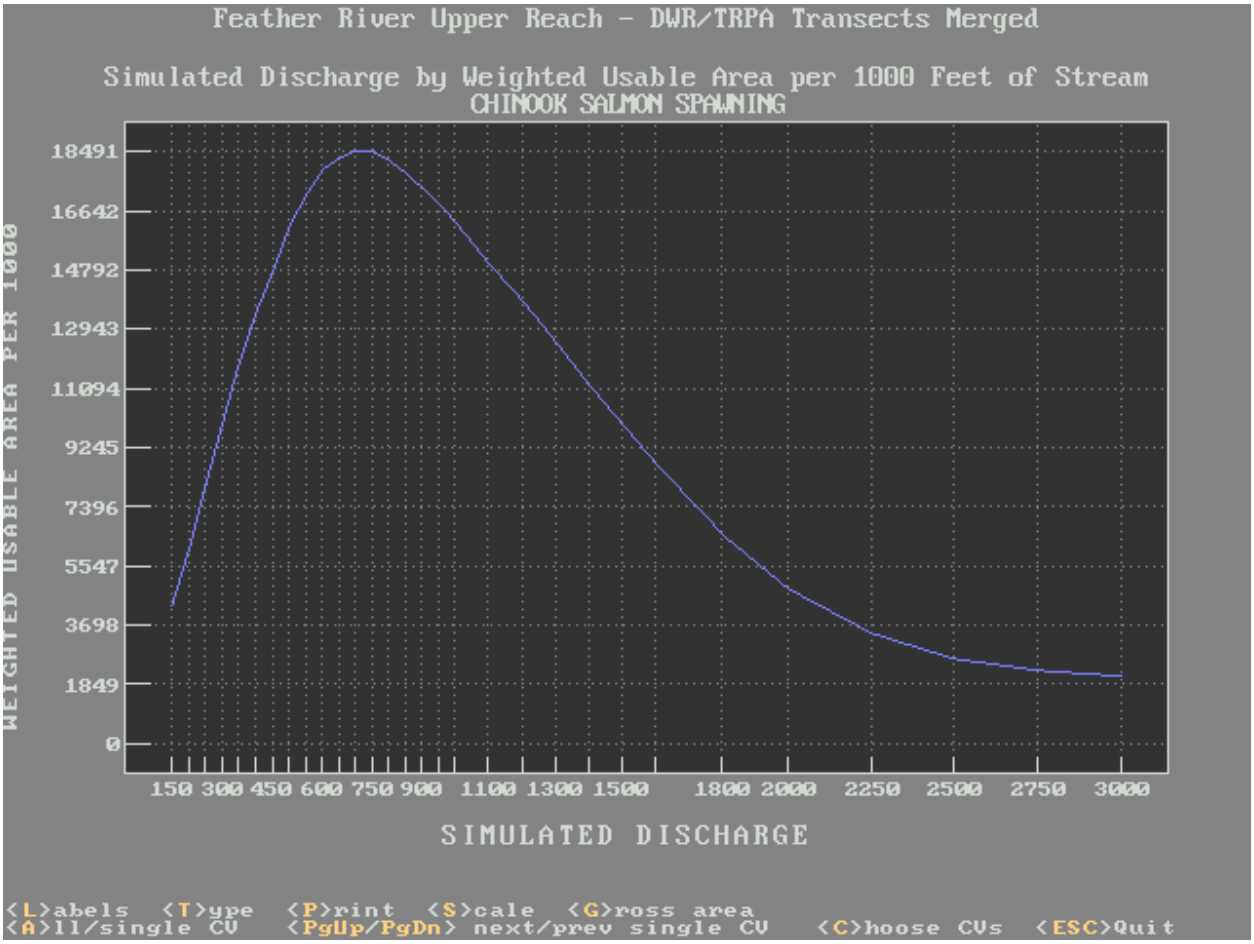
Figure 2: Conceptual Representation of Spawning Habitat



Any proposed flow regime that manipulates the amount of spawning habitat should take into account the number and temporal distribution of Chinook salmon spawners and the amount of habitat required for spawning at any given time throughout the spawning season. The peak of spawning activity in the Low Flow Channel occurs in approximately mid-October through mid-November and represents the portion of the spawning season with the highest amount of competition for spawning habitat. The proposed flow regime should incorporate the objective to provide the maximum amount of suitable habitat at the peak of spawning activity.

The PHABSIM (physical habitat simulation) model produced as part of Phase 2 of Study Plan, SP-F16 is an appropriate tool to evaluate some of the essential questions regarding whether the proposed flow prescription will likely result in successful manipulation of the lateral distribution of spawning habitat in the low flow channel. These questions include: 1) would low flow targets provide adequate spawning habitat for early spawners; 2) how much spawning habitat would be created (and lost due to water velocity spawning habitat constraints) for each increment of flow increase; 3) how much total spawning habitat would be created by implementing the proposed flow regime; 4) would the proposed flow manipulation result in changes to the lateral distribution of spawning habitat; and 5) if PHABSIM output is used to estimate the changes in lateral spawning distribution as a result of the proposed flow changes, do calculations of the redd superimposition index using the model output suggest that the proposed change in flows would reduce overall superimposition of Chinook salmon redds?

Figure 3: Preliminary SP-F16 Phase 2 Results - Low Flow Channel Chinook Salmon Spawning Weighted Usable Area Index



Although the specific analyses of the PHABSIM output on the response of Chinook salmon spawning habitat lateral distribution have not been conducted, the preliminary draft of the Chinook salmon spawning habitat weighted usable area are available, see Figure 3 above.

The range of appropriate low and high flows for developing this flow prescription should also take into account the projected quantity and quality of resulting spawning habitat at those flows. The PHABSIM output should be able to aid in determining logical low flow targets for consideration in this flow prescription by illustrating the habitat availability over a range of flows. The PHABSIM provides an index of the amount of available habitat. An analysis of the actual amount of habitat required to support the early season spawners as well as consideration of potential temperature impacts of low flows early in the spawning season, would need to be evaluated before a definitive flow target could be recommended. The model also could provide velocity information for higher flows to determine the upper range of velocities to consider. This upper range should not be so high that it would scour spawning riffles, yet should be high enough to result in less

favorable conditions for Chinook salmon spawning in the middle of the channel, where redds were constructed during lower flows. Spawning depth and lateral redd distribution could be monitored as part of the adaptive management program to determine the success of manipulating the lateral distribution of spawning habitat and fish behavioral responses to the conditions created.

Another design consideration would be the potential effect of the late spawning season/sustained flow targets on the quality and quantity of steelhead spawning habitat. As demonstrated by the Chinook salmon spawning WUA graph in Figure 3, the amount of habitat can be reduced at higher flows. Any flow recommendation for this Resource Action would also need to evaluate if the prescribed flows provided an adequate amount of steelhead spawning habitat. A WUA for steelhead is not currently available and it has not been investigated yet if one could be generated from existing information (there may not be an adequate number of steelhead spawning observations available). The number of steelhead spawners in the Feather River is not currently known or documented. Relicensing study plan results are not expected to provide quantitative documentation of the number of steelhead spawners.

Other critical evaluation components for the development of the flow prescription include: modeling temperature impacts of flows below current flow regime on downstream water temperatures during the early portion of the Chinook salmon spawning season. The ability to comply with the water temperature requirement of 65°F at Robinson Riffle may be affected if flows lower than 600 cfs are chosen as the low flow requirement early in the spawning season. This potential impact could be modeled by the E&O water temperature model (WQRRS). If lower flows would result in difficulty complying with the Robinson Riffle water temperature requirement, this could potentially be resolved by utilizing colder water releases from Lake Oroville. Hatchery water temperature constraints may limit the ability to use colder water from Oroville reservoir as September 1 – 30 water temperatures may currently be no colder than 48°F and October 1 – November 30 water temperatures are required to be no colder than 47°F per the DFG 1983 operating agreement. If the hatchery water temperature requirements constrain the ability to achieve water temperature compliance requirements at Robinson Riffle at lower flows during the early portion of the Chinook salmon spawning season, the hatchery could potentially be provided with a separate water supply. A separate hatchery water supply proposed Resource Action would require its own set of investigations.

<u>EWG-15A Comparison</u> to EWG-15B Design Considerations - Evaluating the EWG-15A proposed Resource Action will require comparison against EWG-15B, a PM&E with a similar mechanism and framework, but slightly different overall resource goals. EWG-15B suggests providing a low flow for the first part of the Chinook salmon season and maintaining that low flow until spring-run Chinook salmon spawning is believed to be complete. Then, flows would be increased to the target high flow range. While EWG-15A also utilizes flow increase to alter the lateral distribution of spawning, it suggests weekly incremental flow increases throughout the Chinook salmon spawning season in

order to achieve the same high flow target as EWG-15B by the end of the spawning season.

The strategy proposed in EWG-15B is simpler operationally, but relies upon a higher degree of confidence regarding the temporal distribution of the spring-run Chinook salmon spawners, which may be variable from year to year. Additionally, EWG-15B is designed specifically to benefit spring-run Chinook salmon to the extent possible. The strategy proposed in EWG-15A would be slightly more operationally complex to execute, but would reduce potential water temperature compliance issues and would not be susceptible to the variability in run timing. However, EWG-15A is designed to benefit all Chinook salmon spawners equally from the change in lateral spawning distribution, including those Chinook salmon spawning at the middle and end of the spawning period. Any proposed flow prescription designed to achieve this resource objective should be treated as an adaptive management program that would be managed and improved based on monitoring and continued evaluations.

Synergisms and Conflicts:
Sustained high flows through May could potentially benefit programs for increased flows or pulsed attraction flows during this part of the year. Species that could potentially benefit from these increased flows could include Sacramento splittail, sturgeon and spring-run Chinook.

Potential conflicts may include adverse impacts to the quantity and quality of steelhead spawning and salmonid rearing habitat. Additionally, meeting temperature control requirements at Robbinson Riffle may not be possible in reduced early season spawning flows. The sustained high flows will cause power generation opportunity costs.

Uncertainties:

- Probably the greatest uncertainty with this measure is in the ability to manipulate flows to a degree that consistently accomplishes the desired biological response in the fish's preferences for spawning habitat sufficient to achieve movement in the lateral distribution of suitable spawning in the channel.
- Biological response of the fish may be based on a combination of factors in which flows, depths and velocities manipulated in these flow prescriptions are only a part of their basis. Water year type, year class strength and condition factors along with other factors not yet identified will likely require the flow management prescriptions and timing for the program to be adaptive based on annual conditions and monitoring program feedback.
- EWG-15B's program management and success are more susceptible to interannual variations in the temporal distribution of the runs.

Cost Estimate:
If the proposed action were to be evaluated for flows of 400 cfs ramping to a 1000 cfs flow from September 1 – May 30 (protective of steelhead incubation), this action would require a net increase of approximately 160,000 acre feet released through the low flow channel over the current flow regime which would have an annual power generation opportunity cost of approximately $450,000 based on average power production assumptions.

Recommendations:
This proposed Resource Action may improve the potential impacts from (although not quantified in its severity or relative importance to the species' success) superimposition of Chinook salmon redds associated with intensive utilization of spawning habitat in the low flow channel. Further information detailing the likely response of adult spawners to flow changes (primarily from SP-F16) would be needed to aid in determining the low and high flow targets before a definitive flow management prescription could be developed. An adaptive management approach to any flow prescription is recommended in combination with a redd distribution monitoring program to characterize the fish spawning habitat utilization in response to flow changes.

If this Resource Action is to be further developed, additional information anticipated that would be required to develop a recommended flow prescription for an adaptive management program would include: 1) Arial extent of total spawning area delineated from aerial photographs - SP-G2, 2) WUA: for spawning Chinook salmon (and steelhead?) - SP-F16: October 2003; 3) redd superimposition index calculation - SP-F10 Task 2B: Jan 2004, 4) carcass survey data: SP-F10 Task 2B: final report Jan 2004.

The Fisheries Task Force recommendation - Category 2 Waiting (SP-F16 PHABSIM model results)

Resource Action: EWG-13A and 20	**Task Force Recommendation Category: 1**

Proposed Large Woody Debris Placement in the Low Flow Channel and the Lower Feather River

Date of Field Evaluation: April 28, 2003

Evaluation Team: Richard Harris, Carin Loy, David Olson, Koll Buer, and Bruce Ross. Review and comments by Rich DeHaven and Tom Boullion.

Description of Potential Resource Action:
This Resource Action consists of a proposal to place large woody debris (LWD) in the Feather River. The intention is to improve rearing habitat for anadromous fish, improve geomorphic processes and enhance opportunities for recruitment of riparian vegetation.

There are several other resource actions that are either similar to or otherwise related to this measure:

- EWG-13B, proposed to improve rearing habitat in the low flow reach through placement of wood and other materials.
- EWG-16A and EWG-16B, proposing creation of side channel habitat in the low flow reach.
- EWG-17 and EWG-51, that would enhance riparian vegetation to increase shading and habitat complexity.
- EWG-89, that would involve levee setbacks and increase floodplain accessibility to the river.
- EWG-19A and EWG-22, proposing levee setbacks and/or geomorphic restoration in the lower Feather River to improve connectivity between the river and its floodplain.

Nexus to the Project:
Lake Oroville effectively prevents recruitment of LWD from the upstream reaches of the Feather River and its tributaries to the low flow channel, the lower Feather River, and ultimately, to the Sacramento River Delta. Existing sources of LWD are the riparian zone along the river and incidental inputs from orchards. The primary recruitment mechanisms are bank erosion and disposal of wood by landowners adjacent to the river. The amount of LWD generated from these sources is probably less than would have been recruited prior to construction of Lake Oroville. It is also different in quality since coniferous LWD would have been transported to the lower river from the upper watershed. As a result of the blockage of LWD by the dam, LWD may be limited in abundance and size in the river in at least some locations. Inputs of LWD to the Sacramento River and Delta have probably also been reduced. However, this is not solely due to the dam but is also affected by the flow regime, channel geomorphology and the constraints they exert on downstream transport of LWD from the Feather River.

Potential Environmental Benefits:
LWD contributes to a variety of geomorphic and ecological functions in rivers and streams. For example, woody debris can enhance the complexity of rearing habitat and redirect stream flow to create scour pools that serve as holding habitat for anadromous fishes. LWD can store and organize sediment into geomorphic surfaces where riparian vegetation recruitment can occur. Decaying LWD provides a source of instream nutrients for aquatic organisms. Generally, the influence of LWD on stream geomorphology and ecology varies with stream size (Lassettre and Harris. 2001). On larger streams such as the Feather River the effects of LWD on geomorphic process may be somewhat limited as compared to its effects on smaller streams, but it still performs important ecological functions. Most LWD in larger streams is found on floodplain surfaces and at the periphery of the channel. Individual pieces or aggregations of LWD (i.e., debris jams) are less frequently found in mid-channel locations. Stream scale precludes individual pieces or jams from spanning larger streams. On larger streams LWD can provide shelter for salmonids, especially along banks, and when associated with secondary channels, it can help create rearing habitat.

Potential Constraints:
There are two major constraints that will affect this measure. First, the regulated flow regime and lack of sediment sources will reduce the effectiveness of LWD in shaping and creating habitats. Second, there may be some objections to placement of LWD based on impairment of navigability and potential unforeseen effects on channel behavior (i.e., potential for increasing bank erosion).

In the event that it is desirable to use coniferous LWD for restoration and enhancement, a third constraint on placing wood in the lower Feather River is that sources of coniferous LWD may be limited or at some distance from placement sites.

Comments on a draft of this report pointed out the benefits of placing LWD and other materials on rip-rapped banks or in conjunction with new rip-rap projects. This has been done for new rip-rap projects on the American and Sacramento Rivers. There are no known constraints to doing this on the Feather River.

Existing Conditions in the Proposed Resource Action Implementation Area:

Low Flow Channel: The low flow channel of the Feather River is a regulated stream reach. Flows are nearly always about 600 cubic feet per second (cfs), except when peak runoff events require flood control releases from Lake Oroville. During those events, flows may exceed 100,000 cfs for sustained periods. Flows of this magnitude occurred in 1965, 1986 and 1997.

The low flow channel is generally confined between levees. There are some mid-channel bars, lateral bars and islands which are stable within the current flow regime. The slope gradient in the low flow channel ranges from 0.06% to 0.2%. Flow widths

vary from 200-500 feet at normal regulated flows of 600 cfs to 2,500 feet at flood control flows of up to 100,000 cfs. Water velocities range from 1 to 4 feet per second (fps) at 600 cfs to approximately 12 fps at 100,000 cfs.

Riparian vegetation along the low flow channel generally consists of a gallery of mature cottonwoods along the banks and a variety of native and exotic trees, shrubs and herbaceous species both on banks and on islands. Openings available for natural regeneration of riparian species are limited and competition from exotics is extreme. Most existing openings have coarse textured (cobble) substrate, which is unsuitable for regeneration of most native riparian species.

Due to the riparian vegetation composition and distribution, potential on-site LWD contributions to the low flow channel are very limited. The only recruitment mechanism is bank erosion and this is not a major process in the low flow channel.

There is very little formal bank protection in the low flow channel reach. Existing rip-rap is generally confined to protection for highway bridges.

Surveys of LWD in the low flow channel have recently been completed but the data are not yet available. They will show LWD amounts by position (bank, mid-channel, side channel, and backwater) for the low flow channel. Initial impressions indicate that LWD loading in the low flow reach is lower than the loading in the lower Feather River. Also, piece size tends to be smaller in the low flow reach. As a result, there is relatively limited diversity of instream habitat contributed by LWD. The geomorphology of the low flow reach suggests that additions of LWD could have significant benefits.

Upstream sediment delivery to the low flow reach is also blocked by Oroville facilities. No active sediment recruitment or bench formation is presently occurring in the low flow reach. The only source of sediment is bank erosion, which is limited. This is a very minor source in comparison to the amount of sediment trapped by the dam.

The low flow channel is an intensively utilized spawning area for anadromous salmonids. Juvenile salmonid rearing habitat quality and quantity could potentially be improved though increased medium to high complexity LWD availability.

Lower Feather River (below Thermalito): Streamflow in the lower Feather River is mainly determined by releases from Lake Oroville and Thermalito to downstream water users and by inflow from major tributaries (Bear and Yuba Rivers). The streamflow regime is markedly different than a natural streamflow regime. Mean annual streamflow as recorded at gages at Oroville, Gridley, Yuba City and Nicolaus ranges from 4,800 cfs to 8,100 cfs. During the summer months, impaired flow is usually considerably higher than unimpaired flow. Mean monthly impaired flows are less than unimpaired mean monthly natural flows mainly during the late fall to late spring when the reservoir is filling.

Peak flows as recorded near Gridley were in excess of 150,000 cfs in 1965, 1986 and 1997. Under these conditions overbank flooding is widespread. Lesser, but still significant floods have occurred in 12 of the last 42 years based on the Gridley gage.

The lower Feather River is also constrained by levees but in some locations, these are located at some distance from the channel. There are several areas where substantial riparian vegetation and/or orchards exist within levee boundaries. These are locations from which LWD is recruited into the stream from natural erosional processes or intentional placement by orchard operators.

The regulation of moderately-sized peak flows in the lower Feather River may affect natural recruitment of LWD from bank erosion. However, this does not seem to be reflected in LWD inventory data for the lower Feather River (see below). Data on bank erosion will be forthcoming from SP-G2. Observations in the field indicated several instances of LWD recruitment from both riparian vegetation and orchards in areas of bank erosion.

Bank protection in the lower Feather River has been evaluated under SP-G2. Above Yuba City, the most extensive area of rip-rap is located at Gridley (4,000-5,000 feet of stream bank). It presently protects the Gridley Bridge and other structures from bank erosion. Rip-rap is also located at Sunset Pumps. In some locations, presence of rip-rap is difficult to observe because of sediment deposition and vegetation. Below Yuba City, approximately 15 percent of the river bank is rip-rapped on both sides of the stream. Rip-rapped banks represent areas where LWD placement could enhance shelter and rearing habitat for salmonids.

The channel below Thermalito is highly variable in its geomorphology. It is about 59 river miles from Thermalito to the Sacramento confluence. The entire length is classed as Rosgen stream type F, entrenched. Substrate becomes increasingly finer downstream and is mostly sand from River Mile (RM) 39 down to RM 0 at the Sacramento River confluence. Reach sinuousity varies from low (straight channel) to high (at RM 34-35). The effects of levees, as well as resistant geologic formations (e.g., Modesto Formation – lenticular silt and clay lenses) are to reduce overbank flooding and meandering. The lower Feather is deeply incised into hydraulic mining debris (10-25 feet), which further disconnects it from its floodplain.

There are some locations where there is a relatively high diversity of instream geomorphic surfaces. For example, between RM 39-54 there are multiple islands, bars and side channels. These areas of topographic diversity represent places where existing or supplemental LWD could be particularly valuable for enhancement of fish habitat.

Under SP-G2 the occurrence of LWD in the lower Feather River has been mapped. Pieces larger than three inches diameter and three feet long were counted. Most pieces were twice that size. Larger pieces were up to 48 inches in diameter and 100 feet long.

The smaller pieces were in log and debris jams. Although the data are somewhat incomplete, the preliminary results are available. Attachment 1 shows the distribution of LWD pieces by channel position. Over 75 percent of the counted pieces between RM 0 and RM 59 were located on either the right or left bank. The small amount of wood associated with backwater or secondary channels is a reflection of the rarity of those geomorphic conditions in the lower Feather River. Where secondary channels or backwater exists, the amount of LWD is relatively high (see Attachment 3). Attachment 2 shows the number of LWD pieces recorded by river mile. Although the values are highly variable, there is an increased abundance of wood in the section of the river where sinuousity and geomorphic diversity are relatively high. Most of the wood observed was either cottonwood or orchard trees, with some oaks. Recruitment was from the outsides of meander bends or from straight sections of stream. The primary recruitment mechanism is bank erosion although some orchard trees have been intentionally placed in the river (i.e., dumping). LWD appears to have a long residence time in the lower Feather River, probably because of the controlled flow conditions.

As a further illustration of conditions in the lower Feather River, Attachment 3 is a map of LWD occurrence between RM 45 and RM 43. The accumulations at the entrance and exit to the backwater channel below RM 45 are notable. In this type of location on large rivers LWD can play an important role in providing shelter for fish during high flows. Between RM 44 and 43 (Attachment 3) where the stream is straight, most LWD is positioned at the banks. In that type of location LWD can reduce bank erosion and provide valuable rearing habitat and shelter for fish.

At flows in excess of 5,000 cfs most of the LWD in the lower Feather River is submerged and not visible. Consequently, the LWD survey underestimated the true loading. Follow-up field studies indicated that up to 50 percent of the LWD present might not be visible during higher flows. Even at lower flows, partially submerged near-bank and fully submerged mid-channel LWD is not visible.

Design Considerations and Evaluation:
In a river the size of the Feather, LWD placements would need to be strategically located if they are to have effective and sustainable results. Inventory information on LWD occurrence can be used to determine where wood has accumulated or persisted under the regulated flow regime. These locations tend to have high geomorphic diversity and high sinuosity. They would be candidates for enhancement with additional LWD, assuming that field evaluations indicated the potential for creating benefits with additional wood. The other sites that should be considered for LWD placement would include barren, rip-rapped banks. These areas provide little or no cover for fishes and may be in need of geomorphic function restoration as well.

To approach planning an LWD placement project for the Feather River the first step would be to identify suitable locations. The next step would be to examine the existing inventory data at those locations to determine if LWD is clearly deficient. The sites that are suitable and deficient should have the highest priority for treatment. It would be best

to coordinate the selection of sites for LWD placement with other Resource Actions that seek to improve fisheries habitat.

Most LWD placement projects have been done in small to medium-sized streams, especially on the north coast of California. LWD placement has been done on the American and Sacramento Rivers in conjunction with bank protection projects. This has improved the habitat values of what would otherwise be barren, rip-rapped banks. In other larger rivers, such as the South Fork of the Eel River, LWD placement has involved logs extending from banks into the channel for creating local scour pool habitat or shelter.

For LWD structures to perform to their maximum potential, variable flows and sediment should be available. Wood works with variable flows and sediment to create habitats. For example, scour pools are created by the acceleration of flows during floods immediately downstream from a log structure. Neither variable flows nor abundant sediment are available in the Feather River under current management. Nevertheless, even in the absence of either variable flows or appropriately sized sediment, wood placement will create favorable habitat conditions for fish and other organisms (i.e., additional instream shelter). Many additional benefits could be achieved by coordinating planning for LWD placement with other measures proposing alternative flow management, creation of side channel habitats and replenishment of spawning gravels. For example, LWD placed at upstream riffle crests can be used to help retain supplemental gravels.

Generally, the size of logs used in a placement project should correspond to the size of the stream. Spanning LWD structures must be longer than the bankful width and at least 50 percent of the bankful depth in diameter. Using spanning LWD structures in the Feather River is not feasible given its width and the depth. Any placements on the Feather River, regardless of location, should be done with the largest material available, preferably with attached rootwads.

As a rule, LWD placements are usually done as single logs, groups of logs or combinations of logs and boulders that are commonly anchored or cabled together (Flosi et al. 1998). Anchoring would probably be required for any placement projects in the Feather River that are intended to provide site-specific benefits (e.g., enhancement of fish habitat on rip-rapped banks or enhancement of side channel habitat). Wood may be anchored at banks with cable or between natural or artificially placed rock. Logs are sometimes buried in banks as well to increase their stability. In side channels and backwater areas, clusters of logs and boulders joined together with cable would probably be the most stable structures.

Consideration could also be given to use of unanchored wood that would be redistributed by streamflow. However, use of unanchored wood might be less acceptable due to potential effects on navigability and public safety. One argument in favor of unanchored wood is that it would be redistributed throughout the system during

peak flow events and end up at natural accumulation sites. However, transportation of LWD beyond the Feather River to the Sacramento River and Delta would still be obstructed by channel geomorphology and sediment deposits (e.g., sand bars near the confluence.

Some of the most promising opportunities for LWD placement are in backwater and side channel areas away from the thalweg. Mesohabitat maps of side channel and backwater habitats are currently available from SP-G2. Medium to high complexity LWD placements in these areas may enhance juvenile salmonid rearing habitat diversity and quality for the life of the placement (until the next high flow event) or until the break down of the material into lower complexity LWD. Existing inventory information indicates that many of these backwater and side channels already have high levels of LWD (see Attachments 1 and 3). There is also the potential that these backwater LWD placements would become refuges for predators of juvenile salmonids.

Under the current regulated flow regime, LWD placements will provide some level of benefits until the next peak flow event. When that occurs, the magnitude of flooding will redistribute both naturally recruited and placed LWD. This redistribution process should not be considered a design problem but rather an opportunity for the river to define itself. In the event that LWD moves out of the Feather River during extreme flow events it would provide benefits downstream, perhaps as far as the Delta.

There would be permitting requirements for LWD placements. These would include, at the minimum, 1601-1603 Streambed Alteration Agreements from the Department of Fish and Game, a 401 Certification from the State or Regional Water Quality Control Board and a 404 Permit from the US Army Corps of Engineers.

The way to evaluate the effectiveness of LWD placements is to: 1) monitor the placement itself and the habitats it creates; and 2) to monitor fish use of LWD structures and associated habitats. The latter, termed “validation monitoring” has recently gained wide recognition amongst fisheries biologists as the true test of restoration project effectiveness (Botkin et al. 2000). If unanchored wood is used, its movement through the system can be monitored with radiotelemetry.

Synergism and Conflicts:
LWD placement could create conflicts with land users adjacent to the channel if bank erosion is inadvertently increased due to flow deflection. There could be additional public safety concerns due to impaired navigability.

If LWD placements are coordinated with other measures for habitat improvement (e.g., gravel placement, side channel habitat creation) and flow management, there could be synergistic results. Conversely, implementing any of these actions independently of the others could cause conflicts.

Uncertainties:
There are uncertainties related to the experimental nature of LWD placements, in general. There are also uncertainties related to potential adverse effects on other resources. Some concern has been expressed regarding creation of habitat for predators of anadromous fish. Many uncertainties can be avoided by confining LWD placements to those locations where it can be reasonably expected to remain in place at least until the next extreme flood event. Monitoring of placement projects and their use by fish would also be advisable.

Cost Estimate:
The costs for implementing LWD placements vary tremendously. Costs are incurred due to equipment needs, construction materials, and for the wood itself (unless it is freely available). There are some potential sources of LWD, such as corralled LWD at Lake Oroville and flood bypasses. Lands adjacent to the river that are in agricultural uses represent a source of discarded orchard trees. Recent fires in the river corridor have also created sources of wood that could be exploited. The costs for moving this material to placement sites will be proportional to the distance involved. There could also be relatively high costs for gaining access to the river from the adjacent banks for heavy equipment. The third major expense would be for materials used to anchor or otherwise secure wood placements. In general, LWD placement would be less expensive than more intensive habitat creation proposals (e.g., creation of benches and side channels, levee setbacks, etc.). However, each such placement project will probably range in cost from $10,000 to $100,000, depending on its size, complexity and location.

Recommendations:
There are sufficient data available to do further evaluation of this measure. Existing geomorphic mapping, bank condition mapping and reach classification provide data on potential sites for LWD placement to enhance resource values. An inventory of LWD occurrence has been completed and the data from that study will be available by December 15, 2003. . Those two pieces of information can be used to develop at least a preliminary list of sites where LWD may be deficient in the system. From there, more site specific evaluations should be conducted. Site specific considerations include:

- Potential benefits (e.g., improved fish shelter)
- Potential impacts (e.g., bank erosion, impaired navigation, etc.)
- Potential stability of placement
- Costs and logistics (e.g., LWD supply)

Any site specific evaluation should be coordinated with the planning for other Resource Actions in the Feather River. For example, use of wood in conjunction with the creation of side channel habitat (EWG 16A), riparian enhancement measures (EWG-17 and EWG-51), and sediment recruitment/enhancement (EWG-18, EWG-92) should be considered.

If additional measures such as an altered flow regime or geomorphic restoration are ultimately approved for the Feather River, the role of LWD placements should be carefully evaluated. LWD placements may complement these measures or be rendered ineffective by them.

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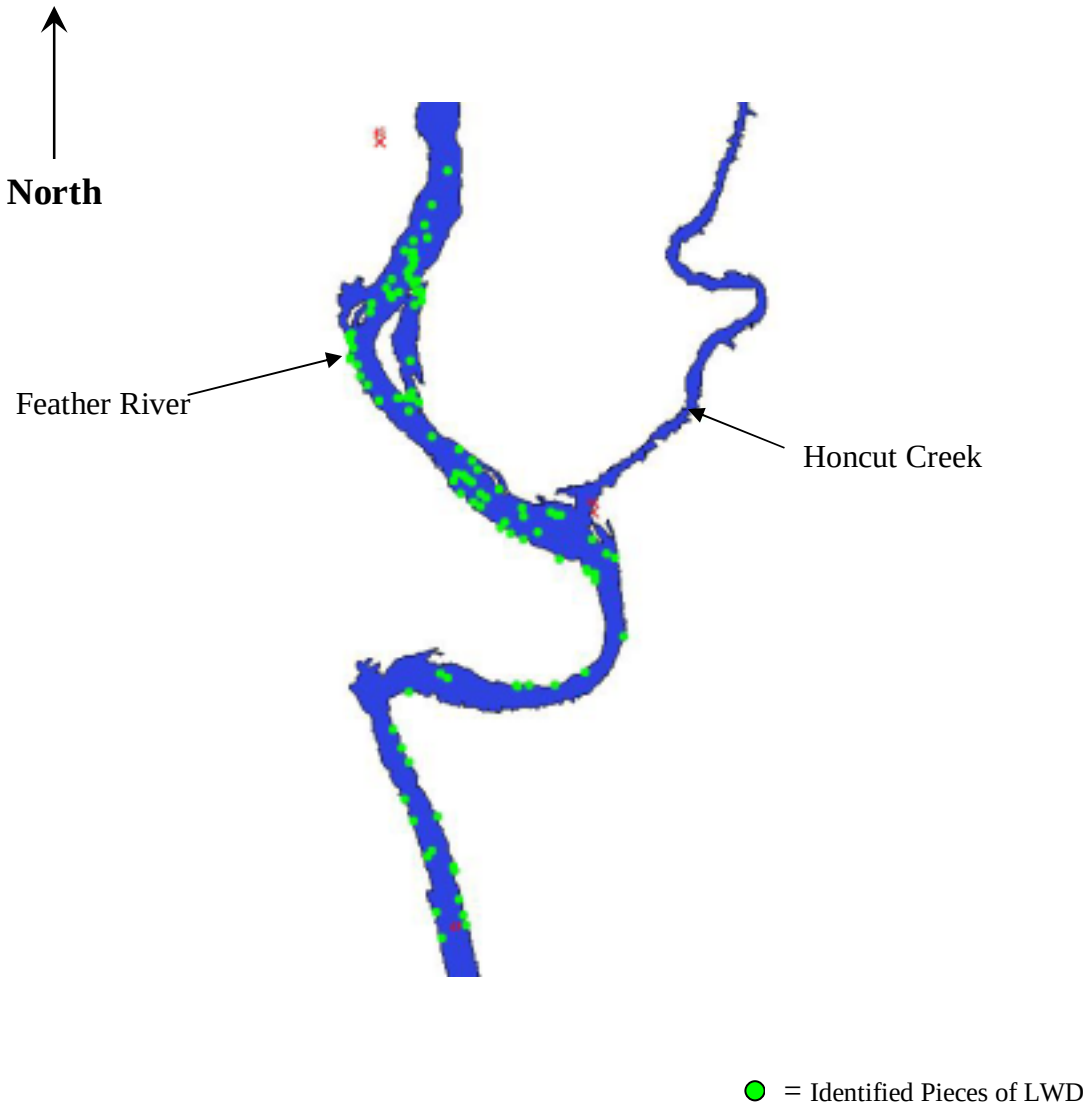
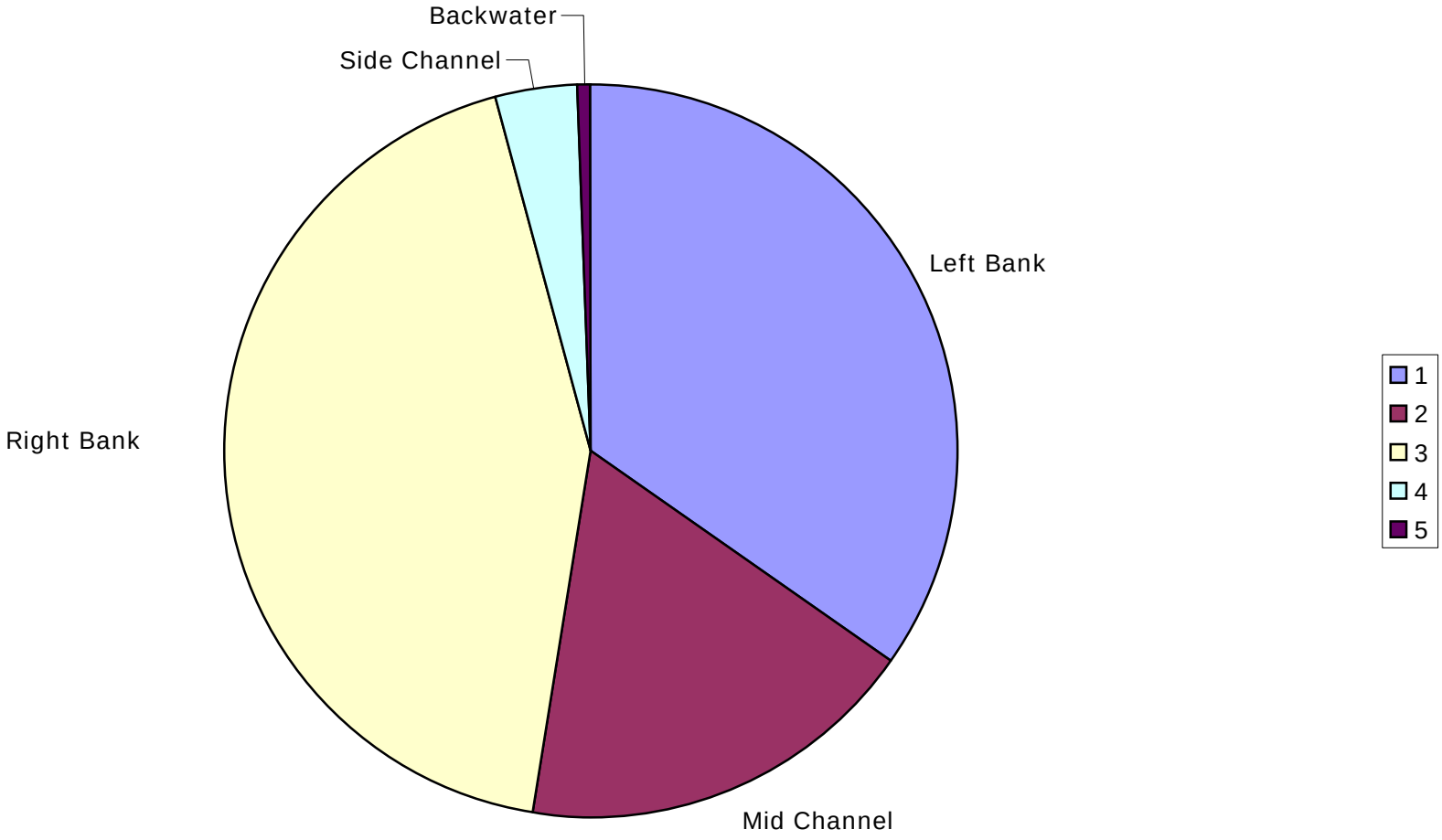
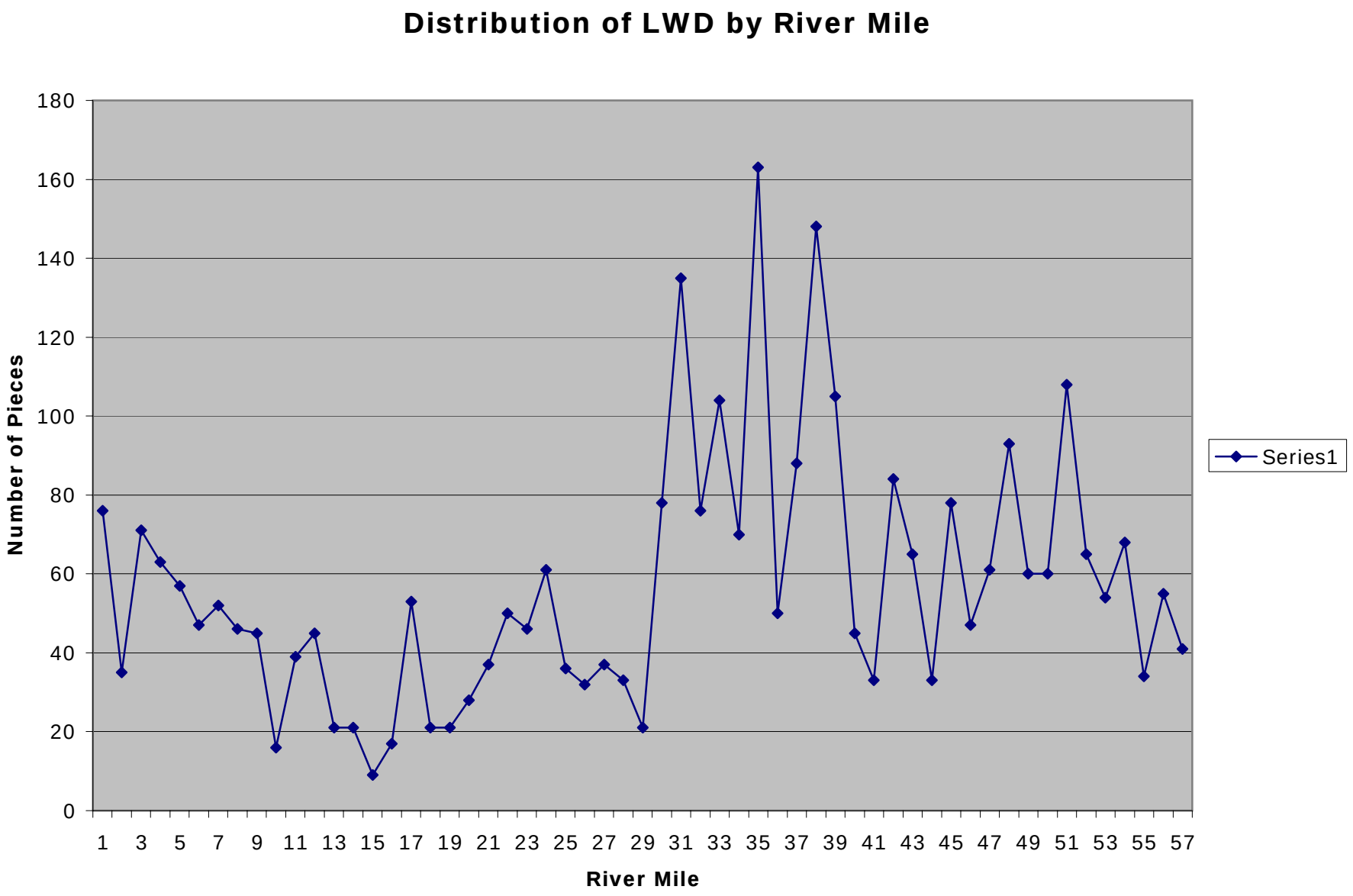


Figure 1. Distribution of LWD in the Lower Feather River (River Mile 43 to 45)

Distribution of LWD by Channel Location




Distribution of LWD by River Mile
Number of Pieces
0
20
40
60
80
100
120
140
160
180
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57
River Mile
Series1

Resource Action: EWG-16A	**Task Force Recommendation Category:** 1

Proposed Creation of Rearing Habitat for Juvenile Salmonid Fish Species

Date of Field Evaluation: June 11, 2003

Evaluation Team: Philip Unger and Jason Kindopp (revised report by Richard Harris)

Description of Potential Resource Action Measure:
Create side-channel habitat adjacent to the low-flow reach in the Feather River. DWR studies have found that juvenile steelhead trout strongly select shallow riffle/glide and near-shore habitats with abundant riparian and in-stream cover. Habitats meeting these criteria are most often found in side-channels. Currently preferred habitats of juvenile steelhead are not common in the low flow channel (LFC). To expand availability of preferred rearing habitat, side channels should be constructed at various suitable areas within the LFC.

Potential sites for side channel creation in the LFC include (from upstream to downstream): Aleck Riffle, Great Western Riffle, Robinson Riffle/Borrow Pond, Steep Riffle, between Eye and Gateway Riffles, and the OWA southeast of the Thermalito Outlet. Side channel creation will be most effective if conducted in combination with base flow increase, planting of riparian vegetation, and re-establishment of flow through historic river channels.

There are several other Resource Actions that are either similar to or otherwise related to this measure:

- EWG-13A and EWG-13B, proposed to improve rearing habitat in the low flow reach through placement of wood and other materials.
- EWG-16B proposing creation of side channel habitat in the low flow reach.
- EWG-17 and EWG-51, that would enhance riparian vegetation to increase shading and habitat complexity.
- EWG-89, that would involve levee setbacks and increase floodplain accessibility to the river.
- EWG-19A and EWG-22, proposing levee setbacks and/or geomorphic restoration in the lower Feather River to improve connectivity between the river and its floodplain.

Nexus to the Project:
Many factors, including flood control levees, construction of the dam at Lake Oroville and regulation of stream flows have cumulatively caused changes in the geomorphology and substrate of the Feather River. These changes have generally reduced the availability of spawning and rearing habitat for anadromous fishes.

Potential Environmental Benefits:
The most immediate potential benefit of the proposed Resource Action is an increase in rearing habitat for juvenile salmonids, but the primary potential benefit is an increase in the escapement levels of naturally produced steelhead trout and spring-run and fall-run Chinook salmon in the Feather River. Hatchery production of anadromous salmonids has a number of potential adverse effects on wild populations of these fish, so natural production should be favored whenever feasible. Secondary benefits of the PM&E include an increase in the forage base of striped bass, Sacramento pikeminnow and other predators of juvenile salmonids; an increase in habitat for riparian plant and wildlife species; and an increase in the aesthetic value of the river corridor.

Potential Constraints:
There are two potential constraints to this measure. First, any increase in the crossectional area of the Feather River could have adverse effects on water temperature. This would occur if the flows in the low flow channel, currently set at 600 cfs, are spread over the larger crossectional area. Second, any side channel habitats that are created will be subject to destruction from occasional flood management flow releases that exceed 100,000 cfs. Flows of that magnitude have occurred three times in the last 42 years.

Existing Conditions in the Proposed Resource Action Implementation Area:
Because of water temperature constraints, the LFC is currently the only portion of the lower Feather River suitable for year-around rearing of juvenile salmonids and is, by far, the most important section of the river for salmon and steelhead spawning. However, habitat with suitable depth, cover and flow velocity conditions for rearing salmonids is limited in the LFC. Rearing habitat in the LFC is particularly important for steelhead, which generally rear for several months to a year or more before emigrating to sea, while most Feather River chinook begin their emigration within a month or two of emerging from their redds.

Juvenile steelhead and Chinook salmon have similar rearing habitat needs. Recent surveys by DWR fisheries biologists found juveniles of both species primarily in glide habitats with instream cover and/or overhead cover (e.g., canopy) (SP-F10 January 22, 2003 Interim Report). Most were found at shallow depths within a couple of meters of the shore. The juveniles of both species gradually shifted to greater use of riffle habitat with higher flow velocities as they grew larger, although the shift was somewhat more pronounced for steelhead than for salmon. Habitat with moderate flow velocity provides the juvenile salmonids with good feeding conditions, and shallow depth and abundance of cover provide refuge from predators. In large, low gradient rivers like the lower Feather River, side channels and tributaries typically provide the sort of riffle/glide, near-shore habitat with abundant cover that juvenile salmonids prefer. Such habitats are uncommon in the LFC.

The LFC of the Feather River can be divided into three reaches on the basis of habitat types. The upstream reach, from River Mile (RM) 67, below the Fish Barrier Dam, to

the Highway 70 bridge (about RM 65.6), has a complex mix of riffle, glide and pool habitat, interspersed with a number of gravel mid-channel bars and channel side bars. Riparian vegetation is moderately well developed in portions of this reach. This reach has several side channels that provide some rearing habitat. The middle reach, which stretches from the Highway 70 bridge to Robinson Riffle at RM 62, has a gentle gradient and is largely comprised of long, deep pools with highly uniform habitat conditions. Most of the riverbank in this reach is straight and steep and has little riparian vegetation. The only exception is an approximately one-mile section downstream of the Highway 162 bridge that includes three riffle/glide areas (Trailer Park Riffle, Mathews Riffle and Aleck Riffle). The Great Western Riffle, which lies in the lower section of the middle reach, is a low-gradient area filled with scattered debris of an old ruined dam. It provides little spawning or rearing habitat for salmonids. Little side channel habitat occurs in the middle reach of the LFC. The downstream reach of the LFC extends about 2.5 miles from Robinson Riffle to Gateway Riffle. This reach, which has more gradient than the middle reach, includes a series of pool, riffle and glide habitats. Gravel bars and mid-channel islands are plentiful in this reach and there is more riparian vegetation here than in the middle reach. Side channel habitat is more plentiful in this reach than in either of the other reaches. Gateway Riffle is about one half mile upstream of the Thermalito Afterbay outlet, which marks the downstream end of the LFC.

The distribution of rearing young-of-the-year salmonids in the LFC did not match the distribution of side channel habitat. Although side channel habitat is most plentiful in the downstream reach, the majority of young-of-the-year steelhead and salmon found during the DWR fisheries surveys were observed or captured in the upstream reach of the LFC (SP-F10 January 22, 2003 Interim Report). Most other fish species, including likely predators such as Sacramento pikeminnow and the black basses, largely avoid the LFC, presumably because of the low water temperatures. As previously noted, Hatchery Ditch had by far the highest density of juvenile steelhead of any of the sampled sites. The authors of the SP-F10 report speculate that the upstream distribution of the young-of-the-year steelhead results from greater spawning by adult steelhead in the upstream reach. They suggest that the blockage of migrating fish by the Fish Barrier Dam and chemical/olfactory cues from the Feather River hatchery effluent cause most steelhead to spawn in the upstream reach. This spawning distribution would explain the concentration of recently emerged fry in the upstream reach. In contrast to young-of-the-year steelhead, age-1 and older juvenile steelhead distribution did match the distribution of side channel habitat.

The sites that have been proposed for creation of side channel habitat are primarily in the downstream reach of the LFC. These sites are Robinson Riffle/Borrow Pond, Steep Riffle, and the section between Eye and Gateway Riffles. The remaining two proposed sites, Aleck Riffle and Great Western Riffle, are in the middle reach.

Design Considerations and Evaluation:
The most important design consideration for creating side channel habitat in the LFC concerns the flow regime of the river. Constructed side channel habitat would likely be altered or eliminated by flood flows. The Oroville Project is currently operated to maintain relatively low, uniform flows through the LFC. High flows occur only during periods of extreme runoff. Therefore, artificially created side channels have a high probability of persisting for a number of years with the current flow regime, although regular maintenance may be required. However, project operations could be altered to more closely mimic a natural flow regime, with frequent periods of high flow and periodic flood events. Frequent high flow events would likely alter or destroy artificially created side channels, defeating efforts at site-specific habitat creation. However, frequent high flows could lead to the formation of natural side channel habitats, particularly if some levees were breached to increase the area of flood plain. Ultimately, this might reduce the need for improving existing rearing habitat.

Another factor to consider in creating a side channel is the risk of causing a shift in the river channel. The new channel could be favored by the river, leading to channel erosion and ultimately abandonment of the old channel. Valuable spawning and rearing habitat could be lost. Evaluating this risk requires a deep understanding of the river's geomorphic processes.

Even without a shift in the river channel, diverting flow to side channel habitat would result in reduced flow in the main channel, with potential adverse effects on main channel habitat. However, in order to maintain the shallow depths and nearshore environment favored by juvenile salmonids, created side channel would have a small cross-sectional area that would require relatively little flow. For instance, the Hatchery Ditch, which is highly productive for juvenile steelhead, typically flows at 25 cfs or less.

As described earlier, rearing juvenile salmonids favor habitat with moderate flow velocities, shallow depths, and abundant instream and overhead cover. Average focal point velocities for juvenile steelhead in the LFC increased with size of the fish from less than 0.1 feet per second (ft/s) to about 2 ft/s (SP-F10 January 22, 2003 Interim Report). Average depth ranged from about 0.2 to 0.4 meters and average distance from shore ranged from less than half a meter to about 2 meters. Microhabitat parameters for juvenile Chinook salmon were similar. The juveniles of both species were associated with small instream cover and overhead cover, but avoided large instream objects. The large instream objects were probably avoided because of their potential for sheltering predators.

Hydraulic modeling would be used to help design side channels with appropriate flow velocities and depths, while judicious routing of created channels through existing areas of vegetation combined with vegetation enhancement and other habitat enhancement measures would be used to provide good cover conditions. The most promising sites for creating suitable side channel habitat with the characteristics favored by juvenile salmonids occur on gravel bars bordering riffles in the main river channel. Sites

adjoining riffles are the only areas with sufficient gradient to ensure that the created side channels would have sufficient flow velocities for the rearing salmonids. Several of the proposed sites have fairly well developed riparian vegetation that would provide excellent overhead cover for the side channel habitat. It is likely that riparian vegetation would recruit along side channels constructed through areas currently lacking vegetation, although artificial enhancement of vegetation would likely result in more rapid development of suitable cover.

Construction of side channel habitat would require moving large volumes of gravel using heavy earth-moving equipment. Such activities have the potential to produce water quality problems, particularly high turbidity. Therefore, construction of the side channels should be restricted to a time of year when sensitive life stages of the salmonids are least abundant in the river. Spring-run Chinook salmon spawn from about mid August through October, fall-run Chinook spawn from about September through December, and steelhead spawn from about November through June. Fry of all three species emerge from their redds in the late winter or spring and most of the salmon have emigrated by June. Therefore, July through mid-August is probably the best period of the year for avoiding impacts on sensitive life stages of these species. In addition, the July to mid-August period has little rainfall and low river flows, so mobilization of disturbed sediments would be minimized at this time.

The success of side channel habitat creation would be judged on the basis of numbers and growth rates of juvenile salmonids found in the channels several years after the habitats were created.

Specific Site Evaluations

None of the proposed sites for side channel development are in the upstream reach of the LFC. However, two existing side channels in this reach, Hatchery Ditch and Moe's Ditch, have been proposed for habitat restoration efforts (EWG-16B). Given the importance of the upstream reach for juvenile rearing, rearing habitat in this reach is particularly important.

Two of the proposed sites for side channel creation, Aleck Riffle and Great Western Riffle, are in the middle reach of the LFC. As previously noted, the middle reach has a dearth of suitable rearing habitat, so habitat created in this reach, if effective, would likely have great value for steelhead and salmon production. The Aleck Riffle site sits on a channel side bar that extends downstream of Aleck Riffle (RM 63.5) on the east bank of the river. The inshore margin of this bar (nearest the levee) has riparian vegetation that would provide good cover if a side channel was routed through it. Gradient at Aleck Riffle may be insufficient for creation of a side channel that would run the entire length of the side bar. If that were the case, a shorter section of the bar, beginning at the upstream end, would be used (Figure 1).

The proposed Great Western Riffle site lies on an open gravel bench along the west bank of the river next to Great Western Riffle (about RM 62.8). Inspection of this site

revealed some drawbacks. First, the river has little gradient at this location (Figure 2). As noted above, potential sites need gradient to produce adequate flow velocity in the created side channel. Second, most of the site is located on a bench that would be inundated only at very high flows. And finally, the site currently has little vegetation (Figure 2).

The rest of the proposed sites for side channel creation are in the downstream reach of the LFC. This reach generally has a higher gradient, more gravel bars, and more riparian vegetation than the middle reach. The reach currently seems to be especially important for rearing age 1+ steelhead and probably provides valuable habitat for emigrating salmon and steelhead. The most upstream site proposed for side channel creation in the reach is the Robinson Riffle/Borrow Pond site (between RM 62 and RM 61). This site has a very complex geomorphology, largely because existing side channels connect the main channel of the river, upstream and downstream, to Robinson Pool, a large borrow pond (Figure 1). These side channels were created by the 1997 flood (Jason Kindopp, DWR, personal communication). A significant portion of the Feather River discharge flows through Robinson Pool. One promising route for creating a side channel at this site runs from the upper end of the existing upstream side channel between the river and Robinson Pool (Figure 3), along the pool side of a berm that separates the pool from the river channel, and into the existing downstream side channel connecting the pool and river (Figure 1). This route, which is approximately 2/5 of a mile long, appears to have adequate gradient and has abundant riparian vegetation along the lower half of the route (Figure 3).

The next proposed site for side channel creation begins just upstream of Steep Riffle at RM 61 (Figure 4). Steep Riffle has a high gradient. Its lower end joins the existing downstream side channel connecting the river to Robinson Pool (Figures 1 and 5). The most likely route for a constructed side channel at this site would begin in the backwater area on the upstream face of the large gravel bar that lies along the north bank of Steep Riffle (Figure 4). A strip of well-developed riparian vegetation lies along the levee side of this gravel bar, and this strip appears to be a natural route for a side channel (Figure 5). Because the gradient of the river at Steep Riffle is so high, it might be possible to provide additional side channel habitat on the gravel bar by creating a meandering side channel. The constructed side channel could rejoin the river at the downstream end of the gravel bar (Figure 4). Alternatively, assuming enough gradient is available, the side channel could be extended beyond the large gravel bar and downstream along the levee to Eye Riffle (about RM 60) (Figures 4 and 6). As described below, the section between Eye Riffle and Gateway Riffle (Figure 6) is the final proposed site for side channel creation. If this site were found to be suitable for side channel creation, if might be possible to join the Steep Riffle side channel to the Eye Riffle - Gateway Riffle channel, thus creating a side channel that would reach from Steep Riffle to Gateway Riffle, about 1.5 miles (Figure 4).

A potential course for a side channel at the proposed site between Eye Riffle and Gateway Riffle would run along a swale on the levee side of a gravel bar that stretches

along the north bank of the river, from upstream of Eye Riffle to the middle of Gateway Riffle (about RM 60.2 to RM 59.7) (Figure 4). This swale is bordered by dense growth of riparian trees and shrubs. Water sits in the upper and lower ends of the swale, creating deep narrow backwater areas (Figure 7). No current was visible in the water at either end of the swale during the field visit, which suggests that the upstream and downstream inundated areas are disconnected. The gradient between Eye Riffle and Gateway Riffle may not be sufficient to provide adequate flow velocity in a side channel running the entire distance of the gravel bar. If the gradient was not sufficient, the side channel could be directed back to the river upstream of Gateway Riffle.

Synergisms and Conflicts:
There are potential synergisms that would occur if side channel habitat creation is coordinated with other Resource Actions proposing geomorphic restoration in the low flow channel (e.g., EWG-89), spawning habitat improvement (e.g., EWG-18/90), placement of large woody debris and other structures (EWG-13A and EWG-13B) and gravel placement (e.g., EWG-92). Coordination with riparian vegetation enhancement and restoration measures would also be beneficial.

Coordinating side channel habitat improvements with measures that propose changes in the flow regime would be essential. This could avoid or at least partially offset potential adverse effects on water temperature in the low flow reach. Also, proposals for periodic peak flow releases would need to consider potential impacts on side channel construction projects.

Potential water quality conflicts could arise due to equipment operations during construction. There would undoubtedly be mitigation measures imposed within permits that will be required for this measure (Department of Fish and Game: 1601-1603 Stream Alteration Agreement, State Water Quality Control Board 401 Certificate of waste discharge and U.S. Army Corps of Engineers 404 Permit).

Uncertainties:
Probably the greatest uncertainty with this measure would be the longevity of the created side channels. As noted previously, there have been three flood events over the past 42 years that have exceeded 100,000 cfs (1965, 1986, and 1997). Flows of that magnitude would probably destroy any created habitats in the low flow channel.

Cost Estimate:
Costs for this measure are difficult to estimate since the number of side channels and their sizes have not yet been determined. However, on a similar project proposed on the Truckee River, costs for channel excavation were on the order of $1 million/1000 feet of channel. Costs for revegetation along the channel were on the order of $13,000/1000 feet of channel. These probably represent relatively conservative (high) costs. For example, excavation costs can be considerably reduced if there are no significant difficulties in achieving channel stability.

Recommendations:
One of the main factors that should be considered in evaluating the feasibility of this PM&E is the likely persistence of any created side channel habitat. More than anything else, this will depend on the frequency, duration and amplitude of high flow events. If the LFC is to continue to receive relatively uniform flows, with only occasional extreme flows, created side channel habitat would be likely to persist for a number of years. However, even under the current flow regime, created side channel habitat may require regular maintenance and periodic reconstruction. According to DFG staff, Moe's Ditch, which was constructed during the 1970s and is the only artificially created side channel currently present in the LFC, had to be regraded almost every year for a period after it was constructed (Koll Buer, DWR, personal communication). It has been completely destroyed and reconstructed several times. The ditch is currently dammed by beavers and has little habitat value for juvenile salmonids. If Oroville Project operations were modified to create more frequent high flow events in the future, artificially created side channel habitat would likely have a short life span.

As previously indicated, the upstream reach of the LFC is the most important area for rearing juvenile steelhead. While habitat restoration has been proposed for two side channels in this area, Hatchery Ditch and Moe's Ditch (EWG-16B), no sites in this reach have been proposed for side channel creation. Given the importance of rearing habitat in the upstream reach, sites for creating new side channel habitat in the reach should be considered.

Figure 1. Potential Side Channels: Aleck Riffle (top), Robinson to Steep Riffle (bottom)

Figure 2. Great Western Riffle: Ruined Dam (top), Cobble Bench (bottom)

Figure 3. Robinson Riffle: Side Channel (in background, top), Gravel Bar (bottom)

Figure 4. Potential Side Channels: Steep Riffle (top), Steep Riffle to Eye Riffle to Gateway Riffle (bottom)

Figure 5. Steep Riffle: Base of Riffle w/ Side Channel at Right (top), Gravel Bar (bottom)

Figure 6. Eye Riffle with Rotary Screw Trap (top), Gateway Riffle (bottom)

Figure 7. Inundated Swale Between Eye Riffle and Gateway Riffle (top and bottom)

Resource Action: EWG-16B	**Task Force Recommendation Category:** 2

Proposed Restoration/Improvement of Rearing Habitat for Juvenile Salmonid Fish Species

Date of Field Evaluation: June 11, 2003

Evaluation Team: Philip Unger and Jason Kindopp (report revised by Richard Harris)

Description of Potential Resource Action Measure:
Restore and/or improve side-channel habitat adjacent to the low-flow channel (LFC) in the Feather River. The two existing side channels at the upstream end of the LFC, Hatchery Ditch and Moe's Ditch, would benefit from habitat and flow enhancements. Hatchery Ditch, a primary steelhead spawning and rearing reach, is currently fed solely by seepage from the Feathery River Hatchery (FRH) settling pond. Discharge in Hatchery Ditch is directly related to water use in the hatchery. Hatchery Ditch requires its own water source for several reasons. First, there may be water quality issues associated with the FRH effluent. Second, chemical/olfactory attraction from the Feather River hatchery effluent may result in stacking up of steelhead spawners and superimposition of redds. Third, seepage from the settling pond percolates through the levee, which may cause damage to the levee. And finally, the ditch needs to be able to function independently of the FRH to allow maintenance on the FRH flowline. This need is particularly pressing since the FRH flowline is overdue for a major overhaul, which requires shutting down the hatchery water supply for several months.

Moe's Ditch is an artificial spawning channel adjacent to Hatchery Ditch. Currently Moe's Ditch lacks flow due to upstream changes in bed morphology, a lack of cover and lack of channel sinuosity.

There are several other Resource Action that are either similar to or otherwise related to this measure:

- EWG-13A and EWG-13B, proposed to improve rearing habitat in the low flow reach through placement of wood and other materials.
- EWG-16A proposing creation of side channel habitat in the low flow reach.
- EWG-17 and EWG-51, that would enhance riparian vegetation to increase shading and habitat complexity.
- EWG-89, that would involve levee setbacks and increase floodplain accessibility to the river.
- EWG-19A and EWG-22, proposing levee setbacks and/or geomorphic restoration in the lower Feather River to improve connectivity between the river and its floodplain.

Nexus to the Project:
Many factors, including flood control levees, construction of the dam at Lake Oroville and regulation of stream flows have cumulatively caused changes in the geomorphology and substrate of the Feather River. These changes have generally reduced the availability of spawning and rearing habitat for anadromous fishes.

Potential Environmental Benefits:
The most immediate potential benefit of the proposed Resource Action is an increase in rearing habitat for juvenile salmonids, but the primary potential benefit is an increase in the escapement levels of naturally produced steelhead trout and spring-run and fall-run Chinook salmon in the Feather River. Hatchery production of anadromous salmonids has a number of potential adverse effects on wild populations of these fish, so natural production should be favored whenever feasible. The majority of young-of-the-year steelhead and salmon found during recent surveys by DWR fisheries biologists were observed or captured in the upstream reach of the LFC (Study Plan, SP-F10 - January 22, 2003 Interim Report). Hatchery Ditch had by far the highest density of juvenile steelhead of any of the sampled sites. Given the importance of Hatchery Ditch and other areas within the upstream reach for salmonid production, rearing habitat in this reach is particularly important.

Secondary benefits of the proposed Resource Action include an increase in the forage base of striped bass, Sacramento pikeminnow and other predators of juvenile salmonids; an increase in habitat for riparian plant and wildlife species; and an increase in the aesthetic value of the river corridor.

Potential Constraints:
There are two major constraints to this measure. The first pertains to the sustainability of any habitat improvements in Moe's Ditch. The ditch has a history of improvements to enhance spawning habitat. These improvements included placement and raking of gravels. High flows through the ditch periodically flushed gravels from the ditch, necessitating repeated replacements. It is probable that new improvements to the ditch would only provide short-term benefits. This issue is discussed further, below.

The second constraint applies to diversion of water from the LFC to Hatchery Ditch or to Moe's Ditch. This would probably entail a reduction in flows unless mandated releases are augmented to accommodate the measure. Depending on the quantity of flow diverted, there could be impacts on habitat values in the LFC.

Existing Conditions in the Proposed Resource Action Implementation Area:
Because of water temperature constraints, the LFC is currently the only portion of the lower Feather River suitable for year-around rearing of juvenile salmonids and is, by far, the most important section of the river for salmon and steelhead spawning. However, habitat with suitable depth, cover and flow velocity conditions for rearing salmonids is limited in the LFC. Rearing habitat in the LFC is particularly important for steelhead, which generally rear one to two years before emigrating to sea. Most Feather River

chinook begin their emigration within a month or two of emerging from their redds. However, with more favorable rearing habitats the residency period of Chinook salmon could probably be increased.

Juvenile steelhead and Chinook salmon have similar rearing habitat needs. DWR fisheries surveys found juveniles of both species primarily in glide habitats with instream cover and/or overhead cover (e.g., canopy) (SP-F10 January 22, 2003 Interim Report). Most were found at shallow depths within a couple of meters of the shore. The juveniles of both species gradually shifted to greater use of riffle habitat with higher flow velocities as they grew larger, although the shift was somewhat more pronounced for steelhead than for salmon. Habitat with moderate flow velocity provides the juvenile salmonids with good feeding conditions, and shallow depth and abundance of cover provide refuge from predators. In large, low gradient rivers like the lower Feather River, side channels and tributaries typically provide the sort of riffle/glide, near-shore habitat with abundant cover that juvenile salmonids prefer. Such habitats are uncommon in the LFC.

The LFC of the Feather River can be divided into three reaches on the basis of habitat types. The upstream reach, from River Mile (RM) 67, below the Fish Barrier Dam, to the Highway 70 bridge (about RM 65.6), has a complex mix of riffle, glide and pool habitat, interspersed with a number of gravel mid-channel bars and channel side bars. Riparian vegetation is moderately well developed in portions of this reach. Hatchery Ditch and Moe's Ditch are in the upstream portion of this reach. The middle reach of the LFC, which stretches from the Highway 70 bridge to Robinson Riffle at RM 62, has little gradient and is largely comprised of long, deep pools with highly uniform habitat conditions. Most of the riverbank in this reach is straight and steep and has little riparian vegetation. The only exception is an approximately one-mile section downstream of the Highway 162 bridge that includes three riffle/glide areas (Trailer Park Riffle, Mathews Riffle and Aleck Riffle). Little side channel habitat occurs in the middle reach of the LFC. The downstream reach of the LFC extends about 2.5 miles from Robinson Riffle to Gateway Riffle. This reach includes a series of pool, riffle and glide habitats. Gravel bars and mid-channel islands with riparian vegetation are common in this reach and side channel habitat is more plentiful in this reach than in either of the other reaches.

The distribution of rearing young-of-the-year salmonids in the LFC did not match the distribution of side channel habitat. Although side channel habitat is most plentiful in the downstream reach, the majority of young-of-the-year steelhead and salmon found during the DWR fisheries surveys were observed or captured in the upstream reach of the LFC (SP-F10 January 22, 2003 Interim Report). As previously noted, Hatchery Ditch had by far the highest density of juvenile steelhead of any of the sampled sites. The authors of the SP-F10 report speculate that the upstream distribution of the young-of-the-year steelhead results from greater spawning by adult steelhead in the upstream reach. They suggest that the blockage of migrating fish by the Fish Barrier Dam and chemical/olfactory cues from the Feather River hatchery effluent cause most steelhead

to spawn in the upstream reach. This spawning distribution would explain the concentration of recently emerged fry in the upstream reach. In contrast to young-of-the-year steelhead, age-1 and older juvenile steelhead distribution did match the distribution of side channel habitat.

Hatchery Ditch is a narrow, shallow, heavily shaded channel that runs along the base of the levee separating the FRH from the LFC (Figures 1 and 2). Well-developed riparian vegetation, including a number of large cottonwood trees, borders the ditch, affording it excellent cover. Flow velocity in much of the ditch was moderately high. Most of the channel has clean gravel substrate and the ditch is heavily used for spawning by steelhead (Jason Kindopp, DWR, personal communication). Inspection of the substrate during the field visit revealed many benthic macroinvertebrates. A long gravel bar lies between Hatchery Ditch and the main channel of the river. Moe's Ditch sits on this bar.

As previously indicated, seepage from the Feather River Hatchery (FRH) settling pond is the sole source of flow to Hatchery Ditch. Prior to the 1997 flood, Hatchery Ditch apparently had less flow and the flow percolated into the gravel, so the ditch was not connected to the river (Koll Buer, DWR, personal communication). It appears that the flood opened the channel and may have affected the levee, increasing the rate of seepage from the settling pond into the ditch (Jason Kindopp, DWR, personal communication). Currently, discharge in Hatchery Ditch is directly related to water use in the hatchery. During the field visit to the site, the settling pond retained little of the water discharged into it and the water appeared to seep rapidly through the levee into Hatchery Ditch (Figure 3). Several large, rapidly flowing seeps were found at the base of the levee near the upstream end of the ditch (Figure 4). The elevation of the channel in this area was several feet higher than that of the river. Because Hatchery Ditch does not get its flow from the river channel and because its upstream end has a higher elevation than that of the river channel, it currently functions more like a tributary than a side channel.

Moe's Ditch is a broad, straight, exposed man-made channel adjacent to Hatchery Ditch (Figures 1 and 5). The channel was initially constructed in the 1970s to enhance salmonid spawning. The ditch has been regraded many times and complete reconstruction has been required after several flood events. The ditch was adversely affected by the 1997 flood and currently provides little spawning or rearing habitat. Young willows border much of the ditch, but they provide little cover.

Moe's Ditch begins at the upstream end of Auditorium Riffle and flows downstream over the gravel bar for about 1/7th of a mile, where it discharges back to the river. The upstream end is clogged with gravel that restricts flow in the channel. Apparently, such blockage has been a frequent problem for the channel (Koll Buer, DWR, personal communication). Because of the low flow, shallow depths and exposure, substrate at the upper end of Moe's Ditch is blanketed with algae. Beavers have constructed a dam near the lower end of the ditch; so much of the channel has been converted into a pool.

Because of low flow, vegetation is heavily encroaching into the channel at the downstream mouth of the ditch (Figure 5).

Design Considerations and Evaluation:
The most important design consideration for restoring and improving rearing habitat in Hatchery Ditch and Moe's Ditch concerns the flow regime of the river. Habitat improvements made in these channels would likely be altered or destroyed by flood flows. The Oroville Project is currently operated to maintain relatively low, uniform flows through the LFC. High flows occur only during periods of extreme runoff. Therefore, habitat improvements in these channels have a high probability of persisting for several years with the current flow regime, although regular maintenance would likely be required. However, project operations could be altered to more closely mimic a natural flow regime, with frequent periods of high flow and periodic flood events. Frequent high flow events would likely alter or destroy habitat improvements or eliminate the channels entirely, defeating habitat restoration and improvement efforts. However, frequent high flows could lead to the formation of natural side channel habitats, particularly if some levees were breached to increase the area of flood plain. Ultimately, this might reduce the need for improving existing rearing habitat.

The most critical habitat improvement need for Hatchery Ditch is to provide a source of water other than the current FRH source. The current situation is unsustainable because of potential water quality issues, over-attraction of steelhead spawners, levee damage, and pressing FRH flowline maintenance needs. Because the upstream end of the Hatchery Ditch channel sits at a higher elevation than that of the adjacent river channel, flow cannot be provided to the ditch by breaching the bar that separates the two channels. Two alternatives have been proposed for diverting river water into the channel. One solution would be to pump water from the river into the upstream end of the channel. The channel currently receives up to 25 cfs, which would require a large pump, but less flow may suffice (Jason Kindopp, DWR, personal communication). In any case, the pump would be too large to be portable and would therefore have to be installed well above flood stage. Other potential solutions would be to construct a flowline to divert water from an upstream location in the main river channel or from the Fish Barrier Dam pool. All of these alternatives would be costly.

Most physical habitat conditions within the Hatchery Ditch channel appear to be good for salmonid rearing habitat. As described earlier, rearing juvenile salmonids favor habitat with moderate flow velocities, shallow depths, and abundant instream and overhead cover. Average focal point velocities for juvenile steelhead in the LFC increased with size of the fish from less than 0.1 feet per second (ft/s) to about 2 ft/s (SP-F10 January 22, 2003 Interim Report). Average depth ranged from about 0.2 to 0.4 meters and average distance from shore ranged from less than half a meter to about 2 meters. Microhabitat parameters for juvenile Chinook salmon were similar. The juveniles of both species were associated with small instream cover and overhead cover, but avoided large instream objects. The large instream objects were probably avoided because of their potential for sheltering predators. The Hatchery Ditch channel

is heavily shaded and is well provided with instream and overhead cover (Figure 1). The channel is generally less than half a meter deep and less than three meters wide, so rearing juveniles are never far from the stream bank. However, during the field visit, flow velocities in some sections of the channel appeared to be high for small young-of-the year salmonids. These sections were relatively straight with uniform substrates and the flows were uniform and swift, providing few flow velocity refuges for small fish (Figure 4). Introducing instream structures in these sections would produce flow breaks that would likely improve the habitat.

Juvenile steelhead collected in Hatchery Ditch typically had full stomachs, so feeding conditions are probably adequate (Jason Kindopp, DWR, personal communication).

Habitat conditions in Moe's Ditch contrast sharply with those in Hatchery Ditch. Moe's Ditch is quite broad and has little flow. A beaver dam backs up the flow in much of the channel, creating a large area of pool habitat. The most immediate need for restoring habitat in Moe's Ditch is to remove the gravels that restrict flow from the river channel. If the channel was opened the flow entering the ditch might wash out the beaver dam. Otherwise the dam would have to be removed mechanically.

The broad channel of Moe's Ditch is suitable for spawning habitat, which was the original objective of the habitat design, but it is too exposed to provide good rearing habitat. A new, narrower channel in the same area would provide better rearing habitat and would be easier to maintain with adequate flows. In addition, a narrower channel could more easily be routed through existing riparian vegetation or be enhanced with vegetation improvements to provide instream and overhead cover. Finally, a narrow channel could be provided with meanders to create more habitat complexity, including variable flow velocities. Hydraulic modeling could be used to help design a channel producing flow velocities and depths suitable for rearing salmonids.

Implementing this measure would require permits from the Department of Fish and Game, Army Corps of Engineers and State Water Quality Control Board. Restoration of Moe's Ditch habitat would require moving large volumes of gravel using heavy earth-moving equipment. Such activities have the potential to produce water quality problems, particularly high turbidity. Therefore, the earth-moving activities should be restricted to a time of year when sensitive life stages of the salmonids are least abundant in the river. Spring-run Chinook salmon spawn from about mid August through October, fall-run chinook spawn from about September through December, and steelhead spawn from about November through June. Fry of all three species emerge from their redds in the late winter or spring and most of the salmon have emigrated by June. Therefore, July through mid-August is probably the best period of the year for avoiding impacts on sensitive life stages of these species. In addition, the July to mid-August period has little rainfall and low river flows, so mobilization of disturbed sediments would be minimized at this time.

The success of habitat restoration and improvement in Hatchery Ditch and Moe's Ditch would be judged on the basis of numbers and growth rates of juvenile salmonids found in the channels several years after the habitats were restored.

Synergism and Conflicts:
There are potential synergisms that would occur if side channel habitat creation is coordinated with other Resource Actions proposing geomorphic restoration in the low flow channel (e.g., EWG-89), spawning habitat improvement (e.g., EWG-18/90), placement of large woody debris and other structures (EWG-13A and 13B) and gravel placement (e.g., EWG-92). Coordination with riparian vegetation enhancement and restoration measures would also be beneficial.

Coordinating side channel habitat improvements with measures that propose changes in the flow regime would be essential. This could avoid or at least partially offset potential adverse effects on the LFC. Also, proposals for periodic peak flow releases would need to consider potential impacts on side channel construction projects.

Potential water quality conflicts could arise due to equipment operations during construction. There would undoubtedly be mitigation measures imposed within permits that will be required for this measure (Department of Fish and Game: 1601-1603 Stream Alteration Agreement, State Water Quality Control Board 401 Certificate of waste discharge and U.S. Army Corps of Engineers 404 Permit).

Uncertainties:
The greatest uncertainty with this measure would be the sustainability of improvements. Peak flows exceeding 100,000 cfs have occurred three times in the last 42 years. Flows of this magnitude (or perhaps even less) would probably destroy the improvements.

Cost Estimate:
Costs for this measure are difficult to estimate. It has not been determined whether or not new channels would be created or existing channels modified.
However, on a similar project proposed on the Truckee River, costs for channel excavation were on the order of $1 million/1000 feet of channel. That was a major reconstruction project and costs for this measure would likely be an order of magnitude less. Costs for revegetation on the Truckee River were on the order of $13,000/1000 feet of channel. That too, probably represents a relatively conservative (high) cost. Channel construction costs can be considerably reduced if there are no significant difficulties in achieving channel stability.

Recommendations:
One of the main factors that should be considered in evaluating the feasibility of this PM&E is the likely persistence of any habitat restorations or improvements implemented in Hatchery Ditch and Moe's Ditch. More than anything else, this will depend on the frequency, duration and amplitude of high flow events. If the LFC is to continue to receive relatively uniform flows, with only occasional extreme flows, habitat restorations

and improvements would be likely to persist for a number of years. However, even under the current flow regime, the habitats may require regular maintenance and periodic reconstruction. According to DFG staff, Moe's Ditch had to be regraded almost every year for a period after it was constructed (Koll Buer, DWR, personal communication). It has been completely destroyed and reconstructed several times. If Oroville Project operations were modified to create more frequent high flow events in the future, improvements and restoration in the habitat of the ditches could have a short life span.

Figure 1. Hatchery Ditch and Moe's Ditch

Figure 2. Hatchery Ditch: Abundant Instream Cover and Overhead Cover (top and bottom)

Figure 3. Feather River Hatchery Settling Ponds (top and bottom)

Figure 4. Hatchery Ditch: Source (top), Straight Channel with Uniform Flow (bottom)

Figure 5. Moe's Ditch: Upstream End (top), Downstream End (bottom)

Resource Action: EWG-18	**Task Force Recommendation Category:** 2
Resource Action: EWG-90	**Task Force Recommendation Category:** 4

Proposed Ripping and/or Raking of Selected Sections in the Low Flow Channel of the Feather River for Enhancement of Salmon and Steelhead Spawning Habitat

Date of Field Evaluation: No field investigation has been conducted. This measure was discussed at a meeting at DWR Red Bluff on August 15, 2003

Evaluation Team: Richard Harris and Koll Buer

Description of Potential Resource Action Measure:
In areas where armoring has occurred, selected sections of the low-flow reach of the Feather River would be ripped and/or raked with the goal of improving spawning gravel quality for Chinook salmon and steelhead. No specific locations have been determined pending the results of Study Plan, SP-G2.

This measure is directly related to EWG-92 that would supplement gravel in the low flow reach.

Nexus to the Project:
Lake Oroville prevents the movement of gravel from upstream sources to the lower Feather River. As a consequence of this, there is no significant recruitment of gravel that is of suitable sizes for use by spawning anadromous salmonids. Regulation of flows and scouring of suitably sized gravel from the low flow reach has further reduced the areal extent of spawning habitat.

Potential Environmental Benefits:
The intention of this measure is to increase the area of suitable salmonid spawning habitat in the low flow reach. This in turn, would reduce the incidence of redd superimposition and improve spawning success.

Potential Constraints:
The only major constraint to this measure would be the possibility of short-term impacts on water quality due to equipment operation in the river.

Existing Conditions in the Proposed Resource Action Implementation Area:
Because of water temperature constraints elsewhere, the low flow channel is currently the only portion of the lower Feather River suitable for year-around rearing of juvenile salmonids and is, by far, the most important section of the river for salmon and steelhead spawning.

Areas suitable for spawning in the low flow reach are well-established stable riffles. All the major ones have names. They have changed very little in location since closure of Lake Oroville. However, most riffles have coarsened in surface texture over time, a

process called armoring. This has reduced their value as spawning habitat. Armoring is particularly evident at the heads of riffles, which coincidently are favored locations for spawning. The degree of armoring was evaluated in surveys done in 1980, 1996 and currently, under SP-G2.

Data exist on subsurface substrate conditions for all major spawning areas. These data indicate that in many locations, gravels of size classes suitable for use in redd construction exist below the armored layer.

There have been some efforts in the past to reduce armoring through ripping or re-arranging spawning gravels. The most significant gravel placements and manipulations were associated with Moe's Ditch, an artificial spawning channel.

Design Considerations and Evaluation:
The most important design consideration for this measure is the quality of gravels underlying the armored layer in the sites designated for treatment. Information on substrate composition for spawning sites will be available from SP-G2 and SP-F10. This measure can be further developed and site selection can proceed when those data have been analyzed.

As briefly discussed below in the Recommendations, this measure could be combined with others as part of a comprehensive approach to spawning habitat improvement. At the minimum, EWG-92 is a complementary measure.

Ripping and raking at spawning sites may require use of heavy equipment. These activities would have the potential to produce water quality problems, particularly high turbidity. Implementation should be restricted to the period of July to mid-August when sensitive life stages of salmonids are least abundant in the river. Permits will be required from the Department of Fish and Game, State Water Quality Control Board and Army Corps of Engineers, at the minimum. NOAA-Fisheries would also have jurisdiction under the ESA.

As with gravel placement, ripping and raking will make temporary improvements in habitat quality that will last as long as there is no extreme flooding event. Flows in excess of 50,000 cubic feet per second (cfs) will probably mobilize gravels of spawning size and return the treated sites to an armored condition. Flows of this magnitude have occurred 12 times in the past 42 years.

One potential method to enhance gravel retention would be to use raked cobbles as upstream berms to protect areas of gravel. Using these in series, analogous to windrows, could protect relatively large patches of gravel from scouring during some peak flow events.

Another design consideration should be emphasizing treatments at upstream riffles. That way, gravels remain in the system for the longest possible time.

The best measures of success for this measure or any other proposing improvements to spawning habitat would be fish escapement. Additional correlative measures would be redd counts and incidence of superimposition.

Synergism and Conflicts:
This measure, along with others proposing gravel placement and use of instream structures and LWD, could all help improve both spawning and rearing habitat for anadromous salmonids in the low flow reach. However, if all measures with similar objectives (including others proposing alternative flow management) are not planned in concert, they could end up conflicting with each other. Specific treatments should be considered tools for habitat improvements within the context of an overall assessment of habitat improvements.

Uncertainties:
The only major uncertainty associated with this measure would be the extent and duration of short-term water quality impacts. Another uncertainty would be the duration of beneficial effects.

Cost Estimate:
Costs for this measure would probably be relatively low. No materials would be required. The only major cost item would be equipment operation time. It is reasonable to assume a cost of about $1,600/day for heavy equipment operation. Most existing riffles could probably be treated within about 10 days for a total cost in the range of $10,000 - $20,000.

Recommendations:
This proposal represents a reasonable approach to improving spawning habitat if the design considerations can be fulfilled. The proposal should therefore, be limited to sites where the quality of gravel underlying the armored layer is suitable for spawning.

This measure could be undertaken independently or it could be combined with EWG-92 that proposes enhancement of gravel supply to the low flow reach. Under EWG-92 three options are presented including one that would involve direct placement of gravels at spawning sites. There are potential water quality concerns associated with direct placement as there would be with ripping and raking. Nevertheless, if a direct placement option were chosen, it would naturally involve raking at the minimum. If suitable gravels exist below armored layers, ripping could reduce the amount of gravel that would need to be supplied.

Resource Action: EWG-89	**Task Force Recommendation Category:** 2

Proposed Spawning Habitat Enhancement by Creating Levee Setbacks

Date of Field Evaluation: June 11, 2003

Evaluation Team: Richard Harris, Philip Unger, Jason Kindopp, and Brad Cavallo

Description of Potential Resource Action: Create levee setbacks to increase meandering nature of river and improve gravel composition in critical spawning reaches of the low flow channel (LFC) of the Feather River. Improvement in gravel composition is to be achieved by allowing the stream to access and erode bank and floodplain deposits currently the boundaries of the levee system. This measure would also seek to increase the amount of fish spawning habitat by increasing the quantity of floodplain inundated by regulated flows.

There are several other Resource Actions that are either similar to or otherwise related to this measure:

- EWG-22, that would attempt to improve connectivity of the river with its floodplain in the lower Feather River by setting levees back.
- EWG-19A, that would modify or create “benches” or floodplain surfaces in the lower Feather River.
- EWG-16A and EWG-16B, which proposes enhancement of existing, or creation of new side channel habitat in the lower Feather River.
- EWG-92, that would improve spawning habitat in the low flow reach by direct placement of gravels.

Nexus to the Project:
The trapping of sediment behind the dam at Lake Oroville, coupled with the regulation of streamflow, have caused reductions in the quantity and quality of spawning habitat for anadromous fishes in the Feather River. The principle change has been an armoring of spawning habitat. The armored layer consists of substrate that is too large for redd construction in many places.

Levees and reduced peak flows have both reduced the accessibility of the Feather River to its floodplain. As a consequence, recruitment of sediment to the river through periodic floodplain and bank erosion has been substantially reduced.

Potential Environmental Benefits:
Most of the Feather River’s LFC is highly constrained by levees. As a result of this and other factors, natural fluvial geomorphic processes (channel migration, gravel recruitment, avulsions, etc.) have been altered, and that may have a negative impact on rearing habitat and spawning gravel quality. Geomorphically complex and active habitats are most closely associated with gradient changes and broad, unconfined

active channel areas. Such habitats, particularly reaches with multiple channels, are typically the most productive rearing habitat for juvenile salmonids in large low gradient rivers like the lower Feather River.

The premise of this Resource Action is that setting levees back from their current positions would allow the river to erode its banks and floodplain. If the composition of the banks and floodplain consists of suitably sized gravels, and if the recruited material finds its way to spawning riffles, there could be improvements in salmonid spawning habitat quality and quantity. Creating levee setbacks would also provide connectivity with larger portions of the active channel and floodplains which are currently cut-off by levees. Increased floodplain area in turn, would increase the potential area of riparian vegetation. In addition, levee setbacks created in the LFC could improve wetlands, habitat for wildlife species, and enhance the aesthetic value of the river corridor.

Potential Constraints:
There are two potential constraints to this measure. First, setting back levees would likely require coordination with the U.S. Army Corps of Engineers (USACE) and possibly, local jurisdictions due to flood management concerns. Unless the levee setbacks are on public lands, private land acquisition would be required as well. Second, unless levee setbacks are coordinated with changes in flow management, it is unlikely that they will actually increase floodplain access or gravel recruitment. Under the current regulated flow regime in the LFC (flows maintained at 600 cubic feet per second (cfs)), enlarging the channel and/or floodplain would simply result in the dissipation of stream power and probably reduce erosion.

Existing Conditions in the Proposed Resource Action Implementation Area:
Habitat for anadromous salmonids in the LFC has been affected by the disruption of natural geomorphic processes due to myriad causes (hydraulic mining, land uses, levees), by the regulation of flow, and by the presence of the dam creating Lake Oroville. The dam blocks sediment recruitment from the upstream basin. Levees, and more specifically, bank armoring, prevent gravel recruitment from banks, abandoned channels, mine tailings, and floodplains.

Regulated flows are of sufficient magnitude to winnow gravels that do exist from spawning riffles resulting in armoring of the remaining substrate. Much of the stream bed substrate in the LFC is composed of larger gravels and cobbles too large for construction of spawning redds by salmon and steelhead. Despite these constraints, the LFC is by far the most important section of the river for salmon and steelhead spawning.

Most of the LFC is closely bounded by a complex system of levees, which include typically older levees, some of which are the responsibility of DWR. The effects of the levees are two-fold. Their principal impact is to disconnect the river from its floodplain, thereby preventing overbank flooding. A secondary impact is to prevent the stream from accessing alluvial deposits that could serve as sediment sources for gravel

recruitment. Although specific information for the LFC is not yet available, most of the levees there are armored with cobbles (not artificial bank protection) that prevent erosion and lateral movement of the stream. Levees surrounding the Oroville Wildlife Area (OWA) have experienced at least two levee breaks due to past floods (at River Mile (RM) 61 and RM 63).

In addition to bank or levee erodibility, other factors that affect erosion are the volume and velocity of streamflow. Streamflow is highly regulated in the LFC. Consequently, there are rarely any floods of sufficient magnitude to initiate bank erosion. Only extreme floods (i.e., >100,000 cfs), such as those that occurred in 1965, 1986 and 1997 affect the LFC. During one of those events (either 1965 or 1986) the levee breaks at the OWA occurred. However, major widening of the channel did not occur, probably because of bank armoring.

Another effect of levees, particularly those that are well-protected against erosion, is to constrict flood flows thus increasing flood velocities and their potential to cause downstream erosion. Virtually the entire LFC is protected by closely set levees. That is not the case further downstream where the distance between levees is wider (between RM 39-54).

Because of water temperature constraints, the LFC is currently the only portion of the Feather River below Oroville dam suitable for year-around rearing of juvenile salmonids. Habitat with suitable depth, cover, and flow velocity conditions for rearing salmonids is, however, limited. Rearing habitat in the LFC is particularly important for steelhead, which generally rear for several months to a year or more before emigrating to sea. Most Feather River Chinook salmon begin their emigration within a month or two of emerging from redds.

In summary, the LFC is extremely important for salmonid spawning and rearing. However, both spawning and rearing habitat are limited. The main factors currently contributing to the limitations on habitat are the presence of the dam (preventing downstream sediment delivery), the regulated flow regime, and to some extent, the presence of levees that confine the channel and prevent development of habitat complexity.

Design Considerations and Evaluation:
The flow regime of the Feather River is the most important design consideration affecting the success of levee setbacks. The Oroville Project is currently operated to maintain relatively low, uniform flows through the LFC. High flows generally occur only during periods of extreme runoff. Creating levee setbacks under these flow conditions would have only limited value because the floodplain would only occasionally receive the high flows necessary to create productive habitat and recruit good quality spawning gravels. In addition, there is also a potential concern that setting back the levees may allow the channel to widen and not increase meandering. Furthermore, an increased

surface area could potentially increase the water temperature of the lower Feather River.

Artificial side channel habitat and spawning habitat channels could be created in some floodplain areas (as discussed in the narrative report for EWG-16A), but such habitat could potentially have relatively high maintenance costs and may be less productive than side channel habitat naturally created by periodic floodwaters. Project operations (related to releases from Oroville Dam) could be altered to have the LFC, as well as the entire Feather River, more closely mimic a natural flow regime, with more frequent periods of high flows, including periodic flood events. Such a flow regime combined with levee setbacks would probably create rearing and spawning habitat for salmon and steelhead. Some contouring (or engineered structures) of floodplain land could be necessary prior to flooding to eliminate areas with potential for stranding redds and juveniles. Based on discussions with DWR personnel, two potentially suitable locations include: 1) the west side of the Feather River (River Mile (RM) 59 to RM 62 and RM 63 to RM 64); and 2) the east side of the Feather River (RM 50 to RM 59). The State reportedly owns the land for each of the above options.

In evaluating flow regimes that would be supportive of this measure, it would be necessary to develop stage-discharge relationships that could be used to evaluate post-levee removal floodplain inundation. The hydraulic modeling program, Fluvial 12 has been calibrated for use in the LFC and could be used to evaluate levee removal and flow management alternatives. Any flow management proposal needs to consider several factors including scheduling of flow to provide rearing habitat when it is most needed by juvenile salmonids. Another issue that would need to be addressed would be prevention of fish stranding. If flow in the LFC is greater than 2,500 cfs any time during October 15 through November 30, the 1983 agreement between the California Department of Fish & Game (DFG) and the California Division of Water Resources (DWR), requires the Oroville Project to provide that minimum flow (less 500 cfs) until the following March. This agreement is designed to minimize dewatering of redds and stranding juveniles in ponds or temporarily inundated channels.

Since the primary objective of this measure is to recruit spawning gravel, then another consideration would be whether or not the areas accessed by the stream due to levee set backs actually have gravel of appropriate sizes. The ability of different flows to move the gravels into the main channel and the likelihood that the gravel that is recruited would be retained there would also require evaluation. There is also some concern that deposits accessed by the stream might have some level of soil contaminants (e.g. from historic mining activities).

A number of undesirable plant species (exotics) inhabit the OWA and other former floodplain areas in the LFC corridor. Flooding of these areas could promote dispersal of the exotics to downstream areas currently free of these species. Mitigation against this would have to be incorporated into the measure.

Creating levee setbacks would likely entail major earthmoving activities. Permits would probably be required from the DFG, State Water Quality Control Board and USACE. To minimize water quality problems associated with such activities, particularly turbidity and sedimentation, the work should be scheduled for summer, when the annual rainfall is lowest in the basin. A July through mid-August timeframe for earthmoving activities would probably present the least adverse effects on water quality on sensitive life stages of salmon and steelhead.

A measurement of success of this Resource Action would be newly created spawning and rearing habitats and their use by salmonids. Success would ultimately be measured by long-term salmon and steelhead escapement levels, although it might not be possible to determine the relative contribution a particular resource action enhancement measure to any increases in escapement.

Synergism and Conflicts:
Coordinating this measure with other measures aimed at replenishing spawning gravels (e.g., EWG-92) and improving the quality of spawning habitat (e.g., EWG-18/90) would be beneficial. It would also be advisable to coordinate planning for changes to the flow management regime with planning for this measure.

Unless there are changes to the flow regime to enhance the effectiveness of this measure, there could be conflicts with efforts to maintain suitable temperatures for salmonids in the LFC. Also, this measure could conflict with flood management objectives.

Uncertainties:
This measure would require complex engineering and environmental design analysis in relation to its main objective. There are several sources of uncertainty regarding this measure: 1) the suitability of potential locations for levee removal; 2) the required permitting and environmental documentation; 3) the key importance of the flow regime; 4) the potential for lands accessed by flows to produce the desired gravels; 5) the retention of recruited gravels at the appropriate places in the LFC (i.e., spawning riffles); and 6) the performance of the measure during extreme flooding events.

Cost Estimate:
Costs for this measure would depend on whether or not land acquisition would be required. Costs would also depend on the amount of levee removed and the amount that would be reconstructed. There is no information available to estimate these costs. However, simple levee breaching, without reconstruction would probably be an order of magnitude less in cost than levee relocation.

Recommendations:
Perhaps the principal issue with this measure is whether or not it is a good way to achieve spawning gravel enhancement. In levee set back projects proposed for other river systems (e.g., Sacramento, Cosumnes, Mokelumne, Truckee) the main objective

has been to increase floodplain area and associated riparian habitat. This is probably a more workable objective for a levee set back project in the low flow reach of the Feather River.

Therefore, this Resource Action should be evaluated for effectiveness in comparison to or in combination with more direct measures for spawning gravel enhancement such as EWG-92. Also, as noted in the narrative report for EWG-94, there is a possibility to both enhance ponds in the OWA and produce gravel for direct placement. That Resource Action, which is incorporated into EWG-16A, EWG-16B, EWG-22, EWG-89, and/or EWG-92, would involve excavating ponds to increase their depth and water surface area. The excavated sediments could then be used for direct placement at spawning riffles.

Combining levee set backs with direct gravel placement would potentially have the effect of enhancing spawning riffle substrate suitability. The widened cross section and reduced stream power would increase the possibilities for gravel retention. This combined measure would not necessarily require major changes to flow management, although potential effects on stream temperature would have to be considered.

Resource Action: EWG-92	**Task Force Recommendation Category:** 2
Resource Action: EWG-91	**Task Force Recommendation Category:** 4

Proposed Gravel Replacement for Enhancement of Salmonid Spawning Areas in the Low Flow Channel

Task Force Recommendation Category: EWG-91 and EWG-92 have been combined into one Resource Action (Resource Action EWG-92). Therefore, EWG-92 has been recommended for *Category 2*, while EWG-91 has been recommended for *Category 4.*

Date of Field Evaluation: No field investigation has been conducted; however, detailed discussions occurred at the DWR-Red Bluff facility on July 28, 2003.

Evaluation Team: Richard Harris, Koll Buer, and Bruce Ross

Description of Potential Resource Action:
Supplement the low flow channel with gravel in the vicinity of spawning riffles, if the ongoing study plan (SP-G2) indicates these areas are found to be of poor quality for spawning. The ultimate goal is to increase the availability of spawning habitat for anadromous salmonids.

There are several other Resource Actions that are either similar to or otherwise related to this measure:

- EWG-16A and EWG-16B, which propose enhancement of existing, or creation of new side channel habitat in the lower Feather River.
- EWG-19A, that would modify or create “benches” or floodplain surfaces in the lower Feather River.
- EWG-22, that would attempt to improve connectivity of the river with its floodplain in the lower Feather River by setting levees back.
- EW-89, that would set back levees to increase meandering nature of river and improve gravel composition in critical spawning reaches of the low-flow reach.

Nexus to the Project:
Lake Oroville prevents the movement of gravel from upstream sources to the lower Feather River. As a consequence of this, there is no significant recruitment of gravel that is of suitable sizes for use by spawning anadromous salmonids. Regulation of flows and scouring of suitably sized gravel from the low flow reach have further reduced the area of spawning habitat.

Potential Environmental Benefits:
The benefits of enhancing the available spawning habitat would include increased production of anadromous salmonids (salmon and steelhead). This in turn, could also potentially reduce the incidence of redd superimposition and genetic integression.

Potential Constraints:
This is a measure that has been done in the past, particularly in association with improving Moe's Ditch as spawning habitat. The main constraint is keeping the gravel at the spawning sites, especially during occasional peak flow events.

Existing Conditions in the Proposed Resource Action Implementation Area:
Habitat for anadromous salmonids in the low flow reach of the Feather River has been affected by the disruption of natural geomorphic processes due to a myriad of causes including: historic hydraulic mining, historic and current land uses, the construction and maintenance of flood control levees, by the regulation of flow in the river, and by the presence of the dam creating Lake Oroville. The dam blocks sediment recruitment from the upstream basin from flowing into the lower Feather River. Levees, and more specifically, bank armoring, prevent gravel recruitment from banks, abandoned channels, mine tailings and floodplains. Periodic peak flows are of sufficient magnitude to winnow smaller-sized gravels from spawning riffles resulting in armoring of the remaining substrate. Much of the stream bed substrate in the low flow channel is composed of larger gravels and cobbles, which are too large for construction of spawning redds by the salmon and steelhead. Despite these constraints, the low flow channel is by far the most important section of the river for salmon and steelhead spawning.

Design Considerations and Evaluation:
Placement of gravel in the low flow reach could be accomplished in one of three ways:
1. Gravel could be introduced into the system in the vicinity of the diversion dam and allowed to migrate downstream.
2. Gravel could be directly placed at spawning riffles.
3. Gravel could be placed in the vicinity of naturally eroding banks, from where it would be transported downstream.

If options (1) or (2) were selected, water quality considerations would require that the gravels be washed before introducing them to the stream in order to prevent increased turbidity. Placing the gravels near naturally eroding banks (Option 3), might eliminate the necessity for washing the gravel, thereby potentially reduce costs to implement the Resource Action. This issue would require further evaluation.

It may appear more efficient to place gravels directly at targeted riffles. However, either introducing gravels at the top of the reach or allowing the gravels to erode from bank positions would probably still have positive effects. Additional information would be needed to determine the best approach for gravel supplementation. Gravel supplementation programs have been implemented elsewhere including the Sacramento River near Redding, the Mokelumne River below Camanche Dam, the Merced River below Crocker-Huffman Dam, and other rivers throughout the Central Valley. Evaluations conducted in association with those efforts can help in the choice of the optimal approach for the Feather River. For example, on the Merced River, gravel

placement directly at spawning riffles did not provide lasting benefits because the gravel migrated downstream.

Under the current flow regime (regulated flows of 600 cfs), particles the size of spawning gravels are not flushed from the low flow channel. Spawning gravel transport occurs when periodic peak flows are between 30,000 and 60,000 cfs. Flows >50,000 cfs have occurred approximately 12 times since closure of the dam. Consequently, gravel placements would have to be repeated after peak flow events in order to maintain the benefits of this measure. Some changes to the flow regime (e.g., periodic pulsed flows) may be necessary to transport gravel to riffles from placement sites

If gravel is supplemented in the low flow reach and is moved downstream by peak flows, this could have positive downstream effects as far as Gridley. The gravel transported downstream could contribute to creation of geomorphic surfaces and point bar development. This would partly restore natural sediment transport processes in the river.

Data exist from SP-G2 on the amount of gravel that was transported in the Feather River prior to closure of the dam. These data could be used to design a gravel supplementation project that would be commensurate in quantity with the impaired flow regime.

Gravel placement could be benefited by the use of instream structures and LWD as proposed in EWG-13A and 13B. Instream structures placed at riffles could assist in retaining gravel and potentially enlarging spawning riffles.

Other approaches could be introduced to increase the availability of spawning habitat. For example, for years Moe's Ditch (near the hatchery) was managed to provide spawning habitat by gravel placement, however, this also proved to be only a temporary benefit. Each year the gravel migrated to the mouth of the ditch and had to be re-graded. That practice has been discontinued, and at the present time, Moe's Ditch does not provide any spawning habitat. Similar projects (i.e., artificial channels), while potentially only temporary, could be considered to provide additional spawning habitat.

Synergism and Conflicts:
Coordinating this measure with other measures aimed at improving gravel composition (through levee set backs (e.g., EWG-89)) and improving the quality of spawning habitat (e.g., EWG-18/90) would be beneficial. It would also be advisable to coordinate planning for changes to the flow management regime with planning for this measure.

There do not appear to be any major conflicts between this measure and other Resource Actions. The only potential environmental issue that would need to be resolved is water quality impacts from gravel placement.

Uncertainties:
Uncertainties would depend on the option chosen for gravel placement. If gravel is placed at the top of the low flow channel or on eroding banks, there would be uncertainty that the gravel would actually reach and be retained at spawning riffles. The other major uncertainty is the length of time that recruited gravel would remain in the system and provide benefits. This can be minimized if the gravel placement is viewed as a continuing process rather than a one-time treatment. Providing annual gravel supplements equal in quantity to what natural recruitment might have been, adjusted for the regulated flow regime, could provide benefits far beyond the low flow channel.

Cost Estimate:
Detailed costs cannot be estimated because of the conceptual nature of this measure. However, the main source of cost will be heavy equipment operation. This cost is in the range of $1,000-2,000/day. Additional costs would be incurred if gravels have to be washed prior to placement. It is assumed that gravels can be obtained at little or no cost from lands owned by DWR (e.g., Oroville Wildlife Area) perhaps in conjunction with other PM&E measures.

Recommendations:
This measure should be considered as a potentially viable solution for the lack of suitable spawning habitat in the low flow reach. However, any approach to supplement the stream channel with gravel would, if not done in conjunction with measures to transport and retain the gravels at the spawning areas, potentially provide only temporary benefits. Therefore, it should be considered in conjunction with Resource Actions designed to enhance gravel retention at targeted riffles (i.e. EWG 13A and 13B.

Further study would be required to determine: 1) what quantities of gravel should be placed; 2) where the gravel should be placed; 3) what modifications to the flow regime may be required to make the Resource Action work; 4) what, if any, instream structures should be used (and where) to enhance retention at spawning riffles; and 5) the feasibility of combining gravel placement with pond enhancement in the Oroville Wildlife Area.